Analysis of Ontario's Electricity System

Introduction

This is a case study of relevance to any country, state or province and will review a number of considerations with respect to wind power. It uses Ontario to illustrate the effects of introducing industrial wind power into an electricity system. The net effect is to increase both natural gas consumption and CO_2 emissions by more than 15 per cent over the alternative of not including wind power in the electricity generation mix.

It is also a replacement for earlier pages and articles *CO_2 Emissions in Ontario's Electricity System*. The previous article which contained additional detail can be accessed in the *Archive* page.

Summary

Section 1 – This section sets the stage by showing the installed capacities for Ontario in 2008 and 2015 and the projected electricity production by plant type. Two scenarios are provided for comparison: the OPA plan from the Integrated Power Supply Plan; and the author's, which is a variation on this plan. The main difference between the two is that the author's projects a higher level of conservation and less gas and nuclear production. An important note is that the OPA scenario for 2015 projects 10,000,000 MWh more electricity production than required.

Section 2 – This describes the reasons for the need for wind shadowing backup to mirror the intermittent, volatile and unreliable nature of wind power. This backup is not the same as: normal electricity system reserves, which are required to provide for scheduled and unscheduled plant outages and extreme weather conditions (unusually hot summers and cold winters); or spinning reserves, which are maintained online to provide for unexpected fluctuations in demand, and which are small and infrequent compared to wind's variations. What is evident is that essentially 100 per cent of the installed wind capacity must be constantly and, largely, quickly available. This is further illustrated in the articles *Germany, A Case Study,* and *Wind Power Is Redundant*.

Section 3 – This provides an explanation of the considerations surrounding wind shadowing/backup, which in Ontario's case (as in most) will largely be gas plants.

Section 4 – A description of the inefficiencies of gas plant production in wind shadowing/backup mode is provided.

Section 5 – The OPA projection for CO_2 emissions by 2015 at 7 million tons per year appears to be low by about 5 million tons per year. The author's model calculates it to be almost 12 million tons. This still shows a reduction from current levels of 64 per cent which is a remarkable achievement. The author's scenario (with less gas production) produces 8.5 million tons of CO_2 emissions, but there are factors which could increase this to levels approaching 12 million tons. Notable is the determination that if wind was not present at all, and gas plants just producing normally, the CO_2 emissions are reduced by more than 1 million tons per year. In other words, wind's presence adds at least 1 million tons of CO_2 emissions per year.

Section 6 – This shows details for the natural gas consumption for different scenarios, including those without any wind in the electricity mix. The author's scenario shows an 18 per cent increase with wind present.

Section 7 – A comparison between Ontario and Canada and four selected countries that have implemented large quantities of wind power is shown. The four countries are heavy users of fossil fuels for electricity generation as are any that are implementing wind power to any degree. It raises the question as to why Canada and Ontario are implementing wind power at all. The same question can be raised for any country, state or province. See the article *What It's All About* for more information.

Appendix A – This appendix contains charts showing wind plant output during periods of high wind production.

Appendix B – The author's gas consumption and CO_2 emissions calculator is described and sample outputs shown.

1. Two Scenarios

This section contains two tables, for 2008 and 2015, when the coal plants are scheduled to be removed from production. Differences are in the actual electricity produced (MWh) for a given available capacity (MW) and provide a basis for discussion of alternatives. Some rounding has been used and precise calculations from these tables will differ slightly from the values shown.

Table 1.1 – Two Scenarios for Ontario in 2008

Plant Type	Installed Capacity (MW)	OPA Scenario		Author's Scenario	
		Electricity Production (MWh)	Capacity Factor	Electricity Production (MWh)	Capacity Factor
Nuclear	11,400	83,000,000	83%	75,000,000	75%
Hydro	7,800	35,000,000	51%	35,000,000	51%
Coal	6,400	29,000,000	52%	29,000,000	52%
Gas	5,400	15,000,000	32%	7,000,000	15%
Wind	700	2,000,000	28%	2,000,000	28%
Other Renewables	100	500,000	57%	500,000	57%
Totals	31,800	164,500,000	59%	148,500,000	53%
Effect of Conservation	1,000	4,000,000	46%	7,000,000	80%
Total Without Conservation	32,800	168,500,000	59%	155,500,000	54%
OPA Target		***155,600,000***		***155,600,000***	

Comments on the scenarios for 2008:

- The CO2 emissions in 2008 is 33 million tons of CO2.
- The author's scenario takes a more conservative view of nuclear production.
- The author's scenario has less gas production and this was originally set to calibrate to the emissions level. As will be seen below there is some question about the OPA CO2 levels, especially for 2015, which was an important part of the calibration process. Gas capacity factors are typically low as shown because of its role in intermediate/peaking supply and as a reserve capacity.
- The wind capacity factor is that which is currently being experienced.
- Capacity factors for hydro are surprisingly low, which may reflect some hydro use in a peaking role and the fact that some hydro is small run-of-river and subject to water levels, as wind is subject to wind availability.
- There is a notable difference between the two scenarios in the capacity factor for conservation measures. Clearly some measures will have less of a 24 hours per day, 7 days a week impact. This will be discussed further for the 2015 comparison.
- The OPA scenario has about 13,000,000 MWh of electricity production greater than requirements, shown as the "OPA Target" in Table 1.
- Overall capacity factors are consistent with other jurisdictions.

Table 1.2 – Two Scenarios for Ontario in 2015

Plant Type	Installed Capacity (MW)	OPA Scenario		Author's Scenario	
		Electricity Production (MWh)	Capacity Factor	Electricity Production (MWh)	Capacity Factor
Nuclear	11,600	85,000,000	84%	75,000,000	74%
Hydro	8,700	39,000,000	51%	39,000,000	51%
Coal	0	0		0	
Gas	12,200	22,000,000	21%	16,000,000	15%
Wind	3,200	8,000,000	29%	6,000,000	21%
Other Renewables	400	2,000,000	57%	2,000,000	57%
Totals	36,100	156,000,000	49%	128,000,000	44%
Effect of Conservation	3,800	19,000,000	57%	27,000,000	81%
Total Without Conservation	39,900	175,000,000	50%	165,000,000	47%
OPA Target		***165,000,000***		***165,000,000***	

Comments on the scenarios for 2015:

- The OPA projects CO2 emissions will be reduced to 7 million tons in 2015 with the removal of the coal plants from production. Further analysis will question this level somewhat.
- Most of the comments for 2008 still apply
- The author's scenario shows a reduction in the wind capacity factor by 2015, which is consistent with experience elsewhere at this level of wind penetration into the electricity system. Ontario will be at the same relative level as Germany, where curtailment of wind output has been necessary, which reduces the capacity factor achieved. Other considerations come into play, such as wear and tear in a very large rotating structure, and turbine blade contamination.
- Although the conservation capacity factor is notably different the question remains what level of conservation can be obtained in terms of electricity used and the author maintains that more aggressive conservation can be achieved, or should at least be targeted. The OPA conservation represents an 11 per cent achievement, and the author's 16 per cent.
- In terms of the conservation replacing coal production, the OPA scenario contributes 52 per cent, and the author's 79 per cent. This illustrates the value of conservation. It would take 6 times the planned wind capacity to equal the effect of 16 per cent conservation in MWh terms, and as will be seen, even this will not have the desired result.
- Again the OPA scenario has 10,000,000 MWh more than required. This is rather unusual and there are two possible explanations for this. One is to protect against the risk of the wind production and/or conservation level not being achieved. The other possible explanation will be given below.

