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CLEAN ENERGY INVESTMENTS FOR NEW YORK STATE

An Economic Framework for Promoting Climate Stabilization and Expanding Good Job Opportunities

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All errors remain our own.

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Highlights of Main Findings

This study examines the benefits of large-scale green energy investments for New York State. It also proposes a policy framework for supporting such investments throughout the state.

Large-scale clean energy investments throughout New York State can advance two fundamental goals:

- Promoting global climate stabilization by reducing carbon dioxide (CO_2) emissions and other greenhouse gas emissions.
- Expanding good job opportunities throughout the state.

Reducing CO_2 Emissions

- The specific aim for clean energy investments will be to achieve, by 2030, a 50 percent reduction below the 1990 level in all human-caused carbon dioxide (CO_2) emissions in New York State.
  - This translates into a CO_2 emissions level of 100 million tons by 2030.
  - Current emissions are at 170 million tons. The emissions reduction by 2030 therefore will need to be 40 percent relative to current levels.
  - CO_2 emissions will fall due to reduced consumption of oil, coal and natural gas in the state. The cuts in natural gas consumption will also support major reductions in methane emissions.

Major Areas of Clean Energy Investments

- **Energy Efficiency.** Dramatically improving energy efficiency standards in New York's stock of buildings, automobiles and public transportation systems, and industrial production processes.
- **Clean Renewable Energy.** Dramatically expanding the supply of clean renewable energy sources—primarily wind, solar, and geothermal power—available at competitive prices to all sectors of New York State's economy.

Job Creation through Clean Energy Investments

- Making the large-scale investments in clean energy projects capable of achieving the 50 percent emissions reduction target by 2030 will generate between 145,000 and 160,000 jobs per year in the state.
- New job opportunities will be created in a wide range of areas, including construction, sales, management, electrical assembly, engineering, and office support.

- Current average total compensation in these occupations ranges between $63,000 – $114,000.
- Employment growth in these areas should create increased opportunities both for women and minority workers to be employed and to raise unionization rates.
- Higher unionization rates should promote gains in compensation and better working conditions in the affected industries.

Just Transition for Fossil Fuel Industry Dependent Workers and Communities

- Fossil fuel consumption in New York State consists almost entirely of natural gas and petroleum. Consumption of these fuels will need to fall by about 40 percent as of 2030 to bring the state's total CO_2 emissions down to 100 million tons.
- About 13,400 workers in New York State are presently employed in nine industries that will be most heavily affected by this 40 percent fossil fuel consumption cut.
- Most of the job losses can be handled through attrition by retirement when workers reach age 65.
    - Regulations are needed to ensure that workers moving into retirement will have their full pensions available to them.
- About 67 workers per year in the nine heavily impacted industries will face displacement as New York State's fossil fuel industry contracts through 2030.
    - A Just Transition program for these workers should include guaranteed reemployment as well as income, retraining, and relocation support.
    - We estimate the total costs of such support to be about $300,000 per worker, amounting to $18 million per year.
- A Just Transition program for heavily impacted communities could also be provided through channeling a relatively high proportion of new clean energy investments into these communities.

A Clean Energy Investment Policy Framework

- We estimate that overall public plus private clean energy investments in New York State are currently in the range of $6 – $7 billion per year.
    - Overall investments will need to rise roughly five-fold in the state to achieve its emissions reduction target. This level of new investment is achievable within an effective policy framework.
- We estimate that New York State could successfully finance clean energy investments at this level on the basis of about $4 – $5.5 billion in annual public funding.
- We consider policies within three broad categories:
    - A polluter fee and related regulations;
    - Financial subsidies and incentives;
    - Direct public spending.

- The policy areas on which we focus include: a polluter fee for CO_2 emissions; renewable energy and energy efficiency portfolio standards; auto fuel efficiency standards; net metering for utilities; and the most effective ways to leverage public funds for expanding overall clean energy investments.
- On the basis of about $4 – $5.5 billion per year in annual public funding, we estimate that there are several ways that New York State can successfully raise total investment from public and private sources adequate to make this transition in overall clean energy investments.
    - This level of public funding can be achieved through the state's existing Clean Energy Fund along with a polluter fee that begins at $35 per ton in 2021 and rises to $75 per ton as of 2030.
    - This would generate an average of about $7.1 billion in annual revenues between 2021 – 2030.
    - This assumes that between 25 – 50 percent of revenues from the polluter fee will be channeled into rebates for New York State residents.
- This transformative clean energy program can be accomplished at little to no cost to consumers. This is because the average cost of delivering a given supply of electricity from clean renewable sources will be roughly equal to, if not cheaper than, virtually all fossil-fuel based technologies.

Zero New York State Emissions by 2050

- New York State can achieve zero emissions by 2050 through continuing clean energy investments in the state.
    - Investments in energy efficiency and clean renewable energy between 2031 – 2050 can be lower than through 2021 – 2030—at between 0.6 – 0.8 percent of state GDP
    - Annual job creation through these investments will range between 50,000 – 90,000 per year
    - Just Transition support for displaced workers over 2031 – 2050 will amount to about $60 million per year.

Summary of Study

This study examines the prospects for transformative clean energy investment projects for New York State. Taken as a whole, these investments should be understood as a major initiative within the state to advance the fundamental goal of global climate stabilization. These investments should be undertaken by both the public and private sectors in New York State, supported by a combination of public investments and incentives for private investors.

This study builds from New York State's existing Reforming the Energy Vision (REV) project and the New York State Energy Plan, which fleshed out a policy agenda based on the REV project. Governor Andrew Cuomo first presented the REV program in April 2014 and reaffirmed New York State's commitments in June 2017. The primary goals of the REV program, which are targeted to be achieved by 2030 in New York State, include: 1) a 40 percent reduction in all greenhouse gas emissions; 2) generating 50 percent of all electricity from renewable energy sources; and 3) achieving a 23 percent improvement in energy efficiency in buildings relative to the 2012 level.

The REV goals and the State Energy Plan are unquestionably significant starting points for advancing clean energy policies in New York State. But they are not adequate to enable the state to achieve emissions reduction goals that meet the challenges we face with global climate change. As such, this study works from a more ambitious set of goals, both in terms of emissions reductions and in achieving broader positive impacts with respect to expanding job opportunities and raising living standards throughout New York State.

The first specific aim on which we focus in this study is to achieve, by 2030, a 50 percent reduction below the 1990 level in all human-caused CO_2 emissions in New York State, along with comparable reductions in methane emissions resulting from natural gas extraction. The second, equally important, goal is to achieve the 2030 CO_2 emission reduction standard while also expanding job opportunities and raising average living standards throughout New York State. The expansion of clean energy investments will need to focus on 1) dramatically improving energy efficiency standards in New York's stock of buildings, automobiles and public transportation systems, and industrial production processes; and 2) equally dramatically expanding the supply of clean renewable energy sources—primarily wind, solar, and geothermal power—available at competitive prices to all sectors of New York State's economy.

In addition to these goals for 2030, this study also explores the prospects for achieving the longer-term aim of bringing CO_2 emissions in New York State down to zero by 2050, while, again, concurrently expanding job opportunities and raising average living standards throughout the state.

Such efforts to rapidly and dramatically drive down CO_2 emissions in New York State are representative of the types of climate stabilization initiatives that need to be advanced throughout the world without further delay. The December 2015 UN-sponsored Paris Climate Agreement was a major milestone on behalf of the global project of climate stabilization. Coming out of the conference, all 196 countries formally recognized the grave dangers posed by climate change and committed to take action to substantially cut all greenhouse gas emissions—from CO_2, but also from other greenhouse gas emission sources, in particular methane.

On June 1, 2017, U.S. President Donald Trump announced that the United States would pull out of the Paris agreement. This decision dealt a severe blow to the prospects for putting the global economy onto a sustainable path toward climate stabilization. But Trump's decision also elicited strong protests throughout the U.S., among citizens in general, as well as a range of political organizations and elected officials. Governor Andrew Cuomo of New York was among the most forceful in restating New York State's support for the Paris Agreement and in pledging to advance an effective climate stabilization agenda in the state through the REV program and the State Energy Plan.

But President Trump's actions notwithstanding, it was also the case that the pledges made by all countries combined at the Paris conference were not close to being adequate to stabilize the climate at a global mean temperature at between 1.5 – 2.0°C above pre-industrial levels no later than 2100—the goal that the Paris Agreement itself recognizes as necessary to achieve climate stabilization. Rather, according to the credible estimate by the environmental research NGO Climate Action Tracker, if all countries were to keep to the pledges they made at Paris, the global mean temperature would rise by between 2.4 – 2.7°C by 2100.[1] (Footnotes are included in this summary section; endnotes are used for the main text.) In addition, even these inadequate pledges were not made legally binding in Paris. Similarly, New York State's REV goals and its State Energy Plan are unquestionably worthy, but are not adequate to enable New York State to advance a sufficiently robust program in support of global climate stabilization.

This study examines measures to reduce that portion of total greenhouse gas emissions produced by burning fossil fuels—oil, coal and natural gas—to generate energy. Climate change cannot be entirely blamed on we humans consuming oil, coal, and natural gas to generate energy. But, on a global scale, people consuming fossil fuels for energy can be blamed for about 70 percent of the problem. CO_2 emissions from burning coal, oil and natural gas alone produce about 66 percent of all greenhouse gas emissions, while another 2 percent is caused mainly by methane leakages during extraction. Agricultural production is the other major source of greenhouse gas emissions, accounting for about 15 percent in total, in about equal shares of methane and nitrous oxide. Controlling methane and nitrous oxide emissions from agricultural as well as other, smaller sources of emissions will of course be necessary to advance a successful global climate stabilization project. But this study will focus on the roughly 70 percent of the problem that we can solve by burning less oil, coal and natural gas, as well as, to a lesser extent, high-emissions renewables, such as corn ethanol.[2]

For the U.S. economy specifically, CO_2 emissions account for about 81 percent of total greenhouse gas emissions. Methane emissions resulting from natural gas production accounts for another 3.2 percent of total greenhouse gas emissions generated within the U.S.

Within this context, New York State can assume a significant leadership role in advancing a climate stabilization project that will be adequate to the challenges we face—that is, building from, but advancing beyond, the positive framework established by its REV program and State Energy Plan. New York can also demonstrate that such a project will create major opportunities to expand job opportunities and launch new industrial development initiatives throughout the state. As we will see, clean energy investments in New York that would be sufficient to put the state on a true climate stabilization trajectory will generate about 150,000 jobs per year within the state.

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1 http://climateactiontracker.org/global.html

2 We rely on three main sources for data on global CO_2 and overall greenhouse gas emissions: the U.S. Energy Information Agency's (EIA) International Energy Statistics, the International Energy Agency's (IEA) World Energy Outlook, and the World Bank's World Development Indicators. There are small differences in details among these three sources. To reconcile these differences, we try to use the source that provides the most recent set of figures for the global economy. We use less recent data, as needed, when they provide an improved level of detail.

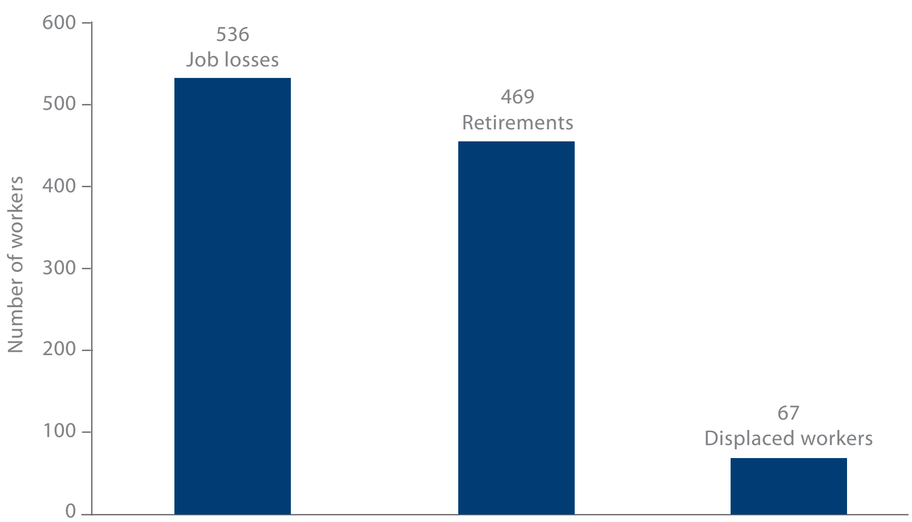
At the same time, the state's fossil fuel related industries will need to contract by 40 percent as of 2030—a rate of decline that would average about 4 percent per year. We roughly estimate that the contraction of these industries will mean a loss of 5,358 jobs in total, equal to 536 jobs per year for 10 years. However, we also estimate that 469 workers per year in these industries will be moving into voluntary retirement at age 65. The result is that only about 67 workers per year will face displacement. Figure S.1 summarizes this result.

As such, we have identified a major and significant disparity between the numbers of jobs created in New York State through clean energy investments and the numbers of workers displaced through the contraction in the state's fossil fuel industry: about 150,000 jobs created per year through clean energy investments versus about 70 workers per year displaced through fossil fuel industry contractions. In our full study, we document how we derive these critical job impact figures.

We recognize that, even with these low figures for job losses in the state as the fossil fuel industry contracts, there are still communities in the state that are, at present, significantly dependent on the fossil fuel industry, particularly in the areas of natural gas distribution, power generation, and pipeline construction. These communities are primarily within Chemung, Nassau, Chautauqua, Kings and Richmond Counties. As we will discuss, the most direct way to support these communities in transition will be to channel a relatively high proportion of new clean energy investments into these communities.

The growth in jobs generated by clean energy investments, in both the areas of energy efficiency and clean renewable energy sources, should increase opportunities for women and minority workers seeking employment in these sectors. This is especially significant given

FIGURE S.1: Estimated Annual Job Losses, Voluntary Retirements and Workers Displaced in New York State's Fossil Fuel Related Industries, 2021– 2030



Source: See Table 30.

that, at present, women and minority workers are underrepresented in the workforce of the relevant industries. The growth of jobs in these sectors will also create new opportunities to increase union coverage for workers employed in these sectors. The rise in unionization rates should, in turn, promote improved compensation levels and working conditions in these sectors.

The study is organized around 10 sections. These are:

1. Introduction
2. Sources of Energy and CO_2 Emissions for New York State
3. Factors in New York State's Low Emissions Levels
4. Prospects for Energy Efficiency
5. Prospects for Clean Renewables
6. Clean Energy Investment Levels and Emissions Reductions
7. Job Creation through Clean Energy Investments
8. Just Transition for Fossil Fuel Industry-Dependent Workers and Communities
9. A Clean Energy Investment Policy Framework
10. Achieving a Zero-Emissions Statewide Economy by 2050

The main findings of the study are as follows:

Current CO_2 Emissions Levels in New York State

As of the most recent 2014 data, CO_2 emissions in New York were at 170 million tons. This emissions level is 18 percent below the state's 1990 level of 209 million tons. New York State's emissions reduction occurred despite the fact that between 1990 and 2014, real GDP in New York grew by 63 percent and population grew by 9.4 percent. Thus, New York State has already made progress toward "decoupling"—i.e. reducing CO_2 emissions while the economy and population have both been growing.

In fact, New York is presently the "cleanest" of all 50 U.S. states, as measured by CO_2 emissions per capita. In New York, as of 2014, CO_2 emissions were 8.6 tons per capita. By contrast, the figure for the U.S. as a whole was 17.0—nearly twice as high as that for New York. New York has reached this relatively low level of emissions per capita because it both operates at a relatively high level of energy efficiency and relies on a relatively "clean" mix of energy sources, including hydro power. New York State also relies heavily on natural gas as opposed to coal. But because of the high level of methane emissions resulting from extracting natural gas through fracking technology, the reliance on natural gas rather than coal does not produce significant reductions in overall greenhouse gas emissions.

Overall, despite this relatively positive emissions performance to date, it will still be necessary for the state to make major further improvements in order for New York, and the U.S. economy more generally, to contribute positively toward global climate stabilization. As one metric, New York's current CO_2 emissions level of 8.6 tons per capita is nearly four times higher than the 2.4 tons per capita figure that is needed just to reduce global emissions by 40 percent as of 2030.

Energy Consumption and CO_2 Emissions Sources

As of 2014, the primary sources of New York State's energy supply are natural gas (38 percent) and petroleum (35 percent). These two sources account for 73 percent of all New York's energy consumption, with total statewide energy consumption at 3.7 quadrillion British Thermal Units (Q-BTUs) as of 2014. In addition, nuclear energy accounts for 12.2 percent and hydro power for 6.7 percent. With both nuclear and hydro, all the energy supplied is in the form of electricity. Coal, again, provides a negligible 1.8 percent of New York's energy supply. In combination, at present, wind, solar and geothermal energy account for 1.3 percent of consumption. These figures make clear that transforming these clean renewable sources into a major provider of energy in New York will be a formidable challenge. CO_2 emissions in New York State are generated almost entirely from combusting natural gas and petroleum, with about 53 percent of emissions due to petroleum, and 43 percent from natural gas.

Prospects for Energy Efficiency

New York State has achieved its relatively high level of efficiency due primarily to two structural features of the state's economy: the reliance by a high proportion of the state's residents on both apartments as their dwellings and commuter rail lines as their regular transportation mode. But further gains in efficiency will need to result through improvements in various forms of mechanical equipment as opposed to further increases in the proportions living in apartment buildings or traveling by commuter rail. More specifically, the main additional efficiency gains throughout the state's economy will need to come from improvements in the operations of both buildings and private automobiles. From a review of the relevant literature, in particular from the U.S. National Academy of Sciences, we conclude that major improvements—in the range of 30 – 40 percent—are possible with relatively low upfront capital expenditures. We assume, specifically, that the average costs throughout the full range of energy efficiency investments will be $35 billion per Q-BTU in efficiency gains.

Prospects for Clean Renewable Energy Sources

We focus on expanding New York State's share of energy supply that will be provided through three clean renewable sources—wind, solar and geothermal energy. We describe the costs to consumers of expanding the supply from these three sources and separately the upfront capital expenditures of building more clean renewable energy productive capacity.

In terms of costs to consumers, we review evidence from the U.S. Energy Information Agency (EIA) showing that, as of 2021, the average costs of delivering a given supply of electricity from clean renewable sources will be roughly equal to, if not cheaper than, virtually all fossil-fuel based technologies. *Consumers should therefore experience no price increases when they purchase energy from clean renewable sources.*

Clean Energy Investments to Achieve Emissions Reduction Goal

To explore the prospects of bringing New York State's CO_2 emissions down to 100 million tons by 2030, along with comparable declines in the methane emissions generated through production and consumption of natural gas, we work with a few basic assumptions as to the state's economic trajectory between now and 2030. In particular, we assume a relatively rapid overall economic growth trend of 2.6 percent per year. Within this growth framework, we then consider two alternative scenarios with respect to the state's energy infrastructure: first, that the energy infrastructure remains basically intact through 2030; and second, that New York undertakes a major expansion in clean energy investments between 2021 – 2030, such that the state both raises energy efficiency and expands its reliance on clean renewable energy sources to the extent necessary to bring statewide CO_2 emissions below 100 million tons. We assume that, realistically, the actual clean energy investment activity will not reach full scale until 2021. But extensive administrative, financing, and contracting activities, along with the first phases of investment projects, will need to occur between 2018 – 2020.

Over the 2021 – 2030 years of primary investment activity, we estimate that investments throughout New York State average about $8.7 billion per year in energy efficiency and $22 billion per year in clean renewable energy, for a total level of clean energy investments at about $31 billion per year. Through investments at this level, the state can bring CO_2 emissions down to about 100 million tons by 2030, along with comparable declines in methane emissions from natural gas production. Total investment spending at this level would average about 1.8 percent of the state's projected GDP between 2021 – 2030, assuming the state's economy did grow at 2.6 percent per year over this period.

Job Creation through Clean Energy Investments

We estimate here the employment effects in New York State of advancing clean energy investments at the level of about $31 billion per year over 2021 – 2030. After estimating the number of jobs that this overall investment level will generate, we then consider indicators of job quality, the profile of the workers engaged in these activities at present, and the prevalent types of specific jobs associated with the major areas of both energy efficiency and clean renewable energy investments. Overall, we find that, for 2021, the first year of the large-scale investment expansion, the total extent of direct plus indirect employment created will be about 160,000 jobs, equal to about 1.8 percent of the state's total workforce. Assuming that labor productivity in these activities improves at an average rate of 1 percent per year, total job creation through $31 billion in clean energy investments will be about 145,000 in 2030.

In terms of job quality, we find that average total compensation for the newly created areas of employment will range between $63,000 and $114,000. We show the proportions of workers in these jobs who have private pensions, are covered by private health insurance and are union members. We also report on the educational credentials of workers currently employed in these areas, as well as the racial and gender composition of workers in these jobs.

Among other results, we find that these jobs are held disproportionately by white male workers and that unionization rates range mostly between 20 – 25 percent of the respective workforces. The growth in employment in these industries that will be generated by large-scale new investments should create increased opportunities both for women and minority workers. The rise in unionization, in turn, should help improve compensation levels in these industries as well as the diversity of the workforce.

Just Transition for Fossil Fuel Industry-Dependent Workers and Communities

In order for New York State to bring total CO_2 emissions down to 100 million tons by 2030, consumption of fossil fuels in the state will need to fall by approximately 40 percent relative to its 2014 level. As a first approximation, it is reasonable to assume that production activity and employment in fossil fuel dependent industries throughout New York State will also decline by approximately 40 percent as of 2030. We consider the impact on employment in nine industries and also propose a set of measures—a "Just Transition" program—to compensate both workers and communities that are, at present, dependent on the fossil fuel industry for their livelihood.

These nine industries include oil and gas extraction and coal mining themselves. They also include seven ancillary industries—support activities for both oil and gas extraction and coal mining, along with natural gas distribution, fossil fuel-based electric power generation, oil and gas pipeline construction, petroleum bulk stations and terminals, and petroleum refining. We find that a total of about 13,400 workers are employed throughout New York State in these industries, amounting to about 0.15 percent of total New York State employment. Of these, about 87 percent are concentrated in natural gas distribution (49 percent), fossil fuel based electric power generation (22 percent), and oil/gas pipeline construction (16 percent). Overall, over the period 2021 – 2030, after we factor in workers' voluntary attrition through retirement at age 65, we estimate that an average of 67 workers per year will face displacement due to the 40 percent contraction in fossil fuel consumption over this period.

Comparable to the figures we report for clean energy investment jobs, we present figures on the indicators of job quality, the profile of the workers engaged in these activities, and the prevalent types of specific jobs associated with natural gas distribution, fossil fuel based electricity generation, oil and gas pipeline construction, and the other fossil-fuel dependent industries. Among other measures, we show that average compensation figures in natural gas distribution and electric power generation are substantially higher than those in clean energy activities—averaging between $139,000 – $156,000. These jobs are also even more heavily dominated by white male employees than is the case with the clean energy industries.

The Just Transition program that we propose has four major elements. These are: 1) guaranteeing the pensions for the workers in affected industries who will retire up until the year 2030; 2) guaranteeing reemployment for workers facing displacement; 3) providing income, retraining, and relocation support for workers facing displacement; and 4) mounting effective transition programs for what are now fossil fuel-dependent communities.

The major additional costs will come through the provision of income, retraining, and relocation support for displaced workers. Again, we estimate that an average of 67 displaced workers per year will require such support. We also estimate that providing adequate support for each of these workers will amount to about $300,000 per worker as a high-end figure, or about $18 million per year in total costs. Support for pension guarantees should mostly be paid for by employers.

Most of the other components of the Just Transition program can be handled through regulatory and industrial policy initiatives that need not entail major new costs. For example, to the degree allowed by law, the private fossil fuel-dependent firms that are maintaining the pension funds for their workers should be prevented from allowing the funds to become significantly underfunded. New employment opportunities for the 67 displaced workers per year could be readily provided within the pool of the roughly 160,000 jobs generated annually through clean energy investment projects, or, more broadly, the pool of 1.2 million public sector jobs within New York's state and municipal labor markets.

Transitional support for heavily-impacted communities can be provided through channeling a relatively high proportion of new clean energy investments into these communities. These investments can be financed through a range of financing policies, including grants or subsidized private loans.

A Clean Energy Investment Policy Framework

In this section, we consider what would constitute an effective package of policies for bringing total investments in energy efficiency and clean renewable energy in New York State to an average of about $31 billion per year over 2021 – 2030. We estimate that, at present, annual private investment in clean energy in New York State is about $6 – $7 billion per year. We are therefore proposing that overall annual clean energy investments will need to increase, on average, by roughly five-fold to achieve a 40 percent emissions reduction as of 2030. Most of this overall annual $31 billion figure for new clean energy investments will need to come from private investments, but with significant public investments complementing the private investment initiatives.

The proposals we consider build from the existing New York State policy framework established by the Reforming the Energy Vision (REV) program and the State Energy Plan. But we examine more ambitious measures that are capable, realistically, of bringing CO_2 emissions in the state down to 100 million tons by 2030 from the 2014 level of 170 million tons and with comparable declines in methane emissions generated through natural gas production. We consider state policies within three broad categories: a polluter fee and related regulations that take account of the social costs of burning fossil fuels as an energy source and help build demand for energy efficiency and clean renewable energy sources; financial subsidies and incentives that lower the costs and risks for private investors for investments in energy efficiency and clean renewable energy sources; and direct public spending that includes investments in infrastructure, procurement and research and development (R&D).

The policy areas on which we focus include: a polluter fee; renewable energy and energy efficiency portfolio standards; auto fuel efficiency standards; net metering for utilities; and the most effective ways to leverage public funds for expanding overall clean energy investments. We conclude that New York State could successfully finance clean energy investments in the state at a level of about $31 billion in public plus private investments per year over 2021 – 2030 on the basis of a minimum of about $4 billion in annual public spending. That level of public funding could be generated through a combination of the state's existing State Energy Fund budget along with 50 – 75 percent of the annual revenues from the polluter fee that begins at $35 per ton in 2021 and rises to $75 per ton as of 2030. Our estimates include an assumption that between 25 – 50 percent of revenues from the polluter fee will be channeled into rebates for residents.

Achieving a Zero-Emissions New York State Economy by 2050

If the New York State economy is able to bring overall CO_2 emissions in the state down to 100 million tons by 2030—a 40 percent decline relative to the 2014 level of 170 million tons and with methane emissions from natural gas production falling by a comparable amount—the state should also be able to achieve a zero emissions economy by 2050. Indeed, New York should be able to reach zero emissions by 2050 basically through continuing the clean energy investment project that would have proceeded from 2021 – 2030. On an annual basis, the scale of the investments in energy efficiency and clean renewable energy between 2031 – 2050 that will be needed to reach zero emissions by 2050 will be significantly more modest than what we describe for the project through 2030. Over 2031 – 2050, we estimate that the average annual clean energy investments costs necessary to reach zero emissions by the end of the period as ranging roughly between 0.6 – 0.8 percent of New York's average GDP, as opposed to the average cost per year of 1.8 percent of GDP for the project over 2021 – 2030. The impact of the investment project on job opportunities throughout the state will be similarly more modest, though still strongly in the positive direction. Depending on the state's level of economic growth over 2031 – 2050, we estimate average job creation through the clean energy investment project as ranging between about 50,000 – 90,000 jobs per year. We also estimate that Just Transition policies for displaced workers over this period in both the fossil fuel and ancillary industries—including income, retraining, and relocation support for all affected workers—would amount to about $60 million per year.

CLEAN ENERGY INVESTMENTS FOR NEW YORK STATE

An Economic Framework for Promoting Climate Stabilization and Expanding Good Job Opportunities

1. Introduction

This study examines the prospects for transformative clean energy investment projects for New York State. Taken as a whole, these investments should be understood as a major initiative within the state to advance the fundamental goal of global climate stabilization. These investments should be undertaken by both the public and private sectors in New York State, supported by a combination of public investments and incentives for private investors.

The first specific aim of this project is to achieve, by 2030, a 50 percent reduction below the 1990 level in all human-caused carbon dioxide (CO_2) emissions in New York State, along with comparable reductions in methane emissions generated through extracting natural gas. The second, equally important, goal is to achieve these 2030 emission reduction goals while also expanding job opportunities and raising average living standards throughout New York State.

The expansion of clean energy investments will need to focus on 1) dramatically improving energy efficiency standards in New York's stock of buildings, automobiles and public transportation systems, and industrial production processes; and 2) equally dramatically expanding the supply of clean renewable energy sources—primarily wind, solar, and geothermal power—available at competitive prices to all sectors of New York State's economy.

In addition to these goals for 2030, this study also explores the prospects for achieving the longer-term aim of bringing greenhouse gas emissions from energy sources in New York State down to zero by 2050, while, again, concurrently expanding job opportunities and raising average living standards throughout the state.

Such efforts to rapidly and dramatically drive down greenhouse gas emissions in New York State are representative of the types of climate stabilizations initiatives that need to be advanced throughout the world without further delay. The December 2015 UN-sponsored Paris Climate Agreement was a major milestone on behalf of the global project of climate stabilization. Coming out of the conference, all 196 countries formally recognized the grave dangers posed by climate change and committed to take action to substantially cut emissions generated by their respective economies.

On June 1, 2017, U.S. President Donald Trump announced that the United States would pull out of the Paris Agreement. This decision dealt a severe blow to the prospects for putting the global economy onto a sustainable path toward climate stabilization. But Trump's decision also elicited strong protests throughout the U.S., among citizens in general, as well as a range of political organizations and elected officials.

Governor Andrew Cuomo of New York was among the most forceful in restating New York State's support for the Paris Agreement and in pledging to advance an effective climate stabilization agenda in the state. Indeed, on June 2, 2017, only one day after Trump announced his decision, Cuomo signed Executive Order No. 166, titled "Redoubling New York's Fight Against the Economic and Environmental Threats Posed by Climate Change and Affirming the Goals of the Paris Climate Agreement." This order reaffirmed the main goals of New York State's project of Reforming the Energy Vision (REV), which Governor Cuomo first presented in April 2014. The primary goals of the REV program, which are targeted to be achieved by 2030 in New York State, include: 1) a 40 percent reduction in all greenhouse gas emissions; 2) generating 50 percent of all electricity from renewable energy sources; and 3) achieving a 23 percent improvement in energy efficiency in buildings relative to the 2012 level.

As we will examine in discussions below, New York State's REV program, and the State Energy Plan, which fleshes out the REV through a range of specific policy initiatives, are certainly a significant positive foundation for advancing climate stabilization in New York State. They are also supportive of the Paris agreement. But this also itself creates serious problems— ones that are of an entirely different character and order than anything resulting from Trump's abrogation of Paris, but serious problems nonetheless. The fundamental issue is that the pledges made by all countries combined at the Paris conference are not close to being adequate to stabilize the climate at a global mean temperature at between 1.5 – 2.0°C above pre-industrial levels no later than 2100—the goal that the Paris Agreement itself recognizes as necessary to achieve climate stabilization. Rather, according to the credible estimate by the environmental research NGO Climate Action Tracker, if all countries were to keep to the pledges they made at Paris, the global mean temperature would rise by between 2.4 – 2.7°C by 2100.[1] In addition, even these inadequate pledges were not made legally binding in Paris.

Similarly, New York State's REV goals and its State Energy Plan are unquestionably worthy, but, as we will discuss, they are not adequate to enable New York State to advance a sufficiently robust program in support of global climate stabilization. Further, as with the Paris agreements, most features of the State Energy Plan and of New York State's climate stabilization program are not legally binding.

Still, the REV program is an important starting point from which the state can advance a climate stabilization program that is adequate to the challenges we face. That is why this study is developed around a set of goals that build from, but are more ambitious than, those presented under the REV program—these more ambitious goals being, again, to achieve a 50 percent reduction below the 1990 level in all human-caused greenhouse gas emissions from energy sources by 2030 and to bring greenhouse gas emissions from energy sources in the state to zero by 2050.

As we examine at length in this study, achieving these emissions reduction targets is fully consistent with the equally important aims of expanding job opportunities and raising living standards throughout New York State. As we will see, clean energy investments in New York that would be sufficient to put the state on a true climate stabilization trajectory will generate about 150,000 jobs per year within the state.

