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Professor Posen, CME 368
Assignment 2: Engineering Economics Case Study

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1.0 Base Case

Ontario Power Generation (OPG) is planning to expand their electricity generation portfolio in Ontario. The two mutually exclusive electricity generation projects under consideration are a wind farm and a natural gas power plant. Each project includes different parameters summarized in Appendix A. From the base parameters provided by OPG, we have adopted an effective interest rate and the minimum acceptable rate of return (MARR) of 3.08%. 3.08% is the effective business interest rate provided by Bank of Canada on 2017-10-27 [1], where rates are updated on a weekly basis. Other considerations to better determine financial feasibility are: carbon tax, fuel costs and facility depreciation.

1.1 Financial Assessment

Present worth analysis (NPV) and incremental modified internal rate of return (iMIRR) have been used to financially compare the two projects. Calculations are provided in the attached excel sheet. The financial calculations adopts the following assumptions:

- Capital costs are accounted at the start of period 1 (or end of period 0) rather than uniformly distributed during construction period,
- Construction starts end of period 0, beginning of period 1, since it is unclear the time of project commencement during the year,
- Salvage value is equivalent to undepreciated capital cost at the end of project lifetime due to uncertainty of salvageable materials market value at the end of project lifetime.
- Each project repeats itself during the lifetime and the costs and revenues are the same throughout repeated cycles.
- Projects are the only one in its class.

The analysis uses a repeated life approach to evaluate the two projects with different time horizons. The after tax cash flow is calculated from the taxes that accounts tax saving from capital cost allowance subtracted from before tax cash flow (costs subtracted from revenue). The cost and revenue for each project is summarized in table 1.1.

	Wind farm	Natural Gas plant
Revenue	Electricity sold	Electricity sold
Costs	Capital Cost Operation and Maintenance	Capital Cost Operation and Maintenance Carbon tax Fuel cost

Table 1.1 Cost and revenue of wind farm and natural gas plant incorporated in financial analysis

Based on the NPV and iMIRR analysis, the financial returns of natural gas plant is significantly higher than wind farm. By using the parameters provided in Appendix A, the present worth of natural gas plant is $3,606,020,363 compared to wind farm of $1,117,791,890, indicating natural gas would be far more profitable. MARR is the minimum acceptable rate of return, and is the minimum return expected on any project, or when the company does not undertake any project. The MIRR of natural gas plant relative to doing nothing is 4.508%, which is higher than MARR of 3.08%, making natural gas plant a more appealing option compared to doing nothing. The MIRR of wind farm compared to natural gas plant is 1.822%, which is lower than MARR, indicating the natural gas plant remains the best option.

2.0 Sensitivity

All values in any project have uncertainty associated with them. However, natural gas prices, the cost of residential power, and the capacity of each plants are among the values most sensitive to change in this project, and could have significant impacts costing millions of dollars with even small percentage changes.

2.1 Natural Gas Prices

Natural gas rates in Ontario are readjusted every 3 months, meaning that over the course of the project's projected lifespan, prices of natural gas could vary significantly. For example, in October 2016 the effective price of natural gas from Union Gas Limited was 10.8927 ¢/m^3, and by October 2017 this price had increased to 17.1859 ¢/m^3 [2]. This type of fluctuation in price is not uncommon based on historical data [2], and could have a significant impact in the overall cost of the project. These prices do not affect wind power, although they do affect natural gas

present value substantially. A price above 40 ¢/m³ makes wind a better choice than natural gas, and every 5 ¢ increase in price costs $1 billion in present worth for the natural gas plant.

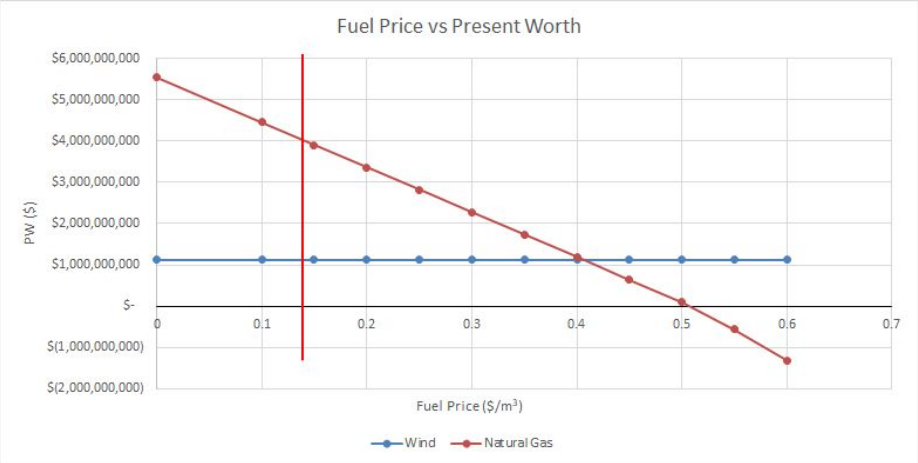

Fig. 3 Change in fuel price compared to resulting change in present worth. Current value shown as vertical red line.

