NEW YORK SOLAR INDUSTRY DEVELOPMENT AND JOBS ACT OF 2011: AN ENVIRONMENTAL ANALYSIS

Workshop in Applied Earth Systems Management
MPA in Environmental Science and Policy, Summer 2011

Columbia SIPA
School of International and Public Affairs

The Earth Institute
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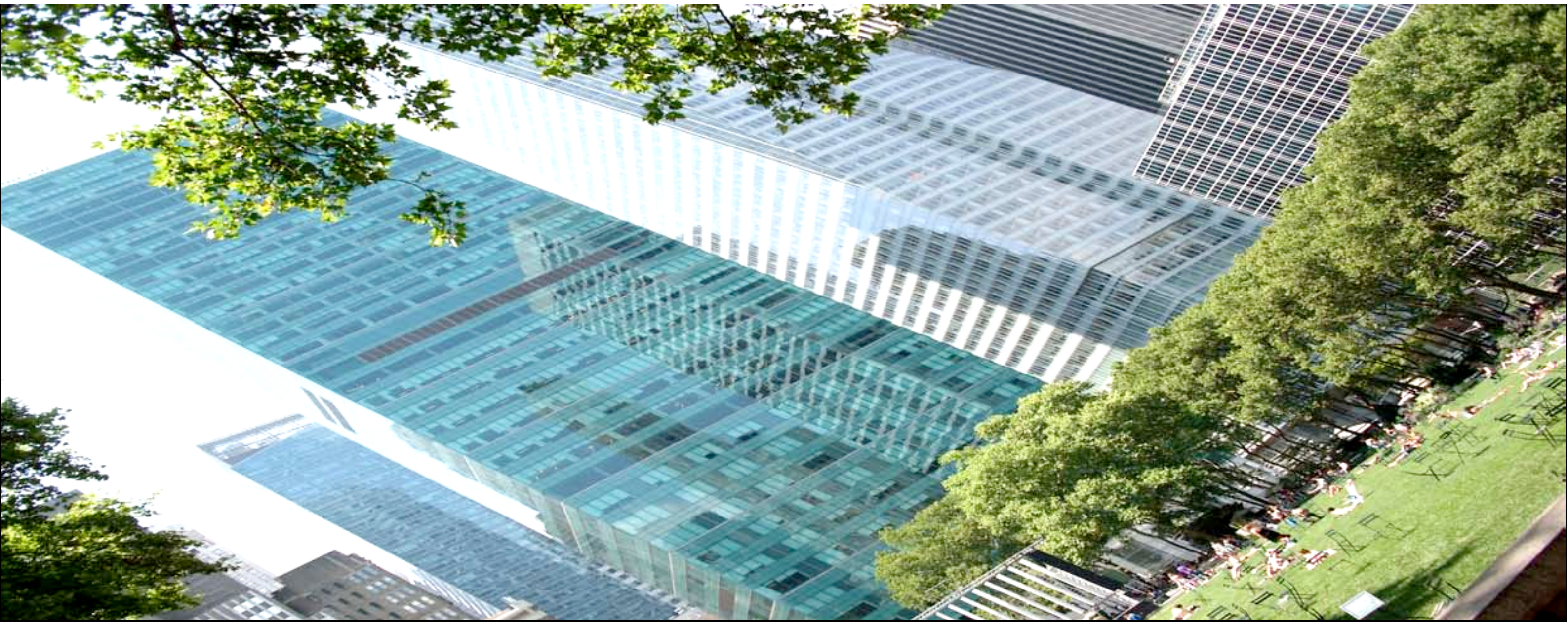
Preface

This report is the culmination of the Workshop in Applied Earth Systems Management for Summer 2011, a core course for the Master of Public Administration in Environmental Science and Policy at Columbia University's School of International and Public Affairs. This report specifically examines and analyzes the New York Solar Industry Development and Jobs Act of 2011 from an environmental perspective. Economic, political, management and social analysis of the bill will be conducted in Fall 2011.



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EXECUTIVE SUMMARY

New York State is the fourth largest energy-consuming state in the U.S. 77% of the state's total energy consumption comes from fossil fuels, which consist of petroleum, natural gas, and coal. The scale of the state's energy consumption further magnifies New York's dependence on fossil fuels. The state's heavy reliance on fossil fuels contribute to environmental and human health problems caused by the extraction and combustion of fossil fuels, as well as global warming.

To reduce the state's consumption of fossil fuels, the New York Solar Industry Development and Jobs Act of 2011 aims to generate 2.5% of New York State's electricity from solar photovoltaic by 2025, which equates to approximately 5000 megawatts (MW). To realize the rapid and sustainable development of the state's solar power industry, the bill proposes the creation of a solar market by mandating the supply and demand of solar energy from electricity generators and suppliers respectively in New York State.

The report presents the findings from our two-fold environmental analysis of the New York Solar Industry Development and Jobs Act of 2011: first, the examination of the environmental problems that the bill seeks to address in relation to New York State's fossil-based energy consumption patterns, followed by the analysis of lifecycle, environmental impacts, and scientific controversies of the bill's proposed solution, solar photovoltaic technologies.

Part I of the report studies the environmental controversies and problems associated with the consumption of fossil fuels. Scientific uncertainties surrounding the cause and effect of fossil fuel related events, such as oil spills and climate change, continue to blur the connection between fossil fuel consumption and its environmental consequences. However, through examining the impacts and by-products generated by oil drilling, hydraulic fracturing, mountaintop removal, and fossil fuel combustion activities, it is clear that their environmental consequences should not be disregarded.

Part II of the report assesses how solar photovoltaic works, as well as the costs and benefits and technical feasibility of solar photovoltaic technologies from an environmental perspective. Solar photovoltaic is found to be a very suitable renewable energy source for New York State due to its energy demand patterns, solar potential, and the flexibility of its electricity infrastructure. While solar photovoltaic is also associated with a small carbon footprint compared to other energy options, toxic by-products and certain emissions generated by its production and disposal processes pose other environmental and human health concerns. Furthermore, controversial debates over solar photovoltaic technologies, including its technological feasibility and cost efficiency, demonstrate the trade-offs associated with the bill's chosen solution.

The report concludes that while the New York Solar Industry Development and Jobs Act of 2011 may not able to comprehensively resolve the environmental problems associated with the extraction and combustion of fossil fuels, it nevertheless drives New York State's energy profile towards becoming a more sustainable one.

INTRODUCTION:
ENERGY CONSUMPTION IN NEW YORK STATE

New York State is the fourth electric largest energy-consuming state in the U.S. – consuming 1,119,091.9 gigawatts-hour (GWh) of energy annually – with its commercial, residential and transportation sectors being the leading energy-consuming sectors.[1] While New York's energy consumption profile mirrors that of many other states, its energy consumption pattern has two salient unique features: low per capita energy consumption due to its infrastructure, and substantial renewable energy sources in its energy mix.

Despite its high-energy consumption rates, New York's per capita energy consumption is the lowest on the continental US. In 2009, New York State accounts for 6.3% (19.3 million) of the country's population[2] but only 4% (1,112,146,100 GWh) of the total primary energy consumption in the US.[3] The State's public transport and home heating systems are among the various factors that contribute to its relatively higher energy efficiency. For instance, as New York households rarely use electricity to heat their homes, they consume 50% less electricity than an average U.S. household.[4]

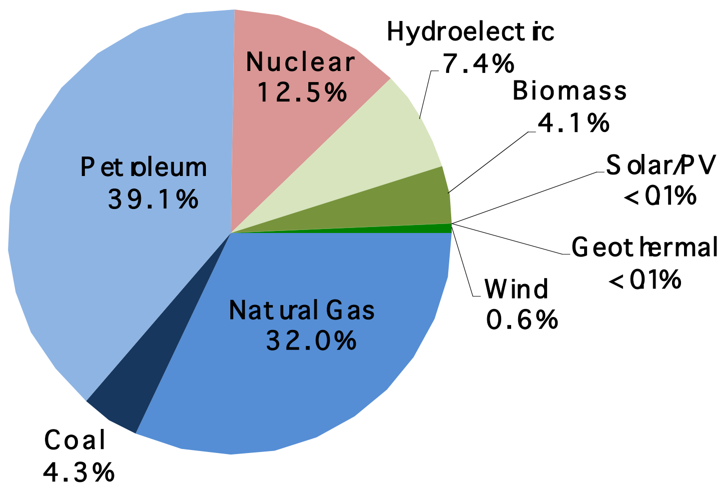

Figure 1: New York State's total energy consumption, 2009

Data source: U.S. Energy Information Administration

Furthermore, unlike many other U.S. states, New York does not depend on one single fuel to generate electricity; it produces electricity from a variety of sources. In 2009, 27% of the State's electricity was generated from nuclear, 26% from natural gas, 18% from hydro, 16% from net electricity imports, 8% from coal, 2% from petroleum, and 3% from other sources (see Figure 13). Conversely, 45%, 23%, and 20% of power generation in the U.S. depends on coal, natural gas, and nuclear, respectively.[5] The mix of electricity sources renders New York State a more flexible power grid as well as a relatively higher resilience to price fluctuations in the energy markets. New York State is also regarded as a state with considerable potential in the realm of renewable energy. New York is currently the largest hydroelectric generator among states east of the Rocky Mountains, as well as one of the top generators of power from municipal solid waste and landfill gas in the U.S.[6]