At the same time, the state's fossil fuel related industries will need to contract by 40 percent as of 2030—a rate of decline that would average about 4 percent per year. But as we show, this rate of decline in New York's fossil fuel related industries should cause only about 70 workers per year in all the state's fossil fuel related industries to become displaced, after we take account of the workers who will move into retirement voluntarily at age 65 by 2030.

There are communities within New York State that, at present, are significantly dependent on the fossil fuel industry, particularly in the areas of natural gas distribution, power generation, and pipeline construction. These communities are primarily within Chemung, Nassau, Chautauqua, Kings and Richmond Counties. The most direct way to support these communities in transition will be to channel a relatively high proportion of new clean energy investments into these communities.

The statewide expansion in jobs generated by clean energy investments, in both the areas of energy efficiency and clean renewable energy sources, should increase opportunities for women and minority workers seeking employment in these sectors. This is especially significant given that, at present, women and minority workers are underrepresented in the workforce of the relevant industries. The growth of jobs in these sectors will also create new opportunities to increase union coverage for workers employed in these sectors. The rise in unionization rates should, in turn, promote improved compensation levels and working conditions in these sectors.

As we are emphasizing in this introductory section, the focus of this study is to advance large-scale clean energy investments in New York State that will contribute towards an effective global climate stabilization program, while concurrently supporting healthy economic growth and expanding job opportunities throughout the state. But we also recognize a broader set of issues are at stake. These include, crucially, the public health impacts resulting from the co-pollutants that are emitted through combusting oil, coal and the corresponding benefits that will result through eliminating fossil fuel combustion. Thus, in addition to CO_2, fossil fuel combustion emits several other toxic air pollutants, including sulfur dioxide, nitrogen oxide, and particulate matter. These co-pollutants are known to cause cancer, cardiovascular disease, and respiratory illnesses. A 2016 study by Shindell et al. found that, for the U.S., a "deep decarbonization" program consistent with the aims of this study would prevent about 300,000 premature deaths by 2030.[2]

Overall, advancing large-scale clean energy investments in New York State offers the prospect of a transformational project in support of both global climate stabilization and the expansion of good job opportunities throughout the state. At the same time, this investment project will need to be managed with tremendous care in order to take full advantage of the opportunities ahead. Without careful management—both in the areas of new investment initiatives as well as the Just Transition measures in support of workers and communities currently dependent on the state's fossil fuel related industries—the major overarching opportunities ahead could get lost.

CO_2 and Methane as Greenhouse Gas Sources in New York State

This study focuses on measures to reduce that portion of total greenhouse gas caused by combusting fossil fuels—oil, coal and natural gas—to generate energy. Climate change cannot be entirely blamed on we humans consuming oil, coal, and natural gas to generate energy. But, considering the most recent global figures from the World Bank (which are for 2012), people consuming fossil fuels for energy can be blamed for about 70 percent of the problem.[3] According to these World Bank figures, CO_2 emissions from burning coal, oil and natural gas alone produce about 66 percent of all global greenhouse gas emissions. Another 2 percent is caused mainly by methane leakages during the natural gas extraction process. Nitrous oxide emissions resulting from energy production and consumption generate modest additional emissions. Agricultural production is the other major source of global greenhouse gas emissions, accounting for about 15 percent in total, in about equal shares of methane and nitrous oxide.

Focusing on World Bank's figures for the United States specifically, CO_2 emissions account for 81 percent of total greenhouse gas emissions. Methane emissions from natural gas production accounts for another 3.2 percent of total greenhouse gas emissions generated within the United States. Thus, for the United States, energy consumption and production accounts for about 85 percent of all greenhouse gas emissions, with CO_2 emissions being the dominant factor.

We recognize that these World Bank figures on relative contributions to total greenhouse gas emissions by methane, both worldwide and within the United States specifically, are not definitive. Two main issues remain unsettled in the research literature: 1) accounting most accurately for the overall level of methane emissions through the production of natural gas; and 2) measuring the extent of toxicity of methane emissions as a greenhouse gas relative to CO_2 emissions. In Appendix 1, we briefly review the relevant debates, and address their significance in terms of our focus on emissions reductions in New York State through 2030.[4]

From our review of the relevant issues in Appendix 1, we conclude that, on balance, the World Bank estimates provide a relatively reliable estimate of the extent to which New York State's production and consumption of natural gas contribute to overall greenhouse gas emissions, including methane emissions. As such, in setting the goal in New York State of reducing natural gas consumption by 40 percent relative to the 2014 level, we assume that this will yield a proportionate reduction in both CO_2 and methane emissions. We focus on CO_2 emissions throughout the study, since, as we have seen, they account by themselves for over 80 percent of all U.S.-based greenhouse gas emissions. At the same time, precisely through proposing a reduction in natural gas consumption in New York State proportionate to the reductions in petroleum consumption (and with coal already being a negligible energy source in the state), it should be clear that we do not regard natural gas as a more favorable source of fossil fuel energy for achieving climate stabilization goals, in New York State or elsewhere.[5]

New York State's CO_2 Emissions Levels and Emissions-Reduction Targets

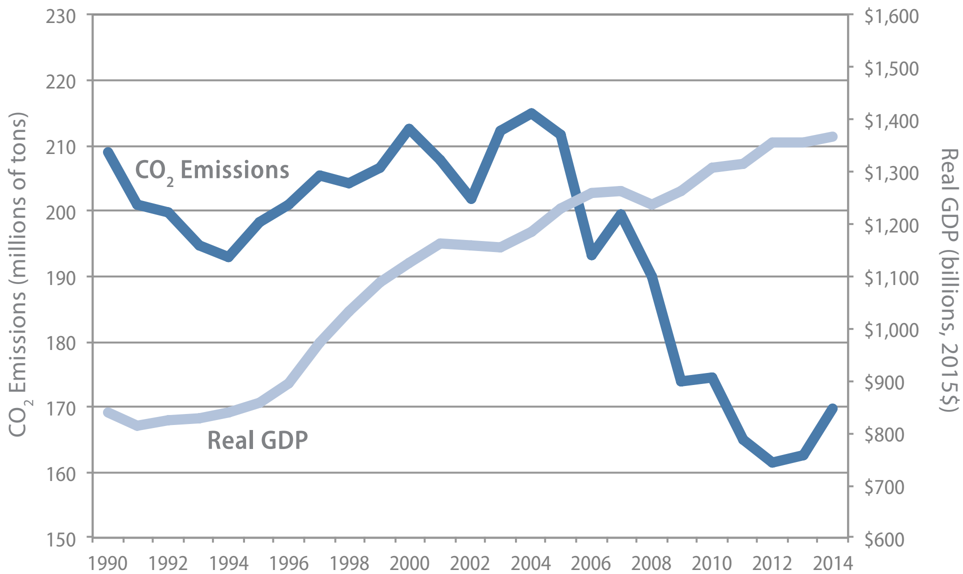
In 1990, total CO_2 emissions in New York State were at 209 million metric tons.[6] Precisely interpreted, this means that CO_2 emissions from all sources in New York State will need to be no greater than 104 million tons by 2030, if the state is going to achieve a 50 percent emissions reduction relative to its 1990 level. For the purposes of this discussion, we will round down this target figure to be as follows: New York State's total CO_2 emissions will need to be no more than 100 million tons as of 2030.

As of the most recent 2014 data, CO_2 emissions in New York were at 170 million tons. This means that, as of 2014, emissions were already 18 percent below the state's 1990 level of 209 million tons. This is despite the fact that between 1990 and 2014, real GDP in New York grew by 63 percent and population grew by 9.4 percent. What these initial figures convey is that New York State has already made progress in reducing CO_2 emissions over the past 25 years, even as the economy and population have both been growing.[7]

Figure 1 shows this pattern of "decoupling" in New York State between 1990 and 2014— with real GDP rising while CO_2 emissions falling. As we see in Figure 1, the decline in CO_2 emissions becomes a consistent pattern only in the early 2000s. We discuss the factors behind this pattern below.

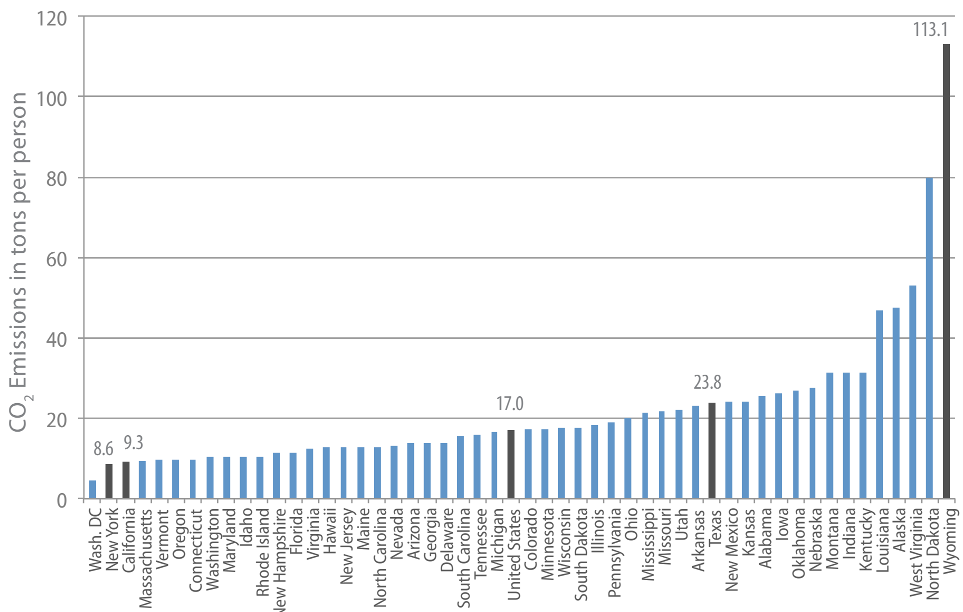
For now, it is important to recognize that New York does at present have the distinction of being the "cleanest" of all 50 U.S. states, as measured by CO_2 emissions per capita. We can see this in Figure 2, which shows CO_2 emissions per capita for all 50 states and Washington, DC as of 2014. As we see, CO_2 emissions in New York State as of 2014 were at 8.6 tons per person. Only Washington, DC is lower at 4.6 tons per person. The figure for the United States overall is 17.0 tons per person. That is, emissions for New York are roughly half the U.S. average. The emissions levels for other large states include California at 9.3

FIGURE 1: New York Carbon Dioxide Emissions and Real GDP, 1990 – 2014



Source: Bureau of Economic Analysis (BEA), Energy Information Agency (EIA).

FIGURE 2: Carbon Dioxide Emissions Per Capita, All States, 2014



Source: U. S. Energy Information Administration, U.S. Census.

tons per person, and Texas at 23.8 tons per person—i.e. nearly 3 times the level for New York. Wyoming has the highest state-level emissions, at 113.1 tons per person—13 times higher than New York.

In comparison with other countries, per capita CO_2 emissions generated in New York State are roughly 40 percent below the 13.5 figure for Canada, even while New York shares an extensive border with Canada and a large share of Canada's main population centers are regionally close to northern New York. New York State's per capita emissions are also about 7 percent below the 9.2 figure for Germany, even while Germany is a global leader among rich countries in bringing down its emissions. Emissions are much lower in a country like India, where the figure is 1.6 tons of CO_2 per capita, only 20 percent as high as the New York figure. But this is only because India's per capita income is approximately 1/50th the average per capita income in New York. We return to this issue below.

Even while recognizing New York State's positive record to date on CO_2 emissions, it is even more important to understand that the state cannot be satisfied with this status quo. As one metric, New York's current emissions level of 8.6 tons per capita is nearly four times higher than the 2.4 tons per capita figure that is needed just to reduce global emissions by 40 percent as of 2030. Moreover, as we will discuss, building a clean-energy economy in New York State represents a tremendous opportunity to both support global climate stabilization and expand good job opportunities throughout the state.

2. Sources of Energy and CO_2 Emissions for New York State

In this section, we review the sources of energy supply and demand in New York State, as well as the factors generating CO_2 emissions in the state. This discussion will provide a necessary background both for analyzing the achievements in New York State in bringing down CO_2 emissions over the past 25 years, as well as for advancing a viable framework to lower emissions much further, to 100 million tons, by 2030.

Table 1 shows New York State's energy consumption profile both in terms of sources and uses of energy. In this table and throughout the study, we measure all energy sources uniformly in terms of British Thermal Units (BTUs). A BTU represents the amount of thermal energy necessary to raise the temperature of one pound of pure liquid water by one degree Fahrenheit at the temperature at which water has its greatest density (39 degrees Fahrenheit). Burning a wood match to its end generates about 1 BTU of energy. We will present figures on energy production and consumption, as appropriate, in terms of both trillions and quadrillion BTUs, referring to the acronyms T-BTUs and Q-BTUs respectively. The box below offers examples of how much energy is provided by 1 Q-BTU.

TABLE 1
New York State Energy Consumption by Sector and Energy Source, 2014
Figures are T-BTUs

	Buildings						
	Residential	Commercial	All Buildings	Transportation	Industrial	TOTAL	% of TOTAL
Natural Gas	618.7	610.9	1229.6	28.3	128.6	**1386.6**	37.6%
Petroleum	173.0	98.4	271.4	921.7	103.7	**1296.8**	35.2%
Nuclear	135.9	258.9	394.8	5.7	49.6	**450.1**	12.2%
Hydro	74.4	141.8	216.2	3.1	28.8	**248.1**	6.7%
Biomass	48.9	32.1	81.0	0.3	53.5	**134.9**	3.7%
Coal	10.0	19.1	29.1	0.4	35.2	**64.7**	1.8%
Wind	9.1	17.3	26.4	0.4	3.3	**30.1**	0.8%
Geothermal	0.7	1.8	2.6	--	--	**2.6**	0.1%
Solar	14.29	0.32	14.61	0.01	0.06	**14.68**	0.4%
Net Imports of Electricity	--	--	--	--	--	**60.0**	1.6%
Total	**1,085.0**	**1,180.6**	**2,265.6**	**960.0**	**402.9**	**3,688.5**	100.0%
% of Total	**29.4%**	**32.0%**	**61.4%**	**26.0%**	**10.9%**	**100%**	---

Source: U.S. Energy Information Agency (EIA) https://www.eia.gov/state/data.cfm?sid=NY#ConsumptionExpenditures

Notes: Electricity use is distributed within each energy source and sector. Electricity figures include losses, distributed by source and sector. We use 2014 data throughout as our most recent set of figures. The EIA does provide figures for 2015 for some data series. For consistency, we continue to refer to the 2014 figures.

How Much Energy Does One Q-BTU Provide in New York State?

Total Statewide Energy Consumption: Total energy consumption in New York State for 2014 was about 3.7 Q-BTUs. This means that 1 Q-BTU corresponds to 3 ½ months of the state's total energy consumption.

Residential Energy Consumption: 1 Q-BTU equals the total average annual energy consumption for the residences of 10 million U.S. households. This corresponds roughly to the annual residential energy consumption for all households in New York as well as those in New Jersey.

Automobile Travel: 1 Q-BTU can provide enough energy for 61 million round-trip automobile journeys between New York City and Los Angeles.

Power Plants: 1 Q-BTU is the amount of electricity generated in one year by 408 averaged-sized U.S. power plants. This is about 7 percent of all U.S. power plants. It is approximately equal to the amount of electricity consumed in nine months in New York State (including electricity-generating losses).

Coal Supply: 1 Q-BTU is roughly equal to the energy contained in 40 million tons of coal. This is the amount of coal that would be loaded onto a freight train that stretches from New York City to Fairbanks, Alaska.

First, as we can see, natural gas is the most heavily consumed energy source. In 2014, New York consumed a total of 1,387 T-BTUs, or roughly 1.39 Q-BTUs of natural gas. This amounts to about 38 percent of the state's total consumption. The next largest source is petroleum, at about 1,297 T-BTUs, or about 1.3 Q-BTUs. This amounts to 35 percent of the total. Thus, natural gas and petroleum account for 73 percent of total energy consumption in New York. As noted above, we emphasize here again that the clean energy program for New York State will entail proportionate reductions throughout the state in *both natural gas and petroleum consumption*. Because of both the CO_2 emissions generated in combustion as well as the methane leakages resulting from production, natural gas cannot be considered a relatively benign "bridge fuel" for advancing a viable climate stabilization program in New York State or elsewhere.

The other major energy sources in New York are nuclear power, at 12.2 percent, hydro at 6.7 percent, and biomass at 3.7 percent. Remarkably, coal is already a negligible energy source in New York, at 64.7 T-BTUs, or 1.8 percent of New York's total energy supply. In combination, wind, solar and geothermal energy account for 1.3 percent of total energy consumption as of 2014. It is evident from these initial figures that transforming these three clean renewable sources into a major provider of energy in New York as of 2030 will be a formidable challenge.

In terms of uses of energy, we see in Table 1 that buildings, including both commercial and residential, account for over 61 percent of all consumption. Transportation accounts for 26 percent and industrial production activities absorb 11 percent. The net interstate flow of electricity accounts for the remaining 1.6 percent. From these figures, it is clear that any program to dramatically reduce emissions must focus first on the consumption of energy in the state's stock of both residential and commercial buildings, and second, in transportation.

Electricity Supply and Demand

To further clarify the profile of energy consumption in New York State, we show data in Table 2 on the uses and sources of electricity in the state. Table 3 provides a summary of the main findings shown in Table 2.

Electricity is, of course, unique in that it is an intermediate energy source, relying on several primary sources for its generation. It is also unique in that, as Table 2A shows, approximately two-thirds of all energy consumed is lost in the conversion process from the primary energy sources to electricity supply, while only one-third is channeled into energy that is

TABLE 2
New York Electricity Consumption and Energy Consumed to Produce Electricity, 2014
Figures are T-BTUs

	Electricity Consumption		Energy Consumed, Including Losses	
A) Electricity Supply	*T-BTUs*	*% of total*	*T-BTUs*	*% of total*
Natural Gas	182.3	35.1%	466.0	34.2%
Nuclear	146.7	28.2%	450.1	33.1%
Hydro	88.7	17.1%	247.4	18.2%
Coal	14.6	2.8%	45.9	3.4%
Wind	13.5	2.6%	37.7	2.8%
Petroleum	6.7	1.3%	18.8	1.4%
Bioenergy	6.6	1.3%	32.3	2.4%
Solar	0.24	0.1%	0.7	0.1%
Geothermal	0	0	0	0
Net Imports of Electricity	60.0	11.6	60.0	4.4%
Total	519.3	100%	1,353.9	100%

B) Electricity Demand	% of total
Buildings	85.9%
Industry	12.2%
Transportation	1.9%
TOTAL	100%

Sources: EIA (https://www.eia.gov/electricity/data/browser/) and Table C9 of the State Energy
Consumption Estimates (DOE/EIA-0214 (2014) and June 2016)).

TABLE 3
Summary Figures on New York State Electricity Consumption and Energy Losses in Electricity Generation, 2014

Electricity Consumption as Share of Overall Energy Consumption	12.5% of Energy Consumption
Energy Consumed in Generating Electricity, Including Energy Losses	36.7% of Energy Consumption
Energy Losses as Share of Energy Consumed in Generating Electricity	66.0%

Source: See Table 2.

consumed. That is why, as we see in Table 3, electricity production requires 1,353.9 T-BTUs of New York's total energy consumption, amounting to 37 percent of all energy consumed in the state, while, as an energy source to final consumers in New York's building, transportation and industrial sectors, electricity provides only about 13 percent of the total energy supplied. One evident way to raise energy efficiency, in New York and elsewhere, would therefore entail reducing the percentage of energy losses through electricity generation.[8]

In terms of electricity demand, we see in Table 2B that, by far, the most prevalent use is for the operation of buildings, accounting for about 86 percent of all electricity demand. Industrial processes are next, consuming about 12 percent of all electricity. At present, electricity is used to only a minimal 1.9 percent in transportation. This is mainly for operating the rail car systems throughout the state. But the share of electricity demand for transportation would rise sharply if the use of electricity-powered cars were to grow through 2030.

Table 2 also shows the primary energy sources used in New York State to generate electricity. As we see, natural gas is the most significant energy source here, providing about 34 percent of the energy needed to generate electricity, including energy losses. The next largest source of New York's electricity supply is nuclear, at 33 percent, including losses. Hydro power is the third largest source of electric power, at 18.2 percent.

It is especially notable that coal is a negligible source for electricity generation in New York, at 3.4 percent of supply, including losses. This stands in sharp contrast with the U.S. overall, in which coal still provides about 33 percent of the primary energy for electricity generation. Wind, solar, and geothermal supply 2.9 percent of the primary energy for electricity consumption in New York, with almost all of that coming from wind.

As we discuss below, the share of electricity supplied in New York through wind, solar, and geothermal energy will need to rise dramatically if New York is going to succeed in bringing overall CO_2 emissions down to 100 million tons by 2030. The challenge here is even greater, given that there are no plans to expand either nuclear or hydro power in New York. Rather, the plan is for hydro generating capacity to remain at its current level. With nuclear power, the two reactors at Indian Point are scheduled to come offline by 2019. The facilities at Nine Mile Point and Ginna are scheduled to be phased out by 2029.[9] These plans for reducing nuclear power generation in New York will mean that overall electricity supply from nuclear should be roughly cut in half by 2030.

CO_2 Emissions Sources for 2014 and 2030

Table 4 shows how New York generated 170 million tons of CO_2 as of 2014 (with energy consumption figures expressed in this table in terms of Q-BTUs). In column 1, we see again that natural gas is the largest source of fossil fuel energy supply in the state, at 1.39 Q-BTUs. Column 2 shows that burning natural gas in New York generated 73.6 million tons of CO_2 emissions, which amounts to a rate of 52.9 million tons of CO_2 per Q-BTU of energy, as shown in column 3. Petroleum use in New York is lower than natural gas, at 1.30 Q-BTUs. But burning petroleum in the state generates a higher level of CO_2 emissions, at 90.1 million tons. This is because petroleum is a somewhat dirtier source of energy than natural gas, generating, as column 3 of Table 4 shows, 69.3 million tons of emissions per Q-BTU of energy supplied. Finally, as we see, coal is the dirtiest fossil fuel energy source, generating in New York 94.2 million tons of CO_2 per Q-BTU of energy. But because coal is used so sparingly in New York, the level of emissions generated by combusting coal is correspondingly modest, at 6.1 million tons.

We can extrapolate from these figures that driving down overall emissions in New York from 170 to 100 million tons by 2030 will require cuts in both natural gas and petroleum consumption in the range of 40 percent, while coal consumption is phased out entirely. Indeed, we can be specific here as to the maximum levels at which New York State can combust natural gas and petroleum if it is going to succeed in bringing down annual CO_2 emissions to 100 million tons by 2030.

As a realistic first approximation, let us assume that natural gas and petroleum will continue to be consumed in New York State to roughly equivalent extents. Petroleum will continue to be needed primarily as a liquid fuel for transportation while natural gas will be used primarily to generate electricity and for heating buildings. Under this assumption, total natural gas and petroleum consumption as energy sources as of 2030 can be no more than 0.8 Q-BTUs apiece. At this level of natural gas and petroleum consumption, total CO_2 emissions in New York State as of 2030 would amount to about 98 million tons. Columns 4 and 5 of Table 4 present the calculations through which we derive this result.

TABLE 4
Sources of CO_2 Emissions for New York State: *2014 Actuals and 2030 Projections*

	2014 Actuals			2030 Projections	
	1) 2014 Energy Consumption *(in Q-BTUs)*	**2) 2014 CO_2 emissions** *(in millions of tons)*	**3) CO_2 emissions per Q-BTU** *(= column 2/ column 1)*	**4) 2030 Energy Consumption** *(in Q-BTUs)*	**5) 2030 CO_2 emissions** *(in millions of tons; = column 3 x column 4)*
Natural Gas	1.39	73.6	52.9	0.8	42.3
Petroleum	1.30	90.1	69.3	0.8	55.4
Coal	0.06	6.1	94.2	0	0
Totals	**2.75 Q-BTUs of energy from fossil fuels**	**169.8**	**61.7 weighted average of emissions per Q-BTU**	**1.6**	**97.7**

Sources: EIA: http://www.eia.gov/environment/emissions/state/; https://www.eia.gov/state/?sid=NY#tabs-1

Note: EIA sources do not assign emissions levels for the 0.135 Q-BTU level of New York energy consumption for biomass.

3. Factors in New York State's Low Emissions Levels

What explains the positive relative performance of New York State in terms of its current level of CO_2 emissions per capita? To obtain a clearer understanding of the factors at play, it will be useful to decompose the emissions per capita ratio into three distinct parts. This yields three ratios, each of which provides a simple measure of one major aspect of the climate change challenge, for New York, the rest of the U.S. states and elsewhere. That is, CO_2 emissions per capita can be expressed as follows:

Emissions/population = (GDP/population) x (Q-BTUs/GDP) x (emissions/Q-BTU).

These three ratios provide measures of the following in each state, regional or country setting:

1 Level of development: Measured by GDP per capita (i.e. GDP/population);
2. Energy intensity: Measured by Q-BTUs/GDP;
3. Emissions intensity: Measured by emissions/Q-BTU.

In Table 5, we show these ratios for New York, as well as, for comparison purposes, some other U.S. states. Some significant observations emerge through considering these ratios. The first, most generally, is that there are three distinct ways in which any country, state or region can achieve a low figure for per capita emissions. The first is for the relevant economic area—the state, country or region—to operate at a low level of economic activity—i.e. at a low GDP level. Thus, as mentioned above, the Indian economy operates with a very low figure for emissions per capita of 1.6. This is entirely due to the fact that per capita income in India is also still extremely low, at about $1,600.

By contrast, per capita income in New York State as of 2014 was about $70,000. This sets New York as having the second highest figure for per capita income among the 50 U.S. states, after Delaware. It is therefore clear from these figures that New York is achieving its

TABLE 5
Determinants of per capita CO_2 emissions levels in various states, 2014:
Level of development, energy intensity and emissions intensity

CO_2 Emissions/population = (GDP/population) x (Q-BTUs/GDP trillions) x (Emissions/Q-BTU)

	CO_2 emissions/ population	GDP/population (2015$)	Energy intensity ratio: Q-BTUs/trillion dollars GDP	Emissions intensity ratio: CO_2 emissions/Q-BTU
New York	8.6 tons	$69,341	2.7 Q-BTUs	45.4 million tons
U.S.	17.0 tons	$54,181	5.7 Q-BTUs	55.0 million tons
California	9.3 tons	$60,945	3.2 Q-BTUs	47.0 million tons
Texas	23.8 tons	$58,798	8.1 Q-BTUs	49.8 million tons
Wyoming	113.1 tons	$67,850	13.5 Q-BTUs	123.2 million tons
West Virginia	53.0 tons	$39,870	10.2 Q-BTUs	130.2 million tons

Source: EIA, U.S. Census, BEA.
Note: Most recent data on CO_2 emissions is for 2014.

low per capita emissions figure not because the state's economy operates at a low level of GDP, but rather, *despite the fact that it operates at a high GDP level.*

With respect to this relatively high average income level, New York could, hypothetically, reduce its per capita GDP figure by 70 percent, to around $22,000, while maintaining its existing energy infrastructure fully intact. But this is obviously not a program for expanding well-being while also reducing emissions. To the contrary, the aim of a statewide clean energy project, again, is to achieve the 2030 emissions reduction level of 100 million tons of CO_2 while the state's economy grows at a healthy rate and job opportunities expand.

In fact, the two factors that are responsible for New York's low level of per capita emissions at present are:

1. *Energy efficiency*: the state, overall, operates at a very high level of energy efficiency. That is, its energy intensity ratio, at 2.7 Q-BTUs per $1 trillion in GDP, is the lowest among the 50 U.S. states.
2. *Relatively* c*lean energy sources*: The state's emissions intensity ratio is 45.4 million tons per Q-BTU of energy, which is 18 percent below the U.S. average of 55.0. The main factor here is that, as we have seen, coal use is negligible in New York. The low level of coal is compensated for through relying more heavily on natural gas than most other U.S. states. New York also relies relatively heavily on nuclear and hydro power. Nuclear and hydro power generate zero CO_2 in producing energy.

We examine both of these factors in further detail in what follows. It is critical to understand where the state is at present with both of these factors in order to understand how to achieve further gains along both fronts—i.e. to raise efficiency levels further and to increasingly rely on clean energy sources.

It is also important to understand the sources of New York State's gains in decoupling— i.e. in reducing emissions from 1990 to the present even while both average incomes and population in the state grew. We can see the factors driving the gains in emissions reduction in Table 6. As the table shows, the state's energy intensity ratio fell from 3.6 to 2.7 between 1990 and 2014, a nearly 20 percent improvement, while the state's emissions intensity ratio fell from 69.0 to 45.4, a 34 percent improvement.

As we have emphasized, one central element of this clean energy investment project for New York State is to promote a healthy GDP growth rate and rising average incomes along with declining CO_2 emissions. In fact, the only realistic ways to deliver higher incomes while also bringing down emissions to 100 million tons as of 2030 will be to both produce further gains in energy efficiency and to expand the supply of clean energy sources, while both natural gas and petroleum consumption fall by 40 percent and coal consumption is phased out entirely. Given this, in the next two sections of this study, we explore the prospects for both dramatically improving energy efficiency and clean renewable energy supply in New York.

TABLE 6
Determinants of New York State per capita CO_2 emissions, 1990 and 2014:
Level of development, energy intensity and energy mix

New York	CO_2 emissions/ population	GDP/population (2015$)	Energy intensity ratio: Q-BTUs/trillion dollars GDP	Emissions intensity ratio: CO_2 emissions/Q-BTU
1990	**11.61 tons**	**$46,680**	**3.6 Q-BTUs**	**69.0 million tons**
2014	8.6 tons	$69,341	2.7 Q-BTUs	45.4 million tons

Source: EIA, U.S. Census, BEA.

4. Prospects for Energy Efficiency

Current Sources of High Energy Efficiency

What are the factors that explain New York State's relatively high level of energy efficiency at present as well as its improvements in efficiency over time? We can, first, explain its high level of efficiency at present relative to the U.S. as a whole by two unique features of the physical infrastructure in New York City and its surrounding areas within the state, including Westchester and Long Island (i.e. Nassau and Suffolk Counties). These two features are: 1) a much higher percentage of people who live in apartment buildings than in the U.S. overall; and 2) a much higher proportion who utilize public transportation, especially rail transit.

These two structural features of the New York City area are, in turn, highly impactful for the state overall, since the population of New York City, at 8.4 million, represents 42 percent of the overall state population. When Westchester, Nassau and Suffolk Counties are added, this brings the total population of the area to about 12.2 million, or 62 percent of the overall state population.

Why are these two factors of the New York City area physical infrastructure so significant? First, with respect to housing, for New York State, about 24 percent of the population lives in apartment units with 20 or more residents. This compares with 8.8 percent for the U.S. overall. On average, energy consumption in apartment units amounts to about half the level as with single-family detached homes.[10]

With respect to transportation, in New York State, about 29 percent of the population relies on public transportation, which contrasts with only 5 percent for the U.S. overall. Moreover, in New York State, roughly 60 percent of all public transportation miles are provided by rail systems—either subway, light rail or commuter rail—as opposed to buses. This is significant since, on average, rail transit is about 25 percent more efficient in moving people than cars. In principle, public buses can also be more efficient than cars, but this depends on the average number of people that ride the buses at any given time, i.e. the "load factor." When we take account of actual average load factors in New York, public buses are generally less efficient than cars.[11]

Thus, relative to the U.S. overall, the much larger reliance in New York State on apartment living and rail transportation is the primary explanation for the State's utilizing energy at a level that is 2.5 times more efficient than the U.S. overall. At the same time, these structural factors have been present for decades, and therefore cannot explain the 28 percent improvement in efficiency within New York State between 1990 and 2014. The explanation for this improvement over the past 24 years is that, within the State, housing, transportation and industrial technologies have all become more efficient over time. However, here the efficiency gains over time are comparable to those for the U.S. economy overall.[12] It is therefore critical to recognize that additional gains in efficiency in New York State will not result from the unique structural features of either the state's building or transportation systems. In other words, achieving further energy efficiency improvements in New York State will need to result from further improvements in equipment that will be broadly applicable throughout the U.S. economy as a whole.

