TECHNICAL REPORT

DIVERGING FROM DIESEL

LEAD ORGANIZATION

Gwich'in Council International

Gwich'in Council International (GCI) represents 9,000 Gwich'in in the Northwest Territories (NWT), Yukon, and Alaska as a Permanent Participant in the Arctic Council; the only international organization to give Indigenous peoples a seat at the decision-making table alongside national governments. GCI supports Gwich'in by amplifying our voice on sustainable development and the environment at the international level to support resilient and healthy communities.

PARTICIPATING ORGANIZATIONS

InterGroup Consultants

For over 40 years, **InterGroup Consultants** has developed and coordinated customized processes that meet our clients' needs. We value sustained and long-term relationships with clients from coast to coast to coast.

Lumos Energy

Lumos Energy is Canada's leading Clean Energy Advisor to Indigenous communities. Lumos provides trusted, qualified, and expert advice to First Nations, Métis and Inuit leaders and communities to finalize participation and partnerships in hydro, solar, wind, biomass, community energy planning, geothermal, and transmission projects.

SPONSOR

Indigenous and Northern Affairs Canada

Indigenous and Northern Affairs Canada (INAC) has an important role to play in the promotion of circumpolar cooperation among the eight Arctic countries through Canada's Northern Strategy. Through active participation in Canada's multilateral (Arctic Council) and bilateral (Russia, Norway, U.S.) fora in the Arctic, and in collaboration with the territories and Aboriginal peoples, INAC works to strengthen governance and improve the quality of life in Canada's North.

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ATTACHMENTS

BACKGROUND

InterGroup Consultants Ltd. (InterGroup) is assisting Gwich'in Council International in developing a plan whereby the Indigenous people of the North can take action to secure alternative energy sources to reduce current reliance on fossil fuel.

This overview summarizes initial findings based on publicly available information regarding costs for fossil fuel thermal power generation in northern off-grid communities in NWT, Nunavut and Yukon that rely upon thermal power generation (diesel or natural gas) for electricity.

FOCUS OF ANALYSIS

The focus of this specific analysis for Gwich'in Council International is to secure publicly available facts and information regarding the true cost of fossil fuels used to provide power to off-grid northern communities. This information will assist in defining "avoided costs" benefits (in terms of the overall total fossil fuel costs displaced) by development of alternative energy sources that reduce current reliance on fossil fuels.

Comprehensive avoided cost assessment of existing and future fossil fuel generation is critical to regulatory approval and financing of alternative energy projects for these communities. The focus of the current analysis is to examine all applicable fuel, non-fuel operating and maintenance (O&M), and capital costs currently incurred by regulated power utility providers in a sample of these northern off-grid communities. Differences among these communities will be noted with regard to these overall costs for fossil fuel generation. Available information is also reviewed on "external" fossil fuel use costs not currently incurred by power utility providers, including social costs for adverse impacts on climate and human health.

APPROACH AND DEFINITIONS

This review focuses on determining the cost of diesel and natural gas fuel, assessing the full range of factors affecting the full cost of fossil fuel use for generation in the specified northern communities. The factors reviewed include variable fuel costs, non-fuel operating costs, health and social costs, environmental damages, as well as government subsidies. The analysis is based on review of publicly available documents, including recent utility General Rate Applications (GRAs) in Northwest Territories (NWT), Nunavut, and Yukon.

Cost information is reviewed in detail in the following three attachments:

1. **Attachment 1 - Current Utility Fossil Fuel Generation Costs**
   This attachment focuses on summarizing publicly available information on reasonably current utility costs for fossil fuel generation in specified northern communities. The factors reviewed include variable fuel costs, non-fuel operating costs, and capital related costs.

   Costs reflect full utility costs as reported in GRAs for the purpose of setting rates, and exclude any subsidies and/or rate equalization measures adopted to reduce actual rates charged to customers in these communities.

2. **Attachment 2 - Fuel Price Formation in the Northern Territories and Potential Near Term Future Additional Utility Fossil Fuel Generation Costs**
   This attachment focuses on the following three factors that may increase utility thermal generation costs in northern communities in the near term (5-10 years), beyond current costs considered in Attachment 1:

   - Fuel price formation (impact of government fuel supply activities and potential changes in base market fuel prices).

   - Diesel capital costs for plant expansion or replacement.

- GHG emission carbon tax impacts on utility fossil fuel costs. Separate cost estimates are provided for GHG emission potential carbon tax impacts at $10 and $50/ tonne of GHG emissions.

3. **Review of Other Fossil Fuel Generation Costs (Social Costs External to Utility Costs)**
   This attachment focuses on summarizing publicly available information on additional social costs (beyond the direct utility costs reviewed in Attachments 1 and 2) imposed by installation and running fossil fuel generation units. Social costs may include direct and indirect impact to health and well-being of populations, impact to animals and plants, climate change, etc. Social costs are not limited to the communities wherein the thermal generation occurs (e.g., GHG emissions related to such thermal generation can impact climate globally).

   As reviewed in Attachment 3, no community specific social cost estimates have been revealed to date. Social and health impact cost estimates per kW.h related to air emissions from diesel and/or natural gas generation as developed by four recent US studies are reviewed to provide preliminary indications of possible external costs.