Notwithstanding its relatively diverse energy profile, as seen in Figure 1, more than 77% of New York's total energy consumption is still fossil fuel based.[7] Such a reliance on fossil fuels poses significant environmental implications. The extraction and combustion of petroleum, natural gas, and coal damage ecosystems, pollute air and water, and contribute to global warming. Recognizing problems caused by its fossil fuel consumption, New York State strives to modify its energy portfolio through various initiatives, such as the renewable portfolio standard adopted by New York Public Service Commission in September 2004, which requires 30% of the State's electricity to be generated from renewable sources by 2015.[8]

The purpose of this report is to examine the effectiveness of the New York Solar Industry Development and Jobs Act of 2011 in addressing environmental problems associated with New York's current energy consumption. Specifically, the report will examine the bill in question in two main sections: the first section explores issues associated with fossil-based energy consumption, including its controversies; the second section assesses the pros and cons of solar photovoltaic (PV) technologies, which is the bill's proposed solution, as well as the compatibility of solar PV systems with New York State's existing energy infrastructure.

Part I: Environmental Problems the Bill Addresses

The Science Behind New York's Energy Consumption

Fossil fuel extraction and combustion processes impact the environment mainly in three ways: they cause ecological damage, pollute the air and water, and induce climate change. To fully appreciate how reliance on fossil fuels causes these environmental problems, one needs to scrutinize the fossil-fuel extraction and combustion processes.

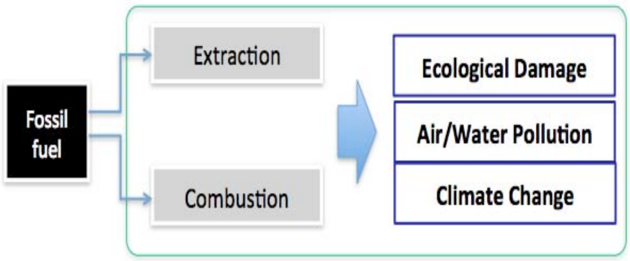

Figure 2: Concept map for environmental problems caused by fossil-based energy use

Extraction of Petroleum

Extraction, which entails drilling, pumping, and transporting petroleum from onshore and offshore underground oil fields runs the risk of accidents such as leakage and major spills. These accidents release oil and when the leaks include refined oil in the form of gasoline includes the release of toxins, such as benzene, into the immediate environment. Leaks of unrefined oil, for example, in the case of offshore oil spill, once oil enters the aquatic system, it creates a barrier that prevents oxygen exchange between surface water and atmosphere. This lack of oxygen exchange, threatens aquatic life and surrounding ecosystems.

The BP Deep-water Horizon oilrig explosion in April 2010 demonstrates the environmental consequences of oil extraction. The explosion killed 11 people and dumped millions of barrels of crude oil into the Gulf of Mexico.[9] This spill polluted the Gulf's aquatic ecosystems, which had negative socioeconomic consequences for the local fishing industry because the fishermen's harvests could not be sold for consumption.[10] The BP Deepwater Horizon event was not the first and only such event. Following the Exxon Valdez spill in 1989, the EPA acknowledged oil spill's threat to the safety of the environment and society and issued a statement in a report to the President, declaring that the nation must recognize that technology and human preparation can only reduce the chance of oil spills but cannot fully prevent them, proving that oil consumption will always remain an environmental threat.[11]

Extraction of Natural Gas

Hydraulic fracturing (also known as "hydrofracking") is one of the main methods used to extract natural gas today; about 90% of the natural gas wells in the U.S. deploy hydraulic fracturing to enhance gas recovery.[12] This method of natural gas extraction disrupts the environment by fracturing the lithosphere and introducing toxins into the subsurface of the Earth, including aquifers.

To extract natural gas through hydrofracking, fluids are pumped deep into the subsurface to propagate a fracture in the rock layers, thereby forcing natural gas bubbles to the surface. The fluids deployed are a mixture of water and

750 chemical compounds, including methanol, lead and benzene. A report from the US House of Representatives Committee on Energy and Commerce disclosed that some of the chemicals used in hydrofracking fluids are regulated under the Safe Drinking Water Act for their health risks.[13] Natural gas extraction via hydrofracking therefore increases the risks of these toxins seeping into the environment, compromising the integrity of both soils and groundwater, and ultimately, human heath. The devastating side effects associated with these chemical toxins include adverse reproduction and neurological impairments and the possibility of cancer.[14] Furthermore, hydrofracking also requires large amounts of water to pressurize the natural gas, which is an unsustainable use of water.[15]

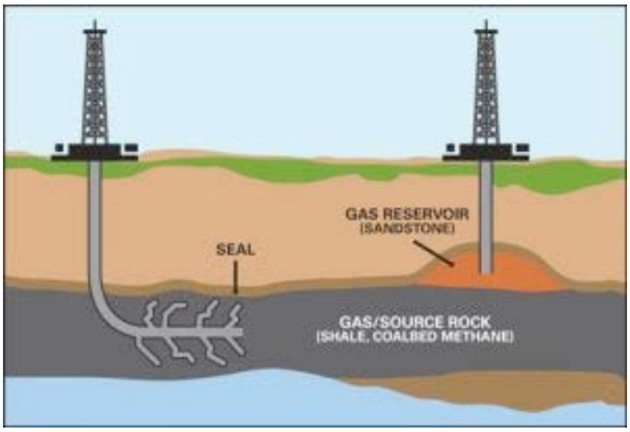

Figure 4: Diagram of hydraulic fracturing processes
Image source: New York Communities for Change

Extraction of Coal

The mining of coal, namely via the mountaintop removal method, drastically alters the topography of the region and deposits large amounts of debris and particles into the atmosphere and hydrosphere. When utilizing the mountaintop removal technique, miners access coal by blowing up a mountain's top, which destroys wildlife habitats and vegetation. Furthermore, the redesign of landscape enables acidic water from acid mines drainage, as well as other mining by-products such as particulates, to easily seep into waterways and aquifers through run-off. Harmful particulates like carbon monoxide and hydrogen sulfide gas are also produced during surface coal mining process, threatening human health.[16]

Figure 3: Change in landscape induced by mountaintop removal practices in Kentucky.
Image source: Indian Country Today Media Network

Combustion of Fossil Fuels

The combustion of fossil fuels emits a host of undesirable compounds, including greenhouse gases (GHG), nitrogen oxides, sulfur oxides, and mercury, into the environment and cause environmental and human health concerns.

Nitrogen oxides released from fossil fuel combustion reacts with ammonia, water vapor and other small particulate compounds in the air to form smog, which is made up of small particles. Apart from impairing visibility and causing eye and nose irritation, small particles from smog penetrate deep into the sensitive parts of the lungs and can cause respiratory diseases such as asthma, respiratory diseases, and lung cancer.[17] When nitrogen oxides and sulfur dioxide emissions react with water molecules in the atmosphere, acidic precipitation is created. Acid rain acidifies water bodies and damages vegetation and sensitive forest soils. Acid rain also accelerates the decay of building materials and paints.

Mercury, another byproduct generated by fossil fuel combustion, is a neurotoxin. It damages the functions of the brain and causes other neurological problems.[18] As mercury bio-accumulate in living organisms, this poisonous substance can find its way into humans when they ingest contaminated aquatic organisms or water. Coal fired electric plants are known to account for approximately 13-25% of the atmospheric mercury found in the environment.[19]

Figure 5: Smog in Los Angeles
Image source: Front Page Magazine

Climate Change

The emission of carbon dioxide from fossil fuel combustion further reinforces the greenhouse effect, which causes global warming. The greenhouse effect is the process by which the absorption and emission of infrared radiation by greenhouse gases in the atmosphere traps heat in the planet's lower atmosphere and surface. While greenhouse effect occurs naturally, anthropogenic activities since the Industrial Revolution have greatly increased the amount of greenhouse gases in the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) has confirmed that "warming of the climate system is unequivocal", and GHG emission concentrations "have increased markedly as a result of human activities since 1750… are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture."[20]

The impacts of climate change include biodiversity loss, extreme weather patterns, and rise in sea levels due to the melting of glaciers. An increase of extreme weather and climatic patterns will affect sensitive ecosystems such as tundra, mangroves, coral reefs, and high-altitude habitats. The degradation of these ecosystems can ultimately lead to extinction of certain plant and animal species. Rising sea levels and extreme weather conditions, such as the growing intensity of hurricanes, are likely to occur at higher frequency and greater intensity.

