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**Appendix D**

**Avoided Air Emissions from the Operation  
of the Arkwright Summit Wind Farm**

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# **Avoided Air Emissions from the Operation of the Arkwright Summit Wind Farm in the Towns of Arkwright and Pomfret, New York**



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## LIST OF ACRONYMS

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CAA	Clean Air Act
CAIR	Clean Air Interstate Rule
CEM	Continuous Emission Monitors
CO <sub>2</sub>	Carbon Dioxide
DOE	U.S. Department of Energy
EERE	Energy Efficiency and Renewable Energy
EGU	Electric Generating Units
EPA	U.S. Environmental Protection Agency
kWh	Kilowatt-Hour
ISO	Independent System Operator
ISO-NE	New England Independent System Operator
MARO	U.S. Department of Energy Mid-Atlantic Regional Office
MWh	Megawatt-Hour
NAAQS	National Ambient Air Quality Standards
NO <sub>x</sub>	Nitrogen Oxides
NREL	National Renewable Energy Laboratory
NYISO	New York Independent System Operator
OAQPS	EPA Office of Air Quality Planning and Standards
OTC	Ozone Transport Commission
PJM	PJM (Pennsylvania, New Jersey, Maryland) Interconnection
PV	Photovoltaic
SIP	State Implementation Plan
SO <sub>2</sub>	Sulfur Dioxide



## 1.0 INTRODUCTION

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This report provides an evaluation of the avoided emissions of selected air pollutants from the operation of the proposed Arkwright Summit wind farm to be located in the Towns of Arkwright and Pomfret in New York with an installed capacity of 79.2 Megawatts (MW).

This report is a prospective evaluation of avoided emissions from the operation of the project. The evaluation applies a methodology developed by Resource Systems Group, Inc (RSG). The methodology is based on generally accepted principles and procedures for estimating air emissions reductions from wind and other renewable electric power generation on the electric grid.

The methodology in this report is consistent with the approach used by other experts in the field. It has been used in previous studies of avoided air emissions from wind and other renewable generation in Maryland, New Jersey, Virginia and parts of the ISO New England, NYISO and the PJM Interconnection power market<sup>1</sup>. The New Jersey study, including its methodology, was published in June 2006 and was co-authored by technical experts from both the National Renewable Energy Laboratory (NREL) and the Global Environment and Technology Foundation, a prominent non-profit organization in the energy and environmental field. In addition, the U.S. Environmental Protection Agency, the Department of Energy, and senior NREL officials have reviewed both the Maryland and New Jersey studies.<sup>2</sup> The Environmental Protection Agency accepted the Maryland study to support its first-ever approval of a renewable energy purchase for nitrogen oxide (NOx) emissions reduction credit in a State Implementation Plan (SIP) under the Clean Air Act.<sup>3</sup> The methodology in the Maryland report also was published by NREL as a model for air emissions assessment for other wind energy projects.<sup>4</sup>

## 2.0 THE ARKWRIGHT SUMMIT WIND FARM

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The proposed Arkwright Summit Wind Farm would be located in the towns of Arkwright and Pomfret, southeast of the southern shore of Lake Erie, southwest of the Village of Forestville, and northeast of the Village of Cassadaga. The Arkwright Summit Wind Farm would sit at elevations ranging from just below 1,700 feet to 2,100 feet above sea level. The area largely consists of deciduous and mixed forests and agricultural pastures, with predominantly rural residential, agricultural, and recreational land use. This report is based on the operation 44 turbines with a total capacity of 79.2 MW. The point of interconnection is along the Dunkirk-Falconer 115 kV line operated by National Grid. The substation and point of interconnect switchyard will be located in Pomfret, NY.

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<sup>1</sup> *Report on the Clean Energy/ Air Quality Integration Initiative Pilot Project of the U.S. DOE Mid-Atlantic Regional Office, June 2006.* 70 Fed. Reg. 24988 (May 12, 2005). See also, Metropolitan Washington Council of Governments, "Plan to Improve Air Quality in the Washington, DC-MD-VA Region," February 19, 2004 at [http://www.mwcog.org/committee/committee/archives.asp?COMMITTEE\\_ID=14](http://www.mwcog.org/committee/committee/archives.asp?COMMITTEE_ID=14) (Scroll down to February 19, 2004, pp. 7-77 to 7-81 and Appendix J, pp. J-71 to J-76).

