Kaya Identity Analysis of New York Climate Action Plan: Quantifying the Challenge

This report and the accompanying documentation spreadsheet describe an analysis that applies a technique used by Dr. Roger Pielke, Jr. to evaluate New York's proposed CO2 emissions reductions policies that form the basis of the New York Climate Action Plan and quantify the challenge of meeting the State's Climate Action Plan goals. In the Climate Fix (Pielke, 2010a) and elsewhere, Dr. Pielke uses the Kaya Identity to project future emissions based on New York State population, economic growth, and technology in a bottom-up approach and a top-down approach that derives the required level of decarbonization necessary to meet the New York Climate Action Plan goals.

New York Climate Action Plan

In August 2009 New York Governor Paterson issued Executive Order 24 formally establishing a State goal of reducing GHG emissions from all sources 80 percent below 1990 levels by 2050, and named the Climate Action Council to determine how to meet the goal. The New York State Climate Action Plan Interim Report (NYS Climate Action Council, 2010) is the initial analysis that documents the preliminary plan to meet this goal. The Interim Report also presents "preliminary quantitative analysis of the costs, savings, and GHG emission reduction potential for individual mitigation policy options relative to a mid-point 40 by 30 benchmark target, i.e., 40 percent reduction in GHG emissions by 2030". In 1990, CO2 emissions were 220.0 million metric tons. The Climate Action goal for 2030 is a 40% reduction or a goal of 132 million metric tons and the goal for 2050 is an 80% reduction or 44 million metric tons.

Approach Methodology

Rather than summarize the methodology employed by Dr. Pielke the following is an extract from Pielke's (2010) recent paper that describes how this approach was applied to proposed Australian emissions reduction policies

> The methodology employed here was employed in Pielke (2009a; 2009b) to structure similar analyses of the United Kingdom Climate Change Act and the Japanese "Mamizu" climate policy. It draws upon Waggoner and Ausubel (2002) who argue that understanding the ability to influence environmental outcomes through policy requires "quantifying the component forces of environmental impact and integrating them." For carbon dioxide emissions relationship of forces leading to carbon dioxide emissions has been called the Kaya Identity, and it can be used to decompose the factors that lead to carbon dioxide emissions from the production and use of energy in the global economy. The identity is comprised of two primary factors: economic growth (or contraction), typically represented in terms of GDP, and changes in technology, typically represented as carbon dioxide emissions per unit GDP.

Each of these two primary factors is typically broken down into a further two sub-factors. GDP growth (or contraction) is comprised of changes in *population* and in *per capita GDP*. Carbon dioxide emissions per unit GDP is represented by the product of *Energy Intensity,* which refers to energy per unit of GDP and *Carbon Intensity,* which refers to the amount of carbon per unit of energy.

Together the four factors of the Kaya Identity explain the various influences that contribute to increasing atmospheric concentrations of carbon dioxide, as follows:

> *(1) Carbon Dioxide Emissions= Population * Per Capita GDP * Energy Intensity * Carbon Intensity*
>
> *(2) P = Total Population*
>
> *(3) GDP/P = Per capita GDP*
>
> > *a. GDP = Economic Growth (Contraction) = P * GDP/P = GDP*
>
> *(4) Energy Intensity (EI) = TE/GDP = Total Energy (TE) consumption/GDP*
>
> > *b. Carbon Intensity (CI) = C/TE=Carbon emissions/Total Energy consumption*
>
> *(5) EI X CI = "Carbon Intensity of the Economy" = TE/GDP * C/TE = C/GDP*

Thus, according to the logic of these relationships, carbon accumulating in the atmosphere can be reduced only by reducing (a) population, (b) per capita GDP, or (c) carbon intensity of the economy. Most proposals advanced by governments and in international negotiations focus on actions that will lead to the reduction of the carbon intensity of the economy (whether or not they are explicitly presented as such), which in this paper is referred to as “decarbonization.” Policies to reduce population or that result in economic contraction are not generally considered by governments as a strategy of emissions reductions. Thus, the Kaya Identity provides a straightforward and useful way to evaluate the proposed and actual performance of policies focused on decarbonization and which are typically called mitigation policies.