Environmental Controversies Associated with New York's Energy Consumption

Notwithstanding these evident adverse environmental impacts associated with fossil-fuel use, there remains strong skepticism over the severity, and even the validity of these observed phenomena or impacts. For instance, when commenting on the BP oil spill in April 2010, Tony Hayward, former CEO of BP, highlighted the uncertain effects of petroleum in the oceans by stating "the Gulf of Mexico is a very big ocean. The amount of volume of oil and dispersant we are putting into it is tiny in relation to the total water volume."[21] The issue of climate change is not immune to scientific uncertainties either. Going against the unequivocal view of the global scientific community, some still claim that climate change is a natural phenomenon (not due to human activities) or that the Earth is not warming. Some have even gone as far as discrediting the scientists, and their observations and models. This skepticism supported by certain special interest groups could hinder the transition towards sustainable energy.

PART II:
ENVIRONMENTAL ANALYSIS OF THE PROPOSED SOLUTION

The Proposed Solution: The New York Solar Industry Development and Jobs Act of 2011

To address the environmental and human health concerns associated with fossil fuel consumption, New York State needs to progressively reduce its reliance on fossil fuels as its main energy source. The New York Solar Industry Development and Jobs Act of 2011 proposes to achieve this goal through market mechanism – the creation of a diverse and competitive solar energy market in New York State. The legislation is designed to stimulate the growth of the solar energy industry in New York State, and thereby increase the generation of renewable energy, create jobs, reduce the long-term costs of electricity generation, and make the existing electricity delivering grid more reliable.

A Market-Based Solution

The legislation aims to develop the State's solar industry by creating a solar market mechanism within New York State. It requires New York State electricity generators of different sizes to supply a determined percentage of solar power specifically generated with solar PV technologies. The legislation simultaneously obligates electricity suppliers in New York State to purchase a determined amount of Solar Renewable Energy Credits (SRECs), which will account for a certain percentage of the suppliers' total electric sales. A SREC equates to the green benefits that come from producing and using one megawatt-hour (MWh) of solar powered electricity instead of one MWh of energy produced through fossil fuel combustion. [22] The percentage of SRECs purchased by electricity suppliers will increase annually from 2013 until 2025. By 2025, 2.5% (5 GW) of New York State's electricity generation will derive from solar PV.[23]

Mandated Market Demand from Electricity Suppliers

As outlined in the legislation, the demand for solar power will come from electricity suppliers in New York State, which include private retail electric suppliers, the New York Power Authority and the Long Island Power Authority. The demand for solar power will be represented through the procurement of SRECs. Electricity suppliers listed above are required to purchase a certain amount of SRECs proportional to their total annual electricity sales.

The bill requires that retail electric suppliers, starting in 2013, purchase SRECs amounting to 0.15% of its total electric sales; this percentage will increase annually to 3.00% in 2025 except when a supplier's annual expenditures on SRECs exceed 1.5% of its annual retail electricity revenues. The legislation allows complying suppliers to bill their customers a flat rate of $0.39 per month to compensate for the supplier's SREC expenses.

If a retail electric supplier fails to meet their SREC obligation, they will make Solar Alternative Compliance Payments. These compliance payments are priced higher than SRECs to encourage retailers to purchase solar credits instead of making the alternative payment. All revenue from the compliance payments will be invested in the solar industry to increase the future supply of SRECs.

The Power Authority of the State of New York and the Long Island Power Authority are also subjected to similar obligations under this legislation as its retail electric supplier counterparts. A key difference, however, is that these entities' annual SREC purchasing obligation will be initially set at 0.33% of their total annual electricity sales, which is double the required amount for the retail suppliers. The SREC purchasing requirements for The Power Authority of the State of New York and the Long Island Power Authority will increase annually to 3.5% in 2025. Additionally, these entities are not allowed to meet their annual percentage obligations by making Solar Alternative Compliance Payments.

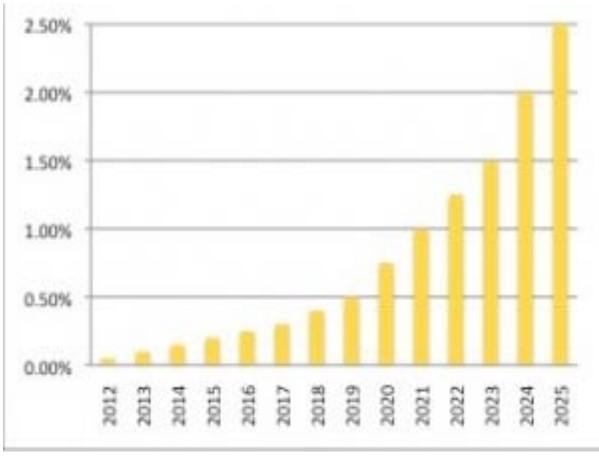

Figure 6: Roadmap for incremental, annual SRECs procurement by retail electric suppliers in New York State from 2012 to 2025
Image source: Vote Solar

Mandated Market Supply from Electricity Generators

On the supply end, the New York Solar Industry Development and Jobs Act aims to create a diverse, competitive solar power market. To do so, the legislation demands the solar power for New York State be provided by electricity generators of all sizes. As stipulated by the bill, electricity suppliers will acquire 20% of their SRECs from small solar power generators, whose capacity is less than 50kW. The scale of small solar generators can range from individuals who install PV cells on the roof of their house to small businesses that generate less than 50kW of electricity with solar PV technology. Electricity suppliers will then procure 30% of their SRECs from mid-sized solar generators, such as farms that install PV cells on different structures, whose capacity exceeds 50 kW. The legislation intends to stimulate demand for solar at these different scales to ensure broad investment and participation in the state's solar industry.

The bill also requires electricity suppliers to produce separate plans for purchasing SRECs from different size generators. Once established, the solar purchasing agreements between electricity suppliers and solar power generators will last fifteen years. To ensure the competitiveness of small solar generators in New York State, electricity suppliers and distributors will pay a predetermined tariff to small-scale solar generators. This tariff aims to dampen initial solar-related costs, including the purchase and installation of solar PV equipment, incurred by small solar generators. The State will determine the tariff rate based on considerations for solar industry expenditure differences between varying market segments, the cost of solar equipment, and existing federal incentives that favor small solar electricity generators.

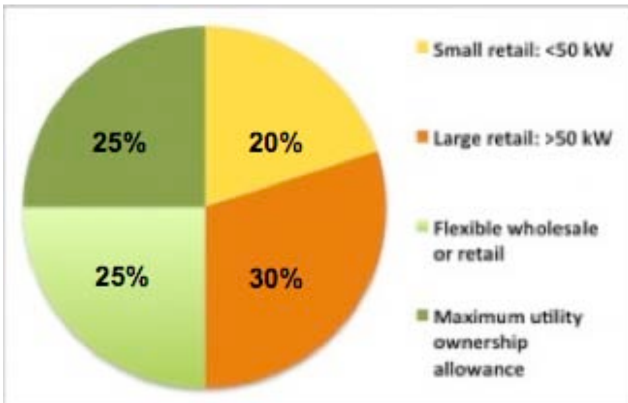

Figure 7: Breakdown of solar power produced by electricity generators of different sizes, as proposed by the NY Solar Industry Development and Jobs Act of 2011
Image source: Vote Solar

Other Economic Benefits

With the legislation jumpstarting the State's solar industry and market, advocates estimate that more than 22,000 direct and induced jobs will be generated and approximately $20 billion dollars will be generated from the creation of a solar market in New York State.[24] The legislation also requires that all employees contracted through the solar purchase agreements to install solar equipment be paid a fair and standard industry wage, which creates an additional attractive element for New York State's solar electricity industry.

The Science behind the Proposed Solution

The New York Solar Industry Development and Jobs Act specifies that solar power needs to be generated utilizing solar PV and not other solar-related technologies. It is therefore essential to understand how solar PV technologies work to not only gain insights to the reasoning behind the bill's requirement, but also to be able to analyze the costs and benefits of the bill's proposed solution.