Strategies for Further Energy Efficiency Gains[13]

Focus on buildings and auto efficiency

As we saw above, buildings account for about 61 percent of all energy consumption in New York State and transportation accounts for an additional 26 percent. Thus, any project to raise efficiency standards significantly will need to focus on building and transportation investments. Moreover, even in New York State, with its uniquely high share of rail transit relative to the rest of the U.S., automobiles, along with gasoline-powered vans, trucks and buses, account for 85 percent of all transportation energy consumption, or 22 percent of all energy consumption.[14] Thus, the project of raising efficiency in New York must first be concerned with buildings and automobiles.

It is also important to not neglect other areas of energy consumption, including industrial efficiency, electricity transmission, and public transportation, given that, collectively, they account for about 20 percent of all energy usage. We assume that a full-scale energy efficiency investment project will include these areas. But we do not explicitly discuss the general prospects or specific cost estimates for these areas in this study.[15] We do, however, provide estimates, in Section 7, of the employment effects of investing in these additional efficiency areas along with the main investments with buildings and automobiles.

Estimating costs of efficiency gains

One careful recent study of the potential gains available in the U.S. economy through energy efficiency investments is the 2010 survey study by the National Academy of Sciences (NAS), called *Real Prospects for Energy Efficiency in the United States*. This study provides detailed descriptions of the main research findings in all major areas of energy consumption in the U.S. economy. For our purposes here, we will want to draw on the main conclusions of the study as well as more recent relevant work regarding the gains that can be achieved with buildings and automobiles.[16] We consider these in turn.

Buildings

The NAS study provides extensive evidence showing that energy consumption in both commercial and residential buildings could fall by approximately 30 percent or more below a reference case for 2030 set by the U.S. Department of Energy. These gains in the range of 30 percent are available through a wide range of "low cost" investments in energy efficiency. By "low cost" investments, we refer to the NAS measure of the "cost of conserved energy." Low-cost investments are those in which the costs of conservation are below the market price of energy from the relevant energy source. For buildings, the relevant energy threshold is the price of delivered electricity or natural gas. Thus, in considering the use of electricity in commercial buildings, the NAS finds that in all the main areas of consumption—including lighting, space cooling, office equipment, ventilation, refrigeration, space heating and other uses of the buildings' thermal shells—savings are available relative to the reference case in the range of 35 percent. The NAS estimated the costs of these savings as being 2.8 cents per kilowatt hour as of the study's 2010 publication date. This compares with the average costs of purchasing electricity in New York as 15.7 cents per kilowatt hour as of September 2016.[17] The NAS estimates the gross costs of achieving these energy savings—i.e. costs prior to factoring in the energy savings available—at about $28 billion per Q-BTU of savings.

The NAS does also analyze the additional potential savings through the use of newer technologies. The study notes that:

> The conservation supply curves …do not take into account a number of newer technologies and whole-building design approaches. These technologies and approaches add to the energy-savings potential identified in the conservation supply curves. Thus, the panel judges that these supply curves represent the lower estimate of energy-saving potential (2010, p. 80).

The NAS study highlights seven areas in which advanced technologies are "the most promising for further improving the energy efficiency of buildings." These include solid state lighting, advanced cooling systems, lower energy consumption in home electronics, reduced consumption in servers and data centers, advanced window technology, and better construction methods for both home and commercial-buildings.

In advancing beyond the lowest cost opportunities for efficiency gains, we therefore have to ask whether we can achieve these further gains at the same average cost of $28 billion per Q- BTU level. In fact, there are valid reasons to assume that costs could actually come down as energy efficiency investments are advanced at a large scale in New York State. These include the following considerations:

- **The average cost of gaining a given amount of efficiency gains in New York buildings remains well within the market price of electricity.** Even if we allow that the average costs of achieving efficiency gains in New York buildings are, at present, significantly higher than the 2010 average figure cited by the NAS study of 2.8 cents per kilowatt hour, the current average costs are still certainly well below the current average price of electricity in the state of 20.1 cents, as of August 2017.
- **The returns on investment in building efficiency are high, but the market has been thwarted because of underdeveloped market and financing infrastructures.** The systems of financing and risk-sharing that enable businesses and homeowners to capture the benefits of high returns without having to carry the full burden of initial financial risk remains immature. Developments in these areas should come rapidly once the initial set of business models, market, structures, and financial innovations take hold.
- **The absolute level of efficiency gains attainable in buildings is very high, as evidenced by the growing number of recently constructed carbon neutral buildings.** Of course, the costs of getting buildings to the point of carbon neutrality are also high at this point, meaning that before reaching carbon neutrality, we begin to approach a point of diminishing returns on investments—i.e. rising costs needed to achieve a given gain in efficiency. At the same time, as the market for efficiency investments expands, the costs of the best upcoming technologies begin to fall. As the NAS study notes, this has certainly been true with LED lighting. Similar opportunities are emerging in the other areas mentioned above—cooling, home electronics, servers and data centers, windows, and construction of both homes and commercial buildings.

In addition to these technical considerations, there are further major efficiency gains achievable through training building superintendents to manage existing building systems at higher efficiency levels. Indeed, an innovative "Green Supers" program was initiated in New York City in 2010, directed by the Service Employees International Union Local 32BJ, and supported by the U.S. Green Building Council, the Building Research Institute and the U.S. Labor Department. The program trains building superintendents to identify and address energy waste, create a green operating plan, and perform cost-benefit analysis for building owners and managers. A 2012 case-study analysis of the program by Steven Winter Associates concluded that the training provided through this program was achieving major efficiency gains. The study found, in particular that "these case studies…have shown that an energy reduction of 5% to 20% is achievable through improving operational efficiency," (2012, p. 5).

Despite all of these factors suggesting falling costs as the level of investment and training of building supervisors expand, there have also been many instances of over-optimism in assessing the prospects for raising efficiency standards in buildings. Thus, while the engineering evidence consistently finds, for example, that investments in building efficiencies will have rapid payoffs, it is still necessary to obtain financing for projects to proceed. Another issue is the hassle factor involved in undertaking such projects. Considering home-weatherization efficiency programs specifically, Allcott and Greenstone write that "Weatherization takes time, and for most people it is not highly enjoyable: the process requires one or sometimes two home energy audits, a contractor appointment to carry out the work and sometimes additional follow-up visits and paperwork," (2012, p. 16). Such matters can create serious difficulties for individual homeowners in particular.

The implication that follows is not that the engineering level of analysis is wrong, or that superintendent training programs such as Green Supers cannot be expanded, but rather that both public policy and private initiatives are needed to tackle the financial issues and the hassle factors that are involved in building efficiency projects. Given these considerations, and the fact that we are assuming that the gains in efficiency will need to occur rapidly within a decade-long time period, it will be prudent to assume that costs will be higher than the average estimated by the NAS. For our purposes, we therefore assume the costs of achieving gains in building efficiency to be in the range of $35 billion per Q-BTU, i.e. 25 percent higher than the NAS estimate.

Transportation

For the purposes of our discussion, we focus here on the case for achieving gains in automobile efficiency as of 2030. Even in the State of New York, with its high proportion of public transportation, 64 percent of all workers in the state commute to their jobs with cars, trucks, or vans.[18]

The starting point for considering efficiency gains in auto transit is the agreement reached in 2011 between the Obama Administration and 13 major auto manufacturers to raise the miles per gallon (mpg) standard for new U.S. cars to 54.5 mpg as of 2025. Pollin et al. analyzed the impact of this measure in detail in the 2014 study *Green Growth*. Again, this analysis drew largely on the 2010 NAS study on efficiency prospects for the overall U.S. economy. The main finding that we extracted from this study is that achieving a 30 percent reduction in emissions from the U.S. auto fleet by 2030 is attainable and at a cost that will be comparable to the costs for achieving efficiency gains in buildings. This analysis factors in efficiency gains through the expanding use of hybrid, hydrogen fuel cell, plug-in electric and battery electric vehicles (see especially pp. 74 – 76).

More specifically, the study found that raising the 2025 mandated efficiency level of new cars from its previous level of 35.9 mpg to 54.5 mpg will mean that the average car on the road as of 2030 will operate at an efficiency level of 42.4 mpg. This will include all vehicles powered by all propulsion systems, including electric vehicles. This efficiency level is roughly 15 percent lower than the average gasoline-powered Toyota Prius sold in U.S. markets in 2016, which are at approximately a 50 mpg level of efficiency.[19]

This average figure for 2030 will, of course, include not only cars produced in 2025 and thereafter—all of which will be at least at the 54.5 mpg level by mandate—but earlier model cars as well that were not subject to this mandate and thereby operate much less efficiently. The 2014 study also estimated that, had the U.S. continued to maintain the earlier 2025 mandate of 35.9 mpg, the overall fleet as of 2030 would be at an average efficiency level of 28.7 mpg. The average efficiency gain from 28.7 to 42.4 mpg is an improvement of roughly 48 percent. The NAS estimated the average cost increase for achieving this higher level of efficiency at about 25 percent above the retail price of standard gasoline engine cars. The average car owner will then also save about $1,000 per year in gasoline purchases.

We do not assume that public transportation efficiency will improve by a comparable 48 percent, but rather at a significantly more modest rate. Thus, for New York State, which operates with a high level of public transportation ridership, we conclude that a rough reasonable estimate of the overall potential efficiency gains in transportation as of 2030 will be around 30 percent. We also conclude that the costs of achieving such efficiency gains are likely to be in the range as those for building efficiency investments, i.e. at about $35 billion per Q-BTU of energy savings.

5. Prospects for Clean Renewables

Assuming that, through aggressive energy efficiency investments, New York is able to bring down overall statewide energy consumption dramatically, it will still be necessary to greatly expand the state's reliance on clean renewable energy sources in order for total emissions to fall to 100 million tons by 2030. We saw in Table 4 that, to bring total CO_2 emissions to no more than 100 million tons, the overall consumption of natural gas and petroleum can be no more than 1.6 Q-BTUs by 2030. This also assumes that coal consumption in New York will have been eliminated altogether and that nuclear energy plants are being slowly phased out.

At present, virtually all of the state's clean renewable supply comes from hydro power. But we are not assuming any significant increase in hydro energy production through 2030. We also are assuming that clean bioenergy sources—primarily cellulosic biofuels—will remain negligible in New York State.[20] This therefore means that the full expansion of clean renewable energy as of 2030 will need to be provided through expanding the production of wind, solar, and geothermal power.

What would be the costs associated with this expansion of clean renewable energy supply? We need to consider any such costs from two distinct perspectives. The first is what the cost increases would likely be for energy consumers, as they substitute wind, solar, or geothermal energy for the existing fossil fuel energy sources. The second is the costs of building the new generating capacity for wind, solar, and geothermal power.

Costs to Consumers

To consider costs to consumers, we refer to the U.S. Energy Department's calculations as the "levelized costs" of supplying electricity through alternative energy sources. The Energy Information Agency (EIA), an office within the Energy Department, describes levelized cost as representing:

> The per-kilowatt hour cost (in real dollars) of building and operating a generating plant over the assumed financial life and duty cycle. Key inputs to calculating levelized costs include overnight capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs and an assumed utilization rate for each plant type.[21]

In short, levelized costs takes account of *all costs* of producing and delivering a kilowatt hour of electricity to a final consumer. The cost calculations begin with the upfront capital expenditures needed to build the generating capacity, continues through to the transmission and delivery of electricity, and includes the costs of energy that is lost during the electricity-generation process.

In Table 7, we present details on average levelized cost figures for four major clean renewable energy sources—hydro, onshore wind, geothermal and photovoltaic solar energy.[22] The figures come directly from the EIA. In panel 7A, we present these average cost figures measured in dollars per megawatt hours of electricity. In panel 7B, we present the same data, but expressed now in terms of billions of dollars per Q-BTU of electricity sup-

TABLE 7A

Estimated Average Levelized Costs of Electricity from Clean Renewable Energy Sources

Plants Entering Service in 2022, simple averages for regional values

In dollars per megawatt hour

	Hydro	Onshore Wind	Geothermal	Solar photovoltaic
Levelized Capital costs	$57.5	$48.5	$30.9	$70.7
Fixed Operations and Maintenance	$3.6	$13.2	$12.6	$9.9
Variable Operations and maintenance	$4.9	0	0	0
Transmission investment	$1.9	$2.8	$1.4	$4.1
Capacity factor	58%	40%	91%	25%
Total System LCOE	$67.8	$64.5	$45.0	$84.7
Levelized Tax Credit	---	-$7.6	-$3.1	-$18.4
Total LCOE, including Tax Credit	$67.8	$56.9	$41.9	$66.3

Source: U.S. Energy Information Agency, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2016," http://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

TABLE 7B

Estimated Average Levelized Costs of Electricity from Clean Renewable Energy Sources

Plants Entering Service in 2022, simple averages for regional values

In billions of dollars per Q-BTU

	Hydro	Onshore Wind	Geothermal	Solar photovoltaic
Levelized Capital costs	$196.2 billion	$165.5 billion	$105.4 billion	$241.2 billion
Fixed Operations and Maintenance	$12.3 billion	$45.0 billion	$43.0 billion	$33.8 billion
Variable Operations and maintenance	$16.7 billion	0.00	0.00	0.00
Transmission investment	$6.5 billion	$9.6 million	$4.8 billion	$14.0 billion
Capacity factor	58%	40%	91%	25%
Total System LCOE	$231.3 billion	$220.1 billion	$153.5 billion	$289.0 billion
Levelized Tax Credit	---	-$25.9 billion	-$10.6 billion	-$62.8 billion
Total LCOE, including Tax Credit	$231.3 billion	$194.2 billion	$143.2 billion	$226.2 billion

Source: U.S. Energy Information Agency, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2016," http://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

Note: Cost Conversion factor is $1 per mwh = $3.412 billion per Q-BTU.

plied. We show figures on total average levelized costs for these four clean renewable energy sources, as well as the seven components comprising these overall average costs—i.e. capital costs, fixed operations and maintenance, variable operations and maintenance, transmission, capacity utilization rates, and tax credits, as they apply. Note that storage costs are included as one component of variable operations and maintenance.

Focusing now on overall costs in dollars per megawatt hour, we see that, for operations entering service in 2022, the average costs per megawatt hour are $41.9 for geothermal, $56.9 for onshore wind, $66.3 for solar, and $67.8 for hydro.

In Table 8, we now show, for comparison purposes, total levelized cost figures for non-renewable sources of electricity, including: 1) coal, with carbon capture and sequestration (CCS) technology; 2) natural gas utilizing conventional technology; 3) natural gas with CCS; and 4) nuclear energy. CCS encompasses a number of specific technologies that capture CO_2 from point sources, such as power plants and other industrial facilities. The captured CO_2 is then transported, usually through pipelines, and stored indefinitely in subsurface geological formations.[23]

Column 1 of Table 8 reports the overall average levelized cost figures for these non-renewable sources. These figures range between $58.1 using conventional natural gas, $84.8 with natural gas and CCS technology, $102.8 with nuclear energy, and $139.5 with coal produced with CCS technology.

In columns 3 – 5 of Table 8, we then show the cost figures for these four non- renewable energy sources relative to onshore wind, solar PV and geothermal energy. As we see, advanced coal with CCS technology ranges between roughly 110 – 233 percent more than the three clean renewable sources. Natural gas produced conventionally is about 12 percent less than solar PV, but 2 percent more than onshore wind and 39 percent more than geothermal. When natural gas is produced using CCS technology, it becomes 28 percent more expensive than solar PV, 49 percent more than wind, and 102 percent more than geothermal. Finally, nuclear energy ranges between 55 percent more than solar PV, 81 percent more than onshore wind, and 145 percent more than geothermal energy.

We emphasize that these cost figures from the EIA are simple averages. They do not show differences in costs due to regional or seasonally-specific factors. In particular, solar energy costs will vary significantly by region and season. Moreover, both wind and solar energy are intermittent sources—i.e. they only generate energy, respectively, when the sun is shining or the wind is blowing. Of course, these factors will need to be fully accounted for when clean renewable energy systems are designed to provide a major share of an economy's overall energy load.

TABLE 8
Average Levelized Costs of Electricity Generated with Clean Renewables versus Fossil Fuels and Nuclear Energy

	Average Total System Levelized Costs				
	1) In dollars per megawatt hour	2) In billions of dollars per Q-BTU	3) Average costs relative to onshore wind	4) Average costs relative to solar PV	5) Average costs relative to geothermal
Coal: *Advanced with carbon capture and sequestration*	$139.5	$40.9 billion	+145.2%	+110.4%	+232.9%
Natural Gas:					
Conventional	$58.1	$17.0 billion	+2.1%	-12.4%	+38.7%
with carbon capture and sequestration	$84.8	$24.5 billion	+49.0%	+27.9%	+102.4%
Nuclear	$102.8	$30.1 billion	+80.7%	+55.0%	+145.3%

Source: U.S. Energy Information Agency, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2016, http://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

Note: Cost Conversion factor is $1 per mwh = $3.412 billion per Q-BTU.

Keeping all such considerations in mind, we can still roughly conclude from these figures that, for the most part, clean renewable energy sources are rapidly emerging into a position at which they can produce electricity at comparable or lower costs than non-renewable sources. As such, assuming that wind, solar and geothermal energy production can be scaled up to meet demand in New York State by 2030, then the costs to the state's consumers of purchasing this energy should not be significantly different than what these consumers would have paid for non-renewable energy. Indeed, overall, the costs to consumers of purchasing electricity from clean renewable sources, including hydro as well as wind, solar, and geothermal power, are likely to be lower than what they would be from either coal or natural gas with CCS technology or nuclear power. This would be true for both existing coal, natural gas or nuclear based electricity-generating plants or newly constructed plants.

Costs of Expanding Renewable Capacity

As we can see in Table 7, by far the largest share of overall costs in generating electricity from renewable sources are capital costs—i.e. the costs of producing new productive equipment, as opposed to the costs of operating that productive equipment once it has been built and is generating energy. The figures in Table 7 show that, once we account for the federal tax credit for renewable energy investments, the levelized capital costs amount to 85 percent of overall costs for onshore wind, 74 percent for geothermal, and 106 percent for solar PV.

Still, these figures are average levelized costs of producing a megawatt or Q-BTU of electricity once the necessary capital equipment is installed and operating. But it is also important to estimate these capital costs as a lump sum—i.e. how much investors need to spend *upfront* to put this capital equipment into place and in running order.

We produce estimates of these lump sum capital costs in Table 9. Specifically, these figures represent the present values of total lump-sum capital expenditures needed to produce one Q-BTU of electricity from onshore wind, solar PV, and geothermal energy.[24] As we see, the average lump-sum costs range from $146 billion per Q-BTU for geothermal, $188 billion for onshore wind, and $215 billion for solar.

If we assume that, roughly speaking, new clean renewable productive capacity will consist of 45 percent respectively from wind and solar PV technologies, and 10 percent from geothermal energy, this would place the average costs of producing one Q-BTU of overall renewable energy equipment at about $200 billion. As we will see below, this average investment figure will be useful in calculating the overall costs of achieving the goal of bringing New York's CO_2 emissions down to 100 million tons by 2030, and what the impact will be of these investments on employment creation.

TABLE 9

Capital Expenditure Costs for Building Renewable Electricity Productive Equipment

Present Values of Total Lump-Sum Capital Costs per Q-BTU of Electricity

Wind	$188 billion
Solar PV	$215 billion
Geothermal	$146 billion
Average costs *assuming investments are 45% wind; 45% solar; and 10% geothermal*	$198 billion

Sources: Table 7 for levelized capital costs per Q-BTU for alternative energy sources. See Pollin et al. (2014) pp. 136 – 37 for methodology in converting levelized costs per Q-BTU into lump-sum capital costs.

6. Clean Energy Investment Levels and Emissions Reductions

The clean energy investment initiative being proposed in this study is designed to achieve again, two interrelated fundamental goals. The first is to bring total CO_2 emissions in New York down to 100 million tons by 2030, from its current level of 170 million tons. The second is to advance this climate stabilization program while the New York State economy grows at a healthy rate between now and 2030, so that job opportunities expand and average well-being rises throughout the state. In this section of the study, we describe the clean energy investment levels that will be needed to bring together these two goals.

To explore the prospects for achieving the 2030 emissions reduction goal within the context of a growing New York State economy, we must, unavoidably, work with some assumptions as to the state's real economic growth trajectory from now until 2030. Thus, we assume that the New York State economy will grow in real (i.e. inflation-adjusted) terms between now and 2030 at an average rate of 2.6 percent per year. This growth trend is significantly faster than the average rate for 2000 – 2014, which was 1.6 percent, or the average rate over the longer period of 1990 – 2014, which was 1.8 percent. However, these two time periods both include the 2007-09 financial crisis and Great Recession, which was the U.S. economy's most severe downturn since the 1930s Depression. It is reasonable to expect that such an event will not recur over the next 15 years. In addition, it is preferable to test the viability of a emissions reduction program when the economy is growing at a healthy rate, during which energy consumption would also be relatively high, as opposed to stagnant growth conditions, during which energy consumption will have declined.

In Table 10, we first report on New York State's real GDP as of 2014 and the projected level in 2030, assuming the economy's average real growth rate is maintained at 2.6 percent through 2030. We see that, under this growth assumption, New York State's real GDP will be approximately $2.1 trillion, as opposed to the 2014 figure of $1.4 trillion. Over the period 2014 – 2030, the midpoint GDP would be $1.7 trillion, assuming, again, that average GDP is sustained at 2.6 percent per year between 2015 – 2030.

Within this framework, we can then project an energy and CO_2 emissions profile for New York State for 2030. We consider two distinct scenarios. For the first 2030 scenario, we assume that the state's energy infrastructure as of 2014 remains basically intact through 2030. We see the results of this scenario in Table 11. Specifically, in column 1 of Table 11, we show the actual breakdown of energy consumption and emissions as of 2014. In

TABLE 10
New York State GDP Levels, 2014 Actual and 2030 Projected

2014 GDP	$1.4 trillion
Projected average GDP growth rate through 2030	2.6 percent
Projected 2030 GDP	$2.1 trillion
Projected midpoint GDP between 2014 – 2030	$1.7 trillion

Source: BEA and authors' projections.

TABLE 11
New York State Energy Consumption and Emissions: 2014 Actuals and Alternative 2030 Projections

	1) 2014 Actuals	2) 2030 *With Approximate Steady State Energy Infrastructure*	3) 2030 *Through Clean Energy Investment Program*
1) Real GDP	$1.4 trillion	$2.1 trillion *(with 2.6% average growth)*	$2.1 trillion *(with 2.6% average growth)*
2) Total Energy Consumption	3.7 Q-BTUs	5.6 Q-BTUs	3.1 Q-BTUs
3) Energy Intensity Ratio (Q-BTUs/$1 trillion GDP)	2.7	2.7	1.5
Energy Mix			
Non-Renewables and Bioenergy			
4) Natural Gas	1.39	2.7	0.8
5) Petroleum	1.30	2.0	0.8
6) Coal	0.06	0.06	0
7) Nuclear	0.45	0.2	0.2
8) Biomass	0.13	0.2	0
Clean Renewables			
9) Hydro	0.25	0.25	0.25
10) Wind, Solar, Geothermal	0.05	0.15	1.1
Emissions			
11) Total CO_2 emissions	170 million tons	288 million tons	98 million tons
12) Emissions Intensity Ratio (CO_2 emissions/Q-BTUs)	45.4	51.5	31.6
13) CO_2 emissions per capita (with 2030 population = 22.4 million)	8.6	12.9	4.4

Sources: See Tables 1 and 10, and authors' projections.

column 2, we then present projected figures, assuming New York's economy grows at an average annual rate of 2.6 percent through 2030 and the state's energy infrastructure remains basically intact. We term this the "steady state" energy infrastructure trajectory for New York.

Thus, we see in row 3, columns 1 and 2, that New York's energy intensity ratio remains constant between 2014 and 2030, at 2.7 Q-BTUs per $1 trillion in GDP. The state's emissions intensity ratio does rise, as shown in row 12, columns 1 and 2, from 45.4 to 51.5 million in CO_2 emissions per Q-BTU of energy. The first reason for this rise is that we have incorporated the phase-out of nuclear energy consumption in New York State. We report this through the figures in row 7, showing nuclear energy falling from 0.45 Q-BTUs in 2014 to 0.2 in 2030. In addition, as shown in row 9, we assume that hydro power supply remains constant at 0.25 Q-BTUs in 2030. We then assume in this steady state scenario that the reduction in consumption from nuclear and the lack of growth in hydro consumption are matched by commensurate increases in natural gas consumption. As such, natural gas consumption nearly doubles in this steady state scenario, from 1.39 to 2.70 Q-BTUs. Other than this, the consumption of energy from the remaining sources, both non-renewable and renewable, grow at exactly the same rate as the economy overall. We see the impact of this economic growth pattern in row 12 of Table 11. That is, total CO_2 emissions increases from 170 to 288 million tons, an increase of 69 percent.

In column 3 of Table 11, we then show the impact on the energy mix and emissions levels of a clean energy program focused on bringing down CO_2 emissions to 100 million tons by 2030. The first component of this program is energy efficiency investments. As noted in section 4, we assume energy efficiency investments will focus first on raising efficiency standards in both residential and commercial buildings, given that over 60 percent of New York State's energy consumption results from operating buildings. As a second target, efficiency investments should be channeled into bringing high-efficiency automobiles into use rapidly enough to lower emissions from the overall auto fleet by 30 percent as of 2030. Efficiency investments should also be channeled into expanding public transportation, industrial operations (such as combined heat-and-power systems), and improving the state's electrical grid infrastructure.

As we show in row 2 of Table 11, the efficiency investments result in reducing the state's overall energy consumption from 5.6 under the 2030 steady state scenario to 3.1 Q-BTUs under the clean energy investment program scenario. This is a reduction of 2.5 Q-BTUs. Following our discussion in section 4, we assume that the costs of achieving 1 Q-BTU of efficiency gains will be $35 billion. As such, the level of investment needed to reduce consumption by 2.5 Q- BTUs will be $87.5 billion. Spread out over 10 years, this level of efficiency investments will average $8.7 billion per year.

We then need to consider the energy mix that will be necessary to allow for 3.1 Q-BTUs of consumption while still maintaining emissions below 100 million tons. As we have seen in Table 4, both natural gas and petroleum consumption will need to fall to no more than 0.8 Q- BTUs each in order to bring overall CO_2 emissions down to 100 million tons by 2030. In other words, total energy supply from fossil fuel sources will be at no more than 1.6 Q-BTUs as of 2030.

This then entails that 1.5 Q-BTUs of energy will need to be provided by alternative sources in order for New York State's overall energy consumption in 2030 to reach 3.1 Q-BTUs. As noted above, we assume that nuclear energy is at 0.2 Q-BTUs, reflecting the phase out of roughly half of the state's operating nuclear facilities. We also assume that hydro supply remains constant at its current level of 0.25 Q-BTUs. We are also assuming that biomass energy falls to zero, given that it generates emissions at roughly the level of coal.[25]

This then means that the remaining 1.1 Q-BTUs of energy supply must be provided by wind, solar, and geothermal energy, as we see in row 10, column 3 of Table 11. As of 2014, wind, solar, and geothermal energy combined to supply 0.05 Q-BTUs to New York State. Effectively then, what we are showing is that close to a full 1.1 Q-BTUs of *new supply* needs to be provided by wind, solar, and geothermal in order for New York to bring overall CO_2 emissions down to 100 million tons by 2030.

As discussed in section 5, we assume that the average lump-sum capital expenditures needed to expand clean renewable energy supply by 1 Q-BTU will be roughly $200 billion. This then means that to expand the clean renewable supply for New York State by 1.1 Q-BTUs will require $220 billion in new capital expenditures. Working, again, with the assumption that this is effectively a 10-year investment program, this implies that the average level of expenditures per year to increase the supply of clean renewable energy by 1.1 Q-BTUs in 2030 will be $22 billion per year.

In Table 12, we summarize the main features of the 2030 clean energy investment program. These include the following:

- **Efficiency.** $8.7 billion per year in energy efficiency investments between 2021 – 2030, amounting to about 0.5 percent of New York's projected midpoint GDP between 2015 – 2030. These efficiency investments will generate 2.5 Q-BTUs of energy savings relative to the steady state growth path through 2030.
- **Clean renewables.** $22 billion per year for investments in wind, solar, and geothermal energy production. This will amount to about 1.3 percent of New York's projected midpoint GDP between 2015 – 2030. It will generate an increase of 1.1 Q-BTUs of clean renewable supply by 2030.
- **Overall program and emissions reduction.** Combining the efficiency and clean renewable investments, the program will therefore cost $30.7 billion per year, or 1.8 percent of New York State's projected midpoint GDP between 2015 – 2030. Overall, this program will generate 3.6 Q-BTUs in either energy savings relative to the steady state scenario or expanding the clean renewable energy supply. The end result of this program will be that overall CO_2 emissions in New York State in 2030 will be 98 million tons.

TABLE 12
New York State Clean Energy Investment Program for 2021- 2030

Energy Efficiency Investments	
Total Investments	$87 billion
Average Annual Investments	$8.7 billion
Average Annual Investments as share of Midpoint GDP	0.5 percent
Total Energy Savings through Investments	2.5 Q-BTUs
Clean Renewable Energy Investments	
Total Investments	$220 billion
Average Annual Investments	$22 billion
Average Annual Investments as share of Midpoint GDP	1.3 percent
Total Capacity Expansion through Investments	1.1 Q-BTU
Overall Clean Energy Investments—Efficiency + Clean Renewables	
Total Investments	$307.5 billion
Average Annual Investments	$30.7 billion
Average Annual Investments as share of Midpoint GDP	1.8 percent
Total Energy Savings or Clean Renewable Capacity Expansion	3.6 Q-BTUs

Source: See Table 11.

Is $31 Billion per Year in Clean Energy Investments Realistic?

The short answer is "yes." To understand why, it is important to consider our estimate of New York State's annual clean energy investment needs within the broader context of the state's overall economic trajectory. As we have already noted above, this $30.7 billion annual investment figure represents about 1.8 percent of New York State's average GDP over 2021 – 2030, assuming that the state continues to grow at about 2.6 percent per year over that 10-year period. In other words, our estimate of New York State's annual clean energy investment needs for bringing CO_2 emissions down in the state by 40 percent as of 2030 implies that roughly 98 percent of all economic activity in New York State can continue to be directly engaged in activities *other than* clean energy investments.

As an additional valuable metric, we roughly estimate that, at present, the level of annual clean energy investments in New York State is already in the range of $6 - $7 billion per year.[26] From this figure, we conclude that clean energy investments in New York State between 2021 – 2030 will therefore need to increase about 5-fold relative to current investment levels. This will certainly be a substantial challenge. But, as we discuss in Section 9 below, New York State does already have a strong policy infrastructure in place to support clean energy investments, mainly through incentivizing private investors. Increasing the level of clean energy investments will therefore primarily entail strengthening this policy framework on the basis of its existing foundation.

7. Job Creation Through Clean Energy Investments

In this section, we estimate the employment effects in New York State of advancing a clean energy investment program in the state at the level we developed in the previous section—i.e. at about $8.7 billion per year in energy efficiency investments over a 10-year investment cycle between 2021 – 2030 and $22 billion per year in clean renewable investments over this 10- year cycle. Total annual clean energy investments will therefore amount to $30.7 billion per year, about 1.8 percent of New York's state midpoint GDP over 2021 – 2030, assuming the state's economy grows at an average annual rate of 2.6 percent.

After estimating the number of jobs that this investment project will generate, we then consider indicators of the quality of these jobs. These quality indicators include average compensation levels, health care coverage, retirement plans, and union membership. We also provide data profiling the types of workers who are employed at present in the job areas that will be created by clean energy investments, including evidence on both educational credentials of these workers as well as their racial and gender composition. We then report on the prevalent types of jobs that will be generated by the energy efficiency and clean renewable energy investments.

Before proceeding with describing our estimates, we will first provide a brief overview of the methodology we used to generate our results. We provide a fuller discussion of our methodology in Appendix 3.