The factors of the Kaya Identity can be used to evaluate these estimates in terms of what is required to achieve the identified goals. The factors can be integrated individually, in “bottom up” fashion based on independent projections for growth in population (2) and per capita GDP (3), to estimate implied rates of decarbonization (5). The overall goal can also be disaggregated in a “top down” manner, starting with overall

GDP growth (a) and deriving implied rates of decarbonization (5) consistent with a specified target.[1]

New York's Historical Trends

The New York Climate Action Plan's baseline year is 1990 so it is appropriate to review the Kaya Identity factors since 1990 as well as project them for the future. NYSERDA publishes an annual 15-year overview of New York State energy related data that includes historical population, gross state product, energy, and CO2 data. Data to be used in the upcoming energy profiles from 1995 to 2009 report (NYSERDA, 2011) were used for the historical analysis. Note that the report itself only goes back to 1995 but the data back to 1990 are available upon request and are included in the supporting documentation spreadsheet described below. The Kaya Identity factors are listed for historical data in Table 1 (Kaya Spreadsheet, Tab Kaya History).

Table 1: New York State Historical Kaya Identity Factors

Year	Population (1000s)	Gross State Product	Per Capita GSP	Total Energy (Tbtu)	Energy Intensity	CO2 MM tons Ceq	CO2 per Capita	CO2 Energy Intensity	CO2 Intensity
1990	17,991	624,344	34.70	3,815.1	6.11E-03	220.0	12.2	5.77E-02	0.35
1991	18,123	606,041	33.44	3,791.0	6.26E-03	211.2	11.7	5.57E-02	0.35
1992	18,247	614,332	33.67	3,849.3	6.27E-03	209.7	11.5	5.45E-02	0.34
1993	18,375	616,896	33.57	3,903.8	6.33E-03	205.7	11.2	5.27E-02	0.33
1994	18,459	627,133	33.97	3,895.8	6.21E-03	203.6	11.0	5.23E-02	0.32
1995	18,524	640,084	34.55	3,918.9	6.12E-03	209.1	11.3	5.34E-02	0.33
1996	18,588	665,717	35.81	4,018.7	6.04E-03	209.8	11.3	5.22E-02	0.32
1997	18,657	670,980	35.96	4,063.5	6.06E-03	214.4	11.5	5.28E-02	0.32
1998	18,756	698,883	37.26	3,961.9	5.67E-03	211.0	11.3	5.33E-02	0.30
1999	18,883	736,540	39.01	4,101.1	5.57E-03	215.3	11.4	5.25E-02	0.29
2000	18,977	777,157	40.95	4,218.9	5.43E-03	222.0	11.7	5.26E-02	0.29
2001	19,089	794,392	41.62	4,060.4	5.11E-03	213.4	11.2	5.26E-02	0.27
2002	19,162	791,689	41.32	4,015.0	5.07E-03	204.5	10.7	5.09E-02	0.26
2003	19,231	808,396	42.04	4,175.9	5.17E-03	216.5	11.3	5.18E-02	0.27
2004	19,298	829,900	43.00	4,247.5	5.12E-03	220.4	11.4	5.19E-02	0.27
2005	19,331	865,741	44.79	4,182.5	4.83E-03	215.0	11.1	5.14E-02	0.25
2006	19,357	912,864	47.16	3,969.2	4.35E-03	197.7	10.2	4.98E-02	0.22
2007	19,423	949,499	48.89	4,096.5	4.31E-03	205.3	10.6	5.01E-02	0.22
2008	19,468	964,755	49.56	4,029.8	4.18E-03	195.2	10.0	4.84E-02	0.20

[1] The terminology of "bottom up" and "top down" is simply descriptive of the approach used in Pielke's (2010) paper.