2. A Closer Look at the Wind Component

Tables 1 and 2 are misleading with respect to the wind power. They give the impression that wind is like any other generation means and a normal component of the electricity system. There is a significant difference in that all the other generation plant types produce steady, reliable electricity, which is what the users of this vital service require. The wind plants do not behave anything close to this. Wind plant electricity production is intermittent, volatile and unreliable, so special handling is required.

Occasionally the wind plants produce at full capacity (MW) and other times produce little or no electricity. There is a range of random conditions in between. The electricity output is dependent upon the vagaries of the wind supply on a minute by minute basis. Further, over the normal operating range of wind turbines, changes in electricity output are magnified by 8 times the changes in wind speed. The annual average of this is what is shown in the tables and almost always used in assessing the value of the contribution of wind power to the electricity supply and our well-being in terms of reduced dependence on fossil fuels and attendant CO2 emissions. This determination of wind's contribution is a simplistic approach that leads to incorrect conclusions. This will be examined in detail in the following sections.

To provide steady electricity, an equivalent amount of other generation capacity has to mirror the wind production over its full range. Statistically over time, with wind penetrations (wind production as a percentage of the total) over a few percentage points, the amount of other generation required in this role is somewhat less than the full wind capacity. In Germany it is 90 per cent, and Ontario will reach the same wind penetration by 2015. This other capacity has to be of a very responsive nature, and this will be discussed further in the following sections. See Appendix A for examples of wind electricity output variation during periods of high production.

The principal of a Danish energy consulting company has described the production of a combination of wind plants as like that of a single, virtual "out of control" power station. He was talking about offshore wind plants, but this illustrates the nature of wind power in high production mode.

By 2015, the installed wind capacity in Ontario will be 3,200 MW. Because the instantaneous value of wind power can be from 0-3,200 MW, an equivalent capacity of other generation means must be available to balance or "mirror" the wind variations within an hour or less. This is particularly true at times of the year and day with high wind production (winter months and at night). The range of variation will be less at times of lower wind production (summer months and daytime). This represents a duplication of capacity. For further confirmation of this see the articles *Germany, A Case Study,* and *Wind Power Is Redundant.*

The likelihood of all wind plants in the province producing at 100 per cent capacity, or not producing at all, at the same point in time is very small. Therefore variations over the full range are unlikely, but in practice they come close during periods of high wind production. Further there will be many frequent and random intermediate fluctuations between these two extremes.

The nature of weather conditions throughout the area wind plants are implemented is one consideration. Geographic dispersion of wind plants is another. However, any *offsetting*, or *mitigating*, effect of these is less than generally, and theoretically, believed because:

- The grid is not a "great leveller" of wind output from all wind plants. Wind effects have to be looked at in a more localized manner. As a result the problems of swings from 0 to 100 per cent production are more significant locally than on an Ontario-wide basis.
- Because of the size of weather systems, correlation between the outputs from the current Ontario wind farms is high.

However, the aggregate *adverse effect* of such local anomalies can be considered to sum up at the province level. For example local curtailment of wind during periods of high production, affect the overall production totals for the province.

3. Wind Shadowing/Backup Considerations

Wind power is introduced because of the expectation, or belief, that it will reduce fossil fuel use and attendant CO2 emissions. Basically, this means coal plants, which represent almost 50 percent of the total electricity production in the countries shown in the article *Electricity Generation Carbon Footprints*, which is a good proxy for world-wide use. Not surprisingly, the leaders in wind implementation are those countries with high coal use.

This section will look at wind production in this role, and from the point of view of electricity produced over long periods of time (a year) in MWh terms. It gives full credit to the aggregate amount of electricity produced by wind plants over a year, which arithmetically averages out the considerable fluctuations that occur in real time. It must be remembered in this analysis that the purpose of introducing wind is to displace fossil fuel use. The following sections will show that the introduction of wind production does not transfer into reductions in fossil fuel use or CO2 emissions. In fact it increases these, system wide.

The preferred generation means to mirror the wind's variations is natural-gas-fuelled plants. There are two types: the more efficient but less responsive Combined Cycle Gas Turbine (CCGT) plants; and the less efficient but more responsive Simple Cycle Gas Turbine (SCGT) plants. When wind is in its high production mode, the SCGT plants will predominate in the mix. During periods of reduced wind production, and less volatility, my analysis includes the consideration that the CCGT plants are used to a greater degree.

By 2015, the OPA plan projects an additional 6,800 MW (to a total of 12,200 MW) in all types of gas plants and an additional 7,000,000 MWh of gas production (to a total of 22,000,000 MWh). This includes at least 1,400 MW of SCGT, in large part for wind shadowing/backup. These increases in gas capacity and production are the largest of all the plant types.

Hydro can also be used as wind shadowing/backup. Most of Ontario's hydro-produced electricity is required for base load demand, and some is used in a peaking role. In theory, there is sufficient hydro electricity production in Ontario's current electricity system to provide the wind shadowing/backup. However, there is not enough additional, sufficiently reliable hydro capacity in Ontario available for this purpose. Insufficient additional hydro capacity is the main reason for the use of gas as wind shadowing backup in most countries, states or provinces. In any event, if hydro is used for wind shadowing/backup, there are two cases, neither of which allows wind to replace coal generation:

- *Case A* – Existing hydro capacity is used. Because the hydro is already supplying some demand, the existing coal plant production is not impacted unless the hydro is replaced by additional non-CO2-emitting generation, such as nuclear. In this case, it is the nuclear production that is actually displacing coal. The wind is simply displacing hydro.
- *Case B* – New hydro capacity is implemented. If such additional potential exists, then the new hydro replaces the coal plant production, and the wind simply replaces the hydro.

The exceptional case is Norway and Sweden, each of which has about the same size electricity system as Ontario. Together they obtain about 75 per cent of electricity from hydro. They are major purchasers of the excess wind production from Denmark, whose electricity system is one-fifth the size of Norway and Sweden combined. It is to their advantage to do so because Denmark has to sell it at a low price and Sweden and Norway save water in their reservoirs in dry seasons. However, there is no reduction in CO2 emissions, although Denmark claims an "accounting" credit for exporting "non-CO2-emitting" wind power.

Quebec is in the same category as Norway and Sweden with respect to hydro. For information on how this might affect Ontario see the *Electricity Alternatives for Ontario* article.

It follows that gas plants will provide most of the wind shadowing/backup, and this is the case in most countries, states and provinces. This is one of the reasons why T. Boone Pickens promotes wind power. He owns a lot of gas assets. Alberta is adding gas turbine plants for this purpose. Spain has added gas capacity, and Germany and Spain have increased gas production. The rest of this analysis assumes that gas plants will be used to the extent that gas production is available. This is simplistic, but it is instructive, and robust conclusions can be drawn.

Table 3.1 provides an analysis of the availability of gas for this purpose in the two scenarios for 2015.

Table 3.1 – Effect of Using Gas Plants Solely for Wind Shadowing/Backup

	Annualized Electricity Production (MWH)	
	OPA Scenario	**Author’s Scenario**
Wind at 100% Capacity	28,000,000	28,000,000
Actual Wind Production	8,000,000	6,00000,000
Required Gas Turbine Production as Wind Shadowing/Backup	20,000,000	22,000,000
Projected Gas Electricity Production	22,000,000	16,000,000
Gas Production Available for Other Roles	2,000,000	(6,000,000)

Comments on the OPA scenario:

- The available gas production is sufficient for the task
- Additional gas production should be reserved for intermediate and peaking roles. As already shown, the OPA scenario has 10,000,000 MWh more than required to meet demand, which is mostly nuclear and could be used to free up hydro for this purpose. Other increased production is available, for example 4,000,000 from hydro.
- Increased conservation will also help.
- In general, this scenario is positioned to handle the demands of shadowing/backup for wind electricity production, as far as the simplistic measure of MWh considerations is concerned.