Methodological Issues in Estimating Employment Creation

Our employment estimates are figures generated directly with data from national surveys of public and private economic enterprises within New York State and organized systematically within the official state-level input-output (I-O) model. The "inputs" within this model are all the employees, materials, land, energy and other products that are utilized in economic activities by public and private enterprises within New York State to create goods and services. The "outputs" are the goods and services themselves that result from these activities that are then made available to households, private businesses and governments as consumers within both domestic and global markets. Within the given structure of the New York State economy, these figures from the input-output model provide the most accurate evidence available as to what happens within private and public enterprises when they produce the economies' goods and services. In particular, these data enable researchers to observe how many workers were hired to produce a given set of products or services, and what kinds of materials were purchased in the process.

Here is one specific example of how our methodology works. If we invest an additional $1 million on energy efficiency retrofits of an existing building, how will the business undertaking this retrofit project utilize this million dollars to actually complete the project? How much of the $1 million will they spend on hiring workers, how much will they spend on non- labor inputs, including materials, energy costs, and renting office space, and how much will be left over for business profits? Moreover, when businesses spend on non-labor inputs, what are the employment effects through giving orders to suppliers, such as lumber and glass producers or trucking companies?

We also ask this same set of questions for investment projects in renewable energy as well as spending on operations within the non-renewable energy sectors. For example, to produce $1 million worth of wind energy productive capacity, how many workers will need to be employed, and how much money will need to be spent on non-labor inputs? Through this approach, we are able to make observations as to the potential job effects of alternative energy investment and spending strategies at a level of detail that is not available through any alternative approach.

Direct, Indirect and Induced Job Creation

Spending money in any area of any economy, including New York State, will create jobs, since people are needed to produce any good or service that the economy supplies. This is true regardless of whether the spending is done by private businesses, households, or government entities. At the same time, for a given amount of spending within the economy, for example, $1 million, there are differences in the relative levels of job creation through spending that $1 million in different ways. Again, this is true regardless of whether the spending is done by households, private businesses or public sector enterprises.

There are three sources of job creation associated with any expansion of spending — direct, indirect, and induced effects. For purposes of illustration, consider these categories in terms of investments in home retrofitting or building wind turbines:

1. *Direct effects*—the jobs created, for example, by retrofitting buildings to make them more energy efficient or building wind turbines;
2. *Indirect effects*—the jobs associated with industries that supply intermediate goods for the building retrofits or wind turbines, such as lumber, steel, and transportation;
3. *Induced effects*—the expansion of employment that results when people who are paid in the construction or steel industries spend the money they have earned on other products in the economy. These are the multiplier effects within a standard macroeconomic model.

In this study, we focus on direct and indirect effects. Estimating induced effects—i.e. multiplier effects—within I-O models is much less reliable than the direct and indirect effects. In addition, induced effects derived from alternative areas of spending within a national economy are likely to be comparable to one another. Nevertheless, we will report the induced effect figures that are generated through the New York I-O model, even while we give them less emphasis in our analysis.

Within the categories of direct plus indirect job creation, how is it that spending a given amount of money in one set of activities in the economy could generate more employment than other activities? As a matter of simple arithmetic, there are only three possibilities. These are:

1. *Labor Intensity*. When proportionally more money of a given overall amount of funds is spent on hiring people, as opposed to spending on machinery, buildings, energy, land,

and other inputs, then spending this given amount of overall funds will create relatively more jobs.

2. *State-level content*. When a given amount of money is spent on New York's clean energy investment program, some of the spending will occur outside of the New York State economy. The I-O model enables us to estimate New York State specific spending proportions as opposed to outside-the-state spending. In fact, as we describe below, we will make low-end assumptions in our estimates as to the share of spending that will be internal to New York.
3. *Compensation per worker*. If $1 million in total is spent on employing workers in a given year on a project, and one employee earns $1 million per year working on that project, then only one job is created through spending this $1 million. However, if, at another enterprise, the average pay is $50,000 per year, then the same $1 million devoted to employing workers will generate 20 jobs.

Time Dimension in Measuring Job Creation

Jobs-per-year vs. job years. Any type of spending activity creates employment over a given amount of time. To understand the impact on jobs of a given spending activity, one must therefore incorporate a time dimension into the measurement of employment creation. For example, a program that creates 100 jobs that last for only one year needs to be distinguished from another program that creates 100 jobs that continue for 10 years each. It is important to keep this time dimension in mind in any assessment of the impact on job creation of any clean energy investment activity.

There are two straightforward ways in which one can express such distinctions. One is through measuring *job years*. This measures cumulative job creation over the total number of years that jobs have been created. Thus, an activity that generates 100 jobs for 1 year would create 100 job years. By contrast, the activity that produces 100 jobs for 10 years would generate 1,000 job years.

The other way to report the same figures would be in terms of *jobs-per-year*. Through this measure, we are able to provide detail on the year-to-year breakdown of the overall level of job creation. Thus, with the 10-year program we are using in our example, we could express its effects as creating 100 jobs per year for 10 years.

This jobs-per-year measure is most appropriate for the purposes of this study, in which our focus is on measuring the impact on employment opportunities of clean energy investments. The reason that jobs-per-year is a better metric than job years is because the impact of any new investment, whether on clean energy or anything else, will be felt within a given set of labor market conditions at a point in time. Reporting cumulative job creation figures over multiple years prevents us from scaling the impact of investments on job markets at a given point in time. For example, if clean energy investments create 100,000 jobs in a given year, we are able to scale that to the size of the New York labor market in that year. At present, 9 million people are employed in New York State. Adding 100,000 jobs would therefore amount to an increase in employment of about 1.1 percent.

If we then assume that the clean energy investments continue for 10 years at the same scale, that would mean 100,000 jobs per year would be created through these investments. That would continue to expand employment opportunities in New York State by around 1 percent per year (allowing also for the natural growth of the state's labor market). However, if we measure this employment impact in terms of cumulative job creation, the 10 years worth of investment would, by this measure, amount to 1 million jobs. It is misleading to compare that cumulative job creation figure to the total of 9 million jobs in New York State at a point in time. If we did want to scale the cumulative job creation figure of 1 million, the appropriate comparison would be with the cumulative job figures for the whole state over 10 years, i.e. a cumulative level of employment over 10 years of 90 million jobs. But this 90 million cumulative jobs figure is not a particularly clear or useful way to understand labor market conditions at any given point in time.

The case of construction jobs. One specific area where it is important to proceed clearly on this issue is in consideration of construction industry job creation. Construction industry jobs created by clean energy investments are frequently regarded as being short-term, while manufacturing jobs are seen as inherently longer term. However, especially in evaluating the impact of alternative areas of spending within a broad clean energy investment agenda, the distinctions are not so straightforward. Of course, any single construction project is limited by the amount of time required to complete that project, while manufacturing activity in a single plant can continue indefinitely, as long as the manufacturer is able to sell the goods being produced at a profit. But if we consider any large-scale clean energy construction project, total job creation over time can vary widely, depending precisely on the annual level of expenditure that is laid out to complete the project.

Consider, for example, a project to retrofit the entire publicly-owned building stock in New York State, in which we assume the entire budget devoted to labor in the project is $5 billion, and each worker on the project receives $50,000 per year in total compensation. This means that, in total, the project will generate 100,000 job years, no matter how these job years are divided up over time. If the annual labor-cost budget for the project is $500 million over 10 years, that means the project will generate 10,000 jobs per year over 10 years, making it a long-term source of job creation. However, if the annual budget rose to $5 billion, that means the project would generate 100,000 jobs, but over just one year.

Incorporating Labor Productivity Growth over the 10-Year Investment Cycle

The figures we use for the I-O tables are based on the technologies that are prevalent at present for undertaking these clean energy investments. Yet we are estimating job creation through clean energy investments that will occur over a 10-year cycle. The relevant production technologies will certainly change over this 10-year period, so that a different mixture of inputs may be used to produce a given output.

For example, new technologies are likely to emerge, making other technologies obsolete. Certain inputs could also become more scarce, and, as result, firms may substitute other less expensive goods and services to save on costs. The production process overall could also become more efficient, so that fewer inputs are needed to produce a given amount of output. Energy efficiency investments do themselves produce a change in production processes—i.e. a reduction in the use of energy inputs to generate a given level of output. In short, the input-output relationships in any given economy—including its employment effects of clean energy investments—are likely to look different in 2030 relative to the present.

We have addressed this issue in depth in previous research (e.g. Pollin et al. 2015, pp. 133 - 44). For the purposes of this study, we will work with two simple assumptions:

1) current input-output relationships will prevail as of 2021, the year in which the clean energy investment program commences in full; and 2) between 2021- 2030, average labor productivity in clean energy investments rises by 1 percent per year.

Job Creation Estimates

In Tables 13 and 14, we present our estimates as to the job creation effects of investing in energy efficiency in New York State. Tables 15 and 16 then present comparable estimates for investments in clean renewable energy in the state. In both cases, we report two sets of figures— first job creation per $1 million in expenditure, then job creation given the annual level of investment spending we have proposed, i.e. $8.7 billion per year in energy efficiency and $22 billion per year in renewable energy. We first report figures for direct and indirect jobs, along with the totals for these main job categories. We then include the figures on induced jobs, and show total job creation when induced jobs are added to that total.

Beginning with the energy efficiency investment figures in Table 13, we show the job creation figures per $1 million in spending for our five categories of efficiency investments: building retrofits; industrial efficiency; electrical grid upgrades; public transportation expansion and upgrades; and high-efficiency private auto purchases. As Table 13 shows, direct plus indirect job creation per $1 million in spending ranges between 5.8 jobs for electrical grid upgrades to 9.1 jobs for public transportation expansion and upgrades.

Spending to bring high efficiency automobiles into operation rapidly will be an important component of the overall efficiency investment initiative. However, our assumption, as shown in Table 13, is that this will not be a source of new job creation. This is because producing high efficiency automobiles will basically substitute for producing lower-efficiency models. Roughly the same level of employment will be needed either way.[27]

In Table 14, we show the level of job creation through spending $8.7 billion per year on these efficiency projects in New York State. We have assumed that 60 percent of the $8.7 billion total is channeled into building retrofits, and the remaining 40 percent supports the other efficiency investment areas equally, at 10 percent of the total each. The result of efficiency investment spending at this level, as we see, will be the creation of about 41,500 direct jobs and 18,500 indirect jobs, for a total of about 60,000 direct plus indirect jobs through

TABLE 13
Job Creation in New York State through Energy Efficiency Investments:
Job Creation per $1 million in Efficiency Investments

	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs Total	Induced Jobs	Direct, Indirect + Induced Jobs Total
Building retrofits	5.0	2.7	7.7	2.1	9.8
Industrial efficiency	6.0	1.9	7.9	2.9	10.8
Electrical grid upgrades	4.2	1.6	5.8	1.9	7.7
Public Transportation expansion/upgrades	7.4	1.7	9.1	2.1	11.2
Expanding high efficiency automobile fleet	0	0	0	0	0

Sources: See Appendix 3.

TABLE 14
Job Creation in New York State through Energy Efficiency Investments:
Job Creation through Spending $8.7 billion per year in Efficiency Investments

ASSUMPTIONS FOR ENERGY EFFICIENCY INVESTMENTS

- 60% on building retrofits
- 10% on industrial efficiency measures
- 10% on electrical grid upgrades
- 10% on public transportation expansion/upgrades
- 10% on expanding high-efficiency auto fleet
  - No job creation through auto purchase subsidies

	Spending Amounts	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs Total	Induced Jobs	Direct, Indirect + Induced Jobs Total
Building retrofits	$5.2 billion	26,208	14,040	40,248	10,972	51,220
Industrial efficiency	$870 million	5,194	1,644	6,838	2,497	9,335
Electrical grid upgrades	$870 million	3,628	1,349	4,977	1,662	6,639
Public Transportation expansion/upgrades	$870 million	6,455	1,505	7,960	1,836	9,796
Expanding high efficiency automobile fleet	$870 million	0	0	0	0	0
TOTALS	**$8.7 billion**	**41,485**	**18,538**	**60,023**	**16,967**	**76,990**

Sources: See Appendix 3.

this energy efficiency investment program. Including induced jobs adds another nearly 17,000 jobs to the total figure. This brings the total job creation figure for efficiency investments, including induced jobs, to roughly 77,000 jobs.

In Table 15, we show the job creation figures for our three clean renewable energy categories—wind, solar, and geothermal power. As we see, the extent of direct plus indirect jobs ranges from 3.7 – 6.4 per $1 million in spending. Adding induced jobs brings the range to between 5.6 – 8.7 jobs per $1 million in spending.

Based on these proportions, we see in Table 16 the levels of job creation in New York State associated with $22 billion per year in annual spending on clean renewable energy. We divide the overall level of annual spending to include $10 billion per year respectively for wind and solar power and $2 billion for geothermal. We also assume, as a low-end estimate,

TABLE 15
Annual Job Creation in New York State through Clean Renewable Energy Investments:
Job Creation per $1 million in Clean Renewable Investments

ASSUMPTION FOR RENEWABLE INVESTMENTS
10 percent of New Manufacturing Activity retained in New York State

	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs Total	Induced Jobs	Direct, Indirect + Induced Jobs
Wind	2.4	1.3	3.7	1.9	5.6
Solar	3.7	1.3	5.0	2.3	7.3
Geothermal	4.4	2.0	6.4	2.3	8.7

Sources: See Appendix 3.

TABLE 16
Annual Job Creation in New York State through Clean Renewable Energy Investments:
Job Creation through spending $22 billion per year in Clean Renewable Investments

ASSUMPTIONS FOR RENEWABLE ENERGY INVESTMENTS

- 45% on solar PV energy
- 45% on wind energy
- 10% on geothermal energy
- 10% of new manufacturing activity in New York State

	Spending Amounts	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs Total	Induced Jobs	Direct, Indirect + Induced Jobs Total
Wind	$10 billion	24,416	12,603	37,019	8,818	55,837
Solar	$10 billion	36,897	13,251	50,148	22,487	72,635
Geothermal	$2 billion	8,819	4,081	12,900	4,500	17,400
TOTALS	**$22 billion**	**70,132**	**29,935**	**100,067**	**45,805**	**145,872**

Sources: See Appendix 3.

that of this total level of new investments in clean renewables needed to deliver 1.1 Q-BTUs of energy in New York by 2030, only 10 percent of the total *manufacturing activity* will take place within New York State. In other words, we assume that 90 percent of the manufactured goods needed to produce 1.1 Q-BTUs of clean renewable energy in New York State as of 2030 will be imported from outside the state.

Following from these assumptions, we see in Table 17 that total direct plus indirect job creation generated in New York by this large-scale expansion in the state's clean renewable energy supply will be about 100,000 jobs. If we include induced jobs, then the total rises to about 146,000 jobs.

Table 17 brings together our job estimates for both energy efficiency and clean renewable energy through spending about $31 billion per year on this project in New York State. We show total figures for direct plus indirect jobs only, then we also show the total when induced jobs are included. We also provide estimates for 2021, the first year of the full-scale investment program, and for 2030, the last year of the investment cycle.

We see in row 10 of Table 17 that total direct and indirect job creation as of 2021 is about 160,000, and about 220,000 jobs when we add induced jobs to the total. As we see in row 11, this level of job creation amounts to between 1.8 and 2.5 percent of total employment in New York State as of 2015, the range depending on whether we include induced jobs in the total. In row 12, we show our job estimates for 2030, assuming productivity gains at an average annual rate of 1 percent. These job figures are 145,000 for direct plus indirect employment and 200,000 jobs, when we include induced job creation.

Indicators of Job Quality

In Table 18, we provide some basic measures of job quality for the jobs that will be generated through clean energy investments in New York State. These basic indicators include: 1) average total compensation (including wages plus benefits); 2) the percentage of workers receiving health insurance coverage; 3) the percentage having retirement plans through their employers; and 4) the percentage that are union members.

TABLE 17

Annual Job Creation in New York State through Combined Clean Energy Investment Program

JOB ESTIMATE FOR 2021

Industry	Number of Direct and Indirect Jobs Created	Number of Direct, Indirect and Induced Jobs Created
$8.7 billion in Energy Efficiency		
1) Building Retrofits	40,248 (25.1% of total)	51,220
2) Industrial efficiency	6,838 (4.3% of total)	9,335
3) Electrical grid upgrades	4,977 (3.1% of total)	6,639
4) Public transportation expansion/upgrades	7,960 (5.0% of total)	9,796
5) Total Energy Efficiency Job Creation	60,023 (37.5% of total)	76,990
$22 billion in Clean Renewables		
6) Wind	37,019 (23.1% of total)	55,837
7) Solar	50,148 (31.3% of total)	72,635
8) Geothermal	12,900 (8.1% of total)	17,400
9) Total Clean Renewable Job Creation	100,067 (62.5% of total)	145,872
10) TOTAL	**160,090**	**220,862**
11) TOTAL AS SHARE OF 2015 NEW YORK STATE EMPLOYMENT	**1.8%**	**2.5%**
JOB ESTIMATE FOR 2030		
12) 2030 JOB ESTIMATE, with 1 percent annual productivity growth	**145,000**	**200,000**

Sources: See Tables 13 – 16.

Starting with compensation figures, we see that the averages range widely, between about $63,000 for workers in the mass transit sector to $114,000 working in industrial efficiency. The average compensation in all of the clean renewable sectors is between about $88,000 - $96,000.

The range is more narrow in terms of health insurance coverage. At the low end, about 44 percent of workers in the building retrofit sector have private health insurance, while about 53 percent working in grid upgrades are covered. The figures in all the clean renewable areas— wind, solar, and geothermal—are between 49 – 53 percent.

There is somewhat more variation with respect to private retirement plans. The low-end figure is in mass transit, where only about 34 percent have private pension coverage, while 55 percent of workers in grid upgrades have such pensions. The figures on union coverage also are more varied. At the low end, only 16 percent of workers in the industrial

TABLE 18
Indicators of Job Quality in New York State Clean Energy Industries: Direct and Indirect Jobs Only

	Energy Efficiency Investments				Clean Renewable Energy Investments		
	1. Building Retrofits *(40,248 workers)*	**2. Industrial Efficiency** *(6,838 workers)*	**3. Grid Upgrades** *(4,977 workers)*	**4. Mass Transit** *(7,960 workers)*	**5. Wind** *(37,019 workers)*	**6. Solar** *(50,148 workers)*	**7. Geothermal** *(12,900 workers)*
Average total compensation	$72,000	$114,300	$87,400	$63,200	$96,100	$88,000	$95,400
Health Insurance coverage, percentage	43.5%	50.9%	52.8%	46.0%	51.8%	49.1%	52.6%
Retirement Plans, percentage	35.8%	43.0%	55.2%	34.0%	41.9%	46.2%	47.4%
Union membership, percentage	24.8%	15.8%	21.7%	40.0%	21.6%	19.3%	19.5%

Sources: See Appendix 4.

efficiency sectors are union members. The high end figure is 40 percent for mass transit workers. In the clean renewable sectors, union coverage ranges narrowly between 19 – 21 percent.

These indicators of job quality will be valuable for purposes of comparison when we consider the jobs that will be lost in New York State as a result of the contraction of fossil fuel production and consumption in the state through 2030. What is especially important to highlight now—in anticipating our discussion in section 8 on workers in New York State's fossil fuel related industries—is that the compensation figures in clean energy industries are low in comparison with those for fossil fuel industry-based workers. As such, one of the aims of a clean energy investment agenda for New York State will be to raise wages, benefits and working conditions in the newly-created clean energy investment industries. Raising unionization rates in these industries will provide an important foundation in support of these goals.

Educational Credentials and Race/Gender Composition for Clean Energy Jobs

In Table 19, we present data on the educational credentials for workers in jobs tied to clean energy investment activities in New York State.

Educational Credentials

With respect to educational credentials, we categorize all workers who would be employed directly or indirectly by clean energy investments in New York according to three educational credential groupings: 1) shares with high school degrees or less; 2) shares with some college or Associate degrees; and 3) shares with Bachelor's degree or higher.

As Table 19 shows, the distribution of educational credentials varies widely depending on the specific clean energy industry. In the areas of building retrofits and mass transit, about half of the workers have high school degrees or less. In the three renewable energy areas, wind, solar, and geothermal, about 40 percent of the workers have high school degrees

TABLE 19
Educational Credentials and Race/Gender Composition of Workers in New York State Clean Energy Industries: Direct and Indirect Jobs Only

	Energy Efficiency Investments				Clean Renewable Energy Investments		
	1. Building Retrofits *(40,248 workers)*	**2. Industrial Efficiency** *(6,838 workers)*	**3. Grid Upgrades** *(4,977 workers)*	**4. Mass Transit** *(7,960 workers)*	**5. Wind** *(37,019 workers)*	**6. Solar** *(50,148 workers)*	**7. Geothermal** *(12,900 workers)*
Share with high school degree or less	49.0%	26.9%	38.8%	49.6%	40.2%	35.2%	35.3%
Share with some college or Associate degree	27.8%	21.6%	28.1%	26.3%	27.9%	26.1%	30.9%
Share with Bachelor's degree or higher	23.1%	51.5%	33.1%	24.2%	31.9%	38.7%	33.9%
Racial and Gender Composition of workforce							
Pct. non-white	37.0%	27.9%	28.7%	54.5%	28.9%	29.0%	31.1%
Pct. female	20.4%	35.1%	22.1%	20.0%	25.4%	28.3%	26.1%

Sources: See Appendix 4.

or less. With industrial efficiency, only about 27 percent of workers are at this lower educational credential level.

At the other end of the credential range, about half of all workers in industrial efficiency have Bachelor's degrees or higher. This is about twice the proportion prevailing with building retrofit and mass transit workers. With grid upgrades and the renewable energy areas, between 32 – 39 percent hold Bachelor's degrees or more.

If we consider this range of clean energy investment areas as a whole, it is clear that there will be new jobs generated at roughly comparable proportions for workers at all educational credential levels. Here again, it will be useful to be able to compare these patterns in educational levels for jobs in clean energy with those for the jobs that will be displaced through the contraction in New York's fossil fuel industries. We consider this in section 8.

Race and Gender Composition

It is clear from the figures in Table 19 that, at present, the jobs created by clean energy investments are held predominantly by white male workers. Thus, the share of jobs held by non-white workers is between 28 – 31 percent in the areas of industrial efficiency and grid upgrades as well as wind, solar and geothermal energy. The two exceptions, where the share of non-white workers is higher, are building retrofits, with 37 percent non-white workers, and mass transit, where, in fact, a 54 percent majority of the workforce is non-white. With respect to gender composition, in all areas but one, the share of female employment is between 20 – 28 percent. The one exception is industrial efficiency, in which the share of jobs held by women is 35 percent.

Despite these large disparities in the current composition of the workforce associated with clean energy investments in New York State, the large-scale expansion of these investments will provide a major opportunity to increase opportunities for non-white and female workers. An initiative focused on equal opportunity in the growing clean energy investment areas could be readily integrated into the broader investment project. Indeed, important initiatives along these lines have been operating in earnest in the unionized construction sector in New York City, in particular, creating significant improvements in both job opportunities and with apprenticeship programs for African-American workers.[28]

Prevalent Job Types with Clean Energy Investments

To provide a more concrete picture of the jobs that will be created in New York State through investments in energy efficiency and clean renewable energy, in Tables 20 – 22 we report on the prevalent job types associated with the various efficiency and renewable energy activities. Table 20 provides data for investments in building retrofits, our largest category of energy efficiency investments. Table 21 combines data for the other efficiency investment areas, i.e. industrial efficiency, electric grid upgrades, and public transportation expansion and upgrades. Table 22 then reports these same figures combined for our three areas of clean renewable energy investments, i.e. wind, solar, and geothermal power. In all cases, we report on the job categories in which we estimate that 5 percent or more of the new jobs will be created through clean energy investments.

It is difficult to summarize the detailed data on job categories presented in these tables. But it will be useful to underscore a few key patterns. First, a high proportion of jobs will be created in the construction industry through all of the clean energy investment activities. Of course, this is true with the 44 percent of job creation through building retrofit investments. But we also find that 14 percent of investments in the other areas of energy efficiency investments and 21 percent in the clean renewable sectors will be in construction. The specific types of construction industry jobs will vary widely, given the different types of construction projects that will be pursued. Thus, investments in building retrofits will create jobs for laborers, carpenters, electricians, supervisors and plumbers. Investments in grid

TABLE 20
Building Retrofits: Prevalent Job Types in New York Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Construction	44.1%	Construction Laborers, Carpenters, Electricians, First-Line Construction Supervisors, Plumbers
Sales	13.6%	Retail Salespersons, First-Line Sales Supervisors, Cashiers, Wholesale Sales Representatives, Real Estate Brokers
Management	12.5%	Construction Managers, Chief Executives, Marketing and Sales Managers, Operations Managers, Financial Managers
Office and administrative support	7.4%	Secretaries, Bookkeeping Clerks, Accounting Clerks, Customer Service Representatives, Stock Clerks

Sources: See Appendix 4.

TABLE 21
Industrial Efficiency, Electric Grid Upgrades, Public Transportation Expansion/ Upgrades: Prevalent Job Types in New York Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Transportation and material moving	17.7%	Bus Drivers, Truck Drivers, Freight and Stock Laborers, Packers, Transportation Attendants
Construction	13.9%	Construction Laborers, Carpenters, Electricians, Boilermakers, Painters
Business and Financial Operations	12.1%	Management Analysts, Accountants, Market Research Analysts, Purchasing Agents, Wholesale Buyers
Management	11.5%	Construction Managers, Marketing Managers, Chief Executives, Industrial Production Managers, Operations Managers
Production	9.5%	Electrical Assemblers, First-Line Production Supervisors, Machinists, Metalworkers, Inspectors
Office and administrative support	8.4%	Secretaries, Bookkeeping Clerks, Accounting Clerks, Customer Service Representatives, Information Clerks
Architecture and Engineering	6.4%	Engineering Technicians, Electrical Engineers, Mechanical Engineers, Drafters, Industrial Engineers
Sales	5.7%	Wholesale Representatives, Retail Salespersons, First-Line Sales Supervisors, Cashiers, Real Estate Brokers

Sources: See Appendix 4.

TABLE 22
Wind/Solar/Geothermal: Prevalent Job Types in New York Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Construction	20.9%	Construction Supervisors, Construction Equipment Operators, Electricians, Pipelayers and Pipefitters
Management	12.9%	Construction Managers, Chief Executives, Marketing Managers, Industrial Production Managers, Operations Managers
Production	11.6%	First-Line Production Supervisors, Power Plant Operators, Inspectors
Office and administrative support	10.9%	Secretaries, Bookkeeping Clerks, Accounting Clerks, Customer Service Representatives, Information Clerks
Architecture and Engineering	6.7%	Engineering Technicians, Mechanical Engineers, Drafters, Industrial Engineers, Electrical Engineers
Business and Financial Operations	6.2%	Accountants, Purchasing Agents, Market Research Analysts, Human Resource workers, Management Analysts
Sales	5.5%	Wholesale Representatives, Retail Salespersons, First-Line Sales Supervisors, Advertising Sales Agents, Cashiers

Sources: See Appendix 4.

upgrades and public transportation projects will provide construction jobs in the additional areas of electricians, boilermakers and painters. The renewable-energy based construction work will also include pipelayers and pipefitters.

Management as well as office and administrative support also constitute a large share of overall job creation across all categories. Management ranges between 11 – 13 percent in all the tables, while office and administrative support ranges between 7 – 11 percent. The managerial jobs will include people in construction, sales, operations and finance.

What emerges generally from these tables is that clean energy investments will generate a wide range of new employment opportunities. This broad range of new opportunities will be available for workers in New York State that have been displaced by the contraction of the state's fossil fuel industry activities, as well as more broadly throughout the state's labor force.

Relative Job Creation through Alternative Spending Targets

What would be the impact on job creation of channeling a given amount of funds into other areas of New York State's economy, as opposed to pursuing the investments on which we have focused in energy efficiency and clean renewable energy? To consider this question, in Table 23, we report figures as to the job creation impacts of spending in three alternative areas: the fossil fuel industry itself, traditional infrastructure—i.e. roads, bridges, tunnels, airports and related areas—and tax cuts. The impact of any tax cuts on jobs results through New York State's residents having more money to spend on their standard baskets of goods and services. As with our previous discussions in this section, we are focusing on the direct and indirect categories of job creation.

As we see in Table 23, the largest impact on job creation among the alternative spending areas is energy efficiency, which generates 6.9 direct and indirect jobs per $1 million in spending in New York State. This is a combined figure for energy efficiency investments, based on the relative weights we have assigned earlier (i.e. from Table 14—60 percent building retrofits, and 10 percent respectively on industrial efficiency, electrical grid upgrades, public transportation, and high-efficiency autos). The figure for renewable energy is lower, at 4.6 direct plus indirect jobs per $1 million. In this case, we are generating this overall renewable energy figure through following the proportional spending levels we report in Table 16, i.e. solar PV and wind both receiving 45 percent of total spending and geothermal energy obtaining the remaining 10 percent.

Considering now the three alternative spending areas, we see that traditional infrastructure investments in New York will generate about 6.4 direct plus indirect jobs per $1 million in spending. This is followed by tax cuts, at 4.5 jobs per $1 million, and then oil and gas, at 3.4 jobs.

Overall then, we see that, comparatively speaking, clean energy investments are a robust source of job creation, especially so in the area of energy efficiency. Combining energy efficiency and clean renewable investments will generate more jobs per dollar of expenditure than any combination between traditional infrastructure, tax cuts and expanding the fossil fuel industry. It is especially notable that the job creating opportunities for energy efficiency investments, in particular, are twice as large as what would result through a project focusing only on expanding New York State's fossil fuel sector.

TABLE 23

Job Creation in New York State Generated through Alternative Spending Targets

Direct plus indirect job creation per $1 million in spending

	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs
Clean Energy Investments			
-- Energy Efficiency	4.7	2.2	6.9
-- Clean Renewables	3.2	1.4	4.6
Alternative NY State spending targets			
-- Infrastructure	4.8	1.6	6.4
-- Household Tax Cuts	3.6	0.9	4.5
-- Oil and gas	2.0	1.4	3.4

Source: See Appendix 3.

8. Just Transition for Fossil Fuel Industry-Dependent Workers and Communities

As we have shown above, in order for New York State to bring total CO_2 emissions down to 100 million tons by 2030, consumption of fossil fuels in the state will need to fall by approximately 40 percent relative to its 2014 level of 2.7 Q-BTUs to about 1.6 Q-BTUs. As we have seen, natural gas consumption in New York State in 2014 was at 1.39 Q-BTUs or 38 percent of total statewide energy consumption and petroleum was 1.30 Q-BTUs, or 35 percent of total consumption. Coal consumption is already negligible in New York State, at 0.06 Q-BTUs, or 1.8 percent of total consumption.

The issue on which we focus in this section is what the impact will be on workers in industries in New York State that are dependent on statewide consumers continuing to purchase fossil fuel energy. In particular, we develop here a Just Transition program for the workers in these fossil fuel dependent sectors who will face displacement as a result of the statewide contraction in fossil fuel consumption. We roughly estimate that production activity and employment in these industries will decline by approximately 40 percent as of 2030, i.e. in rough proportion to the decline in consumption of oil and natural gas that will need to occur for New York State to bring overall CO_2 emissions down to 100 million tons.

On what basis do we expect that production activity and employment in the fossil-fuel dependent industries will decline by approximately 40 percent as of 2030, i.e. at roughly the rate at which oil and natural gas consumption will need to decline to meet the state's emission reduction target? We first emphasize that this expectation is a rough approximation only, though we do believe it is the most reasonable such approximation.

There are reasons to assume that production and employment in the affected industries will decline by less than the full fall in consumption. One factor could be that fossil fuel-related business firms located in New York State could still maintain higher levels of demand for their products with out-of-state customers, even while in-state demand declines by 40 percent. It is also possible that New York State's fossil fuel related businesses will find it profitable to maintain a disproportionately large workforce even while overall demand declines because doing so maintains their operations at the most effective level. By contrast, it could also follow with some firms that the decline in demand for their products will encourage them to lay off workers by a more than proportional extent—i.e. to reorganize production with a higher level of capital intensity. (This pattern would be consistent with the increasing capital intensity of oil production work itself, as reported in the *New York Times*, 2/20/17, https://www.nytimes.com/2017/02/19/business/energy-environment/oil-jobs-technology.html). Some firms could also shut down altogether due to the steady decline in demand (Pollin and Callaci (2016) discuss this latter prospect more fully). Given this range of possibilities—some of which are offsetting—on balance, we conclude, again, that the most reasonable working assumption for our purposes is that the decline in production and employment in New York State's fossil fuel related industries will be proportional to the decline in statewide consumption.

