Synapse
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Tufts Cove 6

WASTE HEAT RECOVERY PROJECT

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Redacted Version

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1. Introduction

Synapse Energy Economics was hired by the Nova Scotia Utility and Review Board to review Nova Scotia Power's (NSPI) proposed waste heat recovery project for the Tufts Cove generating station and make a recommendation on whether to approve the work order.

2. Plant Configuration Options

Three configurations for the Tufts Cove generating station were considered in Synapse's analysis. The first option is to leave Tufts Cove 4 and 5 in their current condition without converting them to the Tufts Cove 6 combined cycle (CC) plant. The other two options include the Tufts Cove 6 combined cycle plant with and without a duct firing addition. The details for each of these three plant configurations are listed below in Table 2.1.

Plant Configuration	Total Capacity [MW]	Capital Cost [$million]
No Tufts Cove 6	98.76	$0
Tufts Cove 6 without Duct Firing	127.3	$55.5
Tufts Cove 6 with Duct Firing	151.3	$66.0

Table 2.1 – Tufts Cove Plant Configurations

A. Capital Cost Analysis

From the 2006 Gas Turbine (GT) World, a steam cycle addition to an LM6000PC will provide 11.4 MW at a total CC cost of $39.5 million. The simple cycle version with just the LM6000PC gas turbine is $13.2 million. The difference in capital cost is $26 million for 11.4 MW of additional capacity, or a capital cost of $2,300/kW without considering the much higher installation costs for a CC unit compared to a simple-cycle GT.

This $26 million CC equipment premium is for a single heat recovery steam generator (HRSG) and a single 11.4 MW steam turbine-generator set.

The unfired Tufts Cove 6 CC unit consists of two HRSGs and one 25 MW steam turbine-generator set. The equipment cost increment for Tufts Cove 6 is likely to be one and a half to two times the equipment capital cost for a single LM6000 CC. In that case, the equipment capital cost for an unfired Tufts Cove 6 would be $40 to $50 million.

Therefore, an installed cost estimate of $55 million for the CC, apart from the $11 million in duct firing costs, appears reasonable.

3. Combined Cycle without Duct Firing

Synapse performed spreadsheet analyses of all three plant configurations based on the Strategist inputs and outputs for the "Reference Case" from the recent integrated resource plan (IRP). This is the "5% DSM + Renewables" scenario. The outputs we focused on are summarized and compared below.

A. Generation and Capacity Factor Comparison

The total generation provided and capacity factors from 2006 to the end of the study period in 2029 are shown below in Table 3.1 for each plant configuration.

	No Tufts Cove 6	TUC6 No Duct Firing	TUC6 With Duct Firing
Units 4, 5, 6 Generation	9,075 GWh	11,953 GWh	12,775 GWh
Minimum Annual Capacity Factor	22%	25%	22%
Maximum Annual Capacity Factor	74%	74%	71%
Average Annual Capacity Factor	44%	42%	39%

Table 3.1 – Tufts Cove 4, 5, and 6 Generation Totals by 2029 and Annual Capacity Factors.

This increase in generation is a result of the increased capacity with the proposed investment. The efficiency of the station is improved with the addition of the steam generator, which allows more electricity to be produced for roughly the same amount of fuel. The additional generation from the TUC 6 project, and the additional generation from the duct firing are both expected to displace generation from the less efficient existing units at Tufts Cove.

B. Unit Displacements

The Strategist output files have projections of the effect of the addition of the combined cycle on the rest of the NSPI system. The primary impact of the investment in Tufts Cove 6 is to displace generation that would otherwise have come from Tufts Cove units 1 through 5. Table 3.2 below shows the 2011 difference in generation, CO2 emissions, and fuel costs when Tufts Cove 4 and 5 are converted to the Tufts Cove 6 combined cycle without the duct firing option.

Units	Generation [GWh]	CO2 Emissions [ktonnes]	Fuel Costs [CDN 2006 PV $k]
TUC 1	-26	-22	-$2,027
TUC 2	-29	-19	-$1,878
TUC 3	-160	-99	-$9,596
TUC 4	-302	-160	-$17,684
TUC 5	-267	-142	-$15,443
TUC 6	822	342	$38,929
Net	**38**	**-100**	**-$7,699**

Table 3.2 – Effect of combined cycle conversion without duct firing on Tufts Cove plant (units 1-6) in 2011.

As Tufts Cove 6 becomes operational, it will displace not just the Tufts Cove units 4 and 5, but also some less efficient gas and oil fired generation from units 1, 2, and 3. This effect continues through the study period and the changes for the first ten years of operation can be seen in Table 3.3 below.