<sup>2</sup> *Op cit.*

<sup>3</sup> 70 Fed. Reg. 24988 (May 12, 2006).

<sup>4</sup> National Renewable Energy Laboratory, Model State Implementation Plan (SIP) Documentation for Wind Energy Purchase in State with Renewable Energy Set-Aside, May 2005, Subcontract Report NREL/SR-500-38075. See <http://www.windpoweringamerica.gov/sips.asp>



## 3.0 THE NEW YORK POWER MARKET

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Electric power generated from wind energy at the Arkwright Summit wind farm will be sold into the New York ISO power market. The plants used in this analysis are shown in Figure 1. In this analysis, the focus is on the upstate power market area. The import and export of power is not considered because in a relatively large power market area such as Upstate New York, relatively little power is imported or exported. Furthermore, the wind farm will typically displace generation on the margin by the same type of variably-dispatched fossil fuel units that are included in this analysis. As a result, there will be very little difference in average avoided emission rates. All displaced generation by wind is expected to occur primarily in the upstate power market area shown and at the plants listed in Table 1. As there is currently transmission capacity for the project, any potential future transmission constraints are not considered in this analysis. These simplifying assumptions are unlikely to significantly affect the results at this level and for the purposes of the report.

## 4.0 AVOIDED EMISSIONS IN POWER MARKETS

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Wind power has zero direct air emissions and will create reduced air emissions from other electrical generators. Wind creates these reductions because of the way the electric power system works. Wind is a “must-run” power source. Once it is installed, wind generation has zero fuel costs and very low operating costs. When wind energy is available, it will displace generation at facilities with higher operating costs and which can be variably dispatched. These are typically fossil-fueled units, as they are in Western New York. The emissions from those fossil-fuel generating units are then avoided. Wind almost never displaces nuclear power, hydroelectric power, or other renewable energy sources, because like wind, these units have low operating costs. Additionally, nuclear power and hydroelectric power are normally fully dispatched and are rarely able to respond to rapidly-changing and unpredictable changes in load.

The electrical generation that is displaced by wind power also varies by time of day and season and with the mix of fossil-fueled generation. In the New York power market area, this mix includes coal, oil, and natural gas. The avoided emissions from all the major pollutants tend to be higher in areas with more coal-fired generation and lower where natural gas is the dominant fuel. Efficiency and the pollution control system performance of fossil-fueled units also are important.

Under some limited circumstance, where there are transmission constraints and at times when hydropower is a large part of the total generation, wind power may curtail hydro-electric power generation. This situation is very rare and will not likely occur in western New York. This displacement could result in higher or lower emissions in any short time period but will have very little effect on annual average avoided emission from the wind farm.