Comments on the author’s scenario:

- Additional production is required for wind shadowing/backup. This could come from: increasing nuclear production (additional 10,000,000 MWh to the OPA level is available) to free up hydro; and/or by increasing gas production to the OPA level (additional 6,000,000 MWh); and/or by looking to the hydro increase (4,000,000 MWh).
- It is unlikely that additional conservation can be achieved.
- This scenario is more stretched by the presence of wind in the generation mix.

In summary, it looks like the OPA knows enough to provide for the consequences of the presence of the projected wind capacity. This should be no surprise.

4. Inefficient Gas Plant Operation in Wind Shadowing/Backup Mode

In gas shadowing/backup mode gas plants are forced to operate less efficiently than in normal use. For example CCGTs are designed to operate for longer periods and can compete with other plants. They are typically used as intermediate supply, between base load and peak power provision. To start CCGTs from “cold metal” takes hours and consumes about $15,000 of natural gas before they can be connected to the grid and deliver power. On the other hand SCGT can respond more quickly, and their normal role is peak power provision.

The more frequent starts/stops and other variations required in wind shadowing/backup mode causes inefficient operation of these plants. This is like the inefficiencies of cars in city versus highway driving. In the case of gas turbines this has been shown to be at least 10 per cent. This means that they consume 10 per cent more gas per MWh than in normal operations. Also, there are increased operations and maintenance costs for the gas plants as a result.

Another factor increasing gas consumption in this role is the need to increase the proportion of SCGT production which consumes more gas per MWh than CCGTs.

5. CO2 Emissions

Gas turbines produce less CO2 emissions than coal plants per MWh. In the case of CCGT plants it is about 60 per cent less. For SCGTs it is about 40 per cent less. I have heard that gas turbines produce more particulate matter of a kind that is more harmful to humans than coal plants, but I have not investigated that consideration.

In wind shadowing/backup mode gas turbines produce 2-3 times the CO2 emissions for every percentage point loss in efficiency experienced, depending upon gas turbine type. So at 10 per cent inefficiency levels, CCGTs produce 20 per cent more CO2 emissions and SCGTs, 30 per cent more. As described in Section 4, there is an increased need for SCGTs versus CCGTs in this mode of operation.

Table 5.1 provides information on the two scenario's projections for CO2 emissions. Examples of the author's model output for these calculations are shown in Appendix B. Although the coal plants may be closed during 2014, there is still some production projected for that year. The 2008 CO2 emission level is 33 million tons per year, and the projected OPA level of 7 million tons in 2015 represents a 79 per cent decrease.

Table 5.1 – Annual CO2 Emissions Projections

	CO2 Emissions (mtons = million tons)	
	OPA Scenario	**Author's Scenario**
Projected Electricity Production		
Gas	22,000,000 MWh	16,000,000 MWH
Wind	8,000,000 MWh	6,000,000 MWh
Projected CO2 Emissions		
OPA	7 mtons	
Author's model assuming wind capacity factor of 28% and no allowances for gas plant inefficient operation	10.5 mtons	
Author's model assuming wind capacity factor of 20% and allowances for gas plant inefficient operation	12.0 mtons	
Author's model assuming wind capacity factor of 20% and allowances for gas plant inefficient operation		8.5 mtons
Author's model with no wind in the electricity system	9.9 mtons	7.2 mtons

It is difficult to see how 22,000,000 MWh of gas plant production could produce only 7 million tons of CO2 emissions per year. Even if the lowest emissions rate of 0.4 tons per MWh (for CCGT) was used the emissions would be 22,000,000 (MWh) x 0.4 (tons/MWh) = 8.8 million tons. The 10.9 million tons assumes a 75:25 split between CCGT and SCGT respectively.

Even the 10.5 million tons of CO2 is questionable considering the effect of lower capacity factors and inefficient operation of the gas plants that should be taken into account.

However, the author's scenario has to find 6,000,000 MWh of production to replace wind. As in the OPA scenario, the author's may have to provide additional MWh of production from existing nuclear and gas capacities for this purpose and to provide for conservation levels not being achieved. This would increase CO2 emissions to a level approaching 12 million tons.

In summary, whether the comparison is 12 million tons with wind and 9.9 million tons without wind (OPA scenario), or 8.5 and 7.2 million tons (author's scenario), the presence of wind at this level adds more than 1 million tons of CO2 emissions per year.

6. Natural Gas Consumption

Apart from not reducing providing CO2 emissions reductions, does the presence of wind reduce the natural gas fuel consumed? Information from the author's model is provided in Tables 6.1 and 6.2. As previously mentioned, the increase is due to the inefficient operating conditions imposed on the gas plants and the necessity of using a higher proportion of SCGTs in the wind shadowing/backup mix.

Table 6.1 – Natural Gas Consumption OPA Scenario

	Natural Gas Consumption (MMcuft = millions of cubic feet)		
	OPA Scenario With Wind	OPA Scenario Without Wind	% Increase With Wind
Projected Gas Electricity Production	22,000,000 MWh	22,000,000 MWH	
Projected Gas Consumption (Author's model assuming wind capacity factor of 28% and no allowances for gas plant inefficient operation)	173,047 MMcuft	154,555 MMcuft	12%

Table 6.2 – Natural Gas Consumption Author's Scenario

	Natural Gas Consumption (MMcuft = millions of cubic feet)		
	Author's Scenario With Wind	Author's Scenario Without Wind	% Increase With Wind
Projected Gas Electricity Production	16,000,000 MWh	16,000,000 MWH	
Projected Gas Consumption (Author's model assuming wind capacity factor of 20% and with allowances for gas plant inefficient operation)	133,195 MMcuft	112,404 MMcuft	18%

7. Comparisons to Selected Countries

The earlier versions of this article contained a table showing a comparison between Ontario and countries with major wind power implementations. An expanded version is repeated here in Table 7.1, because it indicates why the selected countries are turning to wind power and raises the question as to why Canada and Ontario should do the same.

By 2015 for Ontario, the percentage contributions to electricity production are 5 per cent for wind (about the same level for Germany, Spain and Denmark today), 31 per cent for all renewables and 86 per cent for non-fossil fuel. This is a profile that countries in Europe with high wind implementations would envy. Ontario is in the fortunate position of being a model, not a laggard, and more to be coveted than criticized. Table 7.1 provides the profiles as percentages of total electricity generation:

Table 7.1 – Comparisons of Renewables and Fossil Fuel Use in Electricity Production

Percent Electricity Production	Ontario 2008	Ontario 2015	Canada recent	US recent	Germany recent	Spain recent	Denmark recent
Wind	1%	5%	<1%	1%	5%	7%	17% (6%)
All Renewables	22%	31%	58%	8%	14%	19%	23% (12%)
Fossil Fuel	27%	14%	26%	72%	60%	61%	77% (77%)