2.2 Cost of Power

The cost of power to a consumer has no source in the problem statement. However, the Ontario Energy Board (OEB) gives an average value of about $85/MWh, so $110 is order of magnitude correct. Figure 4 shows the cost of energy over the past decade. Over the past year, it has dropped by 4¢/KWh, or $40/MWh. This is due to the *Fair Hydro Act* [9], which is an attempt to set a more equitable price for electricity.

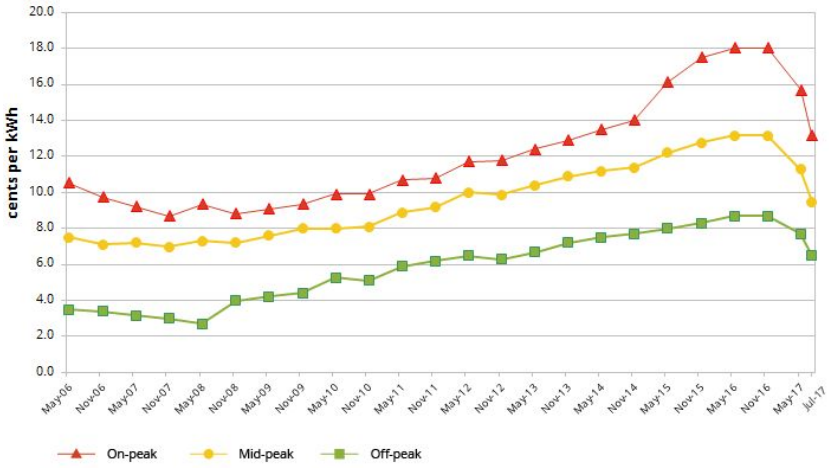

Fig. 4 Residential cost of electricity over the past decade. Currently the on peak cost is 13.2 cents, although that has dropped by 4 cents in the past year. [10]

Figure 5 shows the effect of these fluctuations. Below $50/MWh (off peak price before 2010), wind becomes a better choice than natural gas, although both would be unprofitable. A $50 increase in price can raise the present worth of a wind farm by almost $1 billion, and the present worth of a natural gas plant by $1.5 billion. Based on the trend of the past few years, a $50 change is unlikely, but half of that can be expected within the next two years, although it is likely to be an increase.

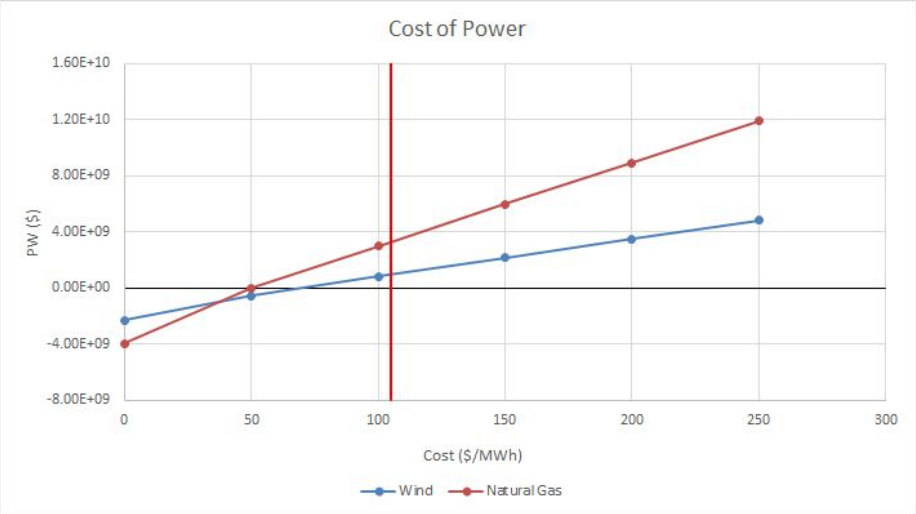

Figure 5 Cost of residential power compared to present worth of a wind farm and natural gas plant. The current price is indicated by the vertical red line. Wind and natural gas are equivalent at about 45$/MWh.

2.3 Capacity

The capacity of the generation methods is the limiting factor for wind. Figure 6 shows the relative present worth versus the capacity of each generation method. Surprisingly, wind has a consistently higher present worth above approximately 30%. However, as natural gas operates at nearly 90% capacity, while wind operates about 40%, natural gas currently has a higher present worth. This means natural gas operating at 90% has the same present value as wind operating at 70%, so a theoretical drop of 40% natural gas capacity could occur without the present worth of natural gas dropping below wind. This is unlikely, since the capacity of a natural gas plant is determined by the operators and demand for electricity, while the capacity of wind generation is determined by the weather. In addition, even if natural gas dropped in capacity, this would save on fuel costs, which would recoup some of the lost revenue from the drop in capacity. Furthermore, capacity of wind is likely to fluctuate daily, and 37% is an average.