The calculations used in this table and elsewhere are contained in an EXCEL spreadsheet named Kaya Identity Spreadsheet Analysis of New York CO_2 Emissions Reductions Policies.XLS, hereafter referred to as the Kaya Spreadsheet. The input data from the NYSERDA Pattern and Trends report are contained in the first six tabs named after the tables in the report. In each tab the original data is in cells highlighted in light green. The NYSERDA data tables do not include CO_2 projections for each year so the annual CO_2 emissions are calculated (Kaya Spreadsheet: Tab CO2) using EIA carbon dioxide emission factors (EIA, 2010, Kaya Spreadsheet: Tab EIA CO2 EF) and primary energy consumption data from different NYSERDA tables (note that the calculation tab references the source tab of each energy value used).

Despite increases in population and Gross State Product (Kaya Spreadsheet: Tab 1.5b), New York CO_2 emissions dropped between 1990 and 2008 (Kaya Spreadsheet: Tab CO2). Population increased from 17,991,000 to 19,468,000 the Gross State Product increased from \$624,344 (millions of 2000 dollars) to \$964,755, and the Per Capita Gross State Product increased from 34.70 to 49.56 over the time period 1990 to 2008 (Kaya Spreadsheet: Tab Kaya Projection). In order to take out year to year CO_2 variations the average of the first three years is compared to the average of the last three years. CO_2 dropped from 220.0 (million metric tons of carbon equivalent) to 195.2 so the Kaya carbon intensity dropped from 0.35 to 0.20. The average rate of carbon intensity decrease was 2.37% (Kaya Spreadsheet: Tab Kaya Projection).

It is appropriate to review why the CO_2 emissions dropped. The average sector primary consumption over the period 1990 to 2008 as shown in Figure 1 indicates that the electric utility sector was the largest primary energy sector at 38% of the total (Kaya Spreadsheet: Tab 2.3). Table 2 lists CO_2 emissions over the historical period for seven sectors, primarily separating coal, natural gas and petroleum as electric generating and everyone else but also separating out gasoline. New York State total emissions dropped 14 million metric tons over this period although there was quite a bit of variation (Figure 2, (Kaya Spreadsheet: CO2 Graph)). CO_2 emissions from coal combustion dropped 5.3 million metric tons, while natural gas CO_2 emissions increased 12.4 million metric tons. CO_2 emissions from gasoline combustion increased slightly but that was offset by a reduction in other petroleum emissions. The primary reason that New York CO_2 emissions dropped over this period was the reduction in the use of residual oil for electric generation because that accounted for a reduction of 16.6 million metric tons. There are several large oil-fired steam electric boiler facilities in New York that burn oil when it is economic to do so. In the last three years the oil-fired energy use has dropped dramatically because the cost differential between oil and natural gas has changed significantly.