Types of Solar PV Technologies

The PV effect is the direct conversion of solar energy into electricity at the atomic level.[25] Substances that have positive and negative di-terminals, such as silicon and other semi-conductors, absorb light energy that energizes the electrons; the absorbed sunlight causes the electrons to move between the positive and negative ends, resulting in the generation of electricity that can be used directly.[26] A solar PV cell works in the same fashion.[27]

There are currently two types of solar PV cells: silicon-based cells, which are the most commonly used, and thin-film cells, which primarily consist of either copper indium gallium (di) selenide (CIGS) or cadmium telluride (CdTe).[28] Thin-film PV cells are becoming important sources of solar PV, as they are lighter, more flexible and adaptable compared to the thicker more ridged silicon cells.[29]

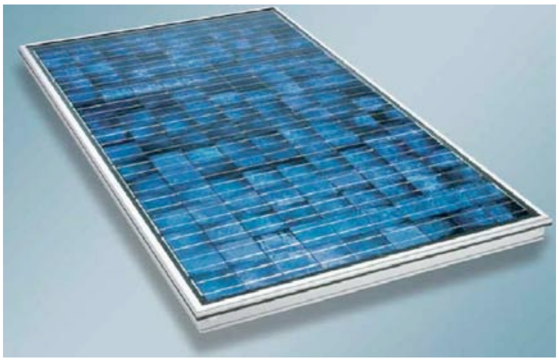

Figure 8: Silicon-based PV cell
Image source: Sky Flair, Ltd.

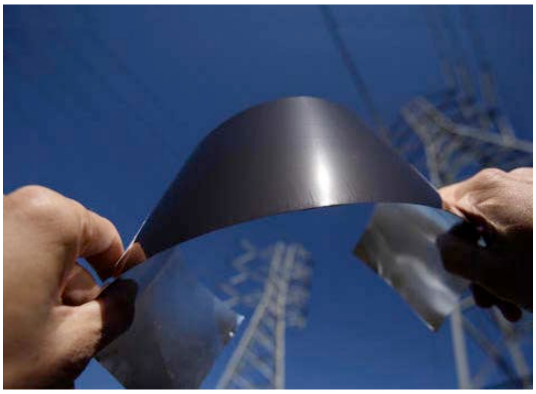

Figure 9: Thin-film PV cell
Image source: Thomas Net

Lifecycle of Solar PV Panels

PV cells are produced by purifying and processing a semi-conductor such as polysilicon, which is processed from quartz (sand).[30] Polysilicon is mixed with trace amounts of boron and phosphorous to create positively and negatively charged semiconductor material. [31] A block of polycrystalline silicon is then sliced into wafers, cleaned and placed in a phosphorus diffusion furnace to create a thin negatively charged layer.[32] Each cell is electrically tested, sorted based on its current output, and electrically connected to other cells to form cell circuits for assembly in PV modules.[33] The production of PV cells is the most energy intensive stage in its lifecycle, accounting for an energy usage of about 1,060 kWh/m^2 per PV panel.[34]

PV cell production generally consumes mineral materials such as aluminum, copper, glass, nickel, steel, and zinc, which are largely distributed throughout the Earth's crust. Silica, presently the primary raw material used for PV cell production, is readily available in abundant supplies. Nevertheless, minerals such as cadmium, gallium, germanium, indium, selenium, and tellurium that are used in thin-film photovoltaic cells are less abundant, and are valued for their special properties without being incorporated with other materials.[35]

PV cells have a lifespan of 20-25 years on average; the actual panels experience wear and tear along with physical decay after approximately 10- 20 years. [36] The PV panels are then decommissioned once they reach the end of their lifespan. The discharge of silicon based PV cells poses infinitesimal environmental concerns, and can be considered as construction waste; however, this is not the case with the disposal of other PV technologies, such as the thin film cells. Raw materials needed for thin film cells have intrinsic value, making their disposal cost ineffective and a cause of environmental and health concerns.[37]

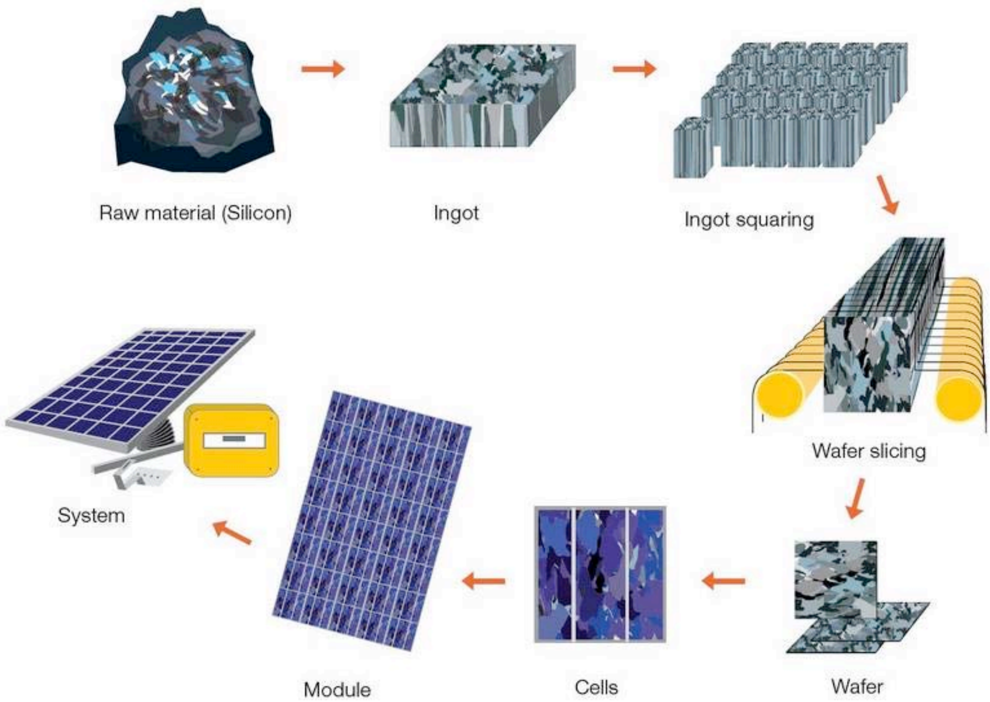

Figure 10: Production cycle of solar PV cells
Image source: European Photovoltaic Industry Association (EPIA)

Solar PV in New York State

With an understanding of the PV technologies established, it is essential to examine how PV technologies will work within the context of New York State to assess the feasibility of the proposed solution.

Nature of NY State's Energy Demand

Blackouts during the summer months can disrupt New York City's electricity supply and compromise the reliability of the state's electric grid. General trends in electricity demand patterns across the U.S. show that annual peak demand is driven by air conditioning loads during the summer time, especially around 3 to 4 pm local time.[38] Sudden peak electricity demand during the day overwhelms the entire electric grid and creates a blackout. The August 2003 blackout in New York was the most severe blackout in North American history, affecting an estimated 55 million people in the northeastern U.S. and eastern Canada.[39] As shown in Figure 13, 27% of New York's electricity is generated by nuclear power. During the blackout in August 2003, the lack of electricity forced all four of New York's nuclear power plants offline for safety reasons. Turning off these nuclear plants caused almost the entire State to lose power during the incident.[40]

To resolve the problems of blackouts, solar PV is a logical power source for New York. While solar energy is known for its intermittent nature, which poses storage concerns at a high penetration level,[41] it is indeed this intermittent nature that makes solar PV suitable for New York. As New York's electricity demand pattern corresponds to that of the PV power output, New York would be able to benefit from solar PV's maximum output during its highest electricity demand hours.

