# $NO_x$ and $SO_2$ Secondary Impact Analysis

TAYLORVILLE ENERGY CENTER

**August 2011**

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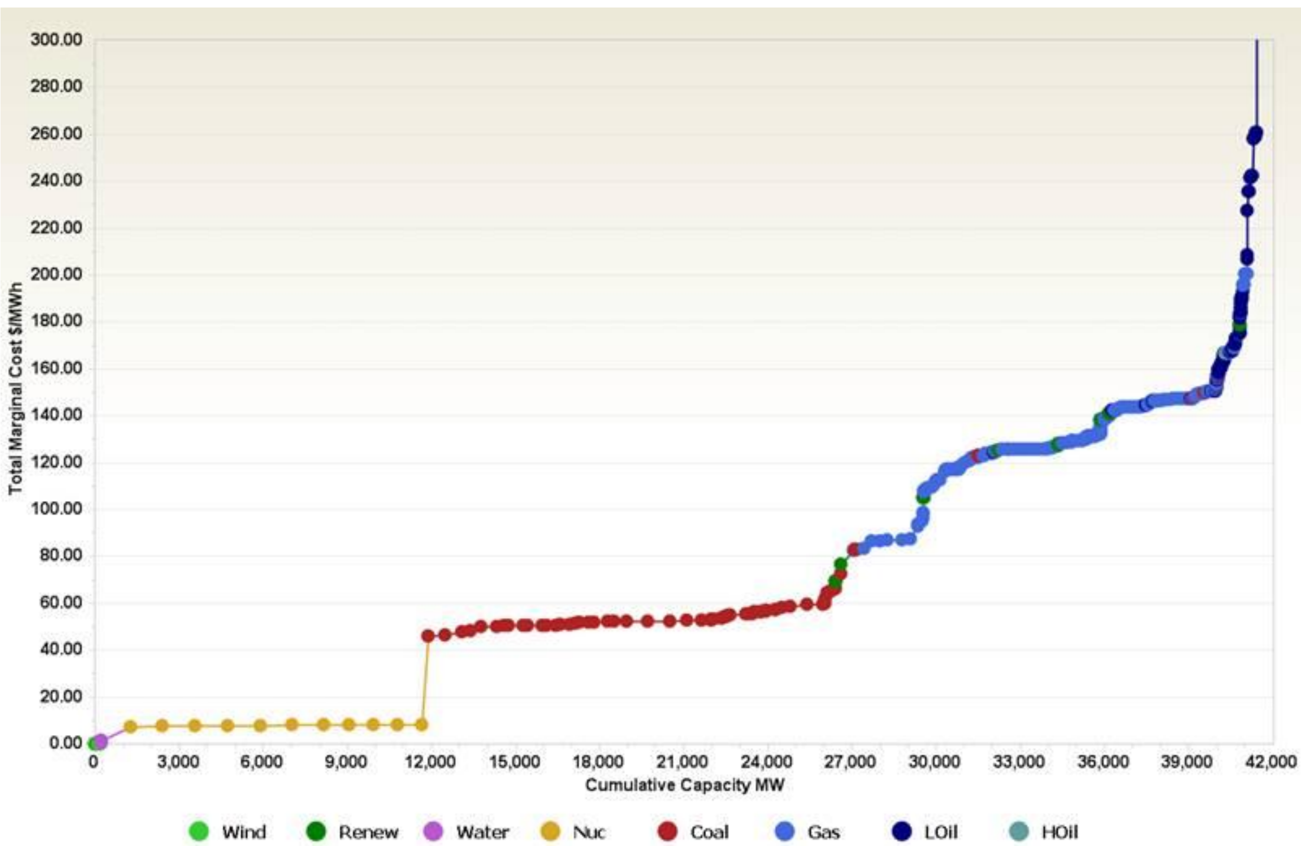
# Taylorville Energy Center

## Executive Summary

To accurately determine the $NO_x$ and $SO_2$ impact of the Taylorville Energy Center (TEC), the project cannot be viewed in isolation. The addition of the TEC to the power supply mix will cause older, less efficient generating units to dispatch less frequently, resulting in lower $NO_x$ and $SO_2$ emissions. The analysis discussed below models the impact that the operation of the TEC would have on $NO_x$ and $SO_2$ emissions in the surrounding area in the year 2017. It shows that there would be a **net $NO_x$ and $SO_2$ reduction of 10,890 metric tons** in that year as a result of the TEC.