## 5.0 ANALYTICAL METHODOLOGY

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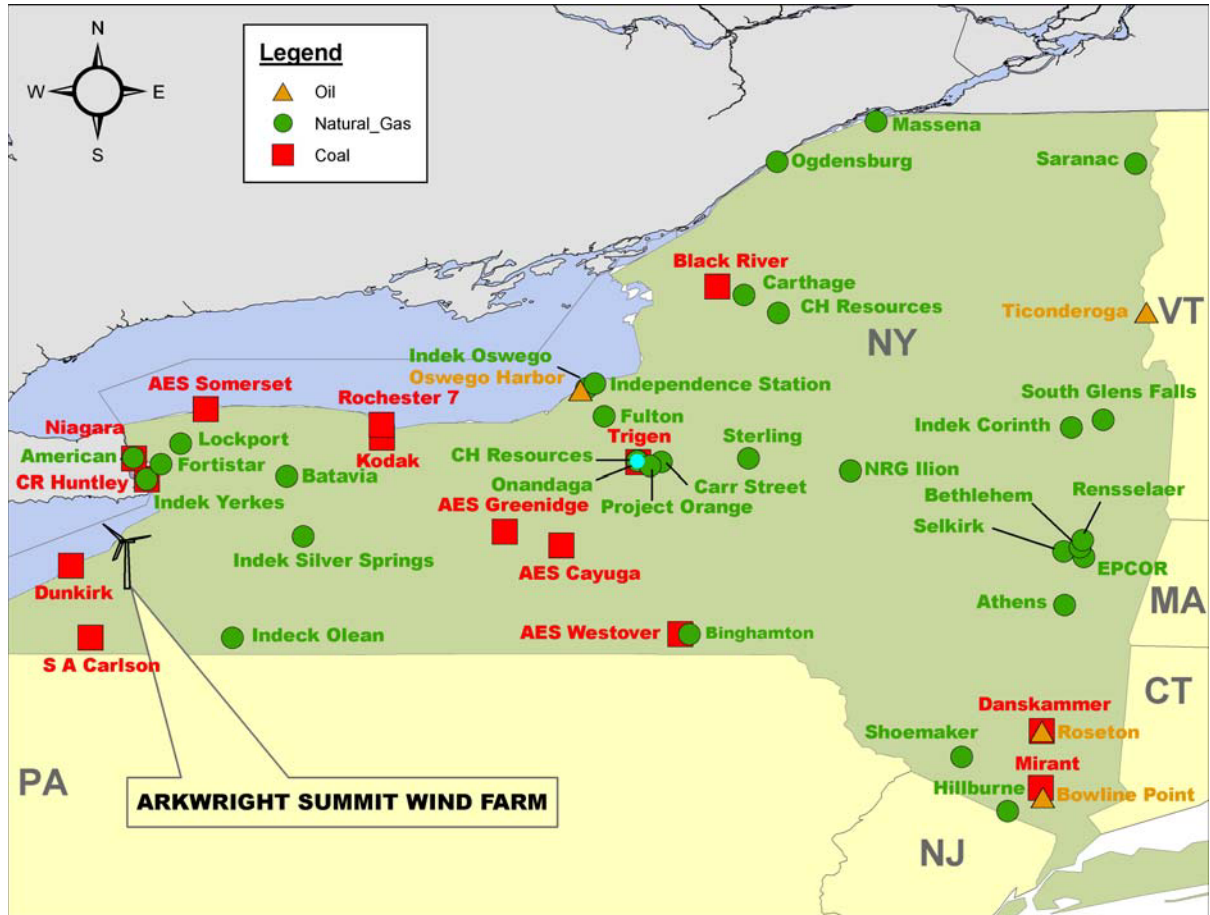
This analysis evaluates the average avoided emissions that will occur when electric generation from the Arkwright Summit Wind Farm is sold into the power grid. This avoided emissions analysis is



based on projected generation from the Arkwright Summit Wind Farm and on EPA emissions data for the fossil-fueled power plants for the year 2005.<sup>1</sup>

The methodology used in this report is the time-matched marginal avoided emissions analysis using an incremental generation-weighted average of the emissions of plants that are variably dispatched to meet changing demand. The analysis matches the projected hour-by-hour generation of the Arkwright Summit Wind Farm with the actual hourly generation of fossil-fueled units in the ISO New York power market area shown in Figure 1.

Figure 1. Map of the Location of the Arkwright Summit Wind Farm and Fossil Fuel Plants in the Analysis



<sup>1</sup> The most recent year for which complete and consistent validated data are available from the EPA is 2005. Changes since 2005 are not expected to have a significant effect on this avoided emissions analysis.



Table 1: List of Major Variably Dispatched Fossil-Fueled Plants in the Analysis<sup>1, 2</sup>

Name	Name
AES Cayuga	Indeck Silver Springs Energy Center
AES Greenidge LLC	Indeck Yerkes Energy Center
AES Somerset LLC	Independence Station
AES Westover	Kodak Park Site
American Ref-Fuel of Niagara	Lockport Energy Associates LP
Athens Generating Plant	Lovett
Batavia Power Plant	Massena Power Plant
Bethlehem Energy Center	Niagara Generating Facility
Binghamton Cogen	North East Cogeneration Plant
Black River Generation	NRG Iliion LP
Bowline Point	Ogdensburg Power
C R Huntley Generating Station	Onondaga Cogeneration
Carr Street Generating Station	Oswego Harbor Power
Carthage Energy LLC	Project Orange Associates LP
CH Resources Beaver Falls	Rensselaer Cogen
CH Resources Syracuse	Rochester 7
Danskammer Generating Station	Roseton Generating Station
Dunkirk Generating Station	S A Carlson
EPCOR, Castleton Facility	Saranac Facility
Fortistar North Tonawanda	Selkirk Cogen
Fulton Cogeneration Associates	Shoemaker
Hillburn	South Glens Falls Energy LLC
Indeck Corinth Energy Center	Sterling Power Plant
Indeck Olean Energy Center	Ticonderoga Mill
Indeck Oswego Energy Center	Trigen Syracuse Energy

Note: The names in Table 1 are those in the EPA CEM database. These plants may also be known by other names.