In principle, there are nine industries that would likely be heavily affected by a significant cut in fossil fuel consumption and production. Of course, the first two would be oil and gas extraction and coal mining. There are also seven ancillary industries that would be heavily impacted. The first two would be support activities for both oil/gas extraction and coal mining. Five additional industries that would be impacted are electric power generation, in which the electricity is generated by fossil fuel energy sources; natural gas distribution; oil and gas pipeline construction and transportation; petroleum bulk stations and terminals; and petroleum refining.[29]

In Table 24, we show employment levels for these nine industries as of 2014. The first thing that stands out in Table 24 is that there is no employment at all in New York for either coal mining or support activities for the coal mining industry.

Beyond this, we see that total employment in the remaining seven industries was 13,393 in 2014. This amounts to about 0.15 percent of the total 2014 New York State workforce of 9.1 million. We further see that this total of 13,393 jobs is heavily concentrated in three industries. These are natural gas distribution, which, as of 2014, employed 6,532 workers, or 49 percent of all workers employed in any fossil-fuel dependent sector in New York; fossil-

TABLE 24
Number of Workers in New York State Employed in Fossil Fuel Production Activities and Ancillary Industries, 2014

Industry	Number of Employed Workers
Oil and Gas Extraction	503 *(3.8% of total)*
Coal Mining	0
Ancillary Industries	
Support Activities for Oil/Gas	438 *(3.3% of total)*
Support Activities for Coal	0
Natural Gas Distribution	6,532 *(48.8% of total)*
Fossil Fuel Electric Power Generation	2,943 *(22.0% of total)*
Oil and Gas Pipeline Construction and Transportation	2,129 *(15.9% of total)*
Petroleum Bulk Stations and Terminals	814 *(6.1% of total)*
Petroleum Refining	34 *(0.3% of total)*
TOTAL	**13,393**
TOTAL AS SHARE OF NEW YORK STATE EMPLOYMENT	**0.15%**

Source: See Appendix 6.
Note: Support Activities for Oil/Gas also includes the sector, "Drilling of oil and gas wells"

fuel electric power generation, which employed 2,943 workers in 2014, or 22 percent of all fossil-fuel related workers in the state; and oil and gas pipeline construction and transportation, with 2,129 workers, equaling 16 percent of the total. In other words, roughly 87 percent of all fossil-fuel industry dependent workers in New York are employed in either natural gas distribution, electricity generation, or pipeline construction and transportation.

Of the remaining 13 percent of fossil-fuel dependent jobs in New York, as Table 24 shows, 814, or 6.1 percent, are employed at petroleum bulk stations and terminals; 503, or 3.8 percent, are in the oil and gas extraction industry; 438, or 3.3 percent, are in oil and gas industry support activities; and 34, or 0.3 percent, are in petroleum refining.

Characteristics of Fossil Fuel and Ancillary Industry Jobs

Table 25 provides basic figures on the characteristics of the jobs in New York State for workers in fossil fuel dependent sectors. We focus first on the 87 percent of the jobs—roughly 12,000 jobs in total—that are in either natural gas distribution, electric power generation, or pipeline construction and transportation (shown in columns 1-3 of Table 25). As the table shows, on average, these are relatively high-quality jobs. The average overall compensation is $139,000 in natural gas, $156,000 in electric power generation, and $118,000 in pipeline construction and transportation. Between 60 – 87 percent of the workers in these three industries have health

TABLE 25
Characteristics of Workers in New York State Fossil Fuel and Ancillary Industries

	1. Natural Gas Distribution (6,532 workers)	2. Fossil fuel electric power generation (2,943 workers)	3.Oil and Gas Pipeline Construction and Transportation (2,129 workers)	4. Petroleum Bulk Stations and Terminals (814 workers)	5. Oil and gas extraction (503 workers)	6. Support activities for oil and gas (438 workers)	7. Petroleum refining (34 workers)
Average total compensation	$139,000	$156,000	$118,000	$165,000	$121,000	$74,000	$63,000
% Health Insurance coverage	83.8%	87.4%	57.3%	80.1%	72.2%	70.9%	78.5%
% Union membership	42.2%	41.1%	26.6%	10.1%	3.5%	3.6%	25.7%
Educational Credentials							
% High school degree or less	23.5%	26.3%	54.4%	36.6%	46.3%	40.0%	42.3%
% Some college or Associate degree	35.8%	38.1%	32.0%	36.0%	24.8%	30.6%	18.3%
% Bachelor's degree or higher	40.7%	35.6%	13.6%	27.4%	28.9%	29.3%	35.8%
Race and Gender Composition							
% Non-white workers	23.6%	25.9%	33.1%	26.1%	14.3%	4.9%	15.6%
% Female workers	29.1%	18.5%	10.4%	24.9%	10.7%	10.5%	19.7%

Sources: See Appendix 6.

care coverage. Roughly 40 percent of the workers in natural gas distribution and electric power generation are members of unions, while the pipeline construction and transportation industry is about 27 percent unionized. Most of the people employed in these jobs have relatively high educational credentials— 41 percent in natural gas distribution have at least Bachelor's degrees, and another 36 percent have some college. The figures are similar within the fossil-fuel based electric power sector. The educational credential levels for workers in pipeline construction are somewhat lower, with about 14 percent holding Bachelor's degrees and 54 percent with high school degrees or less.

Among the industries with lower levels of employment—including petroleum bulk stations; oil and gas extraction; support activities for oil and gas; and petroleum refining—there is a wider range of pay levels and other characteristics relative to what we have seen with the industries with high employment levels. Thus, compensation levels are highest in the petroleum bulk station industries, where the 814 workers in New York State earn, on average, $165,000 per year in total compensation. In oil and gas extraction, with 503 workers, average total compensation is $121,000. But the average compensation drops sharply for the two ancillary industries with the lowest employment in New York, with pay at $74,000 for support activities for oil and gas and $63,000 in petroleum refining. Still, workers in all these industries have relatively high levels of health coverage, ranging between 80 percent in petroleum bulk stations to 71 percent for support activities for oil and gas. The educational credential levels are fairly stable across these four smaller industries. The unionization rate, in contrast, ranges widely. Less than 4 percent of workers in oil and gas extraction and support activities are unionized. This is much lower than the 26 percent among petroleum refining workers. The unionization rate of workers in petroleum bulk stations falls between these two rates at 10 percent.

In terms of racial and gender composition of the existing workforce employed in fossil fuel production and ancillary industries in New York State, we again see, as with the clean energy investment areas, that most jobs are presently held by white males. Indeed, as Table 25 shows, the share of jobs held in the fossil fuel based industries by white males is significantly higher than with the clean energy industries. Thus, the range of all jobs held by non-white workers is between 5 percent for support activities for oil and gas to 33 percent with pipeline construction and transportation. The proportions for female workers are similar for all of the industries covered in Table 25, though the lowest percentages are at around 10 percent, in pipeline construction/transportation, oil/gas extraction, and support activities for oil and gas, rather than the 5 percent low figure we saw for non-white workers. Overall, given these existing patterns, the shift in New York State's energy infrastructure away from fossil fuels and towards clean energy will, by itself, create a more equal distribution of job opportunities by race and gender.

We can gain further detailed information on workforce and employment conditions for workers in these fossil fuel dependent industries in New York State through the data in Tables 26 – 29. In these four tables, we report on the various job categories associated with each of the employers in the fossil fuel related industries. For each industry, we show the most prevalent job categories and the representative occupations in each job category. In Tables 26 – 28, we report separately on each of the three largest employing industries in the state—i.e. natural gas distribution, electric power generation, and pipeline construction and transportation—which account for about 12,000 (87 percent) of the total of about 13,400 workers employed in New York State in fossil fuel related industries. In Table 29, we then show combined figures on the remaining four fossil fuel related industries that are active in New York State.

TABLE 26
NATURAL GAS DISTRIBUTION: Prevalent Job Types in New York Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Office and Administrative Support	21.8%	Secretaries, Billing and Account Collectors, Financial Clerks, Dispatchers
Management	14.5%	Operations managers, industrial production managers, financial managers
Installation, Maintenance, and Repair	12.2%	Truck mechanics, precision instrument repairers, control and valve installers
Computer and Mathematical Occupations	9.1%	Computer systems analysts, operations system analysts, computer programmers
Construction	7.2%	Construction supervisors, construction equipment operators, electricians, pipelayers and pipefitters
Financial Operation Specialists	7.2%	Accountants, financial analysts
Transportation and Material Moving	6.9%	Tractor-trailer truck drivers, sailors and marine oilers, freight movers, cleaners of vehicles
Production	6.3%	First-line production supervisors, power plant operators, inspectors

Source: See Appendix 6.

TABLE 27
FOSSIL FUEL-BASED ELECTRIC POWER GENERATION: Prevalent Job Types in New York Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Installation, Maintenance, and Repair	17.9%	Truck Mechanics, Precision Instrument Repairers, Control and Valve Installers
Office and Administrative Support	17.3%	Secretaries, Billing and Account Collectors, Financial Clerks, Dispatchers
Production	16.1%	First-Line Production Supervisors, Power Plant Operators, Inspectors
Management	11.0%	Operations Managers, Industrial Production Managers, Financial Managers
Architecture and Engineering	9.3%	Petroleum engineers, electrical engineers, engineering technicians, industrial engineers
Construction	7.2%	Construction Supervisors, Construction Equipment Operators, Electricians, Pipelayers and Pipefitters

Source: See Appendix 6.

TABLE 28
OIL AND GAS PIPELINE CONSTRUCTION AND TRANSPORTATION: Prevalent Job Types in New York Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Construction	59.2%	Construction Supervisors, Construction Laborers, Pipelayers and Pipefitters, Equipment Operators
Management	10.7%	Construction Managers, Chief Executive Officers, Operations Managers, Financial Managers
Transportation, and Material Moving	9.1%	First-Line Supervisors of Transportation Workers, Tractor-Trailer Truck Drivers, Gas Compressor Operators, Laborers
Installation, Maintenance, and Repair	6.2%	First-Line Supervisors of Mechanics, Electrical Repairers, Truck Mechanics, Valve Installers
Office and Administrative Support	4.8%	Secretaries, Office Clerks, Accounting Clerks, First-Line Office Supervisors

Source: See Appendix 6.

TABLE 29
OIL AND GAS EXTRACTION AND SUPPORT ACTIVITIES: Prevalent Job Types in New York Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Extraction	27.8%	Derrick Operators; Rotary Drill Operators; Service Unit Operators
Construction	15.5%	Construction Supervisors, Construction Equipment Operators, Electricians, Pipelayers and Pipefitters
Transportation, and Material Moving	13.1%	Tractor-Trailer Truck Drivers, Sailors and Marine Oilers, Freight Movers, Cleaners of Vehicles
Management	10.8%	Operations Managers, Industrial Production Managers, Financial Managers
Business Operation Specialists	7.3%	Purchasing Agents, Human Resources Workers, Management Analysts
Architecture and Engineering	7.2%	Petroleum engineers, electrical engineers, engineering technicians, industrial engineers
Installation, Maintenance, and Repair	5.2%	Truck Mechanics, Precision Instrument Repairers, Control and Valve Installers
Production	5.2%	First-Line Production Supervisors, Power Plant Operators, Inspectors

Source: See Appendix 6

Table 26 shows figures on New York's natural gas distribution industry, by far the largest employer in the state among fossil fuel related industries, with 6,532 workers as of 2014. As we see, roughly 22 percent of employees in this industry are "office and administrative support." These jobs include secretaries, billing and account collectors, financial clerks and dispatchers. Another 15 percent are in "management," including jobs in the areas of operations, industrial production and finance. With these job categories, along with most of the others listed in this table, the skills being utilized in the natural gas distribution industry are likely to be transferable to other industries in New York's economy, including a growing clean energy sector. As such, presenting these features of the workers and jobs in the fossil fuel related industries will be useful as we consider below the issue of providing good new employment opportunities for the displaced fossil fuel industry workers.

Of course, the prevalent job types vary within New York State's other fossil fuel related industries. Thus, with the roughly 3,000 workers employed in electric power generation, the largest job category is "installation, maintenance, and repair," employing about 18 percent of all the workers in New York State in this industry. The representative occupations within this broad job category include truck mechanics, precision instrument repairers, and control and valve installers. But nearly the same share of workers, around 17 percent, are employed in office and administrative support, where the representative occupations are the same as in natural gas distribution.

With pipeline construction and transportation, nearly 60 percent of the roughly 2,100 people employed in the industry in New York are in some area of construction. This includes construction supervisors, laborers, pipelayers and pipefitters, and equipment operators. The next largest category of jobs with pipeline construction and transportation is management, including roughly 11 percent of all workers in the industry. The representative occupations here are similar to the management occupations in other industries.

From the data presented in Tables 26 – 29, we see that a large share of the representative occupations will be in areas that match up well with jobs that will be newly created through clean energy investments in New York State. But that obviously will not be the case with *all occupations* in which workers are now employed in New York State's fossil fuel related industries. As such, any Just Transition program to support displaced workers in New York's fossil fuel related industries will need to be focused on the specific background and skills of each of the impacted workers. We now turn to considering the specific dimensions and features of such a Just Transition program.

Features of a Just Transition Program

We present here a Just Transition program for workers and communities in New York State that has four major elements. These are:

1) Guaranteeing the pensions for the workers in affected industries who will retire up until the year 2030;
2) Guaranteeing reemployment for workers facing displacement;
3) Providing income, retraining, and relocation support for workers facing displacement; and
4) Mounting effective transition programs for what are now fossil fuel-dependent communities.

We describe each feature of this program in what follows, as well as provide estimates of the costs of effectively operating each measure within the overall program.

Attrition by Retirement and Job Displacement

In Table 30, we show figures on employment reductions in fossil fuel production and ancillary industries that would result from a 40 percent cut in fossil fuel production activities in New York State over the 10-year cycle, from 2021 – 2030. We also show data on the proportion of workers in each affected industry that are, at present, 50 years old or over. We assume that these workers will move into retirement on a steady basis between now and 2030. These workers will therefore not be subject to layoffs due to fossil fuel industry cutbacks. But there will need to be guarantees that their pensions will be provided in full once they reach retirement.

Workers who will face retrenchments due to fossil fuel production cutbacks in New York State will therefore be only younger workers—i.e. those not moving into retirement between now and 2030.

TABLE 30
Attrition by Retirement and Job Displacement for Younger Workers through 40 Percent Contraction of Fossil Fuel Sector Activity in New York

	1) Natural gas distribution	2) Fossil fuel electric power generation	3) Oil and Gas Pipeline Construction and Transportation	4) Petroleum Bulk Containers and Terminals	5) Oil and Gas Extraction	6) Support Activities for oil/gas	7) Petroleum Refining	8) Totals
1) Current employment, total	6,532	2,943	2,129	814	503	438	34	13,393
2) Job Losses over 10-year transition *(= row 1 * .4)*	2,613	1,177	852	326	201	175	14	5,358
3) Average annual job losses over 10-year production decline *(= row 2/10)*	261	118	85	33	20	18	1	536
4) Number of workers between 55 – 65 over 2021 – 2030	2,286	1,118	703	350	101	136	11	4,705
*(= row 1 * % of workers 50 and over between 2015 – 2030)*	*(35% of all workers)*	*(38% of all workers)*	*(33% of all workers)*	*(43% of all workers)*	*(20% of all workers)*	*(31% of all workers)*	*31% of all workers)*	*(35% of all workers)*
5) Number of workers per year reaching 65 during 10-year transition period *(= row 4/10)*	229	112	70	33*	10	14	1	469
6) Number of workers requiring reemployment *(= row 3 – 5)*	32	6	15	0	10	4	0	67

Note: *Number of workers per year reaching 65 is actually 35 (i.e., 350/10), but only 33 would be among the job losers due to the transition.

Our approach to estimating the number of workers both moving into retirement and facing displacement is clear through considering the figures in Table 30 on the natural gas distribution industry, shown in column 1. As we see again, at present there are 6,532 workers in New York State employed in natural gas distribution. We assume that this industry will face a 40 percent contraction in 2030 relative to its 2014 production level. As we see in row 2 of the table, this means that total employment in the industry will fall by 2,613 jobs—a 40 percent decline—while 3,919 will remain as of 2030. If we then assume that the contraction in the industry proceeds at a smooth rate over the decade 2021 – 2030, this means that 261 jobs in the industry will be lost each year, as we see in row 3.[30]

We see in row 4 that, at present, 2,286 workers, or 35 percent, of workers employed in natural gas production will be between 55 – 65 years old between 2021 – 2030. If these workers retire at a steady rate over the 2021 – 2030 decade, this means that 229 workers will move into retirement every year over the decade. Given that total job losses each year will average 261 over the decade, that in turn means that 32 younger workers will face displacement, above and beyond the 229 workers who will move into retirement.

We show the equivalent patterns for the other six fossil fuel production and ancillary industries in columns 2-7 of Table 30. Column 8 then shows totals for all the industries. We see, again, in row 1 that total employment in these industries is 13,393. Total job losses as of 2030 will therefore be 5,358, or 40 percent of the current total production level. This translates into an average of 536 job losses per year over 2021 – 2030. We also then see, in row 5, that 469 workers per year will reach retirement age over this time period. That in turn means that a total of 67 workers per year will face displacements, and will need to be placed into new jobs as part of the Just Transition program.

Why Job Displacements Equal only 67 Workers per Year

This result represents a major conclusion within our overall framework for advancing a viable Just Transition program for New York State. It will therefore be useful to examine it in more detail before moving on.

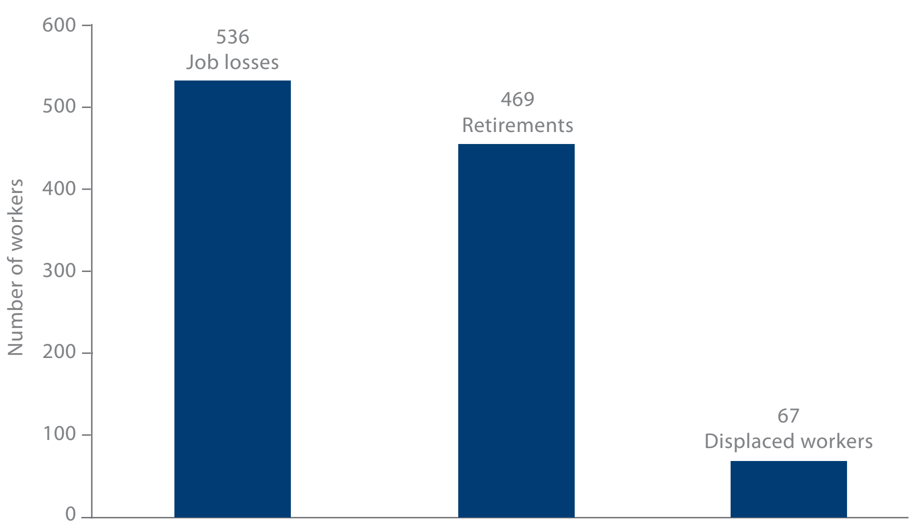
Given that there are approximately 13,400 people employed in the seven fossil fuel related industries in New York State as of 2014, it may appear implausible that there should be only 67 workers per year who would be displaced through a 40 percent industry-wide production decline as of 2030. But this finding is not due to any kind of unreasonable assumptions or incomprehensible mathematical manipulations. In fact, it is a quite straightforward and intuitive result, following from the main findings that we present in Table 30. Consider the following simple, logical steps:

1. **Total number of workers and job losses.** While there are approximately 13,400 people employed in total in New York State's fossil fuel related industries, as we have discussed above, we estimate that, as a first approximation, employment contraction in the industry will be 40 percent as of 2030. This implies that about 60 percent of the 13,400 jobs—i.e. 8,000 jobs—will remain intact as of 2030. The total job losses as of 2030 will therefore be about 5,400, i.e. 40 percent of the current industry employment level of about 13,400.

2. **Job losses per year.** The total of 5,400 jobs will not all be lost at once. Rather, the 40 percent in job losses in these industries will occur over the full period 2021 – 2030. As an average figure, that translates to 540 jobs lost per year between 2021 – 2030.
3. **Voluntary retirements.** We show in Table 30 that about 35 percent of all workers currently employed in New York State's fossil fuel related industries will turn 65 between 2021 and 2030. We assume that these workers will move into voluntary retirement between 2021 and 2030. As we show in Table 30, this amounts to a total of about 4,700 workers moving into voluntary retirement between now and 2030. On an annual basis, this means about 470 workers moving into voluntary retirement per year.
4. **40 percent job losses vs. 35 percent voluntary retirements.** Given that a total of 40 percent of all jobs in the state's fossil fuel related industries will be lost as of 2030, and that 35 percent of workers will move into voluntary retirement as of 2030, that means that only about 5 percent of the total job contraction will need to be experienced by workers who did not move into voluntary retirement.
5. **Worker displacement amounts to 5 percent of total.** Five percent of 13,400 total workers is 670 workers. Spreading this total level of job displacement over 10 years between 2021 – 2030 means that an average of 67 workers per year will be displaced as a result of the 40 percent contraction in the industry between 2021 and 2030.

This is the result that we reach in Table 30, based on the detailed steps that we document in that table. We illustrate the main features of our calculations in Figure 3, so as to further clarify how we reached this important finding.

FIGURE 3: Estimated Annual Job Losses, Voluntary Retirements and Workers Displaced in New York State's Fossil Fuel Related Industries, 2021– 2030



Source: See Table 30.

Pension Guarantees for Retiring Workers

As we have seen, a high proportion of the currently employed fossil fuel and ancillary industry workers will be reaching retirement age by 2030. It is therefore critical that the Just Transition program ensure that these retiring workers be guaranteed secure pensions when they move into retirement. This is especially important, given that the fossil fuel dependent industries will be experiencing contraction in order to achieve the 2030 emission reduction target of 100 million tons, and will likely face financial challenges as a result.

In Table 31, we review the status of the pension funds for most of the firms currently operating in New York State in either the natural gas delivery or fossil-fuel based utility industries, where about 70 percent of all fossil-fuel based workers are employed in the state.[31] The firms are grouped together when they are owned by the same parent firm—as with Algonquin Gas and Texas Eastern, which are both subsidiaries of Spectra Energy.

The main results that we report in Table 31 are broadly representative of the patterns for the firms in the other five fossil fuel related industries operating in New York State.

The table shows the extent to which firms are carrying unfunded pension liabilities as of 2015. We also show the net income level, as well as their allocation of funds for stock

TABLE 31
Status of Pension Funds and Overall Financial Conditions for Natural Gas and Fossil Fuel Electric Power Generation Firms Operating in New York State, 2012 - 2015

(Parent Companies in Parentheses)

	Unfunded pension liability 2015	Net income, 2013-2015	Dividends, 2013-2015	Stock buybacks, 2013-2015
Algonquin Gas Transmission, Texas Eastern Transmission (Spectra Energy)	$39 million	$2.9 billion	$2.7 billion	0
Bowline Point,Oswego Harbor Power (NRG Energy)	$458 million	-$6.7 billion	$551 million	0
Central New York Oil and Gas *(Crestwood Midstream Partners)*	Defined contribution plan	-$2.3 billion	0	0
Columbia Gas Transmission, Iroquois Gas Transmission, TC Ravenswood *(Transcanada-Canada)*	$490 million	$3.7 billion	$5.8 billion	$390 million
Dominion Transmission *(Dominion Resources)*	$273 million	$5.0 billion	$4.2 billion	0
Empire Pipeline *(National Fuel Gas)*	$68 million	-$371 million	$392 million	0
Enterprise Products	No post-retirement benefits reported	$8.0 billion	$8.9 billion	0
Orange Rockland Utilities *(Consolidated Edison)*	$2.6 billion	$3.3 billion	$2.2 billion	0
Tennessee Gas Pipeline *(Kinder Morgan)*	$788 million	$5.3 billion	$7.6 billion	$841 million
Transcontinental Gas Pipeline *(Williams Companies)*	$224 million	$1.7 billion	$4.2 billion	0

Sources: Company 10-Ks, except Transcanada (company annual report). For Transcanada, used IRS 2015 currency exchange rate https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

Note: While Enterprise Products technically paid no dividends on shares, it did distribute $8.0 billion to limited partners, the equivalent of dividends in limited partnerships.

buybacks and dividends between 2013 – 2015. To begin with, most of the firms do have defined benefit pension programs for their workers. The two exceptions are Central New York Oil and Gas, which has a defined contribution program only. Enterprise Products does not report on any post-retirement benefits.

Of the firms with defined benefit programs, all of them are carrying unfunded pension liabilities. However, these unfunded liabilities are not large relative to the firms' income levels, or the funds they are channeling into either dividends or stock buybacks.

For example, Tennessee Gas Pipeline, whose parent company is Kinder Morgan, has the largest unfunded pension liability of the firms reported in Table 31, at $788 million as of 2015. But this firm also earned $5.3 billion in income over 2013 – 2015, paid out $7.6 billion in dividends, and bought back $841 million of their own stocks. There is no reason to expect that Tennessee Gas Pipeline should have any difficulty meeting its pension fund obligations. Another firm, NRG Energy, the parent for both Bowline Point and Oswego Harbor, had, as of 2015, an unfunded pension liability of $458 million. NRG Energy also experienced $6.7 billion in losses over 2013 – 2015, though most of these were driven by $5 billion in asset write-downs, including two struggling Texas coal plants. But it is still the case that NRG Energy paid out $551 million in dividends between 2013 – 2015—i.e. 20 percent more than they are carrying in unfunded pension liabilities.

Given that these firms will need to contract by something like 40 percent through 2030, we cannot expect them to replenish their pension funds over this period as a matter of course. It should therefore be a priority of State policy to mandate full funding, to the extent that this is possible within existing state law or through establishing new regulations. This could also be achieved in coordination with federal government regulators, at the Pension Benefit Guarantee Corporation (PBGC). One way to enforce this would be to prohibit the relevant companies from paying dividends or financing share buybacks until their pension funds have been brought to full funding and then maintained at that level. As needed, the state government, again in coordination with the PBGC, could consider placing liens on company assets when pension funds are underfunded. Through such measures, the pension funds for most of the affected workers can be protected through a regulatory intervention alone, without the government having to provide financial infusions to sustain the funds.

At the same time, there may be individual cases in which one or more of the firms do experience serious financial crises in the future, especially given the fact that the market for their products will be contracting substantially through 2030 and beyond. As a roughly comparable case in point, some coal companies operating in other U.S. states do now already face critical conditions with their pension funds, due to cutbacks in U.S. coal demand. Under such conditions, the pension commitments to the affected workers, in coal nationally as well as all fossil fuel and ancillary industries in New York, will still need to be fully honored.

In addressing the crisis with coal industry pensions, the Obama administration did propose a measure to support the pensions, under its "Power Plus" program that aimed broadly to support coal communities and workers. This proposal was blocked in the U.S. Congress by the Republican majority. But the broader point is that such a measure must be understood as a centerpiece for any Just Transition program for New York. Given the absence of a funding crisis at present, we are not proposing here a level at which such a program may need to be financed in the future. But an insurance-type policy may well be a measure that deserves careful attention in ongoing work to develop the specifics of a New York Just Transition program.

Support for Displaced Workers

As we saw in Table 30, an average of 67 workers per year in fossil fuel and ancillary industries will face displacement through a 40 percent contraction in fossil fuel consumption in New York as of 2050. This will be after 469 workers per year reach the age of 65 by 2030, with their positions not being replaced when they move into retirement. The New York State Just Transition program should, again, provide three types of support for displaced workers: 1) guaranteed reemployment; 2) income support; and 3) retraining and relocation support. We consider each of these in turn.

Guaranteed reemployment

These new employment opportunities could perhaps be in the expanding clean energy sectors, with approximately 145,000 – 160,000 new direct plus indirect jobs created per year in New York State through clean energy investments at the level of $31 billion per year (see Table 17). The new state clean energy projects are likely to be financed at least partially through public-sector funding. Given such public sector funding, the state could require job preference provisions for the displaced workers.

As a broader back-up provision, the job guarantees could be provided within New York's state and municipal job markets. At present, total employment in either state or municipal employment in New York is about 1.2 million. Between this pool of 1.2 million and the additional roughly 150,000 jobs generated by clean energy investments, it should not be difficult to find good new job opportunities for the roughly 67 fossil fuel industry dependent workers per year who will face displacement. These 67 workers constitute less than 0.01 percent of the 1.4 million jobs that are either in New York's state or municipal government sectors or will be created by the clean energy investments in the state needed to drive down CO_2 emissions to 100 million tons by 2030.

Income Support

Though it will not be difficult to find new employment opportunities for the 67 fossil fuel and ancillary industry workers that will be displaced annually on average, there is a high likelihood that the new jobs will be at lower pay levels than the previous jobs. It will therefore be necessary for these workers to be provided with "compensation insurance" so that they experience no income losses in their transition from fossil fuel industry jobs into new positions.

To provide some initial specifics on the costs of such a measure, we propose that all displaced workers receive 100 percent compensation insurance for five years. That is, they will be paid the full difference between any disparities in the compensation they receive in their new job relative to what they received in their previous job in the fossil fuel or ancillary industry.

The data in Table 32 provide a framework for providing a rough estimate as to what the costs would be for such a compensation insurance program. In column 1, the table shows the figures we have seen in Table 30 on the number of workers that would be displaced annually through the project of cutting fossil fuel production in New York by 40 percent as of 2030. Column 2 then shows the average compensation in each of the affected industries at present.

TABLE 32

Estimating Annual Costs of 100 percent Compensation Insurance for Displaced Fossil Fuel Industry Dependent Workers

Average 2014 compensation for New York State government employees = $87,000

	1) Number of displaced workers per year	2) Average compensation in industry, 2014	3) Difference between fossil fuel and public sector jobs *(= column 2 - $87,000)*	4) Annual costs for compensation insurance *(= columns 1 x 3)*
Natural gas distribution	32	$139,000	$52,000	$1.7 million
Fossil fuel electric power generation	6	$156,000	$69,000	$0.4 million
Oil and Gas Pipeline Transportation and Construction	15	$118,000	$31,000	$0.5 million
Petroleum Bulk Storage and Terminals	0	$165,000	$78,000	0
Oil/gas	10	$121,000	$34,000	$0.3 million
Oil/gas support	4	$73,000	$0	0
Petroleum refining	0	$63,000	$0	0
TOTALS	**67**	---	---	**$2.9 million**
TOTAL INSURANCE COSTS FOR 5 YEARS OF COVERAGE				**$14.5 Million** ***($2.9 million x 5 years)***

Sources: See Appendix 6. Estimates based on data in Table 30.

In column 3, we show the difference between these average industry-specific compensation figures relative to the average compensation level for New York State government employees, which, as we see, was $87,000 in 2014. Of course, we cannot assume that all displaced workers will be moved into New York State public sector jobs once they are laid off from their fossil fuel or ancillary industry job. Some will certainly move into the rapidly expanding clean energy industries. But because the public sector employment market can serve as the underlying basis for the displaced workers reemployment guarantees, it is reasonable to work with the New York State public sector compensation figure as a benchmark for our compensation insurance exercise.

Thus, for example, with workers in the natural gas distribution industry, we see in column 1 of Table 32 that the difference in average compensation between these workers in their present jobs and an average New York State job is $52,000. We therefore calculate that average compensation insurance per year for these workers will be $1.7 million (i.e. $52,000 x 32 workers). We then perform the same calculation for the displaced workers in other industries as well. From this we estimate that one year's worth of total compensation insurance for all 67 displaced workers per year will be $2.9 million. Five years' worth of total compensation insurance for all displaced workers in one year will therefore be $14.5 million, which we can round up to $15 million.