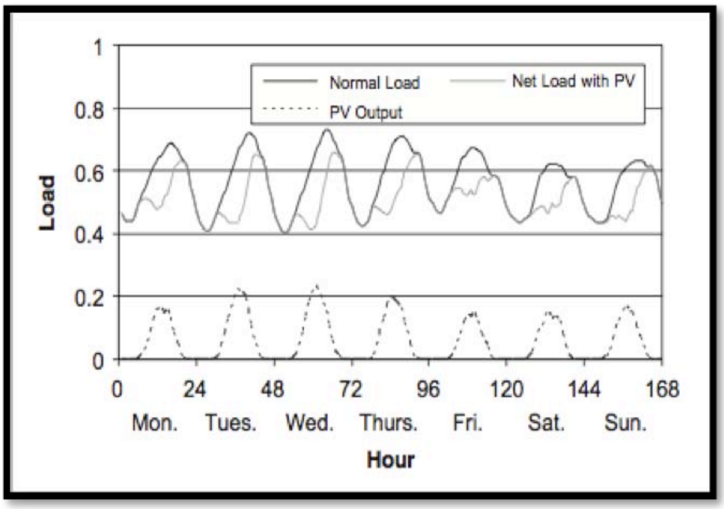

Figure 11: PV output and normal electricity loads of a typical summer week
Image source: "Evaluating the limits of solar photovoltaics (PV) in traditional electric power systems," *Energy Policy*

NY State's Solar Potential

New York State possesses enough solar potential to fulfill the requirements proposed by the legislation. According to the National Renewable Energy Laboratory, New York State has a PV solar potential of approximately 4 to 5 kWh/m^2 per day.[42] Furthermore, the recent New York City solar map released by The NYC Solar America City Partnership found that the square footage of rooftops in New York City suitable for PV module installations is 615 million square feet; this translates to 5.8 GW at peak production in New York City alone, accounting for 40% of the city's electricity demands at peak times.[43] This is well beyond the 5 GW required by the bill's initial solar PV output for the entire state. New York State's solar potential is further illustrated in Figure 12, where it is shown to have more solar potential than Germany, one of the leaders in PV energy in the world.

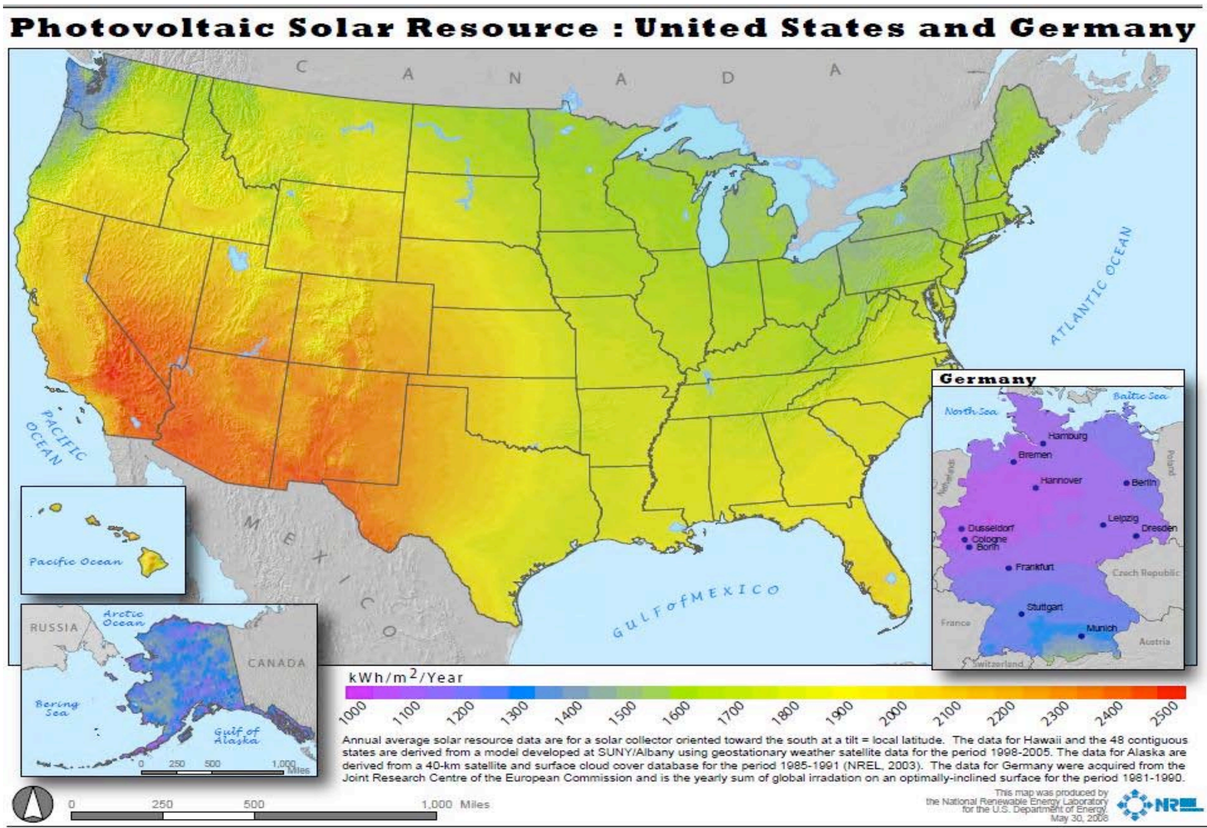

Figure 12: Comparison of solar potential between Germany and the U.S.
Image source: Madville Times

Flexibility of NY State's Electric grid

In addition to having sufficient solar potential to realize the vision of the legislation, New York State's electric grid is also favorable to the introduction of PV as a substantial source of energy. New York State's own energy plan estimates that out of "distributed" (non-utility owned) renewable technologies; solar PV has the highest technical potential.[44]

The flexibility of the existing grid, which is determined by its mix of energy sources, is the largest factor affecting the success of PV integration. As shown in Figure 13, New York State generates electricity utilizing a combination of energy sources, which enables the state to have a relatively flexible grid compared to other states that heavily rely on coal and nuclear to generate electricity. Traditional energy plants are restrained in their ability to scale back output for short periods of time; they need to produce electricity loads above a certain level to avoid significant economic penalties associated with shutting down the plants completely. Nuclear and coal plants are especially known to have such constraints.[45] For a grid like New York's, which uses significant percentages of natural gas and hydropower, it is therefore cheaper to "scale back" when solar PV production is highest and thus reduce storage needs.[46]

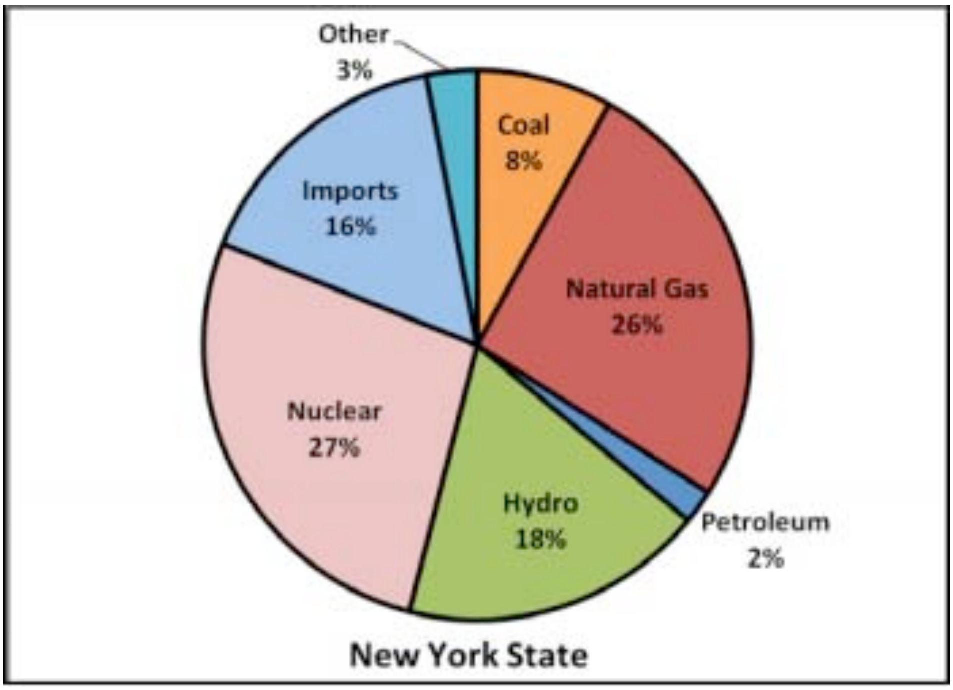

Figure 13: Electricity generation by fuel type in New York State, 2009
Image source: New York State Energy Research and Development Authority (NYSERDA)

Analysis of the Proposed Solution

While New York's energy demand trends, electricity grid, and solar potential enable solar PV to be a favorable renewable energy source in the state, there are still financial, technical and environmental factors inhibiting the large-scale use of this technology. As this report assesses the bill from an environmental perspective, this section will place more emphasis on the environmental pros and cons associated with the proposed solution.

Financial Considerations for Solar PV

Solar PV technologies are not the cheapest renewable energy option currently available. As shown in Table 1, other renewable energy sources, such as wind and hydroelectric power, all cost less to produce per kW/hour. Controversy over the role of subsidies has also led others to argue that the current cost of solar PV and the solar price's decreasing trajectory was due to subsidy policy. Of course, fossil fuels have long received a variety of tax expenditures that have kept its price subsided as well.