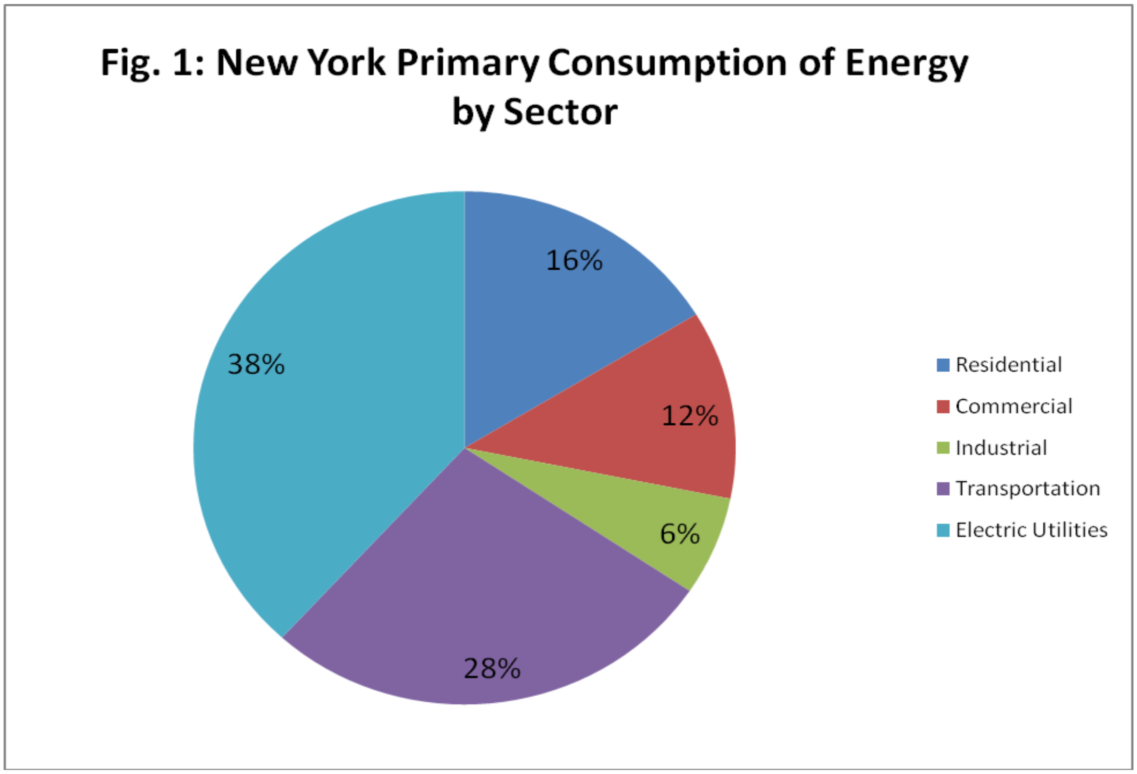
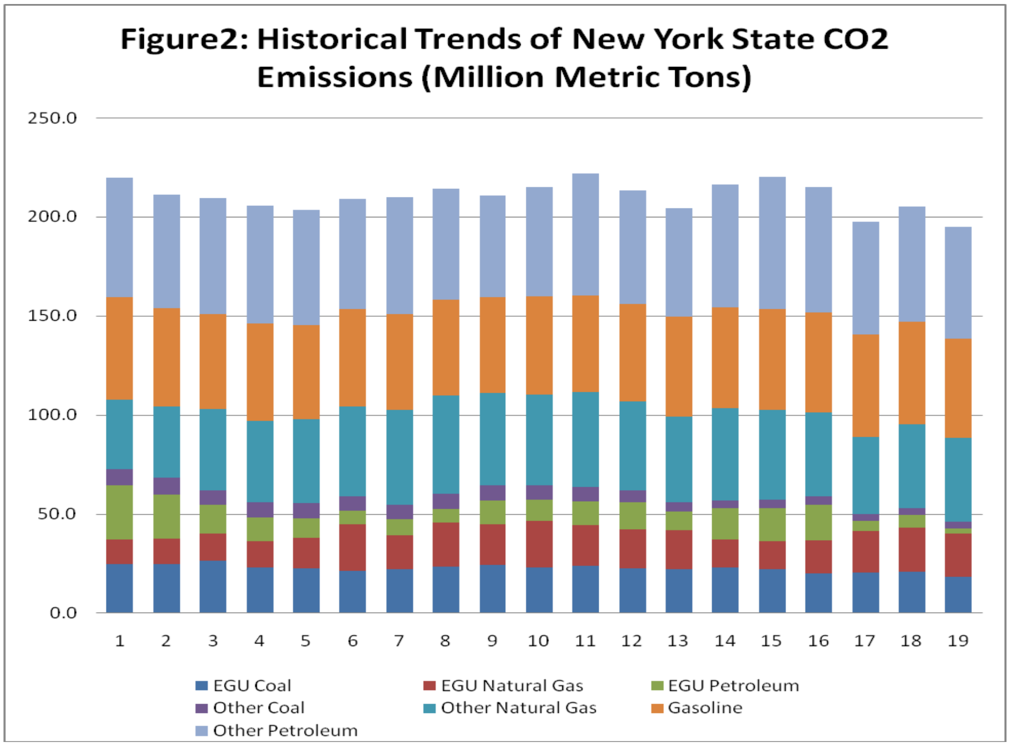