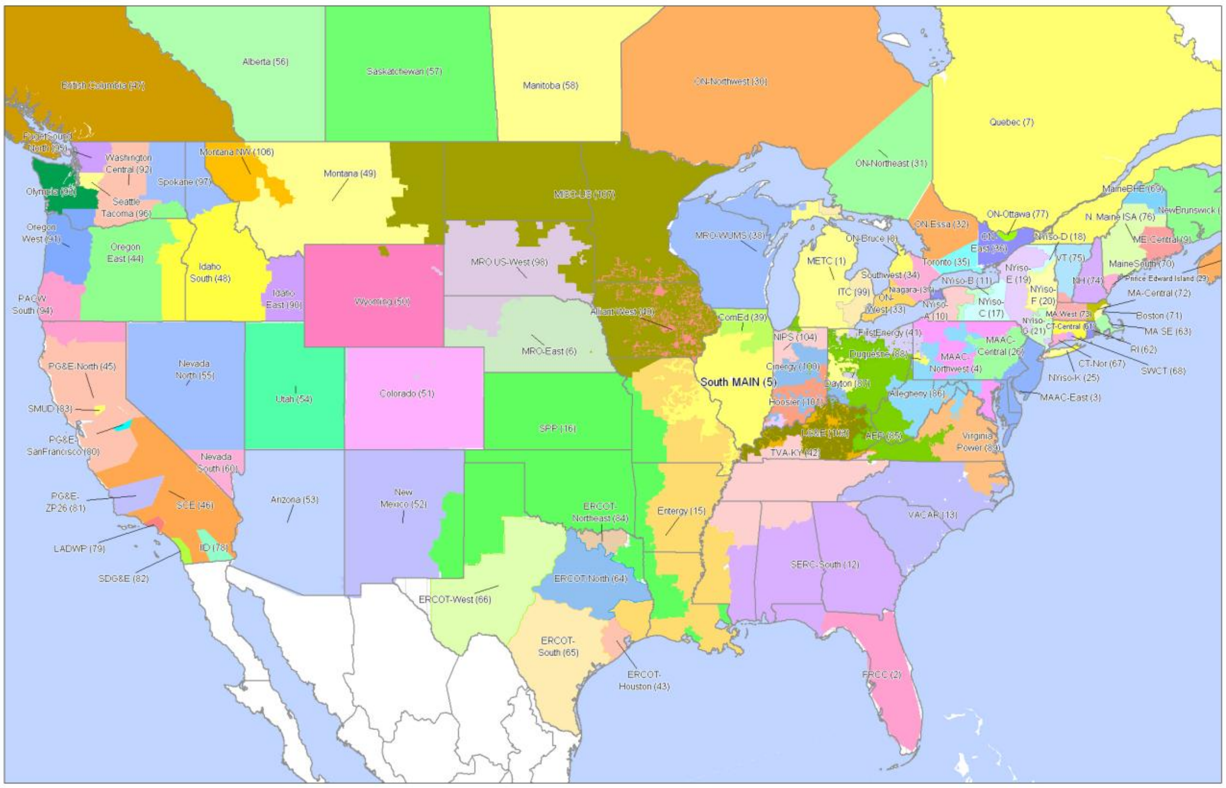
## Dispatch Analysis

In order to support its power trading business, project development business and energy asset acquisition business, Tenaska uses a fundamental dispatch model called Aurora, which is commercially available from EPIS, Inc. Aurora and similar models are used by many participants in the energy sector. Dispatch models use information on the generating units in each of a number of zones to build up a local supply curve for electricity, like the one shown in the figure below. The supply curve is then compared with the forecasted electricity demand in that zone to determine the power price. There are potential transfers of electricity between zones that make the solution more complicated, and the specific operating constraints of different types of units must also be met when building the supply curve from hour to hour. In general, the model simply solves for the least-cost clearing price for power in each zone. The prices are determined on an hourly basis, and the results are typically rolled up to a monthly or annual level.



The Aurora model is packaged with an input database containing information on all of the generating units in North America, as well as information on regional demand and the transmission links between zones. Tenaska uses additional data sources and its proprietary market information to improve the data within this default database.