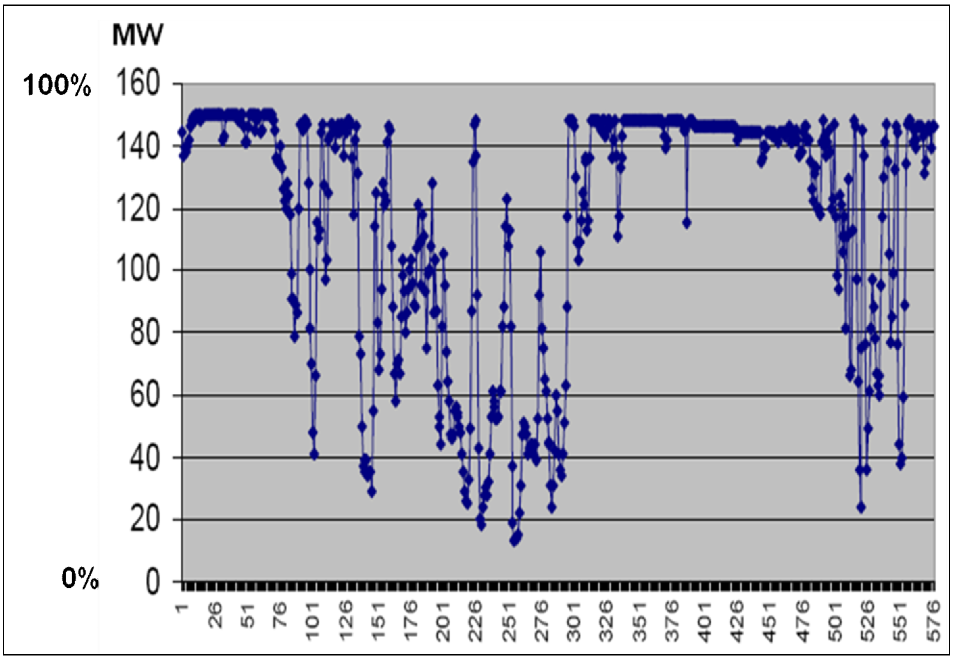
Note that the numbers do not add to 100 per cent. Nuclear production has not been included (it can be calculated by subtracting the totals of All Renewables and Fossil Fuel from 100) except for Denmark, which has no nuclear. Although the numbers shown for European countries are recent and not projected, it is very unlikely that they will change materially by 2015. It should be obvious why they have to excessively promote wind energy.

Denmark is a special case because its exports/imports of electricity are very large and variable. The production percentages shown are four year averages and exceed domestic demand by 13 per cent, largely because of high net exports of wind production. The percentages in brackets show domestic use, which is the basis for proper comparison to the other countries. For more details see the article *Denmark*.

Again, Canada and Ontario are not laggards in the use of renewable energy sources for electricity generation. Also, contrary to popular belief, Germany is not a role model. For more information see *Germany, A Case Study*, *Electricity Generation Carbon Footprints*, *Herr Scheer Needs Energy Rethink*, and the coming response to a recent The Walrus magazine article on energy.

Figures A1, A2 and A3 are examples of wind plant output during high production periods.

Figure A1- Wind Fluctuations for Danish Offshore Wind Plant
(5 minute time series for 48 hours)



Source: for A1 and A2 – Incoteco (Denmark) ApS

Figure A2- Wind Fluctuations for Danish Offshore Wind Plant
(5 minute time series for 48 hours)

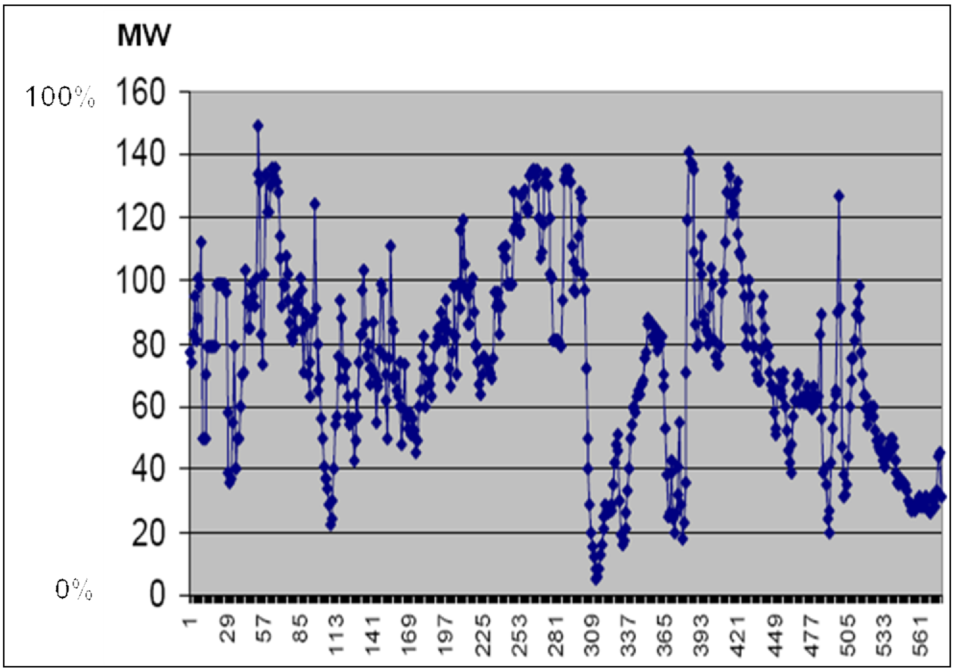
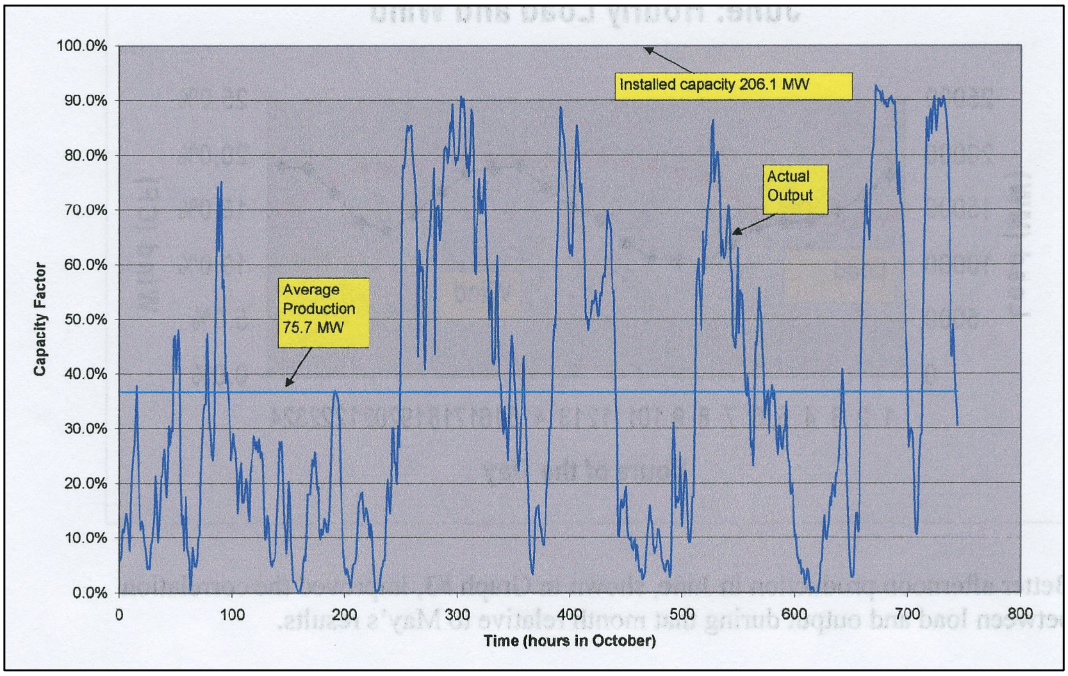


Figure A3 – Wind Fluctuations Fort Burwell Wind Plant in Ontario
(October 2006 – high production month)



Source: Energy Probe

Note that Figures A1 and A2 show wind production at 5 minute intervals and Incoteco reports that these are typical events. Figure A3 is a longer time period and therefore includes some smoothing of the plotted results. All figures represent the full range from 0-100% of wind plant capacity.