Change from 2010 - 2019	Amount
Units 1-6 Generation [GWh]	228
Total Fuel Burned [MBtu]	-11,935
Oil	-8,484
Gas	-3,452
Total Fuel Costs [CDN 2006 $k]	-$54,247
Oil	-$52,889
Gas	-$1,358

Table 3.3 – Effect of combined cycle conversion without duct firing on the Tufts Cove plant (units 1-6) over ten years of operation.

These results indicate an overall increase in generation while also reducing total emissions and fuel costs for the Tufts Cove system. By the end of the study period in the reference case, the CC unit will have a predicted cost savings of $113.8 million and yield a net savings of $58.3 million, $70.2 million including end effects. For the capital cost of $55.5 million, the benefit to cost ratio would be around two to one.

NSPI's filing regarding Tufts Cove 6 included two cases.: the IRP "reference plan" referred to as "5% DSM & renewables, discussed above, and the "5% Spend DSM" resource plan. The later case is identical to the reference plan, but it has investment in new renewable capacity stopping in 2013 with compliance at the level prescribed by the Province's "renewable portfolio standard." We consider this to be less likely that the reference plan. The expected net present value benefits for the Tufts Cove 6 project for this plan are nearly double those for the reference plan.

In addition to those two plans ("reference" and "5% Spend DSM") the recent IRP included analysis of several other "resource plans," the IRP analysis included nearly a dozen "worlds." These are alternate scenarios for the future which require the development of modified resource plans. So, for example, different assumptions were made for the timing and level of DSM savings and or the timing and stringency of environmental constraints (such as carbon emissions pricing and cap levels). The Tufts Cove 6 project was found to be *not* part of the optimal resource plan in two of those runs, specifically the cases named "5% DSM – 20% Benefits" and "5% DSM Stora Portion of DSM Removed from Ind. Secttor" (see page 106 of the May 11, 2007 IRP model results slides). While this does indicate that there are futures in which the Tufts Cove 6 project may be uneconomic, we note that the IRP analysis included a large number of scenarios spanning quite a large range of assumptions, and that the marjority of these found the Tufts Cove 6 project to be economic, including all of the Carbon Hard Cap Worlds. We are convinced that on balance, the range of the IRP scenarios provides an adequate "risk analysis" and that the Tufts Cove 6 investment is likely to be economic.

4. Duct Firing

The proposed addition of duct firing to the combined cycle plant would provide an additional 24MW of net capacity to Tufts Cove 6 for an estimated incremental capital cost of $11 million. However, the economics of this addition appear to be marginal at best.

A. Heat Rates

Duct firing (DF) has a heat rate similar to a simple cycle gas turbine or a thermal unit. In essence, DF in this case is a natural gas-fired boiler, as the duct burners are heating water circulating in a boiler (heat recovery steam generator) to generate electric power in the steam cycle.

The heat rates shown in the Gryphon and Stone & Webster analyses are in the range of expected values for these units. From the 2006 Gas Turbine World Handbook, the simple cycle GT LM6000 HHV heat rate is around 9.0 MBtu/MWh, about 10% higher than the LHV heat rate. The HHV CC thermal efficiency from GT World's CC LM6000 data would be around 46%, and NSPI is projecting 43-45%. It appears that NSPI's projected heat rates are reasonable.

Shown in Table 4.1 below, duct firing would increase the overall heat rate for the Tufts Cove 6 unit, thereby reducing overall fuel efficiency compared to the combined cycle without duct firing.

Plant Configuration	Average Heat Rate [MBtu/MWh]	Incremental Heat Rate [MBtu/MWh]
No Tufts Cove 6	[redacted]	[redacted]
Tufts Cove 6 No Duct Firing	[redacted]	[redacted]
Tufts Cove 6 Duct Fired	[redacted]	[redacted]

Table 4.1 – Heat rate comparison (Source: UARB IR-4b Attachment 1).

Additionally, DF imposes an efficiency penalty on the CC plant when DF is not in use relative to an unfired CC plant. The reason for this is the steam cycle, including the steam turbine, generator, boiler feed-water pumps, and related equipment, are sized for maximum DF. However, when DF is not in use, the steam cycle is operating in a sub-optimal condition. As explained by NSPI in their response to UARB IR-7: "*The higher the rate of DF the greater the load range required of the steam turbine and the more difficult it becomes to maintain good operation in the unfired condition*."

We reviewed the input assumptions for the heat rate of the Tufts Cove 6 unit in the Strategist model, and found that this heat rate penalty was not included in the model. This omission biases the analysis in favor of duct firing.

B. Unit Displacements

The effect of duct firing on generation displacement should be considered since this reduced efficiency could be acceptable if the generation it replaces is less efficient. In Table 4.2 below, this comparison is shown.