The bill also places a financial and regulatory burden on New York State's public and private electricity suppliers. The regulatory provisions of the Act command the purchase of a set and increasing amount of SRECs, and the management and oversight of the Solar Alternative Compliance Payments will serve to keep them higher than the cost of purchasing solar PV.

Nevertheless, it is believed that increasing investments in PV will lead to decreasing in costs of solar PV systems and electricity generation; higher efficiency PV modules will reduce system costs.[47] Compared to current coal-fired plants' efficiency of 33%, most solar PV modules have approximately a 9%–12% efficiency range, and commercial thin-film PV modules have reported a 10.1% stabilized efficiency. Meanwhile, laboratory tests have reported efficiency of up to 41% as long as investments in solar continues to grow.[48] While coal's efficiency is achieved at a very high environmental cost owing to numerous GHG emissions, solar PV technologies are not subjected to these environmental concerns.[49] Proponents of solar PV also argue that because PV power is generated on-site, the technology is indeed cost-efficient since distribution losses are avoided. For instance, companies such as General Electric, convinced of the medium and long-term potential of solar PV generation, have also openly supported the Act because it rewards their investments in PV technology.

Technology	Cost kW/h	Water use kg/kWh	Impacts
Photovoltaic	$0.24	10	Toxins - minor
Wind	$0.07	1	Visual- minor
Hydro	$0.07	36	Ag/River displacement
Geothermal	$0.048	78	Seismic activity, pollution
Gas	$0.05	12-300	Major
Coal	$0.042	78	Major

Table 1: Comparison of costs, water resource usage, and environmental impacts of renewable energy sources
Data source: "Assessment of sustainability indicators for renewable energy technologies"
Renewable and Sustainable Energy Reviews

Technical Considerations for Solar PV

Presently, PV's largest technical disadvantage is the storage considerations it poses. While the level of PV energy proposed (2.5% of the State's electricity sales by 2025) will not represent storage concerns due to the flexibility of the existing grid, current technologies do not meet the needs that will occur at higher levels (20-50% of the State's generated electricity) in the future. Battery technologies, hydro storage, and Compressed Air Energy Storage (CAES) are examples of the storage technologies that need to be improved, especially to compensate for New York's lower levels of insolation compared to other states.[50] This will only occur if innovation, driven by market investment in solar PV, is stimulated by this Act.

Besides storage concerns, there are also various technological feasibility issues associated with solar PV technologies. First, the bill falls short of addressing the much needed improvements in infrastructure to effectively integrate solar energy into New York's electricity grid system. Second, the installations of solar PV panels are not always easy to design due to the movement of the sun throughout the day; the appropriate mounting direction of PV panels will need to be determined somehow at the time of installation. There are also seasonal variations in PV production. While solar PV is expected to fit well with the general summertime electricity demand patterns at low penetration levels, it remains unclear how PV output will interact with the rest of the State's electricity system during non-summer seasons and when PV achieves growing penetration levels.[51] Decline in PV cell electricity generation capacity when the cells are overheated and intermittency due to weather changes have also been controversial issues of technological viability.[52]

Conversely, PV technologies enjoy the technical benefit no other renewable energy source does: the capacity of being multi-scalable. Solar PV is the only renewable energy source that can be reliably integrated into an existing grid from installations of any size.

Environmental Considerations for Solar PV

Solar PV's main environmental benefit is its small carbon footprint in comparison to other electricity generation technologies (see Figure 14). PV cells' carbon dioxide emissions are associated with its production, which is the most carbon-intensive phase of their lifecycle; they do not emit any carbon dioxide when generating electricity. Comparatively, PV generates considerably less life-cycle emissions per GWh than most fossil fuel based electricity generation technologies; approximately 89% of carbon dioxide emissions attributed to fossil-based electricity generation could be prevented through solar PV electricity generation.[53] Moreover, PV cells' energy payback time is projected to be 8.3 years, which is a relatively short time period compared to their average lifespan of 20-25 year.[54] By generating 2.5% of New York's electricity with solar PV, fossil-related GHG and pollutant emissions will be reduced, which will be discussed in details in the following section.

Despite the benefits discussed above, there are several heath, environmental and safety concerns associated with the byproducts of PV cell production and decommission. A number of toxic byproducts are generated during both the production of silicon-based and thin film PV cells. Crystalline silica and fume silica generated from producing silicon-based cells can cause scarring within lung tissues if inhaled. Cadmium products generated from thin film PV cell production are suspected carcinogens. In addition to various toxic, flammable, and explosive byproducts, PV cell production also creates harmful emissions, including carbon dioxide (CO_2), sulfur dioxide (SO_2), and carbon chloride gas, which are all greenhouse gases, and silicon dioxide (SiO_2), which can contribute to the development of bronchitis and lung cancer over time.[55, 56, 57] Furthermore, nitrogen trifluoride (NF_3) used in cleaning PV reactors during the production process is also categorized as a potent GHG by the IPCC, with a global warming potential 12,300 times greater than that of CO_2 compared over the duration of 20 years.[58, 59] NF_3 can also cause asphyxiation especially from the toxic fumes emitted when burned or reacted.

The decommissioning and recycling of solar panels can also cause health and environmental risks if the materials are not disposed of properly. Due to the time lapse of 20-25 years between PV production and waste generation, it is estimated that by 2020, there will be 35,000 tons of PV related waste.[60] It is thus crucial to identify effective disposal and recycling systems for heavy metals used in PV cells before our current round of PV investments become solar wastes. For instance, the assembling of cells currently employs the use of solders, which may contain lead; lead is also used in PV wire coating, posing potential concerns if protocols on safe handling are not followed.[61] While the lead used in solar PV wiring is not specific to PV production and can be replaced by less toxic materials, safe recycling efforts of the materials used in PV modules will be imperative as PV scales up as envisaged in the bill. It is important to note that the bill does not include any plan for disposal of PV cells at the end of their lifecycle; as PV capacity expands and volume of related waste increases over time, PV disposal and recycling is likely to become a larger issue.

To decrease the negative impacts associated with PV disposal and recycling, thin film PV cells, PV paints and other technological innovations in PV module components are being developed to increase solar PV's applicability and efficiency, as well as to reduce production costs.[62] Several research institutions are also exploring organic raw material, such as carbon-based compounds, to replace silicon and even thin film based cells. These compounds provide a potential solution for environmental concerns, and are lighter and more flexible.[63]

Lastly, the installation of 5GW solar PV generating capacity in New York State will have a physical footprint. This has been calculated to be lower in New York than in many other states because of the density of the state's energy allocation, as well as the availability of low-impact sites like brownfields and urban roofs.[64]

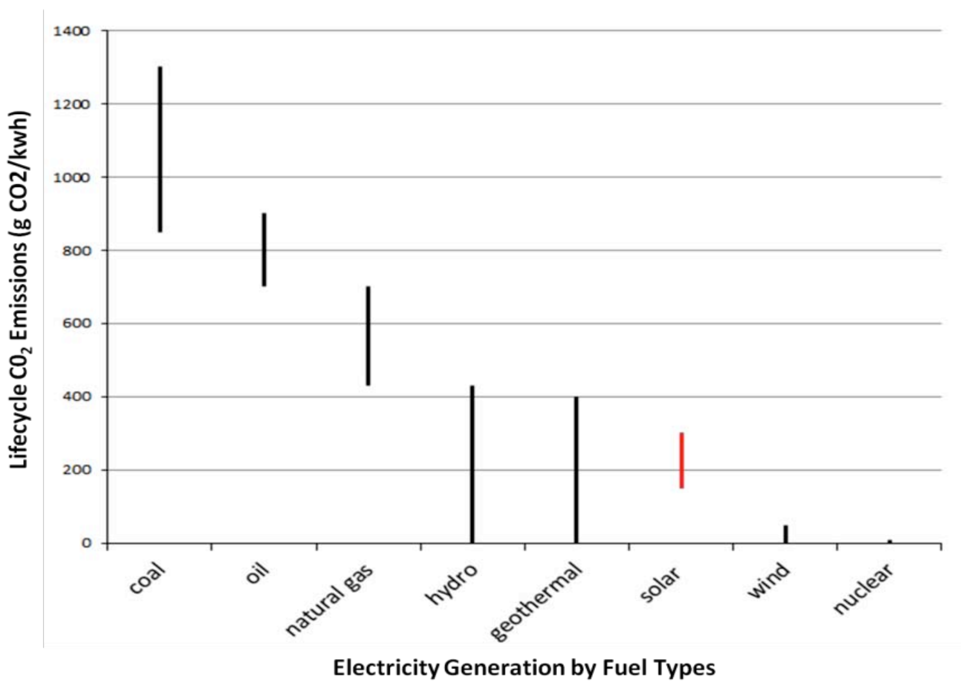

Figure 14: Lifecycle CO_2 emissions from different electricity generation technologies (unit: g CO_2/kwh)
Image source: Stanford Alumni Association

Measuring Success of the Proposed Solution

To measure the success of the bill's proposed solution in terms of environmental impacts, one should consider at the very least the extent that fossil-fuel emissions and ecological damage are reduced, and the net environmental impact associated with the lifecycle of solar PV systems.