The projected hourly wind generation data used in the analysis was provided by Arkwright Summit Wind Farm based on meteorological data that was scaled to reflect generation from 44 wind turbines. The data are for the hourly electric generation for a recent one-year period based on the wind data collected near the Arkwright Summit site. Missing data (approximately one weeks' worth in total) from that record were supplemented with a correlation model using wind data from other sites.

The expected hourly generation estimates for the wind farm are matched by RSG's database model against the hourly generation of the variably dispatched fossil fuel units at plants shown in Figure 1 and Table 1. This information forms the basis for matching and creating the set of generation units in each hour which can be displaced. This analysis identifies the marginal generation units which are dispatched to follow the changing load on the system in this part of the grid. The hourly generation records for the fossil fuel plants have been calculated by using the hourly carbon dioxide (CO<sub>2</sub>) emissions from the continuous emissions monitors (CEMs) and the generation average CO<sub>2</sub> emission rates per MWh for each facility as reported to the U.S. Environmental Protection Agency (EPA).<sup>2</sup> The hourly emission rates for nitrogen oxides (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>) are taken from the CEM data reported to EPA by the owners and operators of the fossil-fueled power

<sup>1</sup> Currently, plans are underway to upgrade the Dunkirk NRG coal-generating facility and other coal facilities, but since these projects have not yet been completed, no actual data is available on the new emissions.

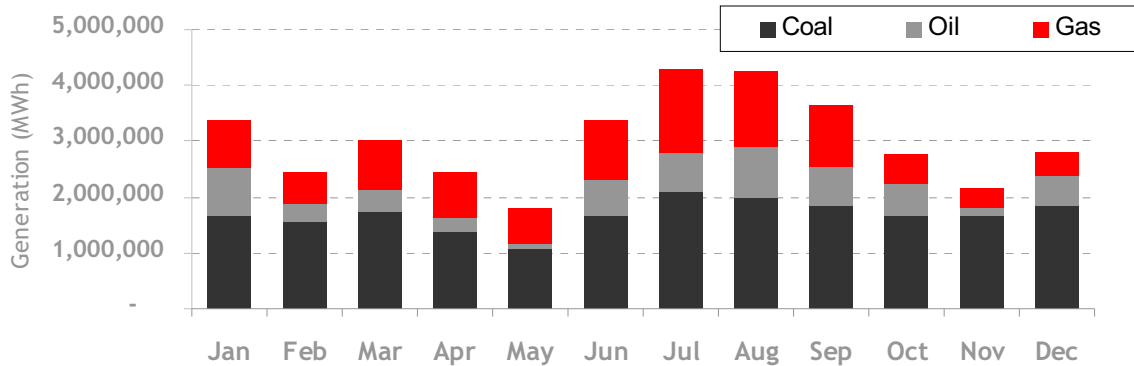
<sup>2</sup> U.S. Environmental Protection Agency, Continuous Emission Monitoring Database, Office of Air and Radiation, "Acid Rain Hourly Emissions Data 2004," CD 2 disks 02/07/06 Distributed by National Technical Information Service, Springfield VA.





plants. The average NO<sub>x</sub>, SO<sub>2</sub> and CO<sub>2</sub> avoided emission rates are then based on a weighted average of the emissions at fossil-fueled units, which are matched at each hour when wind generation occurs. The weighting is based on each generation unit's contribution to the changing load. The variably-dispatched fossil-fueled generation in New York is dominated by gas and coal. This can be seen in Figure 2, which shows the monthly generation of fossil fueled units in Upstate New York by fuel type from the dataset.

Figure 2: Monthly Generation by Fossil-Fuel Type in Upstate New York (2005 Data)