Retraining and Relocation Support

As we have seen above (Tables 19 – 22), the range of new jobs that are being generated through clean energy investments is wide. These jobs vary in terms of the formal educational credentials as well as special skill requirements. Some of the jobs will require skills closely aligned with those that the displaced workers used in their former fossil fuel industry jobs. These include a high percentage of construction-related jobs for efficiency investments as well as most management, administrative and transportation-related positions throughout the clean energy industries. In other cases, new skills will have to be acquired to be effective at the clean energy industry jobs. For example, installing solar panels is quite distinct from laying oil and gas pipelines. This is why a Just Transition program must include a provision for retraining for the displaced fossil fuel industry workers. The Just Transition program will also need to serve as a job placement clearinghouse for all displaced workers.

The U.S. government has already been operating a federal clean energy job training program. This is the Energy Efficiency and Renewable Energy Training Program, which was initially one component of the 2007 Energy Independence and Security Act. The program was then funded as part of the 2009 American Recovery and Reinvestment Act—the Obama stimulus program.

Over 2009 – 2013, the funding allocated specifically for job training programs averaged $75 million per year.[32] This figure can serve as one benchmark for estimating the costs of the program we are describing. We could, for example, scale the New York State figure for annual displaced workers, at approximately 67, relative to the similar figure for the U.S. as a whole, at approximately 2,700.[33] This would suggest that a New York-centered program should amount to about 2 percent of the U.S. program, i.e. at about $1.5 million per year.

But this is likely to be a high-end figure, since this existing federal government program is meant to be available to anyone interested, while the program we are describing is intended for only the roughly 67 displaced fossil fuel industry workers per year. At the same time, concerns were raised that the funding level for this broader program was inadequate, so perhaps the scaled funding figure for New York of $1.5 million annually is not too far from what is realistically required.

Another way to roughly gauge the costs of the targeted program specifically for the displaced fossil fuel workers is with reference to the overall costs of providing community college tuition education. The average annual non-housing costs for community college in New York is presently around $6,300.[34] We assume that workers would require the equivalent of two full years of training, which they would most likely spread out on a part-time basis, as they move into their guaranteed jobs. By this measure, the full annual costs of the training program for 67 workers would be about $840,000.

The midpoint between the $1.5 million for the broadly available clean energy job training program and the costs of two years for community college training, at $840,000, is about $1 million. For our purposes, to give a high-end estimate, we assume that the annual costs for a training program specifically for displaced fossil fuel workers would be around $1.5 million.

In addition to this, some of the displaced workers will need to be relocated to begin their new jobs. For the purposes of our discussion, we assume that one-half of the 67 displaced workers per year will need relocation allowances, at an average of $50,000 per displaced worker.[35] That would bring the annual relocation budget to about $1.3 million. Total annual training and relocation support would therefore be in the range of $2.8 million per year.

Overall Annual Costs for Supporting Displaced Workers

An approximation of the overall annual costs of supporting 67 displaced workers per year will include the following:

1) 100 percent compensation insurance for five years, totaling $15 million per year;
2) Retraining for 2 years, totaling $1.5 million per year; and
3) Relocation support, totaling $1.3 million per year.

This would bring the overall annual costs of supporting these 67 displaced workers to be about $18 million per year. This amounts to an average of about $270,000 per worker. To avoid understating these total costs, we can round this up to a rough average of about $300,000 per worker.

Transition Programs for Fossil Fuel Industry Dependent Communities

As we have seen, the total amount of employment in the fossil fuel and ancillary industries in New York is relatively low, at 13,393. This amounts to about 0.14 percent of total state-wide employment. As such, there will not be more than a handful of communities in the state that will experience job losses that will significantly affect the overall level of economic activity in that community. Nevertheless, there are some communities which will experience the effects of the contraction of the fossil fuel community to a disproportionate extent.

We can obtain a sense of these regional effects through considering employment levels in the fossil fuel and ancillary industries by two measures: 1) the total *number* of jobs or 2) the *proportion* of jobs by county in the five fossil fuel dependent industries that operate in New York State.

In terms of total number of jobs, the five counties with the most fossil fuel based employment are Chemung, Nassau, Chautauqua, Kings and Richmond Counties. But even with these counties, the share of employment for the fossil fuel based industries is no more than 1 percent. Thus, the program to cut fossil fuel activity in the state by about 40 percent as of 2030 would mean a fall in employment in these counties by less than one-half of one percent.

At the same time, this region of New York has already experienced job losses tied to the decline of oil and gas. This has also led to loss of tax revenues. For example, in the city of Oswego in Tioga County, Central New York Oil and Gas is the largest single taxpayer in the county. This company contributed $1.3 million in town and county tax revenues. This amounted to about 15 percent of the school district's budget.[36]

In Chemung County, the major employers were the oilfield service provider Schumberger, and Talisman Energy. But the regional operations of these firms were tied to the development of natural gas fracking activities. New York State placed a moratorium on fracking in 2008, then banned the practice outright in 2015. This led to a sharp decline in county-wide employment. As Chemung County Legislator Rodney Strange said in 2015, "Back in 2010, we had over 100 companies in Chemung County working with the gas and oil industry. Since then, we are down to a handful."[37]

The most direct way to support these communities in transition will be to channel a relatively high proportion of new clean energy investments into these communities. Given that the overall level of required clean energy investment will be in the range of $31 billion per year, channeling something on the order of $1 billion into these communities will provide substantial compensation for the contraction of fossil fuel industry related jobs and tax revenues.

One model for developing such investment projects in these communities would be the Worker and Community Transition program that operated through the U.S. Department of Energy from 1994 – 2004. This initiative was targeted at 13 communities which had been heavily dependent on federal government operated nuclear power and weapons facilities but subsequently faced retrenchment due to nuclear decommissioning. One study of this program, by Lynch and Kirshenberg (2000), published in the *Bulletin of the Energy Communities Alliance*, concluded as follows:

> Surprisingly, the 13 communities, as a general rule have performed a remarkable role in attracting new replacement jobs and in cushioning the impact of the cutbacks at the Energy-weapons complex across the country … The community and worker adjustments to the 1992 – 2000 DOE site cutbacks have been strong and responsive, especially when compared with any other industrial adjustment programs during the same decade.

The experience in Piketon, Ohio provides a good case study of how this program has operated in one community. Piketon had been the home of a plant producing weapons-grade uranium that closed in 2001. The workers in the plant were represented by the Oil Chemical and Atomic Workers union (OCAW—which merged in 1999 with the United Steel Workers). The union leadership was active in planning the plant's repurposing project. The closure could have been economically devastating for the region, but the federal government provided funding to clean up the 3,000 acre complex. The clean-up operation began in 2002, and is scheduled to take 40 years to complete.[38] Currently 1,900 workers are employed decontaminating the site at a cost of $300-$400 million a year. The contractor hired to clean up the site employs union workers and the president of the USW local union is enthusiastic about the long-term prospects for the project and the site (Hendren 2015).

Despite the positive achievements with projects such as Piketon, Lynch and Kirshenberg also note more generally that "The most serious problem facing the energy-impacted communities…was the lack of a basic regional economic development and industrial diversification capacity for most of the regions affected by the cutbacks…" A separate study by Lowrie et al. (1999) reaches the same conclusion. They write:

> The community transition efforts thus far are inadequate, and the cleanup funds being distributed to the sites have become a substitute for adjustment to a post- Department of Energy world. Continued dependence on cleanup jobs at the sites rather than transitioning to a non-DOE economy will exact a toll on long-term economic sustainability (1999, p. 121).

To address this problem directly, community assistance initiatives could encourage the formation of new clean energy businesses in the affected areas. One example of a successful diversification program was the repurposing of a nuclear test site in Nevada to what is now a solar proving ground. More than 25 miles of the former nuclear site are now used to demonstrate concentrated solar power technologies and help bring them to commercialization.[39]

There are also important cases of successful repurposing projects in other countries. Most prominent has been the experience in Germany's Ruhr Valley, which has been the traditional home for its coal, steel and chemical industries. Since the 1990s, the region has advanced industrial policies to develop new clean energy industries.[40] For example, RAG AG, a German coal mining firm, has been developing plans to convert coal mines that are scheduled to close in 2018 into hydroelectric power storage facilities to stabilize energy production when solar or wind power fluctuates. In periods of slack solar and wind energy production, water that was earlier pumped into a surface pool during excess supply periods is dropped through 1,000 meters of pipes to drive the underground turbines. In addition to hydroelectric power storage, the company is also erecting wind turbines on the top of tall waste heaps and installing solar panels on the slopes. Other firms in the region have branched into producing wind and water turbines. This regional transition project has succeeded through mobilizing the support of the large coal, steel and chemical companies and their suppliers, along with universities, trade unions and government support at all levels.

9. A Clean Energy Investment Policy Framework

We have seen in Section 6 that, for New York State to achieve a 40 percent reduction in CO_2 emissions by 2030 relative to 2014—i.e. from an overall level of emissions of 170 to 100 million tons—the state's economy will need to invest an average of roughly $31 billion per year to both dramatically raise the state's energy efficiency standards and to equally dramatically expand the available supply of clean renewable energy. This figure amounts to about 1.8 percent of New York State's average GDP between 2021 – 2030, assuming that the state's GDP grows by an average of 2.6 percent per year over that 10-year period.

In this section, we consider what would constitute an effective package of policies for reaching this $31 billion per year average investment level. As we have discussed above, we estimate that, at present, annual private investment in clean energy in New York State is about $6 - $7 billion per year. We are therefore proposing that overall annual clean energy investments will need to increase, on average, by roughly 5-fold to achieve a 40 percent emissions reduction as of 2030.

As we have discussed above, New York State does already have an extensive clean energy program in place. In its current version, it was presented in April 2014 by Governor Andrew Cuomo as Reforming the Energy Vision (REV). This program has three overarching goals to be achieved by 2030: 1) a 40 percent reduction in all greenhouse gas emissions; 2) generating 50 percent of all electricity from renewable energy sources; and 3) achieving a 23 percent improvement in energy efficiency in buildings relative to the 2012 level. The state's Department of Public Service then fleshed out a "roadmap" for REV with the New York State Energy Plan, presented in June 2015. This broad framework was most recently reaffirmed in Governor Cuomo's Executive Order No. 166, signed on June 2, 2017, titled "Redoubling New York's Fight Against the Economic and Environmental Threats Posed by Climate Change and Affirming the Goals of the Paris Climate Agreement."

Governor Cuomo's June 2017 Executive Order is a brief statement highlighting both the main climate stabilization policy initiatives that have been advanced by the state in recent years as well as its plans moving forward. The initiatives and future plans emphasized in Cuomo's statement include the following:

> New York has already committed to aggressive investments and initiatives to turn the State Energy Plan goals into action through its Clean Energy Standard program, the $5 billion Clean Energy Fund, the $1 Billion NY-Sun solar program, the nation's largest Green Bank, and unprecedented reforms to make the electricity grid more resilient, reliable, and affordable…..
>
> New York is engaged in greenhouse gas reduction activities throughout the state's economy, including through the issuance of the Methane Reduction Plan and participation in regional collaborations seeking greenhouse gas emissions reductions including the Regional Greenhouse Gas Initiative ("RGGI") and the Transportation and Climate Initiative ("TCI")….
>
> Actions to Meet Policy Goals: In order to achieve these objectives, each Affected State Entity shall adopt by March 31, 2018 a plan demonstrating activities and programs that will contribute to the State of New York's achievement of these important policy goals….Affected State Entities

are hereby directed to implement a portfolio of measures that may include but shall not be limited to no- and low- cost operational improvements, retro-commissioning, capital energy efficiency retrofits, and onsite renewable and high efficiency combined heat and power projects.

For our purposes, it will be useful to consider New York State's individual climate stabilization policy initiatives within three broad categories. These are:

Polluter fee and related regulations that take account of the social costs of burning fossil fuels as an energy source and help build demand for energy efficiency and clean renewable energy sources.

Financial subsidies and incentives that lower the costs and risks for private investors for investments in energy efficiency and clean renewable energy sources.

Direct public spending that includes investments in infrastructure, procurement and research and development (R&D).

Our focus is on how, through combining a broad set of policies, the state economy can raise overall public plus private clean energy investments to the necessary level of about $31 billion per year, equal to 1.8 percent of average GDP, between 2021 – 2030. We emphasize at the outset, again, that most of this overall annual $31 billion figure for new clean energy investments will need to come from private investments. A polluter fee and related regulatory policies, along with carefully targeted public investments, can serve to both complement and help incentivize private investments. Similarly, publicly-supported financing programs will be needed to leverage private financial resources, with the private provision of financing providing the bulk of funds necessary to expand overall clean energy investments in New York State to the necessary level of about 1.8 percent of annual statewide GDP.

In examining the range of major policies to expand annual clean energy investments roughly five-fold in New York State between 2021 – 2030, we should also recognize that these state-level policies are likely to be supported by policies established at the federal government level. The most important of these programs are the investment and production tax credits that are currently provided for renewable energy projects.[41] It is true that the Trump administration is likely to seek repeal of many, if not all, of these programs. But it is not a foregone conclusion that they will succeed in such efforts. To date, the investment and production tax credits have not been mentioned as targets for repeal.

Finally, we emphasize that we are offering a broad framework and set of options for the public and policy community to consider moving forward. Our proposals are by no means meant to represent a definitive, fully-worked out set of policy measures that can only be put into action as one whole fully specified program.

Current Financial Subsidies and Incentives

As discussed above, New York State currently supports clean energy investments in the state through multiple specific programs within the framework of the Clean Energy Fund. The fund is managed by NYSERDA. The fund amounts to a total of $5.2 billion to be distributed over 10 years, from 2016 – 2025—therefore at roughly $500 million per year in average annual spending. The revenues to support the fund are provided through a surcharge on electricity bills. This funding source is in addition to the RGGI funds generated through the auction fees on carbon emission permits.

According to the Clean Energy Fund website, NYSERDA is focusing its efforts in four distinct portfolios. As reported on the Clean Energy Fund website[42], these include the following:

- **Market Development ($2.7 billion)** to reduce costs and accelerate customer demand for energy efficiency and other behind-the-meter clean energy solutions, and increase private investment. This portfolio will provide financial support, technical knowledge, data, and education to customers and service providers to accelerate demand for clean energy solutions and will train an advanced workforce able to fill new jobs in the sector. This portfolio also specifically supports initiatives that benefit low- to moderate-income households, including a commitment of at least $234.5 million over the first three years.
- **NY-Sun ($961 million)** to provide long-term certainty to New York's growing solar market and to lower the costs for homeowners and businesses investing in solar power. This portfolio will make solar energy more affordable and accessible for residential and commercial customers, with a goal of bringing solar to 150,000 new homes and businesses by 2020.
- **NY Green Bank ($782 million)** to partner with private financial institutions to accelerate and expand the availability of capital for clean energy projects. This portfolio will increase confidence in lending for clean technologies through a total investment of $1 billion.
- **Innovation and Research ($717 million)** to invest in cutting-edge technologies that will meet increasing demand for clean energy. This portfolio will drive clean tech business growth across five key opportunity areas: smart grid technology, renewables and distributed energy resources, high performance buildings, transportation, and clean-tech startup and innovation development.

The fund has set out specific programs and targets within these four broad portfolios. Some of the primary areas of activity include: large-scale renewables; renewable heating and cooling; energy products; clean transportation; energy storage; grid modernization; building innovations; multi-sector solutions; and workforce development and training.[43]

The coverage of these Clean Energy Fund programs is clearly extensive. But it is unlikely that the current funding level provided, at roughly $500 million per year, will be sufficient to bring total public and private investments to a figure in the range of $31 billion per year—the level we have estimated will be needed to reduce CO_2 investments in the state to 100 million tons by 2030. It is therefore necessary to consider additional sources of public funds as well as a set of effective complementary policies that are capable, in combination, of bringing total statewide clean energy investments within an average range of $31 billion per year between 2021 – 2030.

Fee and Regulatory Policies

Carbon Pricing

The best-known regulatory approach for reducing CO_2 and other greenhouse gas emissions is to establish a price on carbon that reflects the environmental costs of emissions. This can be done in two alternative ways—either through setting a firm limit on emissions—a carbon cap—or through establishing a polluter fee.[44]

Depending on the specific design features of the policy, the cap or penalty can be an effective tool supporting a large-scale transition out of fossil fuels and into energy efficiency and clean renewable energy investments. This policy can also generate large amounts of revenue. The revenue, in turn, can be used in part to help finance a clean energy investment project. Part of the funds will also be needed to support Just Transition policies as well as to rebate a share of the revenues back to residents so as to reduce losses in net incomes for some New York households that would otherwise result through having to pay higher retail prices for fossil fuel energy.

As with most policy interventions, both polluters' penalties and carbon caps have strengths and weaknesses. There is a longstanding debate as to their relative merits. We do not delve into the debate here.[45] Our focus is rather on achieving the emissions reductions goals in New York, and using carbon pricing as a major tool both to significantly reduce fossil fuel consumption in the state, and to generate significant levels of revenue that can help finance the needed large-scale expansion of clean energy investments.

Regional Greenhouse Gas Initiative

Since 2005, New York State has participated in the Regional Greenhouse Gas Initiative (RGGI). RGGI is the first mandatory multi-state program to reduce power sector CO_2 emissions on the basis of a carbon cap framework. The other states participating in RGGI are Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, Rhode Island and Vermont.

RGGI operates as a regional cap-and-trade program. This means that RGGI states establish a regional cap on the amount of CO_2 emissions that electric utility power plants can emit. They implement this cap through issuing a limited number of tradable CO_2 allowances. The September 2016 evaluation of the program by RGGI itself explains the operation of the program as follows:

> Each allowance represents an authorization for a regulated power plant to emit one short ton of CO_2. Individual CO_2 budget trading programs in each RGGI state together create a regional market for CO_2 allowances. This allows market forces to determine the most cost-effective means of reducing emissions, and creates market certainty needed to drive long-term investments in clean energy. Each state's regulations are independent, and are based on the RGGI Model Rule, (2016, p. 4).

The RGGI program in New York State has certainly contributed to the state operating with the lowest per capita CO_2 emissions level in the United States. In addition, the funds generated in New York through RGGI auctions have also been channeled into promoting energy efficiency and renewable energy investments in the state. The 2016 RGGI study summarizes the impact of the New York program as follows:

> New York State invests RGGI proceeds to support diverse strategies that mitigate global climate change and reduce pollution. The strategic goals of RGGI investment in New York are to reduce in-State greenhouse gas emissions through energy efficiency and renewable energy projects, build New York's capacity for long term carbon reduction, empower communities to transition to cleaner energy, stimulate entrepreneurship and growth of clean energy companies in New York, and support innovative financing to increase adoption of clean energy, (2016, p. 33).

The accomplishments to date of RGGI are significant. But as we have seen, the state will need to substantially strengthen its policy initiatives to bring overall statewide CO_2 emissions down to 100 million tons by 2030 from the current level of about 170 million tons. Among other considerations, the level of state revenues generated by the New York RGGI program has not been close to adequate to effectively support clean energy investments at the level needed, of about $31 billion per year.

The 2016 RGGI staff study reports that cumulative revenues generated in New York over the decade 2005 – 2014 totals $728 million (2016, p. 6). This amounts to an average of $73 million per year, or only 0.2 percent of the $31 billion level of investment needed. It also amounts to about 0.004 percent of current New York State GDP. Funds from RGGI can therefore serve as only a modest supplement within the broader Clean Energy Fund, which we discuss in detail below.

Revenue Estimates for New York State Polluter Fee

We consider now the revenue potential of establishing a polluter fee for New York State. Our estimates incorporate the key assumption of this study, which is that the level of CO_2 emissions in New York State will decline by 40 percent, from its 2014 level of 170 million tons to 100 million tons as of 2030. Moreover, we assume that the clean energy program for the state is implemented over the 10-year period, 2021 – 2030. We therefore assume that the polluter fee is implemented in 2021 and continues through 2030.

We provide revenue estimates for the polluter fee under the assumption that the fee begins in 2021 at $35 per ton and then rises steadily to $75 per ton as of 2030.[46] In Table 33, we see the annual revenue generated through these fee rates, both on an annual basis and as an average revenue level for the full 2021 – 2030 decade.

The basic patterns are straightforward. The fee is first imposed in 2021, when CO_2 emissions in New York State are 170 million tons, and the fee is $35 per ton of carbon. This generates $5.95 billion in revenues. We round this figure up to $6 billion. Over the course of the decade, CO_2 emissions fall steadily to 100 million tons, while the penalty rate rises steadily to $75 per ton. Through these two patterns, the annual revenue from fees rises to a peak of $7.6 billion as of 2027 before declining modestly in 2030 to $7.5 billion. As Table 33 shows, the average annual revenue amount is $7.1 billion per year, and the total revenue generated by the penalty over 2021 – 2030 is $71.4 billion.

Overall, we see that the revenues generated by a statewide polluter fee at the rates we have examined for 2021 – 2030 will far exceed the funds that have been produced through the existing RGGI carbon cap program. Specifically, the average annual revenue generated of $7.1 billion is nearly 100 times greater than the $73 million average generated through RGGI between 2005 and 2014.

TABLE 33
Revenue Generation through Polluter Fee for New York State

ASSUMPTIONS FOR CALCULATIONS

1. CO_2 emissions in New York State fall steadily between 2021 – 2030 from 170 million tons to 100 million tons.
2. The penalty rate begins in 2021 at $35 per ton. The rate then rises steadily to $75 per ton as of 2030.

Year	1) Annual Emissions (millions tons—Assume emissions fall by 40% by 2030)	2) Polluter Fee Rate: Dollars per ton of CO_2 emissions	3. Annual Revenue (= columns 1 x 2)
2021	170.00	$35.00	$6.0 billion
2022	162.22	$39.44	$6.4 billion
2023	154.44	$43.89	$6.8 billion
2024	146.67	$48.33	$7.1 billion
2025	138.89	$52.78	$7.3 billion
2026	131.11	$57.22	$7.5 billion
2027	123.33	$61.67	$7.6 billion
2028	115.56	$66.11	$7.6 billion
2029	107.78	$70.56	$7.6 billion
2030	100.00	$75.00	$7.5 billion
ANNUAL AVERAGES	**135.00**	**$55.00**	**$7.1 billion**
TOTAL REVENUE OVER 2021 – 2030	---	---	**$71.4 billion**

Sources: Figures based on table's assumptions.

Managing Distributional Impacts of a Polluter Fee

Establishing a polluter fee will also exert upward pressure on retail prices for fossil fuel energy. Indeed, this is one main purpose of the measure, with rising fossil fuel prices serving to discourage consumption of fossil fuel energy and correspondingly encourage the consumption of clean renewable energy. But this also creates a problem. All else equal, the rise in fossil fuel prices generated by the polluter fee will lower the net incomes for New York residents. In particular, it will disproportionately lower the net incomes of lower income households, since these households spend a higher share of their overall income on necessary energy purchases, including gasoline, electricity, and home-heating fuel.

Focusing on gasoline prices, a rule-of-thumb for estimating the impact of a polluter fee on retail prices is that every $1 dollar in a polluter fee will add about one cent to the retail price per gallon of gasoline.[47] As of October, 2017, the average gasoline price in New York State was about $2.60 per gallon. With a polluter fee at $35, that would raise the average price of gasoline to $2.95 per gallon. A $75 polluter fee would raise the average price to $3.35 per gallon.

Given these impacts on energy prices, the critical design issue with the polluter fee will be to accomplish three aims concurrently. These are to: 1) Significantly discourage fossil fuel consumption; 2) Generate a large enough share of total revenues to support the overall average $31 billion per year clean energy investment level; and 3) Redistribute revenues to counteract the negative effects of the polluter fee on the net income of a share of New York households.

In Table 34, we illustrate the range of possibilities under two sets of policy assumptions. Specifically, we show the level of public funding available for clean energy investments, assuming either 50 percent or 75 percent of all revenue are channeled into new investments, with the remaining funds used for rebates. We then also show the level of public investment funds generated through these alternatives as a percentage of the $31 billion total in average clean energy investments per year that we estimate are needed to bring New York State emissions down to 100 million tons by 2030.

As we see in Table 34, if we assume that polluter fee revenues are divided evenly between investment funds and rebates, that implies that the amount of public funds available to support clean energy investments will average $3.6 billion per year—i.e. 11.5 percent of the $31 billion of total funding needed. If 75 percent of all revenues are used for supporting clean energy investments, then the funds available for investment will be $5.3 billion, i.e. 17.2 percent of the $31 billion needed. We consider below how effective this range of funding will be, serving as leverage to bring total average clean energy investments up to $31 billion per year, including both private and public investments.

TABLE 34
Revenues from Polluter Fee Available for Clean Energy Investments and Rebates

Average Annual Revenue over 2021 – 2030 = $7.1 billion, with Polluter Fee rising from $35 - $75 per ton

Revenues Divided: 50% investment/50% rebates		Revenues Divided: 75% investment/25% rebates	
Funds available for Investment	*Investment funds as pct. of $31 billion total investments*	*Funds available for Investment*	*Investment funds as share of $31 billion total investments*
$3.6 billion	11.5%	$5.3 billion	17.2%

Sources: Revenue estimate from Table 33.

Renewable Energy and Energy Efficiency Portfolio Standards

New York State currently operates with both renewable energy and energy efficiency portfolio standards. We discuss these in turn.

Renewable Energy Portfolio Standards

The original Renewable Energy Portfolio Standard (RPS) was initiated in 2005 and expired in 2015. The program was then extended in 2016 as the Clean Energy Standard, which expires in 2030.[48]

Under the original 2004 – 2015 RPS, the goal that was set was for 29 percent of New York State's total electricity supply to be met with renewable resources by 2015. At least as of the most recent 2014 data, this goal was not likely to be achieved, though the state does appear to have come reasonably close. In Table 2 above, we presented the breakdown in the supply of electricity generated by alternative energy sources. Referring back to Table 2, we see that, among all energy sources used in generating electric power (and excluding energy losses), 17.1 percent came from hydro power alone. In addition, other renewable energy sources for electricity included 2.6 percent from wind, 1.3 percent from bioenergy, and 0.1 percent from solar. In total, these renewable sources add to about 21 percent of New York State's total electricity supply as of 2014.

At the same time, these figures can be misleading. First, as we have seen, most of the 21 percent renewable electricity supply figure is provided by the 17.1 percent coming from hydro power. A significant supply of hydro power is by no means a new development in New York State. Indeed, the world's first large-scale hydro station began operating on the New York side of Niagara Falls in 1895. In addition, the 1.4 percent of electricity generated by bioenergy is not a clean energy resource. In fact, bioenergy generated through most standard technologies is roughly equivalent to coal in the level of CO_2 emissions it produces.[49]

Given that there is no political support for significantly expanding hydro power in the future, that means that expansions of electricity supply from renewable sources will have to rely primarily on wind, solar, and geothermal power. The electricity generated by wind and solar power in New York State is still less than 3 percent of total supply at present.

The RPS goal set for 2030, under the Clean Energy Standard is to achieve 50 percent of the state's electricity from renewable sources by then. Reaching this goal will entail a huge expansion of solar, wind, and geothermal capacity. Our own projection, as presented in Table 11 and the accompanying text, is that wind, solar and geothermal supply will need to increase from its 2014 level of 0.05 Q-BTUs to 1.1 Q-BTUS.

This level of expansion is feasible, though undeniably highly challenging. The primary factor making it feasible is that, as we have shown, the costs of producing a kilowatt of electricity from clean renewable sources are now, on average, at rough parity with fossil fuels. Renewable energy will become still more competitive in relative cost terms through the establishment of a polluter fee. In addition, the efforts by utility companies to meet the state's 2030 Clean Energy Standard will create major pressures to expand the clean renewable supply, assuming that the Clean Energy Standard on electricity generation is truly enforced.

Energy-Efficiency Portfolio Standard

In 2007, the New York State Public Service Commission first issued an order instituting a proceeding to develop an Energy Efficiency Portfolio Standard (EEPS). The order set the goal of reducing electricity usage in New York by 15 percent relative to projected usage for 2015. There were several revisions in the order subsequently, but the basic goal of the 15 percent reduction relative to the 2015 projection remained intact.[50] It is not clear from the available documents whether state officials believe that this specific goal was accomplished. We do know that, in absolute terms, energy consumption to produce electricity did fall in New York State from 1.49 to 1.35 Q-BTUs between 2007 and 2014, an absolute decline of 9.2 percent. This is a significant improvement. But these gains will need to be replicated through 2030 to bring down overall emissions from 170 to 100 million tons of CO_2.

Following from this program, as of January 2016, the Public Service Commission established the State Energy Plan, which was designed as the successor of both the EEPS as well as the state's RPS. Under the State Energy Plan, the one specific goal set in the area of energy efficiency is, by 2030, to reduce energy consumption in buildings by 23 percent relative to 2012 levels. This level of efficiency gain is basically in line with our figures, presented in Table 11, which shows total energy consumption—from buildings as well as in transportation and industrial processes—falling from the actual 2014 level of 3.7 Q-BTUs to 3.1 Q-BTUs as of 2030, a 16 percent decline. This absolute decline in emissions is achieved in the context of the New York State economy growing by about 30 percent over this period (a 2.6 percent average annual growth rate). As we saw above in Table 1, the operation of buildings account for 61 percent of all energy consumption in New York State. So it is appropriate for the State Energy Plan to focus first on achieving efficiency gains with buildings. As we have shown, in Table 12 and the accompanying text, we estimate that to achieve an absolute reduction in consumption of 16 percent in three areas of buildings, transportation and industry will entail investments at around $8.7 billion per year between 2021 – 2030.

Under the State Energy Plan, NYSERDA is authorized to use funds to invest in "any initiative or technology…that constitutes clean energy or energy efficiency." The areas for clean energy investment include clothes washers, boilers, heat pumps, air conditioners, combined heat and power, compressed air, caulking/weather stripping, building insulation, and agricultural equipment, as well as comprehensive whole building investments.[51]

At the same time, these efficiency goals for buildings, like the overall State Energy Plan, "are aspirational goals without any legal mandate or authority." Here again, the critical issue for achieving the REV goal or anything equivalent would be to support a level of financing significantly beyond what is being made available through the roughly $500 million per year total provided by the Clean Energy Fund, with these Clean Energy Funds to be utilized both to expand renewable energy supply and to raise energy efficiency standards.

Auto Fuel Efficiency Standards

New York State is committed to a major regulatory initiative to reduce emissions from automobiles. This project entails both raising fuel efficiency standards for conventional vehicles as well as promoting zero-emissions vehicles, including electric vehicles. As an efficiency measure, these measures would be in addition to the 23 percent reduction in energy consumption in buildings that the REV plan highlights as one of its principal goals.

Specifically, since 1990, New York State has adopted the auto fuel efficiency standards set by California.[52] The California standard requires that new cars operate at a 54.5 miles per gallon standard by 2025, a roughly 50 percent increase over the currently prevailing California standard of 36 miles per gallon. New York will probably be able to maintain this standard for its fleet despite the efforts of the Trump Administration to repeal these standards at the federal level.[53]

As we have discussed in detail in Section 4, achieving this level of improvement in auto efficiency in New York State will make a major contribution toward reducing overall CO_2 emissions in the state. Emissions from transportation sources account for about 38 percent of total statewide emissions, with the largest share of transportation consumption coming from automobiles (i.e. "light duty vehicles".)[54]

Net Metering[55]

Net metering is the compensation arrangement between a utility and a customer with an on-site generation system, typically a solar photovoltaic system. Net metering gives the customer credit for power generation at the utility's retail rate and allows a customer to bank generation during hours or months when it exceeds the customer's consumption.

Net metering is an important policy tool for encouraging private building owners, including private homeowners, to invest in solar photovoltaic systems on their property. New York State has had net metering programs in place since 1997. The specifics of the program have been revised several times. The primary issue is whether there is a cap on the amount of electricity the utilities are required to buy back from customers. The cap was initially set at 1 percent of total electric demand. It was then raised to 3 percent in 2012 and to 6 percent in 2014. As of March 2017, the program was revised, such that the cap would be set so that all net metering projects "should not impact more than 2 percent of each utility's incremental net annual revenue."

It is not clear whether this present cap will act as a significant constraint on expansion of on-site solar photovoltaic systems. This needs to be established clearly. Further, any such constraints need to be minimized, if not eliminated altogether. The justification for maintaining a cap is that, for the most part, net metering provides a benefit for higher-income businesses and households that can afford to install solar photovoltaic systems. Utilities then shift the costs they themselves bear from net metering onto their other customers, who generally are at lower income levels, and who do not install such systems.[56] But to the extent that equity is an issue in the net metering system, this problem can be addressed through other equity-supporting policies, including the polluter fee rebate. Operating the net metering program with few or no constraints is especially important if New York State is serious in achieving its stated REV goal of providing 50 percent of electricity from clean renewable sources. Eliminating constraints on the growth of net metering will greatly encourage private investments in solar photovoltaic systems throughout New York State.