Measuring Reduction in Fossil-Fuel Emissions – GHG and Air Pollutants

The 2007 State Greenhouse Emissions Inventory and Forecasts developed by the NYSERDA estimated that the generation of 57,187 GWh using coal, petroleum and natural gas is responsible for 54.23 million tons of GHG emissions. [65] Solar PV electricity generation target of 5,000 MW installed capacity, as set out in the bill for 2025, equates to a reduction of around 5.26 million tons of GHG emissions (estimations are based on 4 hours of electricity generation of the installed solar capacities and past GHG emissions in CO_2 equivalent.). In addition to GHGs emissions, one should also monitor the amount of relevant air pollutants released into the biosphere as shown in Table 2, including, nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide, and particulate matter (PM).

One could look to the U.S. Environmental Protection Agency (EPA), NYSERDA, as well as New York State's Department of Environmental Conservation (NYSDC) for data relating to these emission indicators. EPA is the institution responsible for estimating the national GHG emissions as well as providing guidance, tools and emissions factors for the preparation of GHG inventories at the state and local level. [66] Moreover, EPA provides emission data of several chemicals and gases regulated by the EPA and state and local environmental agencies through the National Emissions Inventories. [67] At the state level, the NYSERDA is responsible for elaborating the State's GHG inventories, while the NYSDEC is liable in monitoring other pollutant emissions regulated by the Clean Air Act.[68]

	Amount of Air Pollutants **Emitted** due to New York State Electricity Generation in 2005 (tons)	Amount of Air Pollutants **Avoided** by Generating 2.5% of New York State Electricity using Solar PV in 2025 (tons)
Nitrogen oxides (NOx)	64,635	6,169
Sulfur oxides (SOx)	191,262	18,225
Carbon monoxide (CO)	10,456	998
Fine particulate matter (PM2.5)	11,871	1,133
Particulate matter up to 10 micrometer in size (PM10)	16,395	1,565

Table 2: The amount of pollutant emissions emitted as a result of New York State's electricity generation in 2005 and could be avoided by generating 2.5% of New York State's electricity using solar PV in 2025.
Data source: NYSERDA and U.S. Energy Information Administration

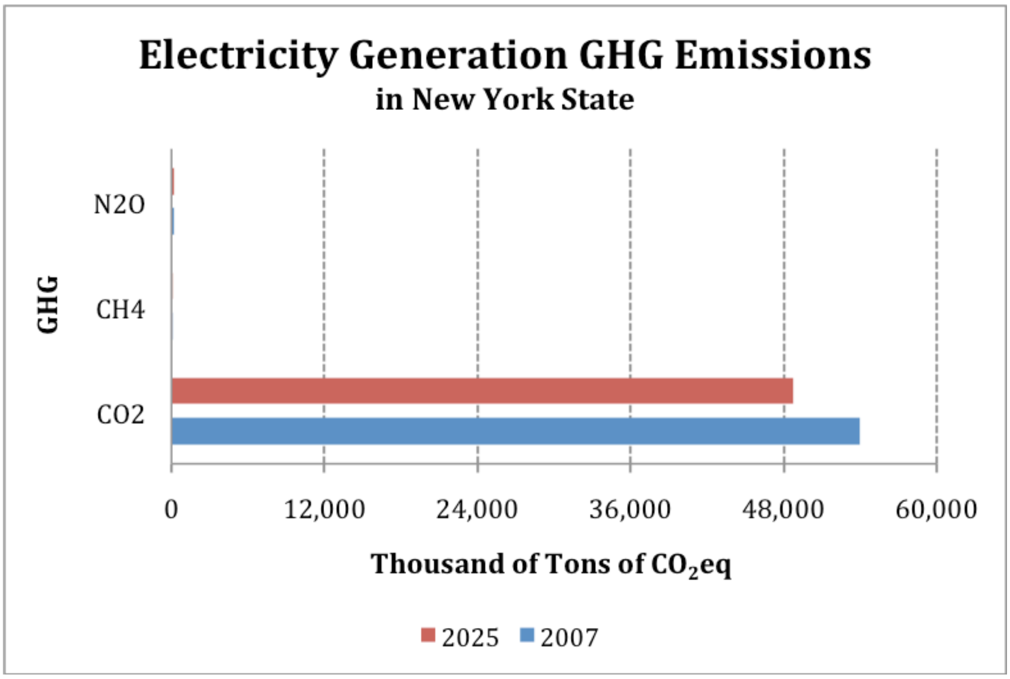

Figure 15: Comparison of greenhouse gas emissions associated with electricity generation in 2007 and 2025, accounting the passage of the bill.

Data source: NYSERDA, Vote Solar, and U.S. Energy Information Administration

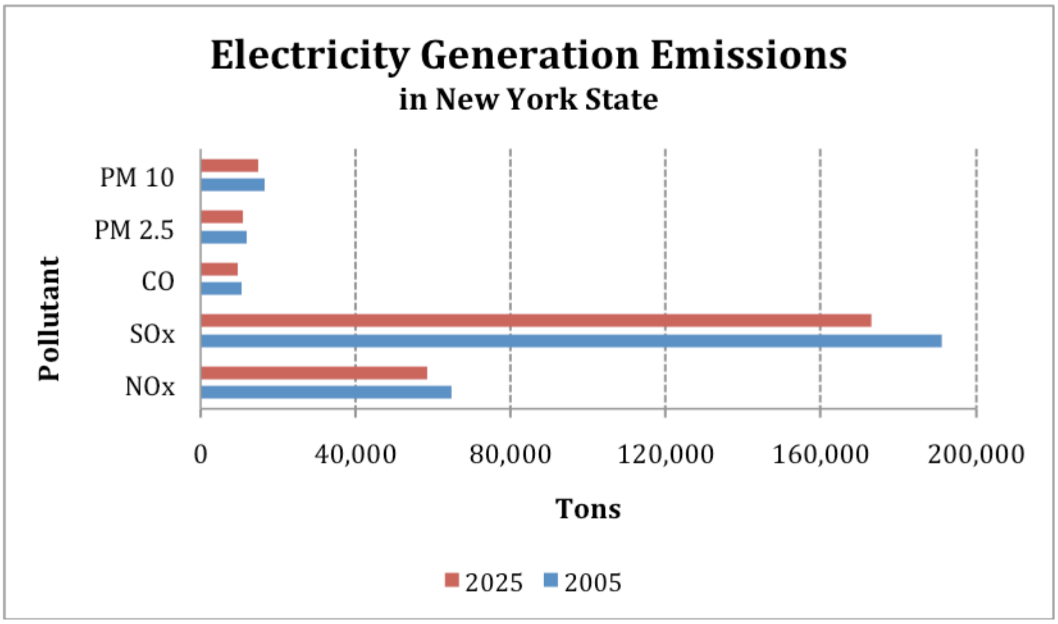

Figure 16: Comparison of pollutant emissions associated with electricity generation in 2007 and 2025, accounting the passage of the bill.

Data source: U.S. EPA, Vote Solar, and U.S. Energy Information Administration

Measuring Reduction in Ecological Damage

Measuring the reduction in ecological damage attributing to the bill is however less straightforward and perhaps, more challenging, primarily due to lack of systemized indicators. For ecological damage caused by fossil fuel *extraction*, we could derive indicators from several federal reports. Recognizing the impacts extractive activities have on ecosystems, the National Environmental Policy Act (NEPA) requires federal agencies to incorporate environmental consideration in their planning and decision-making. Federal agencies are thus obligated to submit Environmental Assessments and Environmental Impact Statements, where environmental footprints of different activities are documented.[69] Moreover, the Superfund program, established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, is also responsible for damage assessment and registration of affected areas on the National Priority List.[70] Examples of ecological damage indicators to look for in these environmental statements include surface of soil contaminated**,** volume of water polluted, and number of individual per species dead or damaged.