Introduction

This calculator was developed to assess the impact of industrial wind power in an electricity system in terms of fossil fuel consumption and CO2 emissions for different scenarios.

The overriding consideration is that gas plants are required to provide shadowing backup to mirror the wind plants' production. As a result the gas plants' efficiency is reduced and gas consumption and CO2 emissions are increased. There will be two types of gas plant involved: Simple Cycle Gas Turbine (SCGT) for fast response, sacrificing operational performance; and Combined Cycle Gas Turbine for better overall performance but less flexible response.

When gas plant production is not mirroring wind production a greater portion of CCGT will be used. When mirroring wind the proportion of gas plant used will change. During wind plant mirroring, which will be on a 24 hour per day, 7 days a week basis, two periods are provided for. The first is that of high wind production, during which the output of the wind plants will fluctuate substantially over the full range of wind plant capacity, with many lesser, random fluctuations in between. The second period is that of low wind production, when there is little or no wind, and the gas plants will operate in a more steady/normal mode.

Although this calculator addresses only wind and gas plants, the most likely combination, the effect of and impact on other generation means in the electricity system have to be considered from time to time. For example if there is not enough gas production assumed to cover the full wind production at 100 per cent of capacity, then either the gas production will have to be increased or other generation production provided. Additional gas production should be possible in most cases as the gas plants characteristics are that they will be running at less than "full" capacity. Care should be taken that reasonable provisions are made outside the calculator to satisfy the requirement.

Many of these considerations will be expanded on further below.

For consistency it is recommended that production values be taken at the generation level, that is, before transmission losses.

Assumptions

The first are the wind plant capacity (in MW) and capacity factor, which are used to calculate wind electricity production in MWh per year.

For the gas plants assumptions cover the percentage of CCGT and SCGT in different roles, as well as the annual gas plant electricity production.

An important assumption is the breakdown between the portion of the year of little or no wind production allowing more normal gas plant operation and the portion of the year of high wind production, which results in abnormal gas plant performance characteristics. Nominally this is assumed to be 50:50. This has to be factored by the skewing of wind production to the high wind period (reducing the gas shadowing/backup in MWh terms). Table B.1 illustrates this point. This is roughly based on the European Union for the Control of Transmission of Electricity (UCTE) report that for two-thirds of the year wind production is less than 20 per cent.

Table B.1 – Adjustment to Wind Capacity Factor for Periods of High/Low Wind Production (assuming 50:50 distribution between high and low and a skewing of 50%)

	Wind Capacity Factor		
	Annual Average	**High Production Period (Annual plus 50%)**	**Low Production Period (Annual minus 50%)**
OPA Scenario	28%	42%	14%
Author's Scenario	20%	30%	10%

Table B.2 – Adjustment to Gas Shadowing/Backup for Periods of High/Low Wind Production

	Adjustment to Gas Shadowing Backup	
	High Wind Production Periods	Low Wind Production Periods
All Scenarios	Subtract 50% of Wind Annual Average Production	Add 50% of Wind Annual Average Production

Gas plant inefficiency in wind mirroring mode is nominally 10 per cent. Increased CO2 emissions in wind mirroring mode is nominally 20 per cent for CCGT and 30 per cent for SCGT.

Finally CO2 emissions for the respective gas plants are: CCGT, 0.4 tons per MWh; and SCGT 0.6 tons per MWh. The CO2 emissions for coal plants are shown for reference and if required as described below. The assumption is that this is CO2 equivalents and imperial tons.

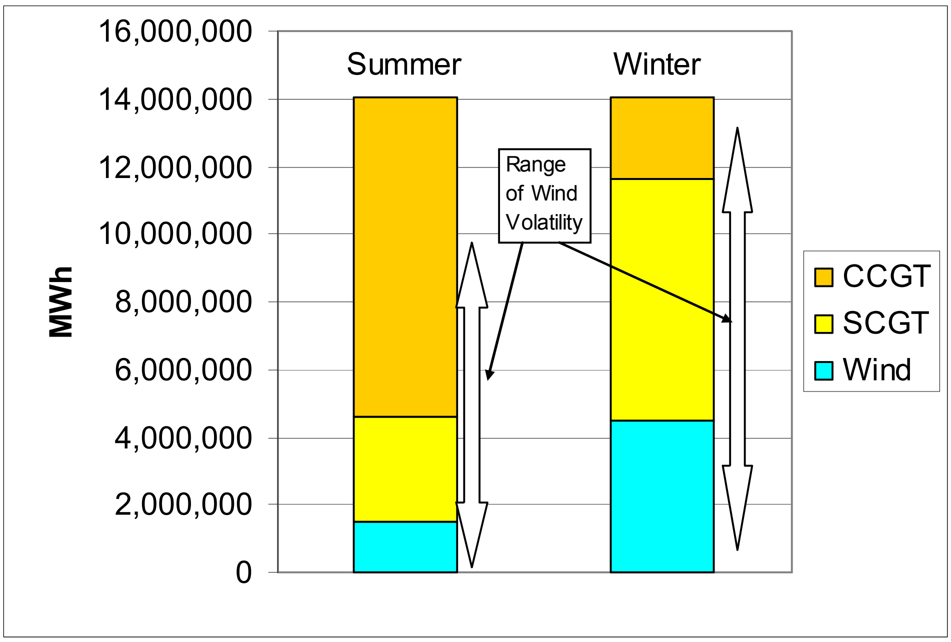
Production Information

This section of the model distributes the gas production among the various modes of operation.

Note that in calculating the gas production required to mirror the wind plants, if there is a negative result, then there must be other non-CO2 producing generation capacity available to fill the shortfall. Hydro capacity would be suitable. However if such is diverted from its normal task (base load, intermediate of peaking capacity) the model results are valid only if nuclear production is substituted. If coal production is used then the associated CO2 emissions component is not included by the model. This could be easily calculated if necessary, using the information in the Assumptions section.

To assist in understanding the calculator, Figure B.1 graphically illustrates the distribution of production among wind, CCGT and SCGT for summer months (late spring to early fall) and winter months (late fall to early spring) for the OPA scenario. The total possible annual wind production is 28,000,000 MWh at 100 per cent of the wind capacity. The assumed nominal distribution of SCGT to CCGT is summer 25:75, and winter 75:25. This can be changed in the calculator.

Figure B.1 – Distribution of Production of Wind and Gas Shadowing Backup Capacity



The range of wind volatility shown is representational, and is not intended to show the sequence of use of the two types of gas plant. As will be seen below, the model assumes that during summer months there is no loss in efficiency in the gas turbine plant operation or increase in CO2 emissions, due to the low level of wind production.

Fuel Consumption

Two calculations are performed: the first is for the base case where no wind is present and gas plants are providing the equivalent demand; and the second is the case that includes wind plants.

Page 2 of the model provides the detailed calculations. For Btu/KWh hour data a report commissioned by the Ontario Power Authority (OPA) from North Star Energy, LLC, was used initially. Because of a labelling inconsistency (MMBtu/KWh should be Btu/KWh) and the data did not appear to match that provided by gas turbine manufacturers, the equivalent information from the CERI report in the OPA Supply Mix Advice, which better met these requirements, was used. Both sets are supplied for completeness.