Leveraging Public Funds for Expanding Total Clean Energy Investments

What level of public funding will be needed to generate a total of $31 billion a year in total new clean energy investments? To help answer that question, it will be useful to briefly review the experience with the federal Department of Energy Loan Guarantee Program, which was one part of the 2009 American Recovery and Reinvestment Act—i.e. the Obama stimulus program. This program helped underwrite about $14 billion in new clean energy investments between 2009 – 2013. Even after taking full account of the large-scale and widely publicized failure of the Northern California solar company Solyndra, the default rate and corresponding financial obligations stemming from this program were modest. According to estimates discussed in Pollin et al. (2014), total losses from the government covered by the government's loan guarantees amounted to about $300 million, i.e. amounting to about 2.1 percent of the $14 billion in new loans for clean energy investments that the government guaranteed. This means that the leverage rate for the loan guarantee program was about $47 in additional clean energy investments underwritten by $1 of federal support.

If the $500 million per year in Clean Energy Funds could be leveraged at the same 47/1 ratio as the federal loan guarantee program, that would suggest that about $24 billion in total spending could be generated through the $500 million in public funds. This would be before drawing on any share of the $7.1 billion per year in state revenue generated by the polluter fee. However, for various reasons, that leverage ratio is certainly too high. One factor is that most of the Clean Energy Fund initiatives are not structured as loan guarantee programs, but rather as either direct loans or outright grants. The leverage ratios for direct loans or grants will be much lower since they do not operate with built-in mechanisms for drawing in private funds to match the outlay of public funds. In addition, the federal loan guarantee program operated on a relatively small scale, providing $14 billion in new loans over four years, averaging therefore about $3.5 billion per year. We are suggesting that total clean energy investments in New York would need to be about 8 times larger, at $31 billion per year. It would be difficult to mount a loan guarantee program on that scale.

On the other hand, the New York Clean Energy Fund, operating with a large increase in funds through the revenues of the polluter fee, includes other features that would support a high leverage ratio. One is that the costs of renewable energy supply are falling, such that, as we have discussed, at the level of retail electricity prices, consumers will not pay anything more on average through relying on renewable energy as the source for electricity. Another factor, as we have also discussed, is that energy efficiency investments pay for themselves over time. As such, loans to finance energy efficiency investments can be structured so the repayment funds are provided directly through energy savings.

In fact, such lending arrangements are already operating in New York, through what is termed "on-bill financing." With on-bill financing, a loan that pays for an energy efficiency or renewable energy investment is repaid through a utility bill and secured by a strong contract with the utility. Additional collateral must be obtained by the lender since non-payment can lead to borrowers having their electricity delivery suspended. New York's on-bill financing program is available for both households and businesses, and for investments in both energy efficiency and solar photovoltaic and other renewable energy projects. As explained at the NYSERDA website, "The payments appear as a separate line item on your utility bill and are financed at a special low interest rate." Another critical point which makes on-bill financing especially attractive to lenders is that the payments are transferable if you sell your property.[57]

Another major factor that can support a higher average leverage ratio is the fact that there are many ways in which financing policies are strengthened through operating in combination with the polluter fee revenues, regulations, and direct public investments. For example, the polluter fee creates incentives to shift out of fossil fuels and to invest in renewable energy and energy efficiency. These incentives are reinforced through the state's renewable energy and energy efficiency standards within the overall State Energy Plan. The market for renewable energy investments and energy efficiency are strengthened further through net metering and on-bill financing projects, as well as the investment and production tax credit programs at the federal level. These private investment incentives will be enhanced further through public investments and procurement projects in clean energy. Public investments will themselves directly add to the stock of renewable energy and will raise the level of energy efficiency in the state-owned buildings. These public investments will enable the markets and new technologies to mature more quickly than they would otherwise. Within this overall framework, low-cost financing through a green bank and loan guarantee programs and other joint public/private efforts should all support a relatively high leverage ratio for the public funds being committed. Finally, the need for large-scale financial resources to fund clean energy projects will be expanding at the same time that investments in fossil fuel energy projects of all sorts will be falling. The decline of the fossil fuel industry will free resources that can then be more readily channeled into clean energy projects.

Overall, these public funds supporting private investments and public/private partnerships should provide critical synergies with the state's direct public investments.

Considering all of these factors, it is certainly difficult to establish firmly what we would expect the average leveraging ratio to be for New York State's public funds in support of the state's overall public plus private clean energy investment project. As an illustrative exercise, let's assume the state channels 75 percent of the $7.1 billion in annual revenue from the polluter fee along with the $500 million from the existing Clean Energy Fund, into investment projects in the state.[58] This would mean an annual investment fund at around $5.8 billion. If we then also assume that this $5.8 billion were itself divided evenly for financing public investments and various incentives to support private investments, this would imply that about $2.9 billion per year would be available both for public investments and incentivizing private investments. With $2.9 billion going directly into public investments, that would mean that an additional roughly $28 billion would be needed in private investments per year to achieve the overall clean energy investment level of $31 billion. This would further imply that the $2.9 billion in available funds for incentivizing private investments would need to be leveraged at an average ratio of $10 in investments for $1 of government incentives—a 10/1 ratio. This 10/1 ratio is about one-fifth the ratio that was achieved with the federal clean energy loan guarantee program over 2009 – 13.

As such, it is reasonable to conclude that New York State could successfully finance clean energy investments in the state at a level of about $31 billion per year over 2021 – 2030 on the basis of the revenue from a polluter fee of $7.1 billion per year plus $500 million per year from the existing Clean Energy Fund budget. We summarize the basic calculations for this illustrative exercise in Table 35 below.

Direct public spending

To date, the New York State Clean Energy Plan does not emphasize public purchasing—i.e. procurement policies that the state could undertake on behalf of achieving its emission reduction targets. For example, New York State does not have a renewable energy procurement standard similar to that operating with the U.S. Defense Department. Under President Obama, the Defense Department had set a goal of meeting 25 percent of its total energy needs with renewable energy by 2025, including both liquid fuels and electricity. To date, this federal program remains intact. Similarly for energy efficiency at the federal level, the 2007 Energy Independence and Security Act (EISA), which was signed into law by then-President George W. Bush, required that most office buildings either owned or leased by the federal government would reduce their energy consumption by 30 percent as of 2015.[59]

Such state-level procurement programs—in the areas of renewable energy purchases, energy efficiency building retrofits as well as with low-emissions and electric vehicle purchases—would clearly be supportive of the state's Clean Energy Plan. These measures would directly reduce emissions within the state. They would also help promote opportunities for private clean energy investments, and thus, strengthen private markets in the clean energy investment areas.

Table 35
A Financing Framework for New York State Clean Energy Investment Program
Average Investment Level ~ $31 billion/year in public and private investments

PUBLIC SOURCES OF FUNDS: $5.8 BILLION

Polluter Fee Revenues: $5.3 billion
- 75% of revenue from polluter fee; 25% for rebates

Clean Energy Fund: $500 million
- Existing funding within State Energy Plan

PUBLIC AND SUBSIDIZED PRIVATE INVESTMENT

Public Investment: $2.9 billion
- One-half of $5.8 billion in public sources

Subsidized Private Investment: ~$28 billion
- One-half of $5.8 billion in public sources
- Public funds for subsidizing private investment: $2.9 billion
- Leverage rate for subsidized private investment
    $10 in private investment supported by $1 of public subsidy

Policies for Leveraging $2.9 Billion in Public Funds into $28 Billion in Private Investments
- Renewable energy and energy efficiency portfolio standards
- Auto efficiency standards
- Net metering/on-bill financing
- Green Bank

CLEAN ENERGY INVESTMENT AREAS

Clean Renewable Energy: $22 billion/year
- Wind, solar, geothermal

Energy Efficiency: $8.7 billion/year
- Buildings, transportation, industrial equipment, grid and battery storage upgrades

Just Transition: $18 million/year
- Compensation insurance, retraining, relocation, community reinvestment support

10. Achieving a Zero Emissions Statewide Economy by 2050

If the New York State economy is able to bring overall CO_2 emissions in the state down to 100 million tons by 2030—a 40 percent decline relative to the 2014 level of 170 million tons and a 50 percent reduction relative to 1990—it should also be able to achieve a zero emissions economy by 2050. Indeed, New York should be able to reach zero emissions by 2050 basically through continuing the clean energy investment project that would have proceeded from 2021 – 2030. Moreover, on an annual basis, the scale of the investments in energy efficiency and clean renewable energy between 2031 – 2050 that will be needed to reach zero emissions by 2050 should be significantly more modest than what we have described above for the project through 2030. As we saw in Table 12, our estimate of the clean energy investment cost for bringing emissions down to 100 million tons by 2030 was about 1.8 percent of New York State's GDP per year between 2021 – 2030. Over 2031 – 2050, as we will see, we estimate that the average annual clean energy investments costs necessary to reach zero emissions by the end of the period as ranging roughly between 0.6 – 0.8 percent of New York's average GDP. The impact of the investment project on job opportunities throughout the state are therefore likely to also be more modest, though still strongly in the positive direction.

This study certainly does not attempt to develop a full assessment as to the technical feasibility of achieving a zero emissions economy in New York State by 2050. In any case, such an assessment has already been advanced, in a careful 2013 study by Jacobson et al. Their study "analyzes a plan to convert New York State's all-purpose (for electricity, transportation, heating/cooling and industry) infrastructure to one derived entirely from wind, water and sunlight…generating electricity and electrolytic hydrogen," (p. 585). Under their plan, overall energy consumption would fall by 37 percent relative to the 2012 level through energy efficiency measures. The energy mix that they propose would be feasible for 2030 would include 50 percent wind, from both offshore and onshore sites; 38 percent solar, with photovoltaic systems in power plants and on rooftops as well as from concentrated solar technology; 5.5 percent hydro, relying mainly on existing productive capacity; 5 percent geothermal, and 1.5 percent wave and tidal power.

Other researchers, focused on regions other than New York State specifically, have also concluded that conversion to an economy relying on clean renewable sources to meet 100 percent of energy demand is technically feasible within a few decades or less. One important study reaching this conclusion is by the Harvard University physicist Mara Prentiss. Prentiss concludes in her 2015 book *Energy Revolution: The Physics and the Promise of Efficient Technology* that "Electricity generated by renewable energy can easily provide 100 percent of the average energy consumption of the United States during those next 50 years, virtually eliminating the negative environmental consequences associated with fossil fuel consumption," (2015, p. 304).[60]

Within a framework that recognizes the technical feasibility of achieving a zero emissions economy for New York by 2050, our focus here is to assess the economic trajectory of how this goal can be accomplished while the state's economy and job opportunities continue to grow. Of course, considering how such a trajectory is likely to proceed entails making a series of assumptions about the economy's long-term growth path. This exercise necessarily becomes increasingly speculative the further out one moves in time. To keep our discussion as realistic as possible, we rely on a small number of assumptions that are credible within the body of knowledge that is available to us at present.

The assumptions on which we will rely are as follows:

1. *Economic growth.* We consider two possibilities for New York State's economic growth trend over 2031 – 2050. The first is that growth proceeds at basically the same rate as we have assumed for 2021 – 2030, i.e. at 2.6 percent per year. In our second scenario, we assume a slower growth trend, at 1.5 percent per year. We present results based on both assumptions.
2. *Energy efficiency.* We have already assumed that New York State will have achieved major gains in energy efficiency between 2021 – 2030, specifically that the state's energy intensity ratio will have fallen from 2.7 to 1.5 Q-BTUs per $1 trillion of GDP—a 44 percent improvement. We assume that further efficiency gains are possible through continued investments, and that the costs of achieving these efficiency gains will remain at $35 billion per Q-BTU, the same cost figure for our 2021 – 2030 scenario. We make this assumption of stable overall costs, based on two ideas: 1) technological improvements will occur in raising efficiency standards; but 2) the 'low-hanging fruit' possibilities for efficiency gains will have dissipated. We assume that these two factors will roughly counteract each other.
3. *Clean renewable energy.* Technological advances in generating, storing and transmitting renewable energy will certainly occur between 2031 – 2050, especially given that these industries will have scaled up dramatically over 2021 – 2030. But in the interests of proceeding cautiously, we assume only a modest rate of average technological improvement for renewables overall—that the average costs of creating 1 Q-BTU of renewable capacity falls at an average rate of 1 percent per year between 2031 – 2050.
4. *Job creation.* We assume that labor productivity increases in all clean energy investment activity at an average annual rate of 1 percent per year. This is the same rate that we have assumed for 2021 – 2030.

Working from these assumptions on 1) economic growth; 2) the costs of achieving energy efficiency gains and an expanded clean renewable energy supply; and 3) labor productivity, we then develop projections as to how New York State's economy would advance toward achieving a zero emissions economy by 2050. We present these results in Tables 36 - 39.

In Table 36, we show New York State GDP projections for 2050 based on our two alternative growth trajectories for 2031 – 2050—i.e. a 1.5 percent and a 2.6 percent trend. Both of these growth paths begin with the same 2030 baseline of $2.1 trillion. This figure is itself a projection, of course, which we derived through assuming that New York State's GDP grows at an average annual rate of 2.6 percent between 2015 – 2030, starting from the 2014 actual GDP level of $1.4 trillion. Based on these assumptions, as we see in Table 36, New York State's GDP will be $2.8 trillion in 2050 with the 1.5 percent growth trend and at $3.5 trillion with the 2.6 percent trend. We then calculate the midpoint GDP levels between 2031 – 2050 under both growth scenarios. These midpoint figures are $2.4 trillion with the 1.5 percent growth trend, and $2.8 trillion with the 2.6 percent trend.

TABLE 36
New York State Average Economic Growth Projections for 2031 – 2050

	Alternative GDP Growth Scenarios	
	1.5% average GDP growth	**2.6% average GDP growth**
Projected 2030 GDP level *From Table 10*	$2.1 trillion	$2.1 trillion
Projected 2050 GDP	$2.8 trillion	$3.5 trillion
Midpoint GDP value for investment spending estimates *(= (2030 GDP + 2050 GDP)/2)*	$2.4 trillion	$2.8 trillion

Source: See Table 10; authors' calculations

In Table 37, we then estimate the investment costs necessary to bring the New York State energy intensity ratio down from the 2030 figure of 1.5 (Q-BTUs of energy/$1 trillion in GDP) to 1.0. We had projected earlier (Table 11) that New York would be at the 1.5 intensity ratio by 2030 under the clean energy investment program we outlined for 2021 – 2030. Table 37 shows that to arrive at a 1.0 energy intensity ratio by 2050 will require $49 billion in new energy efficiency investments between 2031 – 2050 under the 1.5 percent growth scenario and $60 billion under the 2.6 percent growth scenario. Considered on an annual basis, these total costs amount to an average of $2.5 billion per year under the 1.5 percent growth scenario and $3 billion under the 2.6 percent growth scenario.

In Table 38, we perform a comparable set of calculations for clean renewable energy investments between 2031 – 2050. We begin these calculations with the assumption of a 1.0 energy intensity ratio for 2050. This then entails that, in 2050, overall energy consump-

TABLE 37
Energy Efficiency Investments Needed to Bring New York Energy Intensity Ratio to 1.0 by 2050

Energy Intensity Ratio = Q-BTUs of energy/GDP in trillions of dollars

	Alternative GDP Growth Scenarios	
	1.5% average GDP growth	**2.6% average GDP growth**
1) 2050 GDP assumption *from Table 36*	$2.8 trillion	$3.5 trillion
2) Total 2050 energy consumption at 1.5 energy intensity ratio	4.2 Q-BTUs	5.2 Q-BTUs
3) Total energy consumption at 1.0 energy intensity ratio	2.8 Q-BTUs	3.5 Q-BTUs
4) Gains in energy efficiency through 2031 – 2050 efficiency investments *(= rows 2 – 3)*	1.4 Q-BTUs	$1.7 Q-BTUs
5) Costs of achieving energy efficiency gains *(= row 4 * $35 billion)*	$49 billion	$60 billion
6) Costs per year over 20-year investment cycle *(row 5/20)*	$2.5 billion/year	$3 billion/year

Sources: Table 35 and authors' projections.

TABLE 38
Clean Renewable Energy Investments Needed to Reach 100 Percent Renewable Energy Supply by 2050

	Alternative GDP Growth Scenarios	
	1.5% average GDP growth	2.6% average GDP growth
1) 2050 Energy Consumption Level with 1.0 Energy Intensity Ratio *from Table 37*	2.8 Q-BTUs	3.4 Q-BTUs
2) Clean Renewable Energy Supply as of 2030 *From Table 11*	1.35 Q-BTUs	1.35 Q-BTUs
3) Renewable Energy Expansion Needed by 2050 (= rows 1-2)	1.45 Q-BTUs	2.1 Q-BTUs
4) Midpoint cost per Q-BTU of expanding clean renewable supply *Assumes average costs decline at 1% per year relative to 2030*	$180 billion per Q-BTU	$180 billion per Q-BTU
5) Total costs of reaching 100 percent renewable supply *(= row 3 x 4)*	$260 billion	$378 billion
6) Average annual costs over 20-year investment cycle *(= row 5/20)*	$13 billion	$19 billion

Sources: Tables 11, 37 and authors' projections.

tion in New York State will be at 2.8 Q-BTUs under the 1.5 percent growth scenario and at 3.4 Q-BTUs under the 2.6 percent growth scenario. We then see in row 2 of Table 38 that, as of 2030, total energy supplied by clean renewable sources would be at 1.35 Q-BTUs through the clean energy investment project from 2021 – 2030. From this baseline figure, we can derive that the expansion of clean renewable capacity will need to be at 1.45 Q-BTUs under the 1.5 percent growth scenario and 2.1 Q-BTUs under the 2.6 percent growth scenario. As we see in rows 4 – 6 of Table 38, achieving this higher level of productive capacity in clean renewables will require a level of investment averaging $13 billion under the 1.5 percent growth scenario and $19 billion under the 2.6 percent growth scenario.

In Table 39, we then summarize these results to establish cost estimates of achieving a zero emissions economy in New York State as of 2050. As we see, under the 1.5 percent growth scenario, these overall costs will be at $309 billion in total, which averages $15 billion per year over 2031 – 2050. Under the alternative 2.6 percent growth scenario, these costs will amount to $438 billion, or $22 billion per year over the 20-year investment project. As a share of New York State's projected midpoint GDP over 2031 - 2050, these annual cost figures range between 0.6 percent with the 1.5 percent growth scenario and 0.8 percent with the 2.6 percent growth scenario. As mentioned above, these figures are significantly below the cost level we have estimated for the initial 2021 – 2030 investment period that would be necessary to bring New York State's CO_2 emissions down to 100 million tons by 2030. We estimate these costs to amount to about 1.8 percent of the state's average GDP.

TABLE 39
Overall Estimated Costs of Achieving Zero Emissions Economy in New York State by 2050

	Alternative GDP Growth Scenarios	
	1.5% average GDP growth	**2.6% average GDP growth**
1) Total Energy Efficiency Investment Costs *(from Table 37)*	$49 billion	$60 billion
2) Total Renewable Energy Investment Costs *(from Table 38)*	$260 billion	$378 billion
3) Total Clean Energy Investment Costs *(= rows 1 + 2)*	$309 billion	$438 billion
4) Average Annual Costs per year for 20-year investment cycle *(= row 3/20)*	$15 billion	$22 billion
5) Average annual costs per year as percentage of midpoint GDP *(= row 4/Table 36 figure)*	0.6 percent	0.8 percent

Sources: Tables 36, 37, and 38.

Employment Creation through 2031 – 2050 Investment Project

In Table 40, we provide rough estimates as to the level of employment that would be generated by the clean energy investment levels necessary to achieve a zero emissions economy for New York State by 2050. We have estimated these employment figures based on two assumptions: 1) the overall clean energy investment spending levels for 2031 – 2050 as a proportion of the 2021 – 2030 spending level; and 2) our assumption of a 1 percent average annual increase in labor productivity in these clean energy investment projects.

We saw in Table 17 that, for 2030, our estimate of direct plus indirect employment through clean energy investments at $31 billion would be 145,000 jobs. This figure is repeated in row 1 of Table 40. Under our 1.5 percent growth scenario, we estimate that average annual investment spending from 2031 – 2050 would be $13 billion per year, or approximately 42 percent of $31 billion. With our 2.6 percent growth scenario, average annual clean energy investment spending is $19 billion per year, or 61 percent of $31 billion. From these figures, as we see in row 3, we estimate job creation through clean energy investments in 2031 as being 61,000 under the 1.5 percent growth scenario and 88,000 jobs under the 2.5 percent growth scenario. With a 1 percent average rate of labor productivity growth through 2050, we then estimate that job creation will be at 50,000 under the 1.5 percent growth scenario and 67,000 under the 2.6 percent growth scenario.

Just Transition Program

In Table 41, we provide estimates for the Just Transition program for 2031 – 2050. The figures we present in Table 37 are derived from the material we have developed for the 2021 – 2030 period in section 8 of this paper, including in Tables 24, 30, and 32.

TABLE 40
Average Annual New York State Employment Creation through Clean Energy Investments, 2031 – 2050

	Alternative GDP Growth Scenarios	
	1.5% average GDP growth	2.6% average GDP growth
1) Estimated Job Creation through 2030 Clean Energy Investments *(from Table 17)*	145,000	145,000
2) Approximate Average Annual Investment Spending as pct. of 2030 spending *(from Tables 12 and 38)*	42% *(= $13 billion/$31 billion)*	61% *(= $19 billion/$31 billion)*
3) 2031 Employment Creation	61,000 *(= 145,000 x .42)*	88,000 *(= 145,000 x .61)*
4) 2050 Employment Creation, with 1% average annual labor productivity growth	50,000	67,000

Sources: Tables 12, 17 and 38.

TABLE 41
Costs of Just Transition Program for Displaced Workers in Fossil Fuel and Ancillary Sectors: *2031 – 2050 Scenario*

1) Projected number of workers employed in fossil fuel production and ancillary industries in 2030 (from Table 30)	8,035 *(= row 1 – row 2 in Table 30)*
2) Projected number of workers reaching retirement between 2031 – 50. (assumes 50% of workers are 45 years and over in 2031)	4,018 *(= row 1, this table/2)*
3) Average number of workers displaced annually, 2031 – 2050	201 *(= row 2, this table/20)*
4) Annual costs of 100% compensation insurance, retraining and relocation support (at $300,000 per worker)	$60 million *(= row 3 x $300,000)*

Sources: Projections based on figures from Tables 30 and 32.

Thus, for the 2021 – 2030 analysis, we reported in Table 24 that a total of 13,393 workers were employed in New York State as of 2014 at jobs in either fossil fuel production or ancillary industries. Again, fully 87 percent of these jobs are in natural gas distribution, fossil fuel electric power generation and pipeline construction/transportation. In Table 30, we provide the estimate that by 2030, 40 percent of these jobs will be lost, resulting from our assumption that fossil fuel consumption in New York State will itself need to contract by 40 percent in order to bring statewide CO_2 emissions down to 100 million tons as of 2030. This means that 5,358 jobs will be lost in these industries as of 2030. It also implies that, as of 2030, 8,035 jobs will remain in these industries across New York State.

If New York State is going to achieve a zero emissions economy by 2050, that in turn means that all 8,035 jobs will be lost as of 2050. Of the workers employed in these jobs as of 2030, we assume, as a low-end figure, that half of them will retire voluntarily between 2031 – 2050. This retirement rate is proportionally higher than the 35 percent retirement rate that we estimated for 2021 – 2030 based on demographic data, and as reported in Table 30. This is because the 35 percent figure was for 10 years only, as opposed to the 20-year stretch between 2031 – 2050.

From this figure on retirement rates, in row 3 of Table 41 we calculate that 201 workers per year will face displacement due to the fossil fuel industry contracting in New York State. Each of these workers will need to receive the full package of Just Transition support that we described in Section 8 for the period 2021 – 2030. This includes 100 percent compensation insurance when these displaced workers move into their guaranteed new jobs, as well as both retraining and relocation support. We estimated in Section 8 that the average annual cost for providing such Just Transition support for displaced workers would be about $300,000 per worker. This level of support would then imply an overall cost for Just Transition support for individual workers at $60 million per year, as we show in row 4 of Table 41.

Beyond such support for displaced individual workers, our Just Transition program for 2021 – 2030 does also include transitional support for fossil fuel dependent communities. Such support should also be continued over 2031 – 2050, as the fossil fuel industry contraction in New York State proceeds. At this point, we can only vaguely speculate as to which communities throughout the state would be most in need of such support throughout 2031 – 2050. But the prospect for providing such support will remain strong, given that, if the state's zero emissions goal is to be achieved, the clean energy investment project in New York will need to continue at an annual level of investment of between $15 - $20 billion per year.

Appendix 1.
The Contribution of Methane Emissions from Energy Production to Overall Greenhouse Gas Emissions in New York State

There are two primary considerations to address with respect to the impact of methane emissions resulting from natural gas production. They are: 1) The toxicity of methane emissions in contributing to global warming; and 2) The rate of leakage from energy production.

These considerations are inherent to assessing the environmental impact of natural gas production under all types of extraction technologies. But they have increased in significance because of the rapidly expanding use of horizontal drilling and hydraulic fracturing (i.e. fracking) technologies for extracting natural gas. Jackson et al. (2011) describes the incentives behind the growth of hydraulic fracturing technologies as follows:

> Hydraulic fracturing typically involves millions of gallons of fluid that are pumped into an oil or gas well at high pressure to create fractures in the rock formation that allow oil or gas to flow from the fractures to the wellbore….The Interstate Oil and Gas Compact Commission (IOGCC) estimates that hydraulic fracturing is used to stimulate production in 90 percent of domestic oil and gas wells, though shale and other unconventional gas recovery technologies utilize high-volume hydraulic fracturing to a much greater extent than conventional gas development does. Horizontal wells, which may extend two miles from the well pad, are estimated to be 2-3 times more productive than conventional vertical wells, and see an even greater increase in production from hydraulic fracturing. The alternative to hydraulic fracturing is to drill more wells in an area, a solution that is often economically or geographically prohibitive, (2011, pp. 1-2).

Given the rapid expansion in the use of fracking technologies, the following considerations with respect to both toxicity of methane emissions and of methane leakage rates become critical:

Toxicity. Within a 20-year cycle, the impact of a given amount of methane is much greater than that of CO_2 in terms of its capacity to absorb heat, and thereby contribute to global warming. According to the most recent estimate of the Intergovernmental Panel on Climate Change (IPCC), the impact of methane emissions on climate change—i.e. its "global warming potential"—is 86 times greater than a given amount of CO_2 emissions over 20 years and 34 times greater over 100 years.[61]

Leakage rates. When fracking technologies are used to extract natural gas from shale rock, the rate at which methane leaks into the atmosphere is, in general, significantly greater than the leakage rate under conventional vertical drilling technologies. But there are varying estimates in the literature as to what are the actual average leakage rates with fracking. Of course, the impact of greater toxicity of methane will depend on what is this actual average leakage rate.

A 2015 study by Howarth concludes that "shale gas development during the 2009 – 2011 period, on a full life cycle basis including storage and delivery to consumers, may have on average emitted 12 percent of the methane produced (2015, p. 48). A 2016 survey by

Peischl et al. however reported a broad range of leakage estimates of between 0.18 and 11.7 percent for different specific sites in North Dakota, Utah, Colorado, Louisiana, Texas, Arkansas, Pennsylvania and both eastern and central Texas.

A critical question with respect to these estimates is the level at which leakage rates from natural gas production will produce larger global warming impacts than combusting coal. A 2014 analysis by Romm that extends a 2012 study by Alvaraz et al. estimates that this threshold leakage rate is 5.4 percent. This estimate was broadly supported in a 2016 study by Farquharson et al.

Nevertheless, even with convergence on this issue of the threshold average leakage rate at which natural gas production generates worse global warming impacts than coal combustion, it is still difficult to establish the impacts of methane leakages from natural gas production until there is also greater convergence as to what average leakage rates actually are. Given continued uncertainty on this, for our purposes, a reasonable approach is to accept the World Bank's estimates of the impact of overall methane emissions from energy production, focusing on the U.S. case. The World Bank estimates are derived from the Emission Database for Global Atmospheric Research (EDGAR), working with their most recent 2016 findings.[62] Their estimates do incorporate considerations of the range of factors influencing the global warming impact of methane emissions.

Considerations for Assessing New York State Emissions

These various factors regarding natural gas production and methane impact our analysis of overall greenhouse gas emissions generated in New York State in various ways. To begin with, in terms of energy production within New York State, fracking has been prohibited since late 2014. Thus, the contribution of New York State to methane leakages resulting from fracking have been eliminated. On the other hand, New York State consumes a higher proportion of natural gas in its overall energy mix relative to the U.S. overall. As we show in the main text, natural gas provides 38 percent of New York State's overall energy supply, as opposed to 28 percent for the U.S. economy overall. As such, New York's greater reliance on natural gas is supporting fracking production in other states to a disproportionate extent.

Taking these counteracting considerations into account, it is reasonable to conclude that the World Bank estimates as to the share of overall greenhouse gas emissions contributed by methane emissions from energy production within the United States is a reasonable first approximation as to the impact of methane emissions generated within New York State. That is, following the World Bank's estimates, we assume that about 81 percent of all greenhouse gas emissions generated within New York state result from CO_2 emissions produced by combusting fossil fuels, and about 3.2 percent are derived from methane leakages resulting from natural gas production.

Appendix 2.
Sources of Difference with NYSERDA Study on Cost Estimates for Expanding New York State's Clean Renewable Energy Supply

The 2014 report of the New York State Energy Research and Development Authority (NYSERDA) estimates the cost of renewable energy to be approximately $64 billion per Q-BTU, as opposed to the estimate in the present study of approximately $200 billion per Q-BTU. The derivation of the NYSERDA figure through the data is presented in the report's Summary. The authors show on p. 10 of the Summary the total cost of renewable energy provision to be $54 billion over 20 years. In Table S-3 of the Summary, they report the total economic potential of renewable energy to be 0.85 Q-BTUs by 2030.

There appear to be three reasons for the disparity between NYSERDA's figure of $64 billion per Q-BTU and our own figure of $200 billion.

1. **Mix of renewables.** The NYSERDA study includes biomass, solar, hydro, and wind. The PERI study includes solar, wind, and geothermal only. The cost of biomass brings down the average cost of renewables in the NYSERDA study, while exclusion of biomass and inclusion of geothermal bring up the average cost in this study.
2. **Penetration of specific technology types within each renewable category.** We base our cost estimates on a single figure for Levelized Cost of Electricity (LCOE) for solar, wind and geothermal energy, with each of these average figures derived from data presented by the U.S. Energy Information Agency (EIA). This average figure incorporates electricity generation from these three clean renewable sources as they apply to a range of uses, including residential, commercial, and utility-based locations. By contrast, the NYSERDA study presents separate cost estimates for distinct sources of clean renewable energy generation. For example, within NYSERDA's category of solar energy generation, they include separate LCOE figures for small commercial, large commercial, utility scale, and community locations. The penetration of each of these locations, in turn, affects their estimate of overall costs per Q-BTU. This is because, for example, generating solar energy at large commercial photovoltaic projects is significantly cheaper than at residential photovoltaic sites. The NYSERDA study's calculations utilize primarily lower-cost figures, such as for commercial solar photovoltaic, as the basis for deriving their overall cost estimates. This will produce a lower average cost estimate than our figures, which are based on the EIA's average LCOE figures on capital costs.
3. **Regional costs.** The NYSERDA study is based on regionally-specific cost figures, whereas this study utilizes the national average LCOE cost figures provided by the EIA. The EIA shows in Table B2[63] of its 2016 LCOE methodology paper that there is significant regional variation in renewable technology costs. It is possible that the national average used by EIA in the Reference case is higher than the regional costs used in the NYSERDA study, though this aspect of the NYSERDA estimates are not fully presented in their study.

