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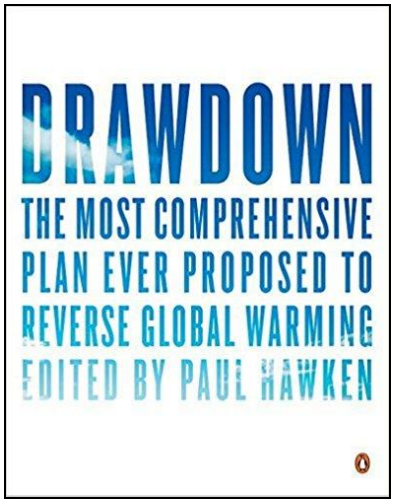
Ulster County Climate Smart Committee
Drawdown Energy Solutions – Cost for NY



Drawdown, a survey of the 100 best climate stabilization solutions edited by Paul Hawken, comes with an ambitious subtitle: "The Most Comprehensive Plan Ever Proposed to Reverse Global Warming." The Ulster County Climate Smart Committee included Project Drawdown in its 2018 agenda and supported events promoting its climate change solutions.

This paper is an attempt to map Project Drawdown's energy solutions to New York and to estimate what it might cost to implement the solutions. The attached spreadsheet summarizes the calculations. For New York, adopting Project Drawdown's energy solutions could cost in the neighborhood of $150 billion by 2050.

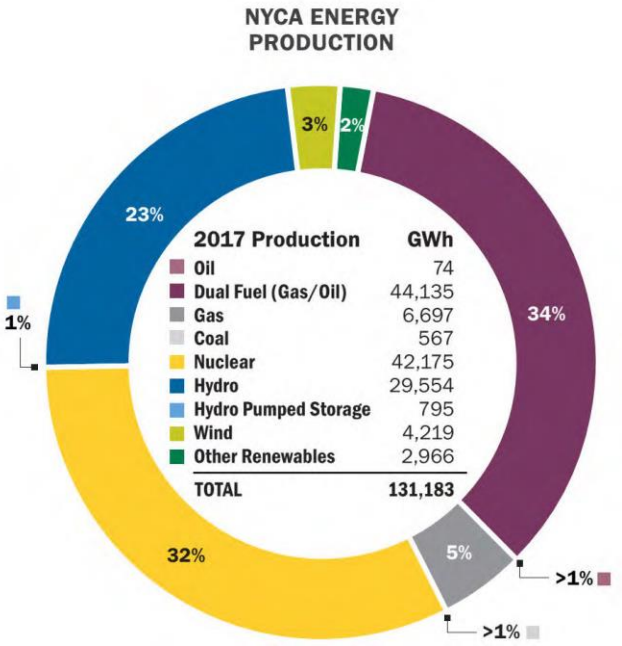
Drawdown asserts, "It did not make or devise the plan, but simply found a plan that already exists. Nothing new needs to be invented. The solutions are in place and in action." This is an unnecessarily modest assessment. What *Drawdown* offers is a different way of looking at the problem of climate change and solutions, and introduces an explicit ranking of solutions based on reductions in carbon dioxide, efficiency of energy generation, and cost. This approach moves beyond the prevailing 'renewables only' approach. Although *Drawdown* provides guidance on a global scale, it doesn't really offer much help in applying these solutions at local and state levels.

Drawdown Energy Solutions

The power sector accounts for around 40 percent of annual worldwide greenhouse gas emissions, making it the highest-emitting sector followed by industry and transportation. Of total worldwide electricity generation, fossil fuels represent 67 percent, nuclear 11 percent, and renewable energy sources just over 24 percent and growing, with the bulk (18 percent)

from large-scale hydropower systems. In New York fossil fuels account for 39%, nuclear 32%, and hydropower 23% of electricity generation.[1]

In the past few years, the efficiency of renewable sources have improved and become more affordable. The Drawdown Electricity Generation Sector includes centralized and decentralized renewable solutions, such as onshore wind power and rooftop solar, respectively, and technologies such as storage and microgrids that enable large-scale integration of renewable energy sources.