The same consideration as that used for gas plant capacity on page 1 applies for adding the wind production amount to the existing gas production level for the case where no wind is present. If sufficient gas production is not available, additional gas production must be added on page 1, or other non-CO2 producing generation means provided for outside the model to meet the absent wind production.

The steps are to provide the electricity production amounts in MWh, and from this information calculate the gas consumed in MMcf/MWh (MMcf is millions of cubic feet). Note that the gas turbine inefficiency factor (Effy Factor 1) is used only in a portion of the wind shadowing/backup mode calculations. This portion is assumed to be the winter months.

The amount of natural gas consumed with wind present is then compared to that without wind present to show the effect of wind on this resource. Don't be surprised to find an increase with wind.

GHG Emissions

The calculation for CO2 emissions follows the same pattern as gas consumption. Note that CO2 increase factors are used in a portion of the wind shadowing/backup mode (Effy factors 2 and 3). Again this portion is assumed to be the winter months.

Typically the results show an increase in CO2 emissions with wind present over the base case of no wind in the generation portfolio.

Feedback

There may be errors in logic or assumptions (or even arithmetic) in this calculator. The author would welcome informed feedback in this connection.

GAS CONSUMPTION AND GHG EMISSIONS - WIND/GAS COMBINATION
(OPA projections with gas plant inefficiencies)

Assumptions

Wind installed capacity	MW	3,200	
Wind Capacity Factor		28%	
Adjustment to wind production in backup for high and low periods		50%	
CCGT/SCGT ratio in normal operations			
CCGT	%1	75%	
SCGT	%2	25%	
CCGT/SCGT ratio in shadowing backup mode			
CCGT	%3	25%	
SCGT	%4	75%	
Time in shadowing backup mode when gas is operating normally		50%	
Time in shadowing backup mode when gas is fluctuating		50%	
Gas inefficiency in fluctuating mode (nominal 10%)		0%	
Factor for calculations of fuel	Effy factor 1	100%	**To use the model enter values here in boxes only**
Increased gas consumption in fluctuating mode			
CCGT (nominal 20%)		0%	
SCGT (nominal 30%)		0%	
Factors for GHG calculations in fluctuating mode			
CCGT	Effy factor 2	100%	
SCGT	Effy factor 3	100%	
Gas production total is normal operations plus wind shadowing backup			
GHG emissions			
Coal	tons/MWh	1.00	
CCGT	tons/MWh	0.40	
SCGT	tons/MWh	0.60	
Gas production	MWh	22,000,000	

It is necessary to make a decision on page 1 (at D, if negative) and page 2 (at P, Amount Added to Replace Wind)
depending upon other available capacity/existing production

Production Information - MWh

Wind Production	MWh	7,848,960		*wind capacity x capacity factor x 24 x 365*
Gas Production	MWh	22,000,000		
Gas production in shadowing/backup mode				
Wind production	MWh	7,848,960		
Gas production in shadowing backup mode	MWh	20,183,040		*72% of wind total possible wind production*
Gas production in normal operations outside shadowing/backup	MWh	1,816,960	D	If negative this backup must come from increased gas or other generation capacity
Check to total gas production		22,000,000		
Gas production shadowing/backup - normal	MWh	14,016,000		*50% of shadowing backup adjusted for low wind period*
CCGT	MWh	10,512,000	E	*75% of above*
SCGT	MWh	3,504,000	F	*25% of above*
Gas production shadowing/backup - fluctuating	MWh	6,167,040		*50% of shadowing backup adjusted for high wind period*
CCGT	MWh	1,541,760	G	*25% of above*
SCGT	MWh	4,625,280	H	*75% of above*

Fuel Consumption - MMcf (million cubic feet)

(See page 2 for details)

Total Gas Consumption assuming wind not present		
CCGT	MMcf	91,178
SCGT	MMcf	63,377
Total	MMcf	154,555
Gas production with wind present		
Gas production in normal operations		
CCGT	MMcf	7,530
SCGT	MMcf	5,234
Gas production shadowing/backup - normal		
CCGT	MMcf	58,089
SCGT	MMcf	40,377
Gas production shadowing/backup - fluctuating		
CCGT	MMcf	8,520
SCGT	MMcf	53,297
Total to compare to base		173,047
Gas Consumption as % of that with no wind		112%

GHG Emissions - million tons of CO2 per year

For total gas production with no wind			
CCGT	mill tons	6.6	*(A from p2) x tons/MWh/1,000,000*
SCGT	mill tons	3.3	*(B from p2) x tons/MWh/1,000,000*
Total	***mill tons***	***9.9***	
(if all CCGT)	***mill tons***	***8.8***	if all CCGT *(C from p2) x tons/MWh/1,000,000*
Gas production in normal operations			
CCGT	mill tons	0.5	*D x %1 x tons/MWh*
SCGT	mill tons	0.3	*D x %2 x tons/MWh*
Gas production shadowing/backup - normal			
CCGT	mill tons	4.2	*E x tons/MWh*
SCGT	mill tons	2.1	*F x tons/MWh*
Gas production shadowing/backup - fluctuating			
CCGT	mill tons	0.6	*G x effy factor 2 x tons/MWh*
SCGT	mill tons	2.8	*H x effy factor 3 x tons/MWh*
Total	***mill tons***	***10.5***	

Calculation of Natural Gas Consumed

Reference: Natural Gas-Fired Generation in the IPSP prepared for the OPA by North Side Energy, LLC
MM = million

Rates of consumption				OPA Supply Mix Advice CERI Attachment p 67		
CCGT	7,150	MMBtu/KWh??		CERI	5,642	Btu/KWh
	7.150	MMBtu/MWh	OK		5.642	MMBtu/MWh
SCGT	9,141	MMBtu/KWh??		CERI	11,765	Btu/KWh
	9.141	MMBtu/MWh	OK		11.765	MMBtu/MWh
Conversion to MMcf	1,021	Btu/cf				
CCGT	0.007003	MMcf/MWh			0.005526	MMcf/MWh
SCGT	0.008953	MMcf/MWh			0.011523	MMcf/MWh
Check math						
For 2007 from reference	284	MMcf/day				
	103,660	MMcf/year				
	13.492	TWh/year				
	7,683	MMcf/TWh				
	7.68307145	MMcf/GWh				
	0.007683071	MMcf/MWh				
	0.0000076831	MMcf/KWh				

Total Gas Production assuming wind not present				
Base amount with wind present	MWh	22,000,000		
Added amount to replace wind	MWh	0	P - Enter Wind Production from page 1 or some other value depending upon other production/capacity to cover wind production	
New total without wind present	MWh	22,000,000	C	
- CCGT	MWh	16,500,000	A	*C x %1*
- SCGT	MWh	5,500,000	B	*C x %2*
Check total	MWh	22,000,000		
Gas production with wind present				
Gas production in normal operations	MWh	1,816,960	I	
- CCGT	MWh	1,362,720	J	*I x %1*
- SCGT	MWh	454,240	K	*I x %2*
Gas production shadowing/backup - normal				
- CCGT	MWh	10,512,000	L	
- SCGT	MWh	3,504,000	M	
Gas production shadowing/backup - fluctuating				
- CCGT	MWh	1,541,760	N	
- SCGT	MWh	4,625,280	O	