However, there are no specific indicators that can readily measure the bill's progress with respect to decreasing ecological damage related to fossil fuel *consumption*. Rather, indicators have to be extrapolated from information provided by a range of environment impacts published by the EPA. It is therefore necessary to systematize information supplied by environmental statements and environmental emergency responses to define concise indicators that evaluate ecological damages. It is also crucial to develop models with which the local effects of ecological damage can be extrapolated from available national data, as it may be too costly to collect data locally.

Moreover, besides the lack of specific indicators measuring ecological damage, there is also difficulty in correlating ecological damages induced by electricity generation in New York because the state procures fossil fuels from various internal or external markets, depending on the fluctuations of their prices. However, with the help of mathematical models, the decreasing impacts of electricity generation based on coal, oil and natural gas could be inferred by considering the relation between the state's size and the millions of MWh generated with solar energy rather than fossil fuels.

Measuring Net Environmental Impacts of using Solar PV

Lastly, it is important to note that the manufacture of PV cells also have associated environmental impacts, as previously discussed. To estimate the net result of changing the State's energy consumption mix, issues related to the life cycle of PV cells should be considered along with the environmental problems addressed by the bill.

CONCLUSION: A FIRST STEP TOWARDS A MORE SUSTAINABLE ENERGY FUTURE IN NEW YORK

The New York Solar Industry Development and Jobs Act of 2011 aims to alter New York State's current fossil-based energy consumption trajectory through a market-based approach to boost the state's development and investments in solar PV, a clean and renewable energy source. Through the creation of a statewide solar marketplace, the legislation seeks to procure 2.5% of the state's electricity from solar PV production by 2025.

It is important to recognize that converting 2.5% of the electricity generated in New York State to solar will not comprehensively solve the environmental problems behind fossil fuel consumption. Nevertheless, it is not the bill's ambition to single-handedly tackle these environmental problems; rather, the bill's intent is to steer the state's energy consumption patterns towards a more sustainable direction. In requiring the generation of electricity from a renewable energy source that is suitable to the state's infrastructure, the bill addresses the root of environmental problems identified in this report by reducing the consumption fossil fuels, even if the reduction is tiny. The transition process must start somewhere, and a modest step like this one can allow for midcourse corrections and fine tuning before we toward wider implementation. Furthermore, the legislation proposes to solve today's environmental problems with a market-based approach, which is expected to exhibit the snowball effect the state's renewable energy investments in the future. While the controversies and scientific uncertainties surrounding solar PV might be valid, it is pertinent to assess solar PV against other energy options. Solar PV is not only an investment that affords impressive environmental benefits compared to other renewable energy sources, but is also one of the most compatible renewable energy options with New York's current electricity infrastructure. While the proposed 5GW of electricity by solar PV may seem insignificant to the state's energy consumption at large, it represents one of the first steps that New York State is taking towards a more sustainable energy future.

Appendix: Detailed Summary of the Act

AO5713B: New York Solar Industry Development and Jobs Act of 2011

Bill Overview

The New York Solar Industry Development and Jobs Act of 2011 will stimulate the growth of the solar industry in New York State. The legislation requires retail electric suppliers, the Power Authority of the State of New York and the Long Island Power Authority to purchase Solar Renewable Energy Credits (SRECs). A SREC equates to the green benefits that come from producing and using one megawatt-hour of solar powered electricity instead of one megawatt-hour of energy produced through fossil fuel combustion.[71] The SRECs purchased will account for a determined percentage of total electric sales. The percentage of SRECs purchased would increase annually from 2013 until 2025 at which point New York State would be fulfilling 3% of its total electricity usage with solar energy.[72]

Section-by-Section Summary of A05713B

S.1 Legislative Intent and Purpose:

The New York Solar Industry Development and Jobs Act of 2011 aims to boost solar energy industry and market development in New York State. The act intends to increase the demand for and generation of sustainable energy, create jobs, reduce the long-term costs of generating electricity, and make the existing electricity delivering grid more reliable. Within this framework, New York will be among the world's top producers of clean energy, drawing positive attention from the global community and significant investment to the State.

S.2 Short Title:

New York Solar Industry Development and Jobs Act of 2011

S.3:

This proposed legislation introduces a relationship between solar energy generators and retail electric suppliers. A solar energy generator is any individual or business that owns and operates a photovoltaic device, which convert solar radiation directly into electricity and are one of the world's fastest growing solar electricity generation technologies. A retail electric supplier refers to an entity that sells electricity to consumers; a supplier can also be a distributor of solar energy.

The New York Solar Industry Development and Jobs Act would require that retail electric suppliers, starting in 2013, purchase SRECs amounting to 0.15% of its total electric sales; this percentage will increase annually to 3.00% in 2025 except when a supplier's annual expenditures on SRECs exceed 1.5% of its annual retail electricity revenues. If this is the case, its annual requirement for SRECs will stay at 1.5% of its total annual expenditures for subsequent compliance years until the supplier's spending on SRECs falls under 1.5% once again. The legislation allows complying suppliers to bill their customers a flat rate of $0.39 per month to compensate for the supplier's SREC expenses.

If a retail electric supplier fails to meet their SREC obligation, they will make Solar Alternative Compliance Payments. These compliance payments are priced higher than SRECs to encourage retailers to purchase solar credits instead of making the alternative payment. All revenue from the compliance payments will be invested in the solar industry to increase the future supply of SRECs.

The bill directs suppliers to acquire SRECs from different size generators. At least 20% of suppliers' SRECs will be procured from small solar power generators (i.e., individuals who have installed photovoltaic cells on the roof of their house) and 30% from any sized solar generators (i.e., farms that installed photovoltaic cells on different structures) to stimulate demand for solar at these scales and ensure broad investment and participation in the state's solar industry. The bill also stipulates that suppliers produce separate plans for purchasing SRECs from different size generators. The solar purchasing agreements between suppliers and solar power generators will last fifteen years, and electricity distributors will pay a tariff to small solar generators. The rate of the tariff will consider solar industry expenditure differences between varying market segments (personal, small business, not-for-profit), the cost of solar equipment and existing federal incentives that favor small solar electricity generators. The bill also requires that all employees contracted through these solar purchase agreements to install solar equipment be paid a fair and standard industry wage.

Beginning in 2014, each retail electric supplier will submit an annual report of its progress to the legislation's success. This report will include:

1. The number of megawatt hours of solar energy sold to New York State energy consumers
2. The number of SRECs associated with the aforementioned energy
3. The number of Solar Alternative Compliance Payments made
4. The annual electricity sales revenue and the amount of money spent on SRECs
5. The number of SRECs purchased from small, medium and large solar power generators
6. The number of SRECs acquired through the devised solar purchase agreements
7. The monetary amount of tariffs paid to small solar energy generators

S.4:

The New York State Solar Industry Development and Jobs Act also establishes a relationship between solar energy generators and the Power Authority of the State of New York, a public corporation acting as an electricity provider (New York Power Authority, 2011). This public authority will be subject to similar obligations under this legislation as its retail electric supplier counterparts. A key difference, however, is that the Power Authority of the State of New York's annual SREC purchasing obligation will be initially set at 0.33% of its total annual electricity sales and increase annually to 3.5% in 2025. Additionally, this public authority is not allowed to meet its annual percentage obligations by making Solar Alternative Compliance Payments.

The Power Authority of the State of New York will release solicitation plans and solar purchase agreements similar to the ones devised by retail electric suppliers. These plans will be submitted to the Comptroller, Governor, Speaker of the Assembly, temporary President of the Senate, and Chairs of the Senate and Assembly Energy Committees for review. Beginning in July 2014, the Power Authority of the State of New York will also submit annual reports to the aforementioned parties. This report will detail the public authority's progress in procuring SRECs by including the following: 1. The number of SRECs purchased to meet annual obligations 2. The number of SRECs purchased from small, medium and large solar power generators 3. The number of SRECs acquired through the devised solar purchase agreement
S.5:
The New York State Solar Industry Development and Jobs Act also establishes a relationship between solar energy generators and the Long Island Power Authority. The Long Island Power Authority is a not-for-profit electricity provider (Long Island Power Authority, 2011). Under the New York State Solar Industry Development and Jobs Act, the Long Island Power Authority is subject to the same regulations as the Power Authority of the State of New York mentioned above.
S.6:
If any portion of this legislation is found to be unconstitutional by a court, it can be removed from the bill without affecting the legitimacy of the remaining stipulations.
S.7:
The stipulations in this legislation will be enforced immediately. If a comparable federally sponsored solar electricity program is implemented, this bill can be repealed.

Image Sources

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