Electric Energy Production in New York State by Fuel Source – 2017, *Power Trends 2018*

Some Energy Solution's Objections

Despite Paul Hawken's claim that, "we have in hand now, in a practical way, the solutions that are needed in order to reverse global warming," not everyone would agree. There are significant obstacles; some of the solutions offered in the energy sector are strongly opposed – the role of nuclear power and natural gas as transitional fuels is not readily accepted.

Project Drawdown fails to address the question of increased or lessened need for electricity; assumptions about future electricity requirements will drive investments in generation. Nor does Project Drawdown consider the land use and environmental issues that are beginning to emerge with the deployment of large-scale solar and wind renewables.

Undoubtedly *Drawdown* is an important contribution for understanding the transition from a fossil fuel to a renewable based economy, but *Drawdown's* most meaningful contribution may be to shift the discussion to an explicit consideration of carbon dioxide emissions in the context of an integrated and interrelated model of generation sources.

Project Drawdown for New York

Project Drawdown lists sixteen sources of electricity to replace fossil fuel generation. Each solution is ranked by its contribution to reducing CO2 emissions, its net cost and net savings. Below is a table of the Drawdown solutions and associated estimates of CO2 reductions in metric gigatons.

Two Drawdown solutions don't apply in New York. It's generally understood that New York has no deep underground heat sources to support geothermal generation. And concentrated solar seems to work best in deserts, an environment New York lacks.

[1] NYISO, *Power Trends 2018*, May 3, 2018, https://home.nyiso.com/wp-content/uploads/2018/05/2018-Power-Trends_050318.pdf

Cost Calculations

To calculate the cost for Project Drawdown in New York, it's necessary to convert the gigatons of avoided CO2 into a value of the electrical generation contributed by each solution. The U.S. Energy Information Administration states that electrical generation in New York emits 512 lbs of CO2 per MWh. Dividing lbs/MWh into the gigatons of avoided CO2 associated with each solution yields a ratio of the electrical generation needed to achieve the emission reductions for that solution.

Drawdown Energy Solution	Gigatons Avoided CO2
Onshore Wind Turbines	84.6
Solar Farms	36.9
Rooftop Solar	24.6
Geothermal	16.6
Nuclear	16.1
Offshore Wind Turbines	14.1
Concentrated Solar	10.9
Wave & Tidal	9.2
Methane Digesters (Large)	8.4
Biomass	7.5
Solar Water	6.1
In-Stream Hydro	4.0
Cogeneration	3.8
Methane Digesters (Small)	1.9
Waste-to-Energy	1.1
Micro Wind	0.2
Gigatons CO2 Reduced	246.0

The NYISO *2018 Load & Capacity Data*, the "Gold Book," provides 20-year forecasts for electrical consumption and generation in New York.[2] The NYISO's forecasts are essentially flat showing a uniform need of about 155 TWh/year [3] extended out to 2038.

In state New York generation provides about 131 TWh with the rest obtained from hydroelectric sources in Canada and natural gas and coal generators in Pennsylvania and Ohio. For the purpose of this exercise, New York's electrical usage through 2050 is set at 155 TWh a year.

New York's large scale hydroelectric generators contribute about 30 TWh, and are not subject to replacement by Drawdown solutions. Nuclear, which contributes 42 TWh, is considered vulnerable and is included in the Drawdown replacement calculations. The forecasted 155 TWh, less 30 TWh of large scale hydroelectric, requires 125 TWh to be replaced by Drawdown solutions.

After dropping geothermal and concentrated solar from the calculations, a proportional amount of the 125 TWh is assigned to each solution based on avoided CO2 emissions. This quantity, in TWh, is shown on the attached spreadsheet under the column labeled 'NY TWh Generation.'