Gas Consumption assuming wind not present - MMcf				
Base amount with wind present				
Added amount to replace wind				
New total without wind present				
- CCGT	MMcf	91,178	*A x MMcf/MWh*	
- SCGT	MMcf	63,377	*B x MMcf/MWh*	
Check total	MMcf	154,555		
Gas Consumption with wind present				
Gas production in normal operations				
- CCGT	MMcf	7,530	*J x MMcf/MWh*	
- SCGT	MMcf	5,234	*K x MMcf/MWh*	
Gas production shadowing/backup - normal				
- CCGT	MMcf	58,089	*L x MMcf/MWh*	
- SCGT	MMcf	40,377	*M x MMcf/MWh*	
Gas production shadowing/backup - fluctuating				
- CCGT	MMcf	8,520	*N x effy factor 1 x MMcf/MWh*	10% inefficiency
- SCGT	MMcf	53,297	*O x effy factor 1 x MMcf/MWh*	10% inefficiency
Total	MMcf	173,047		
Percent		112.0%		

GAS CONSUMPTION AND GHG EMISSIONS - WIND/GAS COMBINATION
(OPA projections with gas plant inefficiencies)

Assumptions

Wind installed capacity	MW	3,200	
Wind Capacity Factor		20%	
Adjustment to wind production in backup for high and low periods		50%	
CCGT/SCGT ratio in normal operations			
CCGT	%1	75%	
SCGT	%2	25%	
CCGT/SCGT ratio in shadowing backup mode			
CCGT	%3	25%	
SCGT	%4	75%	
Time in shadowing backup mode when gas is operating normally		50%	
Time in shadowing backup mode when gas is fluctuating		50%	
Gas inefficiency in fluctuating mode (nominal 10%)		10%	
Factor for calculations of fuel	Effy factor 1	110%	**To use the model enter values here in boxes only**
Increased gas consumption in fluctuating mode			
CCGT (nominal 20%)		20%	
SCGT (nominal 30%)		30%	
Factors for GHG calculations in fluctuating mode			
CCGT	Effy factor 2	120%	
SCGT	Effy factor 3	130%	
Gas production total is normal operations plus wind shadowing backup			
GHG emissions			
Coal	tons/MWh	1.00	
CCGT	tons/MWh	0.40	
SCGT	tons/MWh	0.60	
Gas production	MWh	22,000,000	

It is necessary to make a decision on page 1 (at D, if negative) and page 2 (at P, Amount Added to Replace Wind)
depending upon other available capacity/existing production

Production Information - MWh

Wind Production	MWh	5,606,400		*wind capacity x capacity factor x 24 x 365*
Gas Production	MWh	22,000,000		
Gas production in shadowing/backup mode				
Wind production	MWh	5,606,400		
Gas production in shadowing backup mode	MWh	22,425,600		*80% of wind total possible wind production*
Gas production in normal operations outside shadowing/backup	MWh	-425,600	D	If negative this backup must come from increased gas or other generation capacity
Check to total gas production		22,000,000		
Gas production shadowing/backup - normal	MWh	13,803,200		*50% of shadowing backup adjusted for low wind period*
CCGT	MWh	10,352,400	E	*75% of above*
SCGT	MWh	3,450,800	F	*25% of above*
Gas production shadowing/backup - fluctuating	MWh	8,196,800		*50% of shadowing backup adjusted for high wind period*
CCGT	MWh	2,049,200	G	*25% of above*
SCGT	MWh	6,147,600	H	*75% of above*

Fuel Consumption - MMcf (million cubic feet)

(See page 2 for details)

Total Gas Consumption assuming wind not present		
CCGT	MMcf	91,178
SCGT	MMcf	63,377
Total	MMcf	154,555
Gas production with wind present		
Gas production in normal operations		
CCGT	MMcf	0
SCGT	MMcf	0
Gas production shadowing/backup - normal		
CCGT	MMcf	57,207
SCGT	MMcf	39,764
Gas production shadowing/backup - fluctuating		
CCGT	MMcf	12,456
SCGT	MMcf	77,923
Total to compare to base		187,349
Gas Consumption as % of that with no wind		121%

GHG Emissions - million tons of CO2 per year

For total gas production with no wind			
CCGT	mill tons	6.6	*(A from p2) x tons/MWh/1,000,000*
SCGT	mill tons	3.3	*(B from p2) x tons/MWh/1,000,000*
Total	***mill tons***	***9.9***	
(if all CCGT)	***mill tons***	***8.8***	if all CCGT *(C from p2) x tons/MWh/1,000,000*
Gas production in normal operations			
CCGT	mill tons	0.0	*D x %1 x tons/MWh*
SCGT	mill tons	0.0	*D x %2 x tons/MWh*
Gas production shadowing/backup - normal			
CCGT	mill tons	4.1	*E x tons/MWh*
SCGT	mill tons	2.1	*F x tons/MWh*
Gas production shadowing/backup - fluctuating			
CCGT	mill tons	1.0	*G x effy factor 2 x tons/MWh*
SCGT	mill tons	4.8	*H x effy factor 3 x tons/MWh*
Total	***mill tons***	***12.0***	

Reference: Natural Gas-Fired Generation in the IPSP prepared for the OPA by North Side Energy, LLC
MM = million

Rates of consumption				OPA Supply Mix Advice CERI Attachment p 67	
CCGT	7,150 MMBtu/KWh??			CERI	5,642 Btu/KWh
	7.150 MMBtu/MWh	OK			5.642 MMBtu/MWh
SCGT	9,141 MMBtu/KWh??			CERI	11,765 Btu/KWh
	9.141 MMBtu/MWh	OK			11.765 MMBtu/MWh
Conversion to MMcf	1,021 Btu/cf				
CCGT	0.007003 MMcf/MWh				0.005526 MMcf/MWh
SCGT	0.008953 MMcf/MWh				0.011523 MMcf/MWh
Check math					
For 2007 from reference	284 MMcf/day				
	103,660 MMcf/year				
	13.492 TWh/year				
	7,683 MMcf/TWh				
	7.68307145 MMcf/GWh				
	0.007683071 MMcf/MWh				
	0.0000076831 MMcf/KWh				

Total Gas Production assuming wind not present					
Base amount with wind present	MWh	22,000,000			
Added amount to replace wind	MWh	0	P - Enter Wind Production from page 1 or some other value depending upon other production/capacity to cover wind production		
New total without wind present	MWh	22,000,000	C		
- CCGT	MWh	16,500,000	A	*C x %1*	
- SCGT	MWh	5,500,000	B	*C x %2*	
Check total	MWh	22,000,000			
Gas production with wind present					
Gas production in normal operations	MWh	0	I		
- CCGT	MWh	0	J	*I x %1*	
- SCGT	MWh	0	K	*I x %2*	
Gas production shadowing/backup - normal					
- CCGT	MWh	10,352,400	L		
- SCGT	MWh	3,450,800	M		
Gas production shadowing/backup - fluctuating					
- CCGT	MWh	2,049,200	N		
- SCGT	MWh	6,147,600	O		
Gas Consumption assuming wind not present - MMcf					
Base amount with wind present					
Added amount to replace wind					
New total without wind present					
- CCGT	MMcf	91,178	*A x MMcf/MWh*		
- SCGT	MMcf	63,377	*B x MMcf/MWh*		
Check total	MMcf	154,555			
Gas Consumption with wind present					
Gas production in normal operations					
- CCGT	MMcf	0	*J x MMcf/MWh*		
- SCGT	MMcf	0	*K x MMcf/MWh*		
Gas production shadowing/backup - normal					
- CCGT	MMcf	57,207	*L x MMcf/MWh*		
- SCGT	MMcf	39,764	*M x MMcf/MWh*		
Gas production shadowing/backup - fluctuating					
- CCGT	MMcf	12,456	*N x effy factor 1 x MMcf/MWh*		10% inefficiency
- SCGT	MMcf	77,923	*O x effy factor 1 x MMcf/MWh*		10% inefficiency
Total	MMcf	187,349			
Percent		121.2%			