Table 2: New York State Primary Consumption of Energy by Sector % of Total

Year	Residential Tbtu	Commercial Tbtu	Industrial Tbtu	Transportation Tbtu	Electric Utilities Tbtu
1990	15.6%	10.8%	7.1%	28.8%	37.6%
1991	15.5%	10.9%	7.1%	27.8%	38.8%
1992	16.8%	11.2%	7.5%	26.8%	37.6%
1993	16.8%	11.5%	7.6%	26.9%	37.3%
1994	16.6%	11.4%	7.9%	26.5%	37.6%
1995	16.1%	11.2%	8.9%	27.0%	36.8%
1996	16.7%	11.3%	9.1%	26.8%	36.0%
1997	16.4%	12.5%	8.8%	26.5%	35.8%
1998	15.3%	12.2%	8.1%	26.9%	37.5%
1999	16.0%	12.8%	6.0%	27.0%	38.2%
2000	17.5%	13.2%	5.8%	26.3%	37.2%
2001	16.9%	12.9%	5.0%	26.3%	38.9%
2002	15.9%	12.9%	4.5%	26.9%	39.8%
2003	17.1%	13.3%	4.3%	27.1%	38.2%
2004	16.3%	13.6%	4.1%	27.9%	38.1%
2005	16.8%	11.3%	4.3%	27.5%	40.1%
2006	15.0%	10.7%	4.3%	29.4%	40.6%
2007	16.1%	11.1%	4.1%	28.5%	40.2%
2008	16.0%	10.9%	3.9%	28.8%	40.3%
Average	16.3%	11.9%	6.2%	27.3%	38.2%



Evaluating New York's Climate Action Plan Using a Bottom-Up Approach

In the bottom-up approach New York projections are made for each of the factors in the Kaya Identity: population, economic growth, and technological change. As noted previously, according to the logic of the Kaya Identity relationships, carbon accumulating in the atmosphere can be reduced only by reducing (a) population, (b) per capita Gross State Product, or (c) carbon intensity of the economy.

If everything else stays the same, one would expect that more people results in more CO2 emissions. The U.S. Census Bureau (2010) projects New York State population to 2030. There is a small projected growth rate and the population in 2030 is expected to be 19,477,000. Compared to a baseline population (average of 2004 to 2008) of 19,375,000 the projected population increase represents a small increase of 1.005 in the CO2 emissions. Because the population of New York is not expected to change significantly the CO2 related change should also be insignificant.

Economic activity as measured by per capita Gross State Product is the second factor in the Kaya Identity. An increase in economic activity should also result in increased CO2 emissions. The average annual Per Capita New York Gross State Product growth rate from 1990 to 2008 was 2.02%, for the ten-year period 1999 to 2008 was 2.91% and for the last five years, 2004 to 2008, was 3.36% (Kaya Spreadsheet: Bottom Up tab). The Per Capita Gross State Product for a baseline of 2004 to 2008 was 46.7. Compounding the lowest historical annual average growth rate (2.02%) increases the Per Capita Gross State Product to 76.6 by 2030. In the absence of any other initiatives, this increase in economic activity is expected to increase CO2 emissions from the baseline of 206.7 to 339.1 million metric tons in 2030. This is 1.6 times the baseline emissions and 2.6 times the New York Climate Action Plan goal of 132 million metric tons of CO2.

The third factor in the Kaya Identity is technological change expressed as carbon intensity. In order to reduce CO2 emissions, New York certainly would prefer to reduce carbon intensity (by increasing energy efficiency and reducing the use of fossil fuels) and not by imposing limits on population or economic activity. As noted earlier between 1990 and 2008 the average rate of carbon intensity decreased by 2.37% per year. However, it is not clear if the primary cause of New York's decarbonization in the past (fuel switching away from residual oil) can be counted on to achieve the technological change needed for future reductions goals.

In order to meet the New York State Climate Action Plan goal of 132 million metric tons of CO2 the carbon intensity has to be reduced. In the absence of economic growth (assuming no significant population growth) CO2 emissions would have to be reduced from the current baseline of 207 million metric tons and the average annual decarbonization rate needs to be 1.7% until 2030 (Kaya Spreadsheet: Bottom Up tab). When the expected effect of economic activity is considered then CO2 emissions would have to be reduced from 339 million metric tons and the average annual decarbonization rate needs to be 2.9% until 2030.