Change from 2010 - 2019	Amount
Units 1-6 Generation [GWh]	11.7
Total Fuel Burned [MBtu]	-1,039
Oil	-710
Gas	-331
Total Fuel Costs [2006 CDN $k]	-$6,323
Oil	-$4,731
Gas	-$1,591

Table 4.2 – Effect of combined cycle conversion with duct firing on the Tufts Cove plant (units 1-6) after ten years of operation.

The results show that the overall effect on the Tufts Cove plant from the duct firing addition will increase generation and reduce total fuel use. These changes are small and cumulatively just barely offset the estimated incremental capital cost for duct firing.

C. System Reliability, Ancillary Services, and Wind Integration

It appears that NSPI system will have surplus capacity for the foreseeable future. This situation, analyzed in the context of the recent IRP, occurs as a result of system capacity additions that are driven by provincial policy and/or justified on an energy displacement basis. The expected annual reserve margins go as high as 30% (NSPI response to UARB IR-10e Attachment 1). With large amounts of surplus capacity on the system, it is unlikely that a capacity addition such as the 24 MW for the duct firing at Tufts Cove 6 will have significant value in terms of capacity adequacy for meeting system peak loads.

It is expected that Nova Scotia will add large amounts of renewable capacity to its system in the coming years. The Province has a renewable energy standard that calls for system sales to be 5 percent from renewable sources by 2010 and 10 percent from renewable sources by 2013 (Source: Nova Scotia Renewable Energy Standard Regulations). It is expected that the vast majority of this renewable electricity will be generated from new wind turbines in the Province. Moreover, the recent IRP analyzed scenarios (including the "reference case") in which large amounts of additional wind capacity is brought online after 2013, going well beyond the 10 percent level. Adding these large amounts of intermittent (or "variable") wind generation to a system the size of NSPI's poses technical challenges, in terms of the ability of the available generating capacity to follow variations in load. The Tufts Cove 6 duct firing capacity could have value toward "backing up" or "firming" the wind capacity additions. However, the possible ancillary services or wind firming benefits of project were not analyzed in the Company's work order application in this case. We note also that the Strategist model that was used for the economic analysis does not have the capability to analyze ancillary services and wind integration issues. Nonetheless, it is possible that adding a stand alone combustion turbine unit (at the Tufts Cove site or elsewhere on the NSPI system) could provide the ancillary services function, at comparable or lower cost, and without imposing the heat rate penalty on the Tufts Cove 6 combined cycle unit.

We anticipate that the Province's ongoing wind integration analyses will shed some light on the value of gas-fired generating capacity in terms of integrated system operation with wind generation.

5. Conclusion

The conversion of Tufts Cove units 4 and 5 into a combined cycle without duct firing appears to be well justified based on the cost savings of burning natural gas at an improved efficiency over the course of the study period. The same cannot be said for the duct firing option.

Looking at an economic comparison of the plant configurations on a cumulative net present value basis, the duct firing can again be seen to have only a small benefit of around $0.8 million over a twenty year study period. When end effects are taken into account there is only a slight increase of $0.1 million.

Reference Case (5% DSM + Renew)	Capital [M$]	Predicted Cost Savings [M$]	Net Savings [M$]	Full Study Period + End Effects [M$]
No TUC6	$0.0	$0.0	**$0.0**	$0.0
TUC6 No Duct Firing	$55.5	$113.8	**$58.3**	$70.2
TUC6 Duct Fired	$66.0	$125.1	**$59.1**	$71.1
Duct Firing Increment	$10.5	$11.3	**$0.8**	$0.9

Table 5.1 - Economic comparison of Tufts Cove 6 for the reference case through the end of the study period (2029) and including end effects (Source: NSPI Tufts Cove 6 Project Proposal, Appendix II).

This small benefit does not justify the installation of the duct firing option. The inclusion of duct firing in the Tufts Cove 6 project worsens the heat rate of that project when it is not operating in duct firing mode. If additional gas fired generating capacity is needed to provide ancillary services and/or “firm up” wind generation, there are advantages to providing that capacity as a stand-alone combustion turbine. Additionally, the 24MW of capacity is not needed in a system with large amounts of surplus capacity (NSPI response to UARB IR-10e, Attachment 1).

It is our recommendation that the combined cycle conversion to Tufts Cove 6 be approved to proceed without the inclusion of duct firing. If additional analysis (e.g. wind integration studies) or system development (e.g. rapid load growth) indicate that additional gas fired capacity with a heat rate in the 9,000 to 10,000 BTU/kWh rate would be necessary or economic, then that capacity can, we believe, be economically added in the form of a new combustion turbine unit rather than as duct firing at Tufts Cove 6.