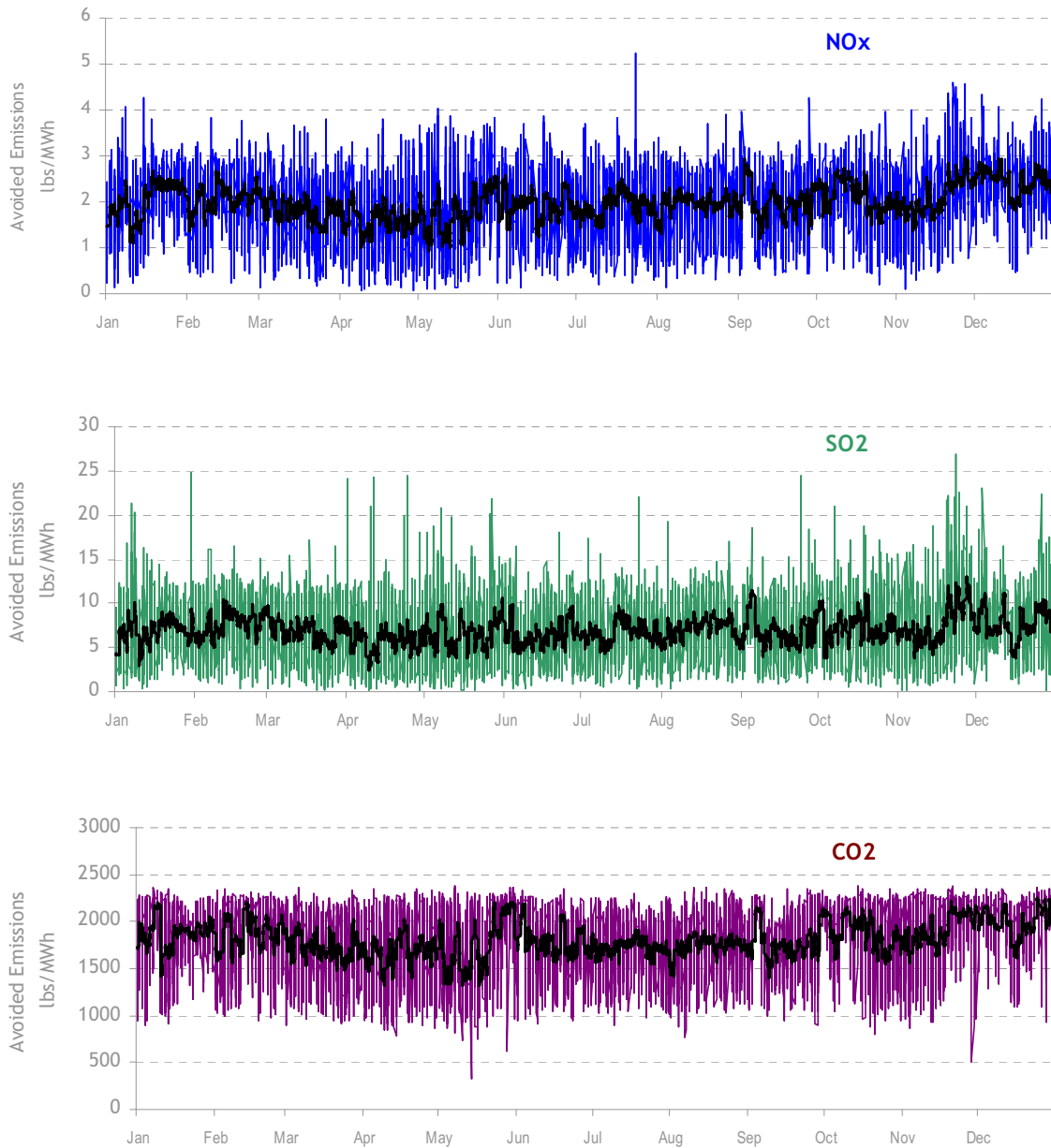


## 6.0 RESULTS

The annual avoided emission can be expressed in terms of the average rate in lb/MWh and as total annual emissions for the plant. Table 2 shows the average annual avoided emission rates for NO<sub>x</sub>, SO<sub>2</sub> and CO<sub>2</sub> in lb/MWh resulting from the wind power generation at the Arkwright Summit Wind Farm. Figure 3 shows the hourly average avoided emission rates for NO<sub>x</sub>, SO<sub>2</sub> and CO<sub>2</sub> for one year.



Figure 3: Average Hourly Avoided Emission Rates from Arkwright Summit Wind Farm (2005 emissions data<sup>1</sup>)



In addition to the avoided emissions of NO<sub>x</sub>, SO<sub>2</sub> and CO<sub>2</sub> shown in Table 2 and Figure 3, the Arkwright Summit Wind Farm will also result in significant avoided emissions of fine particulate matter, mercury, volatile organic compounds, carbon monoxide and other toxic air pollutants. All of these pollutants can have adverse public health impacts. The avoided emissions of these pollutants cannot be quantified as accurately as NO<sub>x</sub>, SO<sub>2</sub> and CO<sub>2</sub> because they are not subject to continuous monitoring requirements. However, these additional avoided emissions will in general follow the same pattern as the avoided emissions of CO<sub>2</sub>.