Evaluating New York's Climate Action Plan Using a Top-Down Approach

A top down analysis uses the Kaya Identity factors with assumptions of future economic growth and population growth to determine per capita economic growth. The decarbonization rate needed for the economy to meet the New York Climate Action goals can then be calculated.

In this analysis assumptions were made for future economic growth spanning the possible range of alternatives (Kaya Spreadsheet: Top Down tab). Figure 3 shows the historical decarbonization rate and future projections for five values for the increase in Gross State Product (0.5% to 2.5%). The annual average decarbonization rates necessary to meet the 2030 goal ranges from 2.1% to 3.2%. Ultimately, the carbon intensity of the New York economy is going to have to be reduced between 40 and 65% in the next 20 years.

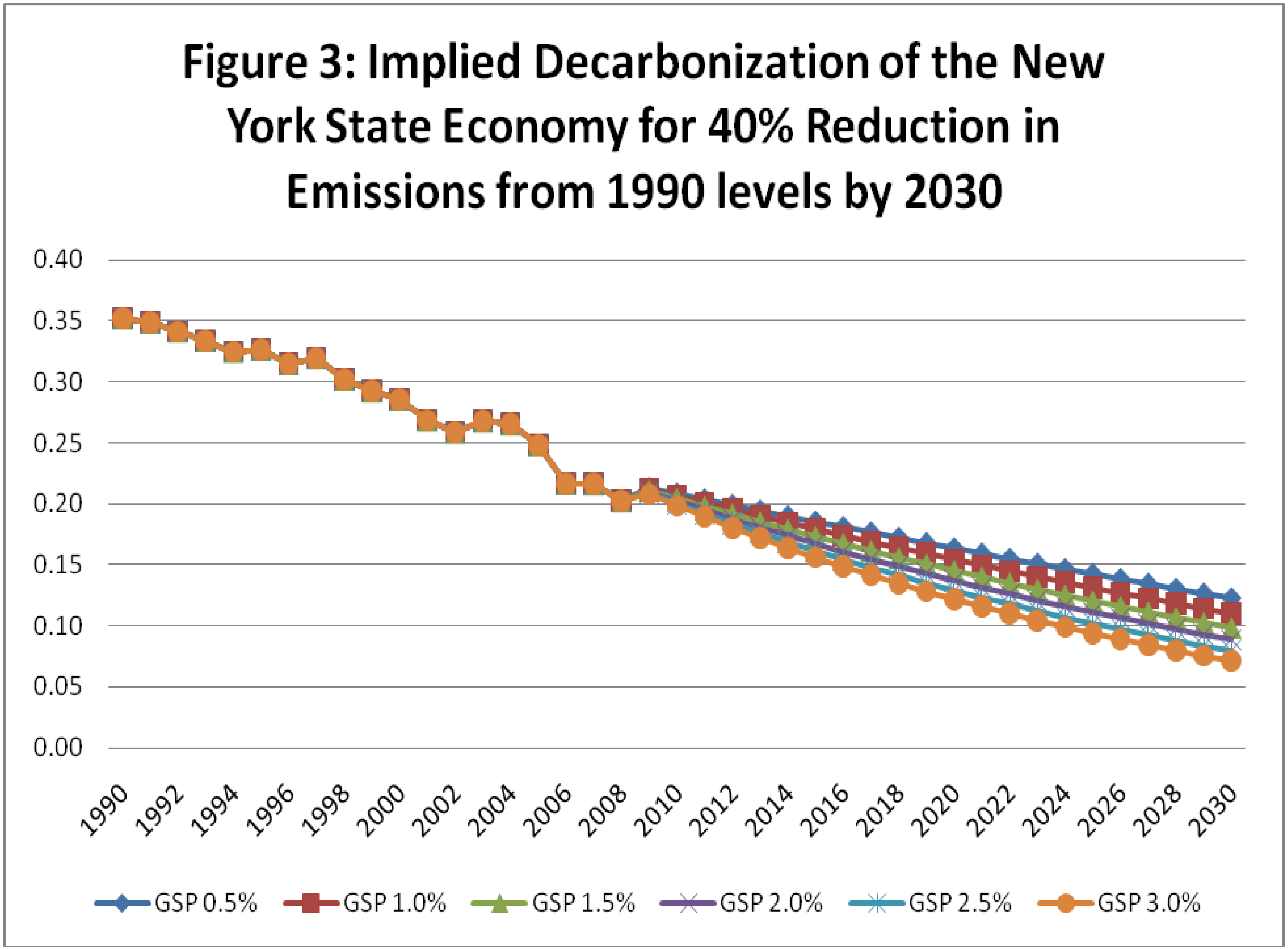


Figure 3: Implied Decarbonization of the New York State Economy for 40% Reduction in Emissions from 1990 levels by 2030
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
GSP 0.5%
GSP 1.0%
GSP 1.5%
GSP 2.0%
GSP 2.5%
GSP 3.0%

Decarbonization Alternatives

In order to put challenge to meet the New York Climate Action Plan CO2 goals in perspective, it is instructive to compare the power output of existing New York carbon-free facilities with the current sources of New York energy. The New York Independent System Operator prepares an annual report that forecasts peak demand, energy requirements, energy efficiency, and emergency demand response; existing and proposed resource capacity; and existing and proposed transmission facilities that includes a summary of operations at existing facilities (NYISO, 2010). Table 3 lists data from the Maple Ridge Wind Farm and all the existing nuclear facilities in the State. In addition the table includes an estimate of the maximum wind potential for 66 on-shore