The Aurora model topology includes 108 zones across the U.S. and Canada as shown in the figure below. The TEC will be located in southern Illinois with electrical interconnection to northern Illinois (ComEd zone). This zone is well connected to many surrounding zones, and the model solution includes the potential transfer of electricity between northern Illinois, southern Illinois (South MAIN zone), and other areas of the South and Midwest. For the analysis described here, these transfers impact the local energy requirements in northern Illinois, but the secondary effects of the TEC's operation are measured only by changes in the operation of generating units in the South MAIN and ComEd zones.




Using this approach and topology, Tenaska determined the impact that the operation of the TEC would have on $NO_x$ and $SO_2$ emissions in the surrounding area. The main idea is that although the TEC will emit $NO_x$ and $SO_2$ from its operations, it displaces the need to run other older, less-efficient coal-, gas-, and oil-fired generating units which have higher $NO_x$ and $SO_2$ emission rates. These older, less-efficient plants are pushed farther out on the supply curve and run less often. Thus the net $NO_x$ and $SO_2$ emissions attributable to the TEC within the interconnected grid system are less than the emissions of the plant when viewed in isolation, and this results in an understatement of estimated $NO_x$ and $SO_2$ emissions reductions.

This synoptic approach affords a greater view of the whole impact of the facility, and is conceptually consistent with the methodology used for the Clean Development Mechanism adopted by the U.N. Framework Convention on Climate Change. It should be noted that the Clean Development Mechanism itself is governed by a complicated set of protocols which Tenaska did not attempt to replicate in this analysis, but the intent and overall design is the same.

The details of the analysis are as follows:

- An hourly model forecast for the calendar year 2017 was completed.
- For each hour modeled, it is possible to identify the output from the TEC, and the marginal unit required to serve load in Illinois. The marginal unit is determined by identifying the last megawatt required to serve load in both the South MAIN and ComEd zones as well as the direction of power flow to and from South MAIN and ComEd. When power is flowing from ComEd to South MAIN, the unit in ComEd is the marginal unit in Illinois, otherwise it is the unit in South MAIN.
- The marginal generating unit has a known fuel type (most often coal or gas), a known $SO_2$ and $NO_x$ emission rate, and a known heat rate (the property of the unit that measures its efficiency in terms of how much fuel is burned in any given hour to produce one megawatt of electricity).
- When the TEC is operating, it displaces megawatts that would otherwise need to be produced by a generator at a position just beyond the location of the marginal unit on the supply curve. Tenaska's method conservatively assumes that the properties of the displaced unit are the same as the modeled marginal unit.
- Thus, knowing the output from the TEC and the properties of the marginal unit, the amount of $NO_x$ and $SO_2$ displaced in any hour can be calculated as

$$\text{Displaced } SO_2 \text{ or } NO_x \text{ (tons)} = \frac{\text{Taylorville Output (MW)}}{} * \frac{\text{Marginal Unit Heat Rate (MMBtu)}}{\text{(MW)}} * \frac{\text{Marginal Unit } SO_2 \text{ or } NO_x \text{ Rate (lbs)}}{\text{(MMBtu)}} * \frac{1 \text{ ton}}{2000 \text{ (lbs)}}$$

- The total $NO_x$ and $SO_2$ displaced by the TEC's operation is simply the sum of this displacement calculated for each hour modeled.
- Similarly, the total $NO_x$ and $SO_2$ emissions from the TEC itself can be totaled from the hourly model output, and this total can be compared to the amount of $NO_x$ and $SO_2$ displaced by the unit's operation.

**Model Results**

A summary of the model results for the TEC is shown in the following table. Over the course of the year, Tenaska projects that the unit will operate at a 78%[1] capacity factor and will emit roughly 167 tons of $NO_x$ and 484 tons of $SO_2$[2]. However, at the same time the unit prevents about 2,644 tons of $NO_x$ and 8,246 tons of $SO_2$ from being emitted by other facilities, either older and less-efficient gas generating units or coal units with higher $NO_x$ and $SO_2$ emission rates. The TEC is particularly effective at displacing coal generation because the must-run portion of the facility that operates around-the-clock to support the coal gasification process also produces approximately 285 MW of additional energy that displaces coal in the off peak hours. The must-run portion of the plant operates even in off-peak hours when coal units are marginal.