<sup>1</sup> The daily moving average is shown by a black line.



The results of the analysis in terms of average avoided emissions rates are provided in Table 2. These rates are likely representative of the situation in 2006 through 2010. In future years, the magnitude and pattern of avoided emission rates will be similar but will be affected by future changes in the distribution of fossil-fueled generation in New York and adjoining power market areas.<sup>1</sup>

Table 2: Average Annual Avoided Emission Rates from Arkwright Summit Wind Farm (lbs/MWh)

	NOx	SO <sub>2</sub>	CO <sub>2</sub>
<b>Annual</b>	2.0	7.0	1,827

The total annual avoided emissions from the operation of the Arkwright Summit Wind Farm are shown in Table 3 and the monthly avoided emissions are shown in Figure 4. This figure highlights the fact that wind creates the greatest amount of avoided emissions in the fall, winter, and spring. This is because wind potential is weakest in the summer months. In addition, NOx emissions are limited in the summer months due to the NOx allowance cap during the ozone season. This divergence between the ozone season and annual NOx emissions may change somewhat because annual NOx emissions reductions are required under the Clean Air Interstate Rule (CAIR) starting in 2009.<sup>2</sup>

Table 3: Total Annual Avoided Emissions from Arkwright Summit Wind Farm (Tons per year)

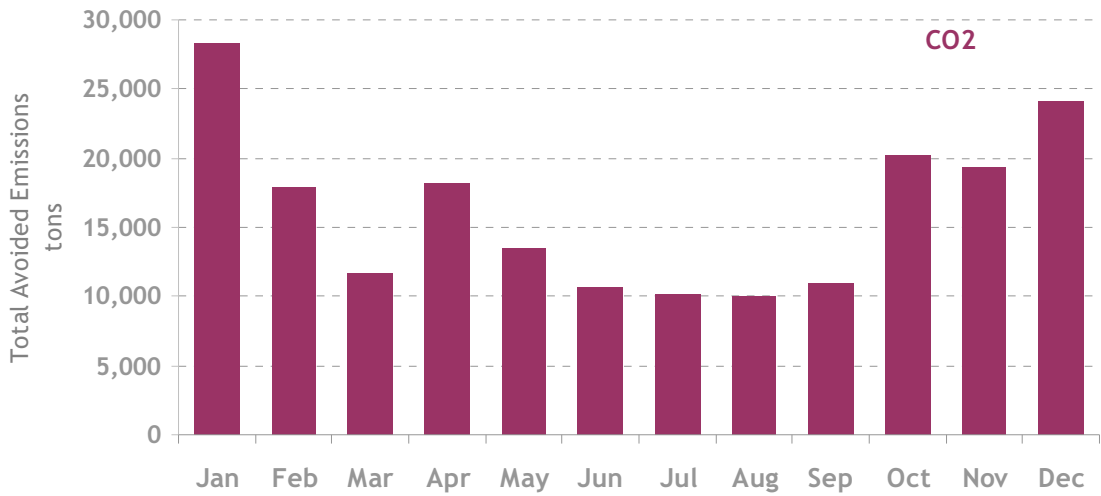
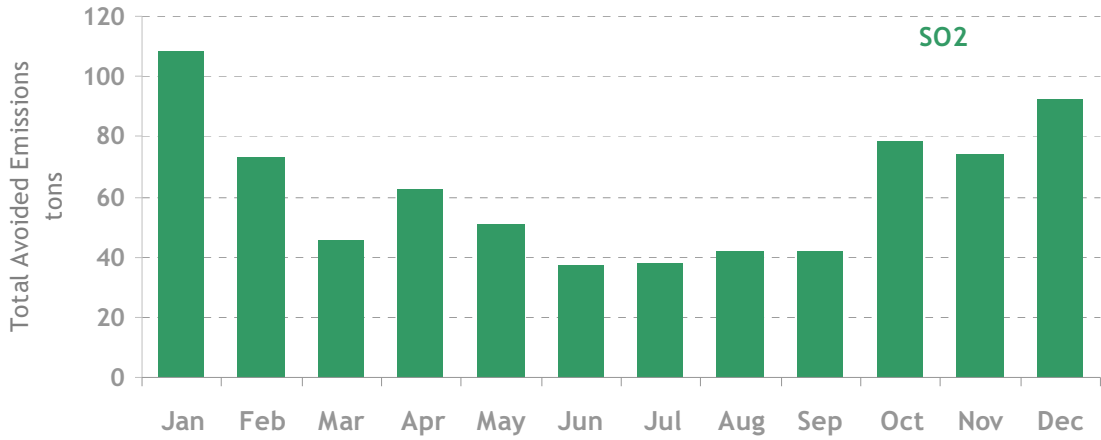
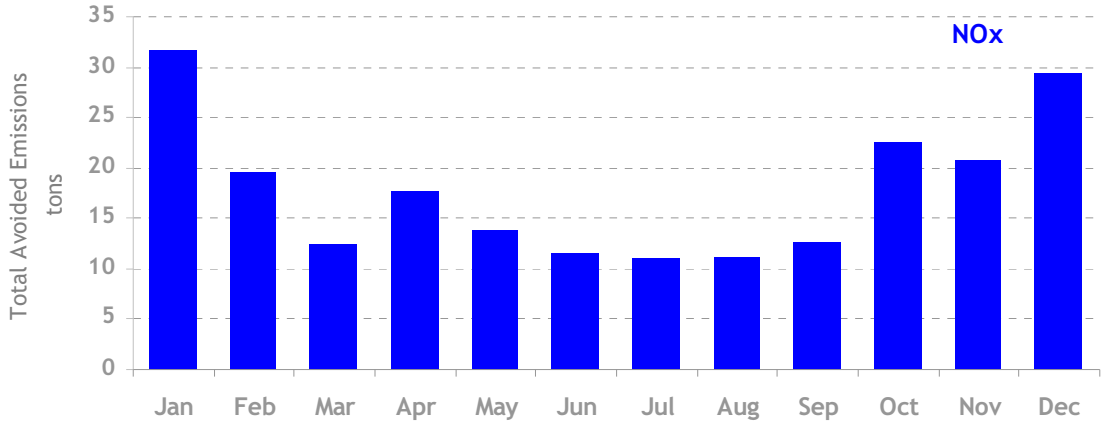
	NOx	SO <sub>2</sub>	CO <sub>2</sub>
<b>Annual</b>	214	746	195,183