Capacity Factors

The cost of a generator is usually dependent on its capacity rated in MW, also known as *Nameplate Capacity*. But there are differences between a generator's nameplate capacity and the amount of electricity it actually produces. Nameplate capacity is an indication of a generator's maximum output measured in MW, and electricity generated over a specific period is measured in megawatt-hours (MWh). A one megawatt generator operating at full capacity for one hour produces 1 MWh of electricity.

[2] NYISO, *2018 Load & Capacity Data*, April 9, 2018, Available at https://home.nyiso.com/wp-content/uploads/2018/04/2018-Load-Capacity-Data-Report-Gold-Book.pdf

[3] TWh, terawatt hours, equivalent to 1,000 gigawatt hours or 1,000,000 megawatt hours

The *Capacity Factor* is a measure of actual electrical generation as a percentage of potential maximum generation. A generator with 1 MW capacity operating at full capacity for full year, or 8,760 hours, would produce 8,760 MWh of electricity and have an annual capacity factor of 100%. A 1 MW generator producing 5,000 MWh in the same period will have a capacity factor of 57% (5,000/8,760).

Generators do not operate at their full capacity all the time and output varies according to weather, operating conditions, fuel costs, market prices, or scheduling by the grid operator. The ability to operate at full capacity is also dependent on the type of facility, the fuel, and the unit's technology.

Price per MW

The price per MW and the capacity factors associated with different renewable technologies can be rich source of controversy in any discussion about the application of renewables, but below are the assumptions that are used in the attached spreadsheet. Left out because of the lack of good data and references are some of the more unconventional solutions identified in *Drawdown*. Others are welcome to submit references.

Drawdown Energy Solution	Capacity Factor	$/MW (Millions)
Onshore Wind Turbines	25%	$1.5
Offshore Wind Turbines	40%	$10.0
Solar Farms	15%	$2.0
Rooftop Solar	13%	$3.5
Nuclear	95%	$12.5
In-Stream Hydro	60%	$5.0

Wind Turbines: Onshore and offshore wind turbines are essential components in the conversion to renewable energy. A whitepaper release by the Alliance for a Green Economy (AGREE) and the Nuclear Information and Resource Service (NIRS) explaining how FitzPatrick nuclear plant's output could be replaced by renewable energy, estimated recent onshore wind turbine cost at $1.5 million per MW.[4] A 25 percent capacity factor for onshore wind is consistent with New York's experience.[5]

Offshore wind turbines are generally larger than the onshore versions, and because of more consistent winds, are able to generate more power. A 40 percent capacity factor is reasonable for offshore wind. The Block Island Wind Farm installed five, 6-MW wind turbines at a cost of $300 million, or $10/MW.[6,7]

Photovoltaic Solar: Residential rooftop solar and utility scale solar farms are important sources of renewable energy. The capacity factor for solar farms is a little higher than residential rooftop solar because of the opportunity to optimize the placement and orientation

[4] Alliance for a Green Economy and Nuclear Information and Resource Service , *Replacing FitzPatrick*, October 2015, Available at https://www.nirs.org/wp-content/uploads/2016/07/replacingthefitzpatricknuclearreactor.pdf
[5] *Power Trends 2018*, p 26
[6] "The Block Island project was a marriage of Rhode Island political will and New York financial expertise. Initial financing for the $300 million project came from the D. E. Shaw Group, a big investment firm based in Manhattan."
[7] Gillis, Justin, *America's First Offshore Wind Farm May Power Up a New Industry*, The New York Times, August 22, 2016, https://www.nytimes.com/2016/08/23/science/americas-first-offshore-wind-farm-may-power-up-a-new-industry.html

of solar panels. Rooftop solar installations are constrained by the roof's orientation. The solar capacity factors for solar are consistent with New York's experience.[8]

Nuclear: Nuclear energy is included as a solution in Project Drawdown. The estimated cost of the 2300 MW, Vogtle nuclear project in Georgia was originally $14 billion, but it is now $27 billion.[9] Others are forecasting additional cost escalation. The cost for new nuclear power in this exercise is set at $12.5 million/MW. (At this cost, replacing the 2000 MW Indian Point nuclear plant would be about $25 billion.)