GAS CONSUMPTION AND GHG EMISSIONS - WIND/GAS COMBINATION
(Author's projections with gas plant inefficiencies)

Assumptions

Wind installed capacity	MW	3,200
Wind Capacity Factor		20%
Adjustment to wind production in backup for high and low periods		50%
CCGT/SCGT ratio in normal operations		
CCGT	%1	75%
SCGT	%2	25%
CCGT/SCGT ratio in shadowing backup mode		
CCGT	%3	25%
SCGT	%4	75%
Time in shadowing backup mode when gas is operating normally		50%
Time in shadowing backup mode when gas is fluctuating		50%
Gas inefficiency in fluctuating mode (nominal 10%)		10%
Factor for calculations of fuel	Effy factor 1	110%
Increased gas consumption in fluctuating mode		
CCGT (nominal 20%)		20%
SCGT (nominal 30%)		30%
Factors for GHG calculations in fluctuating mode		
CCGT	Effy factor 2	120%
SCGT	Effy factor 3	130%
Gas production total is normal operations plus wind shadowing backup		
GHG emissions		
Coal	tons/MWh	1.00
CCGT	tons/MWh	0.40
SCGT	tons/MWh	0.60
Gas production	MWh	16,000,000

To use the model enter values here in boxes only

It is necessary to make a decision on page 1 (at D, if negative) and page 2 (at P, Amount Added to Replace Wind)
depending upon other available capacity/existing production

Production Information - MWh

Wind Production	MWh	5,606,400	*wind capacity x capacity factor x 24 x 365*
Gas Production	MWh	16,000,000	
Gas production in shadowing/backup mode			
Wind production	MWh	5,606,400	
Gas production in shadowing backup mode	MWh	22,425,600	*80% of wind total possible wind production*
Gas production in normal operations outside shadowing/backup	MWh	-6,425,600 D	If negative this backup must come from increased
Check to total gas production		16,000,000	gas or other generation capacity
Gas production shadowing/backup - normal	MWh	10,803,200	*50% of shadowing backup adjusted for low wind period*
CCGT	MWh	8,102,400 E	*75% of above*
SCGT	MWh	2,700,800 F	*25% of above*
Gas production shadowing/backup - fluctuating	MWh	5,196,800	*50% of shadowing backup adjusted for high wind period*
CCGT	MWh	1,299,200 G	*25% of above*
SCGT	MWh	3,897,600 H	*75% of above*

Fuel Consumption - MMcf (million cubic feet)

(See page 2 for details)

Total Gas Consumption assuming wind not present		
CCGT	MMcf	66,311
SCGT	MMcf	46,092
Total	MMcf	112,404
Gas production with wind present		
Gas production in normal operations		
CCGT	MMcf	0
SCGT	MMcf	0
Gas production shadowing/backup - normal		
CCGT	MMcf	44,773
SCGT	MMcf	31,121
Gas production shadowing/backup - fluctuating		
CCGT	MMcf	7,897
SCGT	MMcf	49,403
Total to compare to base		133,195
Gas Consumption as % of that with no wind		118%

GHG Emissions - million tons of CO2 per year

For total gas production with no wind			
CCGT	mill tons	4.8	*(A from p2) x tons/MWh/1,000,000*
SCGT	mill tons	2.4	*(B from p2) x tons/MWh/1,000,000*
Total	***mill tons***	***7.2***	
(if all CCGT)	***mill tons***	***6.4***	if all CCGT *(C from p2) x tons/MWh/1,000,000*
Gas production in normal operations			
CCGT	mill tons	0.0	*D x %1 x tons/MWh*
SCGT	mill tons	0.0	*D x %2 x tons/MWh*
Gas production shadowing/backup - normal			
CCGT	mill tons	3.2	*E x tons/MWh*
SCGT	mill tons	1.6	*F x tons/MWh*
Gas production shadowing/backup - fluctuating			
CCGT	mill tons	0.6	*G x effy factor 2 x tons/MWh*
SCGT	mill tons	3.0	*H x effy factor 3 x tons/MWh*
Total	***mill tons***	***8.5***	

Reference: Natural Gas-Fired Generation in the IPSP prepared for the OPA by North Side Energy, LLC
MM = million

Rates of consumption			OPA Supply Mix Advice CERI Attachment p 67		
CCGT	7,150 MMBtu/KWh??		CERI	5,642 Btu/KWh	
	7.150 MMBtu/MWh	OK		5.642 MMBtu/MWh	
SCGT	9,141 MMBtu/KWh??		CERI	11,765 Btu/KWh	
	9.141 MMBtu/MWh	OK		11.765 MMBtu/MWh	
Conversion to MMcf	1,021 Btu/cf				
CCGT	0.007003 MMcf/MWh			0.005526 MMcf/MWh	
SCGT	0.008953 MMcf/MWh			0.011523 MMcf/MWh	
Check math					
For 2007 from reference	284 MMcf/day				
	103,660 MMcf/year				
	13.492 TWh/year				
	7,683 MMcf/TWh				
	7.68307145 MMcf/GWh				
	0.007683071 MMcf/MWh				
	0.0000076831 MMcf/KWh				

Total Gas Production assuming wind not present					
Base amount with wind present	MWh	16,000,000			
Added amount to replace wind	MWh	0	P - Enter Wind Production from page 1 or some other value depending upon other production/capacity to cover wind production		
New total without wind present	MWh	16,000,000	C		
- CCGT	MWh	12,000,000	A	*C x %1*	
- SCGT	MWh	4,000,000	B	*C x %2*	
Check total	MWh	16,000,000			
Gas production with wind present					
Gas production in normal operations	MWh	0	I		
- CCGT	MWh	0	J	*I x %1*	
- SCGT	MWh	0	K	*I x %2*	
Gas production shadowing/backup - normal					
- CCGT	MWh	8,102,400	L		
- SCGT	MWh	2,700,800	M		
Gas production shadowing/backup - fluctuating					
- CCGT	MWh	1,299,200	N		
- SCGT	MWh	3,897,600	O		
Gas Consumption assuming wind not present - MMcf					
Base amount with wind present					
Added amount to replace wind					
New total without wind present					
- CCGT	MMcf	66,311	*A x MMcf/MWh*		
- SCGT	MMcf	46,092	*B x MMcf/MWh*		
Check total	MMcf	112,404			
Gas Consumption with wind present					
Gas production in normal operations					
- CCGT	MMcf	0	*J x MMcf/MWh*		
- SCGT	MMcf	0	*K x MMcf/MWh*		
Gas production shadowing/backup - normal					
- CCGT	MMcf	44,773	*L x MMcf/MWh*		
- SCGT	MMcf	31,121	*M x MMcf/MWh*		
Gas production shadowing/backup - fluctuating					
- CCGT	MMcf	7,897	*N x effy factor 1 x MMcf/MWh*		10% inefficiency
- SCGT	MMcf	49,403	*O x effy factor 1 x MMcf/MWh*		10% inefficiency
Total	MMcf	133,195			
Percent		118.5%			