<sup>1</sup> 70 Fed. Reg. 25162 (May 12, 2005).

<sup>2</sup> 70 Fed. Reg. 25162 (May 12, 2005).



Figure 4: Average Monthly Total Avoided Emission from Arkwright Summit Wind Farm



## 7.0 COMPARISONS

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The average avoided emission rates for SO<sub>2</sub>, NO<sub>x</sub>, and CO<sub>2</sub> shown in Table 2 can be compared with emission rates for the entire NYISO power market area derived from EPA eGRID non base-load emission rates. The eGRID annual 2005 non base-load emission rates for ISO New York are 0.54 lb/MWh for NO<sub>x</sub>, 2.03 lb/MWh for SO<sub>2</sub> and 1,102 lb/MWh for CO<sub>2</sub>.<sup>1</sup> The eGRID non base-load emission rates for upstate New York are generally comparable, although slightly lower than in this analysis. The reason for the different avoided emission rates is primarily due to differences in methodology. The eGrid database simply averages the emission rates of all non base-load plants. It does not identify the marginal plants, nor does it calculate the marginal emission rates. It does not take into consideration the time matching of wind generation. The eGRID database approach is much less accurate than the model used in this report. However, there is a broad agreement on emission rates.

## 8.0 EFFECT OF CAP AND TRADE PROGRAMS

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The avoided emissions estimates from the operation of the Arkwright Summit Wind Farm are those that may reasonably be expected to take place through the operation of the New York power grid. Although it is clear that wind energy reduces the energy production of fossil fuel-fired generation at individual power plants or units and reduces actual emissions at those plants, the impact of wind generation on total overall emissions is more complicated for pollutants that are subject to regulation under emissions caps and trading programs.

With or without a cap and trade program, the effect of wind power generation is to avoid emissions from displaced generation at fossil fueled plants. In the case of cap and traded pollutants, the emissions allowances that are not used as a result of the wind generation may be banked for future use, or traded to another generator within the program. Therefore, the emissions avoided may be replaced by the fossil-fueled generator at another time, or through surplus allowance trading, to another plant at another place. However, the overall emissions rate throughout the regional grid will be reduced, even if the cap on fossil-fueled generators is not reduced. An additional benefit is that as the avoided emissions from wind or other renewable energy technologies increase on the grid, the overall cost of reducing the emissions cap decreases.