sites in New York from a U.S. Department of Energy (DOE) recently completed analysis of wind integration that represents the maximum amount of wind energy possible within the State. The Eastern Wind Integration and Transmission Study (NREL, 2010) analyzed individual wind plants from the Eastern Wind Data Study database to examine scenarios for various wind energy penetration levels.

Table 3: New York State Carbon-Free Electric Generating Unit Performance in 2009

Facility	SUM CRIS Capacity (MW)	Description	NYISO 2009 Net Energy GWh	Maximum Potential Capacity GWh	Annual Capacity Factor (%)
Maple Ridge I Wind Farm	231	140 Vestas V82 1.65 MW turbines	527.9	2,023.6	26.1%
Maple Ridge II Wind Farm	91	55 Vestas V82 1.65 MW turbines	203.4	795.0	25.6%
NREL EWITS	14,500	66 on-shore facilities	33,136.6		26.1%
Indian Point 2	1,040	Nuclear	8,837.4	9,113.9	97.0%
Indian Point 3	1,040	Nuclear	7,704.9	9,113.9	84.5%
JA Fitzpatrick	859	Nuclear	7,398.1	7,524.0	98.3%
Nine Mile 1	631	Nuclear	4,991.4	5,523.2	90.4%
Nine Mile 2	1,148	Nuclear	9,919.6	10,059.1	98.6%
Ginna	582	Nuclear	4,635.6	5,098.3	90.9%

In the baseline period of 2004-2008 the average energy consumption from coal burning was 254.9 TBtu. The NYSERDA Patterns and Trends report lists the primary consumption of energy (TBtu) for electric generation by fuel type (Kaya Spreadsheet, Tab 2.4ab) and the electric generation by fuel type (Kaya Spreadsheet, Tab 2.5) so the amount of energy used (TBtu) to generate power (GWhr) can be calculated. In 2009 Nine Mile Point 2 generated 9,919.6 GWh. The average coal EGU generation per energy consumed was 97.33 (Kaya Spreadsheet, Tab 2.5). As a result in 2009 the net energy of Nine Mile 2 was equivalent to 101.9 TBtu of coal generation (Kaya Spreadsheet, Tab Replacement). Therefore, in order to replace 254.9 TBtu of coal generation 2.5 more Nine Mile 2 units (254.9/101.9) will need to be constructed.