[1] The 78% capacity factor is based on the assumption that Taylorville will be self supplying the auxiliary loads associated with the SNG Island and $CO_2$ compression, which would reduce the net output to be exported to the grid to be approximately 602 MW. If it is determined to supply these auxiliary loads with purchased power, the net output of the Facility is expected to be somewhat over 760 MW, and the capacity factor would increase significantly since all of the increase would come from the 1x1 must run portion of the facility. However, this should not affect the net emissions reduction analysis because, if TEC is not supplying he referenced auxiliary loads, other units in the market will be operated to do so.

[2] NOx and SO2 emissions from the TEC assume maximum emission rates. Actual emissions are likely to be lower.

| Taylorville Energy Center | |
| --- | --- |
| Projected Operations for 2017 | |
| Capacity Factor | 78% |
| Total $SO_2$ Emissions | 484 Tons |
| Total $SO_2$ Displacement | 8730 Tons |
| Net $SO_2$ Impact | -8246 Tons |
| Total $NO_x$ Emissions | 167 Tons |
| Total $NO_x$ Displacement | 2811 Tons |
| Net $NO_x$ Impact | -2644 Tons |
| Percent of Time Displacing Coal | 60% |
| Percent of Time Displacing Gas | 40% |

Appendix A shows the 20 units (or groups of units) which were projected to be displaced most often over the course of the year 2017.

A similar analysis was completed for a standard gas-fired combined-cycle unit, a solar photovoltaic unit and a wind unit, each with the same maximum operating capacity as the TEC.[3] The intent was to determine how effective the TEC is at reducing the total $NO_x$ and $SO_2$ emissions in the Illinois area compared to other technologies. Results are shown in the table below.

[3] The standard combined-cycle unit was modeled with a 6,800 Btu/kWh heat rate and a variable operating cost of $3.32/MWh. Typical start-up costs for a 7FA-type combined-cycle unit were included, the same as other combined-cycle units in the model. Fifteen percent of the maximum output is in the form of duct firing with a heat rate of 9,100 Btu/kWh.

| Taylorville and Alternate Technologies | | | | |
|---|---|---|---|---|
| Projected Operations for 2017 | | | | |
| | **Taylorville** | **Combined-Cycle** | **Solar** | **Wind** |
| Capacity Factor | 78% | 11% | 22% | 30% |
| Total $SO_2$ Emissions | 484 Tons | 2 Tons | 0 Tons | 0 Tons |
| Total $SO_2$ Displacement | 8730 Tons | 516 Tons | 2598 Tons | 3704 Tons |
| Net $SO_2$ Impact | -8246 Tons | -515 Tons | -2598 Tons | -3704 Tons |
| Total $NO_x$ Emissions | 167 Tons | 13 Tons | 0 Tons | 0 Tons |
| Total $NO_x$ Displacement | 2811 Tons | 241 Tons | 844 Tons | 1100 Tons |
| Net $NO_x$ Impact | -2644 Tons | -228 Tons | -844 Tons | -1100 Tons |
| Percent of Time Displacing Coal | 60% | 16% | 55% | 63% |
| Percent of Time Displacing Gas | 40% | 84% | 45% | 37% |

The TEC is more effective at reducing $NO_x$ and $SO_2$ emissions than a standard combined-cycle unit because it runs more often. The TEC is modeled as two segments. First, there is a must-run component of the plant that runs at a 92% capacity factor, in order to support the expected operations of the gasification facility. This segment is associated with the plant operating with only one of its two combustion turbines. The second and larger segment is modeled as the incremental gas burn required to move the unit from its minimum output to its maximum output. This occurs during all hours from June 15 through September 15, all on-peak hours the remainder of the year and if the hourly price in the Aurora model is greater than the incremental cost of increasing the output during all other off-peak hours. This dispatch protocol led to a 65% capacity factor for the second segment. The weighted average of the two segments leads to a 78% capacity factor for the unit.

In contrast, the standard combined-cycle unit is not required to run at minimum output in all hours of the year, and will only operate as it is economic to do so. The model contains commitment logic to determine the best pattern of minimum output and maximum output to create the most value for the plant as hourly prices change throughout the day. In this study, an 11% capacity factor was determined for the standard combined-cycle unit. Thus, the additional run time associated with supporting the gasification process is in the end a benefit for the $NO_x$ and $SO_2$ emissions in the area. Part of the TEC is always operating, even in overnight hours when higher-emitting coal plants are setting the price and standard gas combined-cycle units are not profitable to operate. This enhances the $NO_x$ and $SO_2$ displacement that the TEC achieves.