Appendix 3.
Methodology for Estimating Employment Creation through Clean Energy Investments

We developed the employment estimates for New York State using an input-output model. Specifically, we used for this study IMPLAN v3. This is an input-output model which incorporates data from the U.S. Department of Commerce as well as other public sources. The data set used for the estimates in this report is the 2014 New York State data.

An input-output model traces linkages between all industries in the economy as well as institutional sources of final demand (such as households and government). A full discussion of the strengths and weaknesses of input-output (I-O) models and their application to estimating employment in the energy sector can be found in Appendix 4 of Pollin et al. (2014).

To date, I-O models do not identify renewable energy industries such as wind, solar, or geothermal, or energy efficiency industries such as building retrofits, industrial efficiency, or grid upgrades as distinct activities within the model. However, all of the components that make up each of these industries are contained in existing industries within the models. For example, the hardware, glass production, and installation industries that are all activities within "solar" are each an existing industry within the I-O model. By identifying the relevant industries and assigning weights to each, we can create "synthetic" industries that represent each of the renewable energy and energy efficiency industries within the model. Below we show the industries and weights used in this study. A full discussion of the methodology for creating synthetic industries can be found in Garrett-Peltier (2017).

The energy industries and weight of each component industry are shown in Table A3.1, below.

Scaling Manufacturing Activity

The employment estimates produced in the IMPLAN model are disaggregated into over 400 sectors. After modeling the energy industries above, we aggregated the estimates into the following sectors:

- Agriculture
- Extraction and Utilities
- Construction
- Manufacturing
- Trade and Transportation
- Services

The expansion of clean energy that we propose in this report is significant, and occurs rather rapidly, over a 10-year period. While it may be possible for construction and service activities to keep pace with the rapid scaling up of clean energy consumption in New York State, we assume that manufacturing facilities will take longer to develop. Specifically, we assume that while manufacturing activity will indeed expand within New York State in the

TABLE A3.1
Composition and weights for modelling energy industries within the I-O model

Energy Industries	Composition and weights of industries within I-O model
Building retrofits	50% residential repair construction, 50% non-residential repair construction
Industrial Efficiency	30% environmental and technical consulting services, 20% repair construction of non-residential structures, 10% air and ventilation equipment, 10% heating equipment, 10% A/C, refrigeration, and warm air heating equipment, 10% all other industrial machinery manufacturing
Grid Upgrades	25% infrastructure construction, 25% mechanical power transmission equipment manufacturing, 25% miscellaneous electrical equipment manufacturing, 25% other electronic component manufacturing
Public Transport/Rail	30% construction of other new non-residential structures, 21% motor vehicle body and parts manufacturing, incl. electrical equipment, 6% railroad rolling stock manufacturing, 43% transit and ground passenger transportation
Wind	26% construction of new power and communication structures, 12% plastic and resin manufacturing, 12% fabricated structural metal manufacturing, 37% other industrial machinery manufacturing, 3% mechanical power transmission equipment manufacturing, 3% electronic connector manufacturing, 7% miscellaneous professional, scientific, and engineering services
Solar PV	30% construction of new power and communication structures, 17.5% hardware manufacturing, 17.5% mechanical power transmission equipment manufacturing, 17.5% capacitor, resistor, coil, transformer, and other inductor manufacturing, 17.5% miscellaneous professional, scientific, and engineering services
Geothermal	15% drilling wells, 45% construction of new non-residential structures, 10% pump and pumping equipment manufacturing, 30% R&D
Nuclear	100% nuclear electric power generation
Oil and Gas	23% extraction of natural gas and crude petroleum, 5% drilling oil and gas wells, 4% support activities for oil and gas, 9% natural gas distribution, 55% petroleum refineries, 1.5% industrial gas manufacturing, 2.5% pipeline transportation
Coal	21% coal mining, 4% support activities for mining, 40% electric power generation, 35% rail transportation

first ten years of clean energy expansion, most of the new manufacturing activity will occur out-of-state. We therefore make the conservative assumption that manufacturing will increase by 10 percent relative to the overall increase in clean energy activity. Thus the employment multipliers will be lower in this constrained case than if we were to assume that all sectors, including manufacturing, scaled up at the same pace, as shown in Table A3.2. For the purposes of this study, and to err on the side of underestimating rather than overestimating employment, we use the constrained multipliers in the right-most column in our estimates.

TABLE A3.2
Employment multipliers per $1 million in unconstrained and constrained cases

	If all sectors expanded 100%	Constrained: Manufacturing expands 10% only
	Direct, indirect, and induced jobs per $1 million	
Wind	7.4	5.6
Solar PV	9.2	7.3
Geothermal	9.0	8.7

Appendix 4.
Characteristics of Jobs Created by Clean Energy Investments

Our strategy for identifying the types of jobs that would be added to the economy due to an investment in one of the seven energy efficiency and clean energy sectors involves two steps.

The first step is to calculate each of the 526 industry shares of total employment created through a specific investment program. We calculated the percentage of new employment generated in each of these 526 sectors through our input-output model as explained in Appendix 3.

Next, we apply this information on the industry composition of the new employment created by an investment with data on workers currently employed in the same industrial mix of jobs. We use the characteristics of these workers to create a profile of the types of jobs and the types of workers that will likely hold the jobs created with each investment. These characteristics include types of occupations, gender, race/ethnicity, union status, credential requirements, earnings and job-related benefits.

Our information about the workers currently employed in the industrial mix of jobs created by an investment comes from the Current Population Survey (CPS). The CPS is a household survey administered by the U.S. Census Bureau, on behalf of the Bureau of Labor Statistics of the U.S. Labor Department. The basic monthly survey of the CPS collects information from about 60,000 households every month on a wide range of topics including basic demographic characteristics, educational attainment, and employment status. Among a subset of its monthly sample—referred to as the outgoing rotation group (ORG)—respondents are asked more detailed employment-related questions, including about their wages and union status. The CPS' survey in March includes a supplement, referred to as the Annual Social and Economic survey (ASEC) that asks additional questions, particularly about income, poverty status, and job-related benefits. We pool five years of the most current CPS data available as of the writing of this report—2011-2015—for our analyses.[64]

To create a profile of the types of jobs and the types of workers that will likely hold the jobs created with each investment, we weight the CPS worker data with the industry shares generated by IMPLAN. This creates a sample of workers with an industry composition that matches that of the jobs that we estimate will be added by investing in a clean energy/energy efficiency sector.

Specifically, we use the IMPLAN industry shares to adjust the sampling weights provided by the CPS. The CPS-provided sampling weights weight the survey sample so that it is representative at various geographic levels, including national and state. We adjust the CPS-provided sampling weights by multiplying each individual worker's sampling weight with the following:

$$S \text{ x } \frac{\text{IMPLAN's estimate of the share of new jobs in worker i's industry j}}{\sum \text{CPS sampling weights of all workers in industry j}}$$

where S is a scalar equal to the number of direct and indirect jobs produced overall by the level of investment being considered. For example, say New York's investment in mass transit of $1 billion would generate 10,000 direct and indirect jobs, then S is equal to 10,000.

Some of the 526 IMPLAN industries had to be aggregated to match the industry variable in the CPS, which has 242 categories, and vice versa. For example, among IMPLAN's 526 sectors, there are 13 construction sectors while the CPS has only one construction industry. In the end, 194 industry sectors are common to both IMPLAN and the CPS.

We use these adjusted sampling weights to estimate job-related health insurance and retirement benefits, and union membership among workers in the specific industrial mix of jobs associated with each type of investment. We also estimate demographic characteristics, such as percent female and percent non-white, as well as workers' educational attainment. Finally, we determine what are the most prevalent occupations held by workers in the industrial mix of jobs associated with each type of investment.

The total compensation estimates for jobs in clean energy sectors are based on the 2014 Quarterly Census of Employment and Wages (QCEW). The QCEW tabulates employment levels monthly and wages quarterly through a joint effort by the Bureau of Labor Statistics of the U.S. Labor Department and the State Employment Security Agencies (SESAs). The QCEW provides a near-census of U.S. jobs (98 percent), and includes all unemployment insurance (UI) covered workers. A small group of workers are not covered by the QCEW. These workers include: members of the armed forces, the self-employed, proprietors, domestic workers, unpaid family workers, and railroad workers covered by the railroad unemployment insurance system.

As with estimating worker characteristics, we use the industry shares of employment generated by IMPLAN to estimate total compensation for jobs in clean energy sectors. Specifically, we used the IMPLAN industry shares, for the direct and indirect jobs, to estimate weighted average annual wages for each clean energy sector.

We then inflate this figure to add the value of the average level of benefits typically received by workers in the industrial mix of jobs associated with each type of investment. To determine how much we should inflate the average pay rate by, we calculate a ratio of total compensation to wages/salaries using 2014 data from the Bureau of Economic Analysis (BEA, Tables 6.2D and 6.3D). Specifically, for each clean energy or energy efficiency investment, we create a weighted average of the total compensation data using the IMPLAN industry shares aggregated up to the 2-digit level, and then again for the wage/salary data. We then apply the ratio of: (the weighted average of total compensation)/(weighted average of wages/salary) to our estimate of average annual wages.

All dollar figures are inflated to 2015 dollars using the CPI-U.

Appendix 5.
Employment Impacts of New York State Clean Energy Investment Program on the State's Energy-Intensive Industries and Retail Gasoline Sector

As noted in the main text, we do not anticipate significant employment losses in either New York State's energy-intensive industries, such as paper or aluminum manufacturing, or in the retail gasoline sector. We consider these distinct sectors in turn.

Energy-intensive industries. The state's energy-intensive industries will not be expected to reduce their overall energy consumption to an extent greater than the overall New York State economy. Rather, as with the rest of the New York State economy, these industries will be able to lower their overall energy consumption through energy efficiency investments. They will also be able to purchase clean renewable energy at prices that should be equivalent to, if not lower than, those from fossil fuel energy sources.

To the extent that these industries presently require fossil fuel energy sources only for specific production technologies, these resources will continue to be available to them, as necessary. Within the overall clean energy transition process that we have described in this study, we assume that fossil fuel energy supplies will be provided in New York State through 2050. In the intervening years between now and 2050, we would expect that the technologies on which energy-intensive industries rely will be able to transition into using clean renewable energy sources in their production processes.

Retail gasoline stations. Beginning in the 1970s, with the widespread adoption of self-service gas pumping, retail gasoline stations had already significantly reduced their employment requirements for operating their businesses. At present, most retail service stations maintain minimal staffing for the purpose of pumping gas for customers.

In addition, again beginning in the 1970s, most businesses in this sector relied to a declining extent on selling gasoline as their source of business revenues.[65] In fact, most businesses in this sector now sell a wider variety of products than just gasoline or diesel.

In particular, the gas station sector has become increasingly dominated by an expanding number of retail outlets that combine gas sales with other products and services such as convenience store products and quick-service food products. Importantly, as the industry research firm IBISWorld notes, these "convenience store products are more profitable than gasoline, making it beneficial for operators to focus on the convenience business." According to IBISWorld's figures, in 2016, 87 percent of the nation's overall gas station workforce was in "gas stations with convenience stores (NAICS 44711)," while the remaining 13 percent was in "other gas stations (NAICS 44719)." This compares to 81 percent and 19 percent in 2008, respectively.[66] In 2016, the employment figures for New York are 24,369 jobs in gas stations with convenience stores (82 percent) and 5,187 jobs in standalone gas stations (18 percent).

A formal 2015 paper on this issue by U.S. Census Bureau researchers concludes as follows:

> Employment by gasoline stations increased between 1977 and 1992, a period during which many stations converted from full-service to self-service pumps, outsourcing to customers tasks previously performed by employees….We show that self-service stations employ approximately 0.4

> fewer workers per pump. At the same time, stations that adopted self service expanded their size and diversified operations by adding convenience stores, mitigating the job-loss impact of self service (Basker et al 2015, p. 1).

Additionally, popular media reports provide anecdotal evidence of how gas stations are adapting to the decline in gasoline demand. Among other new areas for growth are charging stations for electric vehicles, fueling with alternative fuels such as hydrogen, and ride-sharing and driverless vehicle services. For example, the *Washington Post* reported on 6/28/16 that Tesla is "in talks with a major gas station and convenience store chain that could vastly expand the EV-maker's network of charging stations." The article concludes that "Tesla's quiet talks with this company could help redefine the gas station as we know it," (Fung, 6/28/16).

Appendix 6.
Characteristics of Jobs in Fossil Fuels Industries

The primary data sources that we use to estimate characteristics of jobs in the fossil fuels industries is the American Community Survey (ACS) and the Quarterly Census of Employment and Wages (QCEW).

The ACS is an annual household survey administered by the U.S. Census Bureau and serves as the Census' primary method for collecting detailed information about the U.S. workforce and overall population in between decennial censuses. The ACS is specifically designed to provide estimates at the state and local levels, surveying roughly 3 million households. In order to get sufficient sample sizes to generate reasonable estimates on workers in each of New York's fossil fuel sectors, we pool the most recent five years of ACS data available, 2010-2014.

The QCEW tabulates employment levels monthly and wages quarterly through a joint effort by the Bureau of Labor Statistics of the U.S. Labor Department and the State Employment Security Agencies (SESAs). The QCEW provides a near-census of U.S. jobs (98 percent), and includes all unemployment insurance (UI) covered workers. A small group of workers are not covered by the QCEW. These workers include: members of the armed forces, the self-employed, proprietors, domestic workers, unpaid family workers, and railroad workers covered by the railroad unemployment insurance system.

We use the ACS to estimate the characteristics of workers and their jobs in the fossil fuel industries, including workers' health insurance coverage, educational attainment, age, race and gender. We also use the ACS to identify the most prevalent occupations among the jobs in fossil fuel industries. The ACS, however, does not collect data on union status of workers. For unionization rates, we use the CPS-ORG data files (described above). However, pooling five years of CPS data still produced insufficient sample sizes. To create larger samples, we pooled data across nearby states in the New England and Mid-Atlantic regions with New York, including Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, and Pennsylvania.

The ACS industry categories do not match up exactly with the fossil fuel sectors that we analyze in this report. As a result, in some cases, our ACS estimates are based on industry categories at a higher level of aggregation than the 6-digit NAICS code level that we are able to get employment and compensation figures for from the QCEW. In Table A6.1, we show side-by-side the industry sectors available in the ACS compared to those available in the QCEW. The CPS industry sectors are identical to those used in the ACS.

As noted above, the annual average 2014 employment and wage levels we report in the main text are estimates published directly by the QCEW. There are two exceptions. In both cases, we combine similar individual sectors into larger aggregated sectors. For the annual wage, we use an employment- weighted average. Specifically, we combine the figures for "Drilling oil/gas wells" and "Support activities for oil and gas." This is because all of our other job characteristics, based on the ACS data (discussed above) are only available for these sectors combined. We also combine the sectors "Pipeline transportation of natural gas," "Pipeline transportation of refined petroleum," and "Oil and gas pipeline and related structures construction" for a similar reason and for ease of exposition.

All dollar figures are inflated to 2015 dollars using the CPI-U.

TABLE A6.1
Fossil Fuel Industry Sectors by Data Source

QCEW		ACS/CPS	
NAICS 6-Digit Code	**Industry Title**	**ACS/CPS 3-Digit Code**	**Industry Title**
211110	Oil and gas extraction	370	Oil and gas extraction
212110	Coal mining	380	Coal mining
213111	Drilling oil/gas wells	490	Support activities for mining
213112	Support activities for oil and gas		
213113	Support Activities for coal mining		
221112	Fossil fuel electric power generation	570	Electric power generation, transmission, and distribution
221121	Natural Gas Distribution	580	Natural gas distribution
324110	Petroleum Refining	2070	Petroleum refining
237120	Oil and Gas Pipeline Construction	770	Construction
486210	Natural Gas Pipeline Transportation	6270	Pipeline Transportation
486910	Refined Petroleum Pipeline Transportation		
424710	Petroleum Bulk Stations and Terminals	4490	Petroleum Wholesale

Endnotes

1 http://climateactiontracker.org/global.html

2 More specifically, the 300,000 premature deaths figure includes both the impact of what Shindell et al. (2016) refers to as "clean energy policies," which would prevent about 175,000 premature deaths; and "clean transportation policies," which would prevent another 120,000 premature deaths.

3 These figures come from the World Bank Indicators, http://wdi.worldbank.org/tables. These tables were last accessed on 10/20/17.

4 Note that our main concerns here are distinct from other environmental impacts of methane emissions caused by natural gas extraction, including the contamination of groundwater. See Jackson et al. (2011) on the issue of groundwater contamination.

5 Pollin et al. (2014, pp. 193-96) examines the idea of natural gas serving as a "bridge fuel," i.e. as a more clean-burning source of fossil-fuel energy as clean renewable energy supplies expand incrementally. They show that this strategy is not capable of putting the U.S. on an adequate climate stabilization path even with considering only CO_2 emissions generated by natural gas combustion.

6 Reference is: http://www.eia.gov/environment/emissions/state/, Summary Table. Hereafter, we will drop the reference to "metric" tons and refer, as shorthand, simply to "tons" of CO_2, with the "metric" measure being implicit in all such references.

7 These reductions in CO_2 emissions have been offset to some extent by the rise in methane emissions resulting from the increase in the extent of natural gas extraction through fracking technologies. As we have reviewed above, the increase in methane emissions resulting from the rise of fracking is certainly an unfavorable development. But its overall global warming impact remains significantly smaller than the impact of CO_2 emissions generated by from fossil fuel combustion.

8 Various approaches to reduce energy losses in electricity generation are described in Prentiss (2015).

9 The source for the future plans for nuclear energy in New York is: http://www.eia.gov/nuclear/generation/xls/usreact15.xlsx

10 According to the Energy Information Agency, as of 2009, single-family detached homes averaged 103.6 million BTU per household, whereas multifamily homes with more than five units averaged 46.3 million BTUs per households: http://www.eia.gov/consumption/residential/data/2009/index.php?view=consumption#summary In fact, the factor creating this differential is that the floor space averages 1,500 square feet, as opposed to single-family homes, which average 2,500 square feet. Per square foot, single-family homes are more energy efficient than apartments, averaging 42,600 BTUs per square foot, versus apartments at 54,500 BTUs per square foot.

11 But buses can certainly also become more efficient than automobiles through encouraging increased passenger utilization of buses. Pollin et al. 2014, Appendix 1 discusses approaches to increasing bus transportation usage. The data sources for this paragraph include the 2015 American Community Survey for the figures comparing New York with the U.S. in terms of public transportation usage; NY State Transportation Statistics at a Glance, 2012, for figures on rail versus bus transportation usage: https://www.dot.ny.gov/divisions/policy-and-strategy/darb/dai- unit/ttss/repository/Table1_TranspStatsGlance_Update.pdf; and Pollin et al. Table A1.1, p. 326 for relative load factors for cars, rail and bus transportation.

12 See Pollin et al. (2014), pp. 38-39.

13 Energy efficiency gains can be, and frequently are, referred to as avoided fuel costs or as "negawatts," "negabarrels" or "negadollars." These alternative terms emphasize the point that gains in efficiency translate into lower costs to achieve a given level of energy-derived services.

14 http://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_use/tra/use_tra_NY.html&sid=NY

15 We do consider them in detail in Pollin et al. (2014).

16 We provide an extensive review of the NAS study in Pollin et al. (2014).

17 https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a It is also important to recognize that this average cost figure of 20.1 cents per kilowatt hour includes a wide range of prices according to region and the sectors consuming electricity.

18 https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/state_transportation_statistics/new_york/html/fas t_facts.html

19 Our estimates for average fuel efficiency levels for automobiles as of 2030 are lower than those derived by both the Energy Information Agency, whose estimate was at 44.0 mpg and the Environmental Protection Agency, whose estimate was 49.3 mpg. We are working with our own lower estimate, so that we remain conservative in assessing the prospects for achieving efficiency gains within the auto transport sector. The references for the EIA figure are: Vehicle age from BLS CEX survey http://www.bls.gov/cex/pumd_data.htm#csv, file ovb15.csv, variable VEHICYR. Projected CAFÉ standards from EIA, http://www.eia.gov/outlooks/aeo/data/browser/#/?id=7- AEO2016&cases=ref2016~ref_no_cpp&sourcekey=0, Light Duty Vehicles. The reference for the EPA figures is: Vehicle age from BLS CEX survey http://www.bls.gov/cex/pumd_data.htm#csv, file ovb15.csv, variable VEHICYR.

20 Pollin et al. (2014) pp. 113-16 presents a discussion of the prospects in the United States overall for cellulosic bioenergy.

21 http://www.eia.gov/outlooks/aeo/electricity_generation.cfm

22 We do not consider here either offshore wind or solar thermal technologies. According to the EIA, the levelized costs of these technologies remain much more expensive than the alternative clean renewable sources. They should therefore be considered as secondary renewable sources until significant levelized cost reductions are achieved.

23 To date, there are no commercial scale CCS operations in place. Pollin (2015), pp. 25 – 27 provides a brief review of the feasibility and desirability of CCS technologies. The conclusion from this review is that there are several major problems associated with CCS technologies, which together render the approach unsuitable as a major clean-energy strategy.

24 These figures, again, are based on the EIA's estimates of levelized costs for projects coming online in 2022. As such, these estimates incorporate the EIA's estimates as to the trajectory of cost reductions in renewable energy through 2022. The full methodology for generating these costs is presented in Pollin et al. (2014) pp. 136-37. Our cost estimates are significantly higher than those reported in the 2014 study Energy Efficiency and Renewable Energy Potential Study of New York State by the New York State Energy Research and Development Authority (NYSERDA). In Appendix 2, we provide a brief discussion as to the sources of the differences between our respective sets of cost estimates.

25 See Pollin et al. (2014), pp. 113 – 115 on emissions generated by conventional bioenergy sources, including biomass and corn ethanol.

26 To our knowledge, to date, there are no sources that directly report on the current level of clean energy investments in New York State. Our estimate of the current level is between about $6 - $7 billion per year based on investment figures for the U.S. as a whole, along with detailed evidence on the clean energy investment climate in New York State relative to the rest of the country. First, Bloomberg New Energy Finance reports that for the U.S. as a whole, clean energy investments totaled $58.6 billion in 2016 (https://about.bnef.com/clean-energy- investment/https://www.greentechmedia.com/articles/read/global-clean-energy-investment-dropped-18-in-2016- with-slowdown-from-china). The GDP for New York State in 2016 was about 8.1 percent of total U.S. GDP. Thus, if clean energy investments in New York State were proportional to its share of U.S. GDP, that would imply that these investments would amount to about $4.7 billion in 2016. Yet it is almost certain that New York State is investing proportionally more in clean energy than at a level proportional to its state GDP. As we have seen, emissions per capita in New York State are the lowest among the 50 states. Its per capita emissions level, at 8.6 tons, is roughly half the U.S. average of 17 tons per capita. As we discuss further in Section 9 below, New York State also already has a relatively strong set of clean energy investment incentive programs in place, certainly relative to the average among the other 49 states (even while these programs are not themselves sufficient to bring statewide emissions down to 100 tons as of 2030). As such, it is reasonable to assume that current annual levels of clean energy investments in New York State are likely to be at least 30 – 50 percent higher than the U.S. average as a share of the state's GDP. This would suggest that current clean energy investment levels are presently in the range of $6 – $7 billion per year, rather than $4.7 billion.

27 Nevertheless, it is still critical to support the purchase of high-efficiency autos with consumers, through, for example, subsidizing credit for such purchases.

28 Lawrence Mishel (2017) recently surveyed the key patterns between 2006 – 15. His main findings include the following: 1) Black workers are far more represented in the union construction workforce (21.2 percent) than in the nonunion construction workforce (15.8) and minorities overall now comprise 55.1 percent of

NYC blue-collar construction workers (white workers are 44.9 percent); 2) Among younger workers, black workers are even more underrepresented in the nonunion (14.8 percent) relative to the union (21.0 percent) construction sector; 3) Minorities comprised 61.8 percent of all NYC residents' apprenticeships in 2014, as opposed to a 36.2 percent share in 1994; and 4) Black union construction workers earn 36.1 percent more than black nonunion construction workers.

29 These ancillary industries correspond roughly to some of the major industries in which indirect employment occurs resulting through fossil fuel sector production, as defined in the input-output tables. In estimating the number of workers who would require some form of support through a Just Transition program, it is more accurate to focus on the direct employment figures for these ancillary industries as opposed to utilizing the indirect employment data from the input-output tables. Among other factors, a high proportion of the employment generated indirectly through fossil fuel industry activity will also have indirect links with clean energy investments. We would therefore not expect that a large share of the workers employed through indirect links will experience net job losses as the fossil fuel industries contract. Moreover, beyond these nine industries, we do not expect that a clean energy transition in New York State will produce significant employment losses in other industries, such as retail gasoline stations or industries that utilize energy inputs intensively, such as paper and aluminum manufacturing. We briefly review the situations for gas stations and energy-intensive industries in Appendix 5.

30 Pollin and Callaci (2016) examines in detail the case in which industry contraction does not occur as a smooth pattern, but rather more sporadically, including through large-scale job losses, tied perhaps to full-scale firm closures, in some years along with lesser declines in other years.

31 No data on pension funds were available on two firms in these industries. These are Millennium Pipeline and Northport. The reason the data are more difficult to obtain for these firms is that Millennium is a joint venture and the parent company for Northport, National Grid, is a UK firm.

32 See Pollin et al. (2014), pp. 310-311.

33 See Pollin and Callaci (2016).

34 http://www.collegetuitioncompare.com/compare/tables/?state=NY

35 According to the 2015 article in Moneyzine "Relocation Expenses," these expenses for an average family range between $25,000 and $75,000 (https://www.money-zine.com/career-development/finding-a-job/job-relocation-expenses/). The costs include: selling and buying a home, including closing costs; moving furniture and other personal belongings; and renting a temporary home or apartment while house-hunting for a more permanent residence. For our calculations, we assume the midpoint figure of $50,000.

36 https://energyindepth.org/marcellus/natural-gas-opponents-biting-the-hand-that-feeds-them/

37 http://www.stargazette.com/story/news/local/2015/07/15/baker-hughes-leaves-chemung-county/30207345/

38 In May 2016 Congress legislated to maintain funding for the site: http://www.portman.senate.gov/public/index.cfm/press-releases?ID=84DB38D2-5B4C-434F-BC68- B14E60DFA440

39 U.S. Department of Energy, "U.S. Departments of Energy and Interior Announce Site for Solar Energy Demonstration Projects in the Nevada Desert," Press release, 7/8/10, http://energy.gov/ articles/us-departments- energy-and-interior-announce-site-solar-energy-demonstration-projects-nevada.

40 The description in this paragraph is based on Galgoczi (2015) and Dohmen and Schmid (2011).

41 See Pollin et al. (2014) for further discussions on these federally-based clean energy investment programs.

42 file:///C:/Users/rpollin/Downloads/clean-energy-fund-fact-sheet%20(2).pdf

43 https://www.nyserda.ny.gov/About/Clean-Energy-Fund

44 The "polluter fee" policy is also commonly referred to as a "carbon tax". These two terms are interchangeable in substance. But "polluter fee" is the term of choice among groups supporting this measure in New York State. As such, this term will be used most frequently in upcoming New York State policy debates around climate change. It is therefore appropriate to use this term in our present discussion. Some useful references on this issue include Boyce (2017), Mathur and Morris (2012), Komanoff and Mattiessen (2014), Breslow et al. (2014), and Fremsted and Paul (2017).

45 Pollin et al. (2014) presents the basic issues in this debate. Goodstein and Polasky (2014) provides a more extensive textbook treatment.

46 These proposed rates are in line with those modeled by the U.S. Energy Department, based on both the Kerry-Lieberman and Waxman-Markey emissions reduction bills introduced into the U.S. Senate in 2009. See Pollin et al. (2014), Appendix 5 for further discussion.

47 A gallon of gasoline produces approximately 20 pounds of carbon dioxide. If we express the carbon price in terms of short tons (i.e. 2,000 pounds) that means that: [1 gallon of gasoline (= 20 pounds of carbon)] x [$1/1 ton (=2,000 pounds) = 1 cent per gallon of gasoline. See https://www.fueleconomy.gov/feg/contentIncludes/co2_inc.htm for establishing the 20 pounds of weight in a gallon of gasoline. Incorporating possible shifts in demand resulting from the carbon price, a 2009 study by Metcalf finds that a $15 per ton carbon tax for the U.S. economy would raise retail prices as follows: 14.1 percent for electricity and natural gas; 10.9 percent for home heating; 8.8 percent for gasoline; 2.2 percent for air travel; and between 0.3 and 1 percent for other commodities.

48 http://programs.dsireusa.org/system/program/detail/93 describes the original RPS. The Clean Energy Standard is presented here: http://programs.dsireusa.org/system/program/detail/5883

49 See Pollin et al. (2014), pp. 113 – 115.

50 http://programs.dsireusa.org/system/program/detail/4513

51 http://programs.dsireusa.org/system/program/detail/5861

52 http://www.dec.ny.gov/chemical/8575.html

53 Carey, Nick, and David Shepardson. "Big win for automakers as Trump orders fuel economy standards review." Reuters, March 16, 2017.

54 This figure is an approximation, based on the data, presented in Table 4, showing that burning petroleum accounts for about 53 percent of all emissions and, in Table 1, that transportation accounts for about 71 percent of all petroleum consumption. This 0.53 x 0.71 = 0.38.

55 http://programs.dsireusa.org/system/program/detail/453

56 The description of the current cap on net metering at the DSIRE website states that "the provision is put in place to limit the impact …[of the new program] on non-participants." See: http://programs.dsireusa.org/system/program/detail/453

57 https://www.nyserda.ny.gov/All-Programs/Programs/On-Bill-Recovery-Financing-Program

58 This also assumes that the funding from a polluter fee would substitute for the $73 million per year that NYSERDA now distributes out of its RGGI carbon cap program.

59 Detailed discussions of these programs are presented in Pollin et al. (2014), Chapter 8.

60 Prentiss does, however, recognize that, beyond providing the average level of energy demanded at any given time is the challenge of meeting the specific energy demand needs, given that wind and solar power both are intermittent energy sources. Thus, she explains that technological advances will also be necessary to achieve an energy infrastructure that relies on renewable energy for 100 percent of supply. She writes that "The question of whether renewable energy could provide all of the actual instantaneous energy needs of the United States is an open question that depends on how fluctuating renewable energy sources can be harnessed to provide power on demand. A revolutionary advance in large-scale energy storage would greatly ease the transition to a 100 percent renewable- energy economy; however, a combination of increases in energy efficiency due to widespread adoption of existing technologies and a "smart grid" that pools energy supply and demand over large geographical areas may allow a renewable energy economy to flourish even without large-scale energy storage," (2015, p. 2). A broadly similar assessment as to the potential for renewable energy to supply 100 percent of energy needs for India was developed by Prof. S.P. Sukhatme in his 2013 paper, "Can India's Future Needs of Electricity be Met by Renewable Energy Sources?"

61 The IPCC's findings are described in Romm (2015). But perhaps reflecting some ongoing uncertainty in the IPCC estimates, the U.S. Environmental Protection Agency reports the global warming impact of methane relative to CO_2 as being "more than 25 times greater over a 100-year period" (https://www.epa.gov/ghgemissions/overview-greenhouse-gases).

62 The full reference to the EDGAR research on this issue can be found here: https://data.worldbank.org/indicator/EN.ATM.METH.KT.CE?view=chart

63 http://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

64 We use the CPS data files provided by the Center for Economic and Policy Research (CEPR) which standardizes variables across years (www.ceprdata.org). CEPR also provides an hourly wage measure in their

data files that includes overtime, tips and commissions, as well as adjusts for top-coding and imputes hours for workers that report weekly earnings and work schedules with "varying hours."

65 According to research consulting firm, Oliver Wyman's Energy, less than 30 percent of the average gas station's profits derive from gasoline and diesel ("In 2035, self-driving cars may make 2 a.m. the busiest hour at the digital gas station," by Irfan Bidiwala and Eric Nelsen, Forbes, April 18, 2017.)

66 IBISWorld Industry Report 44711, Gas Stations with Convenience Stores in the US, February 2017, by Dmitry Diment. IBISWorld Industry Report 44719, Gas Stations in the US, November 2016, by Andrew Alvarez.

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