Mini hydroelectric power station with 12 kilowatts of installed power produces around 33,000 kilowatt-hours of electricity per year in Bruton, Somerset, England.

Drawdown In-Stream Hydro Solution

In-Stream Hydro: Bard College received a $1 million NYSERDA grant that will allow the college to develop micro-hydro projects at dams on its Montgomery Place property. The first project is a 12 KW micro hydro water turbine at the Annandale dam that will generate an estimated 61,000 kWh/year. This works out to an impressive 60 percent capacity factor.

The 12 KW mini hydroelectric power station referenced in *Drawdown* generates 33,000 kWh, about half of the output expected from the Annandale dam project.[10]

There are no established cost estimates for micro hydro, so cost is arbitrarily set at $5/Watt, which is greater than PV solar, but less then offshore wind.

Cost by Solution

Having calculated the TWh contributed by each solution proportional to its avoided CO2 emissions, established the solution's capacity factor and cost/MW, it's possible to calculate the cost for each Drawdown solution needed to convert New York to renewable generation. The attached spreadsheet shows a total implementation cost of $147.6 billion.

[8] *Power Trends 2018*, p 26
[9] Maloney, Peter, *Oglethorpe, MEAG vote to move forward with Vogtle nuclear project*, Utility Drive, September 24, 2018, https://www.utilitydive.com/news/oglethorpe-meag-vote-to-move-forward-with-vogtle-nuclear-project/533104/
[10] *Drawdown*, p 27

Drawdown Energy Solutions
Cost for New York

NY Generation (TWh)	155.00	100.0%
Existing Large Scale Hydro	30.00	19.4%
Drawdown Generation	125.00	80.6%

Drawdown Energy Solution	Gigatons CO2	Generation NY @ 512 lbs CO2/MWh	NY TWh Generation	Percent NY Generation	Capacity Factor	Nameplate Capacity MW	$/MW (Millions)	Solution Cost (billions)	Cost /TWh (millions)
Onshore Wind Turbines	84.6	0.16523	48.40	31.2%	25%	22,100	$1.5	$33.1	$685
Solar Farms	36.9	0.07207	21.11	13.6%	15%	16,065	$2.0	$32.1	$1,522
Rooftop Solar	24.6	0.04805	14.07	9.1%	13%	12,358	$3.5	$43.3	$3,073
Geothermal	16.6								
Nuclear	16.1	0.03145	9.21	5.9%	95%	1,107	$12.5	$13.8	$1,502
Offshore Wind Turbines	14.1	0.02754	8.07	5.2%	40%	2,302	$10.0	$23.0	$2,854
Concentrated Solar	10.9								
Wave & Tidal	9.2	0.01797	5.26	3.4%					
Methane Digesters (Large)	8.4	0.01641	4.81	3.1%					
Biomass	7.5	0.01465	4.29	2.8%					
Solar Water	6.1	0.01191	3.49	2.3%					
In-Stream Hydro	4.0	0.00781	2.29	1.5%	60%	435	$5.0	$2.2	$951
Cogeneration	3.8	0.00742	2.17	1.4%					
Methane Digesters (Small)	1.9	0.00371	1.09	0.7%					
Waste-to-Energy	1.1	0.00215	0.63	0.4%					
Micro Wind	0.2	0.00039	0.11	0.1%					
Gigatons CO2 Reduced	246.0	0.42676	125.00	80.6%			Implementation Cost	$147.6	

Rooftop Solar (MW)	12,358
Number of 5 KW Systems	2,471,589
In-Stream Hydro (MW)	435
Number of 12 KW Systems	36,281