The TEC is more effective at reducing net $NO_x$ and $SO_2$ emissions when compared to a solar photovoltaic generation facility of equal capacity. The energy produced by the solar facility versus the energy produced by the TEC is an important factor. While the maximum solar output was modeled the same as the TEC, at 602 MW, it is necessary for the total energy produced by the solar facility to reflect the inherent variability of the available solar radiation. In this study, a 22% capacity factor was modeled, which is based on the potential solar radiation in Illinois. In addition, the solar generation facility will only generate during the day, when is it less likely to be displacing higher emitting coal plants.

The TEC is also more effective at reducing net $NO_x$ and $SO_2$ emissions when compared to a wind generation facility of equal capacity. Again, the energy produced by the wind facility versus the energy produced by the TEC is an important factor. While the maximum wind output was modeled the same as the TEC, at 602 MW, it is necessary for the total energy produced by the wind facility to reflect the inherent variability of wind. In this study, a 30% capacity factor was modeled, which is typical of high-end wind turbines in the Midwest.

Since the wind generation facility displaces other $NO_x$ and $SO_2$ emitting sources only when the wind is blowing, it is possible that the actual $NO_x$ and $SO_2$ displacement for the wind generation facility could be significantly different than what has been modeled due to the actual total generation as well as the generation profile.

**Summary**

These analyses demonstrate the importance of viewing the change in emissions of the entire system, rather than focusing on the emissions from one plant in isolation. It is clear that when viewed in this context, the operations of the TEC will indeed improve the $NO_x$ and $SO_2$ emissions in the surrounding regions by introducing a supply of low-cost, clean-coal generation.

## Appendix A

For each hour modeled for the Taylorville $NO_x$ and $SO_2$ secondary impact analysis, it is possible to identify the marginal unit required to serve load in Illinois. The marginal unit is determined by identifying the last megawatt required to serve load in both the South MAIN and ComEd areas as well as the direction of power flow to and from South MAIN and ComEd. When power is flowing from ComEd to South MAIN, the unit in ComEd is the marginal unit in Illinois; otherwise it is the unit in South MAIN.

The list below identifies the 20 units (or group of units) in Illinois which were projected to be marginal most often in 2017.

| Displaced Unit | % of Time Marginal | County | State | Fuel | Commercial Online Year |
|---|---|---|---|---|---|
| | | | | | |
| Crawford (IL) 7 | 18.01% | Cook | IL | Coal | 1958 |
| Small Unit Other 13000 39* | 7.61% | | | | |
| Powerton 5 | 6.30% | Tazewell | IL | Coal | 1972 |
| Small Unit NI-Gas 9000 39* | 4.83% | | | | |
| Cordova Energy Center CC | 4.43% | Rock Island | IL | Gas | 2001 |
| Will County 3 | 3.82% | Will | IL | Coal | 1957 |
| Kincaid Generation LLC 1 | 3.61% | Christian | IL | Coal | 1967 |
| Grand Tower CC1 | 3.45% | Jackson | IL | Gas | 2001 |
| Will County 4 | 2.84% | Will | IL | Coal | 1963 |
| Waukegan 7 | 2.45% | Lake | IL | Coal | 1958 |
| Joliet 29 8 | 2.16% | Will | IL | Coal | 1966 |
| Holland Energy Facility CC1 | 1.97% | Shelby | IL | Gas | 2002 |
| Fisk Street 19 | 1.86% | Cook | IL | Coal | 1959 |
| Dallman 2 | 1.77% | Sangamon | IL | Coal | 1972 |
| Powerton 6 | 1.44% | Tazewell | IL | Coal | 1975 |
| Crawford (IL) 8 | 1.43% | Cook | IL | Coal | 1961 |
| Kendall County Generation CC2 | 1.18% | Kendall | IL | Gas | 2002 |
| Kincaid Generation LLC 2 | 1.10% | Christian | IL | Coal | 1968 |
| Rockford II Energy Center GT3 | 0.96% | Winnebago | IL | Gas | 2002 |
| Nelson Energy Center CC2 | 0.91% | Lee | IL | Gas | 2010 |
| Other | 27.87% | | | | |

*The "Small Units" are located in Northern Illinois
** While physically located just across the state line in Indiana, the State Line Energy facility is located in the Commonwealth Edison control area and is modeled as such in Aurora