Table 4 compares three carbon-free replacement alternatives to three energy sources: coal, residual oil, and the projected increase in energy for a Gross State Product annual average growth rate of 2.02% and total energy growth rate of 0.34%. In order to displace coal and residual oil completely in New York and cover the expected increase in energy needed slightly more than four nuclear units comparable to Nine Mile 2 or 79 wind farms the size of and with the operating characteristics of Maple Ridge 1 would be needed. Finally note that the NREL maximum projected penetration of on-shore wind in New York would not be sufficient to cover the energy to replace coal, residual oil and increased energy.

Table 4: Replace Energy with Potential Carbon-Free Generation Facilities.

		Nine Mile 2		Maple Ridge 1		All NY EWITS	
	Tbtu	Replace	GWhr/Tbtu	Replace	GWhr/Tbtu	Replace	GWhr/Tbtu
Coal	254.9	2.5	101.9	47.0	5.42	0.75	340.5
Increased Energy	22.1	0.2	93.7	4.4	4.98	0.07	312.8
Residual	142.5	1.5	96.8	27.7	5.15	0.44	323.3
Total	419.4	4.2		79.1		1.3	

The last question is whether the elimination of coal and residual oil burning in New York would meet the New York Climate Action Plan goal of a 40% reduction. For the baseline (average 2004 -2008) coal and residual oil energy use the CO2 emissions were 46.5 million metric tons and the total NY CO2 emissions were 227.9 million metric tons. The 2030 goal is 132 million metric tons so the elimination of coal and residual oil leaves a shortfall of 49.4 million metric tons for the goal (Kaya Spreadsheet: Tab CO2). In fact even in a likely unrealistic scenario in which the use of all distillate oil, kerosene and LPG (for a total of over 1,000 Tbtu of energy displaced) is eliminated leaves a shortfall of 7.8 million metric tons or 6% for the 2030 goal even when assuming no growth for the other carbon emitting sources, including mobile source gasoline.

References

National Renewable Energy Laboratory, 2010. Eastern Wind Integration and Transmission Study. November http://www.nrel.gov/wind/systemsintegration/ewits.html.

New York Independent System Operator, 2010. 2010 Load & Capacity Data "Gold Book", Version 1 Released April 2010. November, http://www.nyiso.com/public/webdocs/services/planning/planning_data_reference_documents/2010_GoldBook_Public_Final_033110.pdf.

New York State Climate Action Council, 2010. New York State Climate Action Plan Interim Report – November 9, 2010. November 10, http://nyclimatechange.us/InterimReport.cfm.

New York State Energy Research and Development Authority, 2011. Patterns and Trends: New York State Energy Profiles: 1995-2009, in press. Data to be included in report provided by Christopher Hall, November 2010.

Pielke, Jr., R. A., 2009a. The British Climate Change Act: A Critical Evaluation and Proposed Alternative Approach. Environmental Research Letters, Vol. 4, No. 2. doi: 10.1088/1748-9326/4/2/024010.

Pielke, Jr., R.A., 2009b. Mamizu Climate Policy: An Evaluation of Japanese Carbon Emissions Reduction Targets. Environmental Research Letters, Vol 4, No. 4. doi:10.1088/1748-9326/4/4/044001.

Pielke, Jr., R.A., 2010a. *The Climate Fix: What scientists and politicians won't tell you about global warming.* Basic Books, 276 pp., ISBN 978-0-465-02052-2.

Pielke, Jr., R.A., 2010b. An Evaluation of the Targets and Timetables of Proposed Australian Emissions Reduction Policies. Submitted to Environmental Science & Policy, 14 October 2010,

United States Census Bureau, 2010. Interim Projections of the Total Population for the United States and States: April 1, 2000 to July 1, 2030, November 9, http://www.census.gov/population/projections/SummaryTabA1.pdf

United States Energy Information Administration, 2010. Carbon Dioxide Emission Factors (1980 - 2006), November, http://www.eia.doe.gov/oiaf/1605/ggrpt/excel/CO2_coeff.xls.

Waggoner, P. E., Ausubel, J.E., 2002. A framework for sustainability science: A renovated IPAT identity. Proceedings of the National Academy of Sciences, Vol. 99, pp. 7860-7865.