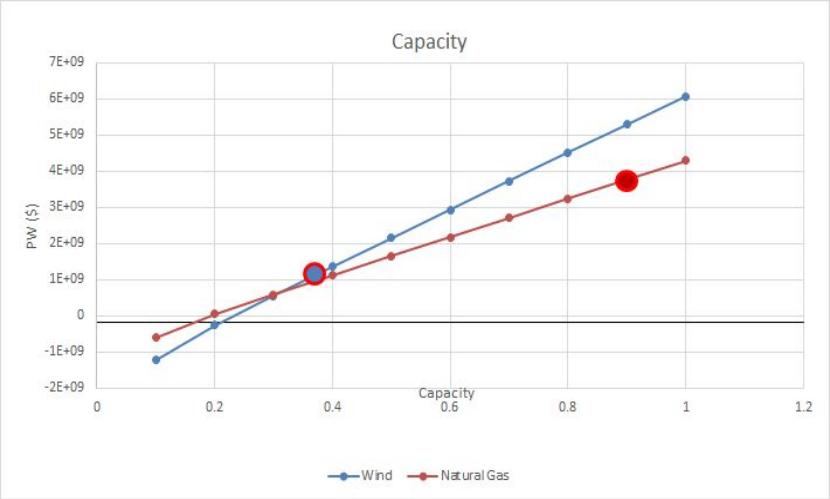

Figure 6 Operating capacity of wind farm and natural gas plant. Current capacities are indicated by the large dots. Wind has a consistently higher PW than natural gas for equivalent capacities, however natural gas is currently operating at a 50% higher capacity.

Part C: Other Considerations

While a decision regarding whether to invest in Wind Power or Natural Gas Plant could be made from a strictly financial perspective, other factors such as the effect on the natural environment and other less direct financial costs must be considered in the analysis.

For example, residents near the proposed wind farm oppose the disruption to the natural landscape a wind farm may cause. However, these disruptive claims would be largely insignificant in comparison to a natural gas plant, if the main issue was simply a disturbance to the land in the area. If ecological or health effects were a concern such as habitat disruption, “the National Wind Coordinating Collaborative concluded that these impacts(habitat destruction) are relatively low and do not pose a threat to species populations” [3]. Additionally, the Chief Medical Officer of Health in Ontario found that “the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects” [4].

Political opposition exists against the natural gas plant option. While the direct emissions of natural gas are 50%-60% less than what a new coal plant would emit, drilling and extracting natural gas from wells and its transportation in pipelines results in the leakage of methane, accounting for an additional 1% - 9% more emissions of methane [5]. While natural gas is

certainly a more environmentally responsible option than burning coal, the emissions produced still have consequences, such as the indirect costs associated with pollution.

For example, the Government of Canada values the social cost of carbon at $40.7/tonne of CO_2, meaning that if 552,026.1 tonnes/year are emitted from the natural gas power plant, the social cost of this pollution would be $22,467,462/year[6]. This represents an effect nearly as significant as the carbon tax rate of $50/tonne being implemented across Canada by 2022, but would likely not be accounted for in a standard cost analysis. Since the operating lifespan of the natural gas power plant will be 50 years, this unbooked value is quite considerable, and when compared to the capital cost of the natural gas plant of $2,788,000/MW of capacity, the social cost of natural gas is perhaps a consideration that could be used by NGO's or similar to argue against its implementation.

The wind farm installation is also expected to require new power lines, which would add an unknown cost to the project (unspecified km of line) and require approximately 3 months of congestion on a 400-series highway, resulting in delays of approximately an hour to the 80,000 commuters using the highway. Using a cost of congestion of $12.80USD($16.35) per person-hour, this would result in a cost of congestion of $118 million over the three months[8]. This represents a significant cost compared to the present worth of over one billion for the wind farm. However, it is not known what alternative traffic routes may be considered to avoid the one hour delay caused by the construction of a wind farm, and it is assumed the congestion would occur exactly as described.

Despite the aforementioned additional effects, it still appears that because of the significant difference in financial analyses between the wind farm and natural gas plant, the natural gas plant would be preferred. The rate of return exceeded MARR for the natural gas plant and present worth was approximately triple that of the wind farm, and further analyses into additional effects showed any change in this decision is unlikely because of the high financial disparity between the two options. Until wind can operate at a higher capacity, or the cost of fuel increases dramatically, the natural gas plant would be the preferred option for OPG to implement.

Appendix A: Project Parameters

Option 1: Wind Power	**Option 2: Natural Gas Plant**
Construction start: 2017	Construction start: 2017
Construction period: 3 years	Construction period: 5 years
Operating life: 30 years	Operating life: 50 years
Capital cost: $2,788,000/MW installed capacity	Capital cost: 917,000/MW installed capacity
Annual fixed O&M cost: $49,000/MW installed capacity	Annual fixed O&M cost: $13,170/MW installed capacity
Fuel use: none	Fuel use: 183 m^3/MWh
Expected capacity factor: 37%	Expected capacity factor: 87%
*Facility Depreciation: 30% [11]	*Facility Depreciation: 25% [12]
Carbon Dioxide Emission factor: none	*Carbon Dioxide Emission factor: 53.07 kg/MBtu [13]
Corporate tax rate: 27%	
Capacity 400 MW	
Electricity Revenue: 110$/MWh	
*Fuel cost: 17.7694¢/m^3 [2]	
*Carbon tax: $50/tonne CO_2 [14]	
*Effective interest rate: 3.08% [1]	

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