In the case of NO<sub>x</sub> and SO<sub>2</sub>, which are subject to cap and trade regulatory programs, the actual emissions reductions can only be credited for air quality regulatory purposes by the allocation and retirement of allowances in accordance with guidelines issued by the EPA.<sup>2</sup> In the case of CO<sub>2</sub>, New York and other northeastern states that are part of the Regional Greenhouse Gas Initiative (RGGI) have implemented a limited CO<sub>2</sub> emissions cap regulation. EPA's Clean Air Mercury Rule, providing cap and trade requirements for mercury emissions from electric generating units, was struck down by the D.C. Circuit Court of Appeals.<sup>3</sup> Therefore, avoided mercury emissions are unaffected by cap and trade regulation. In the future, allowance allocation and retirement for NO<sub>x</sub> will depend on how EPA and New York implement regulations concerning the EPA's Clean Air Interstate Rule or

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<sup>1</sup> US EPA eGRID Summary Data <http://www.epa.gov>

<sup>2</sup> U.S. Environmental Protection Agency, "Guidance on State Implementation Plan (SIP) Credits for Emission Reduction Measures from Electric-sector Energy Efficiency and Renewable Energy Measures," August 2004.

<sup>3</sup> State of New Jersey, et al., v. Environmental Protection Agency, No. 05-1097, slip op. (D.C. Cir. Feb. 8, 2008). The court found that EPA had violated the requirements of the Clean Air Act by removing electric generating units from the list of sources regulated under Section 112 of the Act without making the required findings. As a result, the court also struck down EPA's Clean Air Mercury Rule.



replacement regulations.<sup>1</sup> For CO<sub>2</sub>, this will depend on how the states and the federal government manage greenhouse gases.

## 9.0 CONCLUSIONS

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Significant avoided air emissions may be expected to result from electric power generation by the Arkwright Summit Wind Farm. The avoided emissions will include NO<sub>x</sub>, SO<sub>2</sub> and CO<sub>2</sub>, which have been quantified. In addition, there will be significant avoided emissions of fine particulate matter, mercury, volatile organic compounds, carbon monoxide, and other toxic air pollutants. The avoidance of emissions of all these pollutants has public health benefits and contributes to the mitigation of global warming. The avoided emissions from the wind farm will also reduce the overall cost of lowering the cap on NO<sub>x</sub> and SO<sub>2</sub>, and in the future the cost of limiting greenhouse gas emissions in the US.

The avoided emissions will also have specific environmental benefits. The avoidance of NO<sub>x</sub> emissions will contribute to reducing the occurrence of high ozone days in New York, New England and Eastern Canada. This, coupled with reductions in SO<sub>2</sub>, will reduce the impacts of acid precipitation on regional forests and lakes. The avoidance of fine particulate matter, NO<sub>x</sub>, and SO<sub>2</sub> will contribute to reducing regional haze and respiratory health risks. Lastly, avoided mercury emissions will contribute to efforts to reduce human exposure to environmental mercury, a compound that is both directly dangerous to human health and indirectly dangerous through the consumption of fish.

Most significantly, the reduction in CO<sub>2</sub> emissions will contribute to the mitigation of the potentially severe impact of global warming on the climate of New York and the world. To put the impacts in perspective, the greenhouse gas avoided emissions benefits of the Arkwright Summit Wind Farm are equivalent to taking approximately 36,347 cars off the road.<sup>2</sup> At the present time, the development of commercial wind power is one of the more cost-effective means of reducing carbon dioxide emissions and therefore of mitigating the pending climate crisis. This important environmental benefit of avoided emissions should be considered in balancing other impacts of the Arkwright Summit Wind Farm.

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<sup>1</sup> 70 Fed. Reg. 25162 (May 12, 2005). The Clean Air Interstate Rule is in abeyance as the result of a US court case. New York has provision for 10% of the total NO<sub>x</sub> allowance allocation to be set-aside for renewable energy.

<sup>2</sup> Based on an average consumption of 554 gal/year for passenger cars and 19.4 pounds of CO<sub>2</sub> per gallon. Source: [http://www.bts.gov/publications/national\\_transportation\\_statistics/csv/table\\_04\\_11.csv](http://www.bts.gov/publications/national_transportation_statistics/csv/table_04_11.csv)