SUMMARY OF CURRENT AND POTENTIAL FUTURE UTILITY COST ESTIMATES

Table 1 provides a summary of estimates from Attachments 1 and 2 for current (and certain potential future) costs incurred by utilities to provide thermal power generation for ten off-grid communities in NWT, Nunavut and Yukon. As reviewed in Attachment 1, due to rate equalization regimes and other measures, not all of these costs are recovered through rates charged to customers in these communities - however, these costs reflect amounts actually paid (or potentially payable in future) by utilities.

Current Utility Costs reflect recent General Rate Application cost information, as reviewed in Attachment 1. This information highlights the relative importance of fuel versus other costs (non-fuel operating and maintenance, and capital depreciation and financing returns for existing assets) for northern community fossil fuel generation.

In summary, fuel costs for diesel and natural gas power generation (including fuel tax, refining, processing and transport costs) range from 19 cents/kW.h (diesel generation in Destruction Bay, Yukon which is on the Alaska Highway) to 54 cents/kW.h (diesel generation in Old Crow, Yukon where fuel is often flown in). In NWT and Nunavut, fuel costs for fossil fuel generation in the sample communities range from 27 cents/kW.h to 34 cents/kW.h. Overall, fuel costs for diesel and natural gas generation account for 46-52% of total current utility fossil fuel power generation costs in the four sample NWT communities, 46-58% in the four sample Nunavut communities, and 46-71% in the two sample Yukon communities.

The balance of the fossil fuel generation costs incurred currently by these utilities are for non-fuel O&M and capital (depreciation and financing related to debt and equity returns). These non-fuel costs range from 21 to 22 cents/kW.h in the sample Yukon and Nunavut communities to 31 cents/kW.h in the sample NWT communities.

Potential GHG carbon tax costs reflect potential added utility costs in the next five years for carbon taxes at two potential levels ($10 and $50/ tonne GHG emissions). These preliminary estimates indicate potential future near-term added utility fuel tax costs of 1 to 5 cents/kW.h related to GHG carbon taxes.

Table 1: Summary of Fossil Fuel Generation Costs in Northern Communities

			Currrent Utility Costs[1]			Potential GHG Tax Cost[2]	
Territory	Community	Fossil Fuel Generation (MWh)	Fuel ($/kW.h)	Other Costs ($/kW.h)	Total Costs ($/kWh)	Based on $10/tonne ($/kWh)	Based on $50/tonne ($/kWh)
NWT	Inuvik-Diesel	16,996	0.33	0.31	0.64	0.01	0.05
	Inuvik-Natural gas	11,330	0.27	0.31	0.58	0.01	0.04
	Tuktoyaktuk-Diesel	4,142	0.29	0.31	0.61	0.01	0.05
	Fort McPherson-Diesel	3,424	0.34	0.31	0.66	0.01	0.05
Nunavut	Iqaluit-Diesel	60,741	0.29	0.21	0.50	0.01	0.05
	Cambridge Bay-Diesel	10,267	0.29	0.21	0.50	0.01	0.05
	Rankin Inlet-Diesel	17,625	0.28	0.21	0.49	0.01	0.05
	Baker Lake-Diesel	9,518	0.27	0.21	0.48	0.01	0.05
Yukon	Old Crow-Diesel	2,264	0.54	0.22	0.76	0.01	0.05
	Destruction Bay-Diesel	1,789	0.19	0.22	0.41	0.01	0.05

Notes:

1 See Attachment 1.

2 See Attachment 2.

Attachment 2 also reviews the following additional factors that may increase fossil fuel power generation utility costs in the next 5 to 10 years in these northern communities:

Delivered fuel prices - A large portion (e.g., 50% or more) of current delivered fuel prices for thermal power generation in these communities is for refining, processing, taxes and transportation, i.e., costs separate from the basic oil or natural gas commodity price. Attachment 2 reviews specific factors affecting delivered fuel prices in the NWT, Nunavut and Yukon communities examined in this analysis. Aside from potential reductions in LNG processing and haul costs to serve some of these communities, the main factor that may affect future delivered fuel prices remains the potential for increases in basic commodity prices (given that current prices reflected in Table 1 tend to be lower than in the not-so-distant past). Higher oil and/or natural gas fuel commodity prices would affect delivered fuel costs through added transportation costs as well as higher commodity price component of the delivered fuel cost.

Capital costs for fossil thermal plant expansion or replacement - Current annual capital costs for utility fossil fuel power generation in these communities reflect current cost of plant in service as well as current financing costs. These costs will underestimate the future capital cost needed per unit to the extent that diesel plants in many of these northern communities are aged and significantly depreciated (in terms of capital cost balance still in rate base) and new plant will be needed in the near term. In addition, higher capital costs will also be required by utilities if and when interest rates (and allowed return on equity) start to increase above the relatively low levels experienced in recent years.

EXTERNAL SOCIAL COSTS FOR FOSSIL FUEL POWER GENERATION

In addition to the direct utility costs related to the fossil fuel electricity generation as reviewed in Attachments 1 and 2, there are also other impacts, or indirect social costs, imposed by installation and running of fossil fuel generation units. Social costs may include direct and indirect impact to health and well−being of populations, impact to animals and plants, climate change, etc. Social costs are not limited to the communities wherein the thermal generation occurs, e.g., GHG emissions related to such thermal generation can impact climate globally.

Preliminary review has not revealed any defined guidelines regarding the determination of relevant social costs related to thermal generation in northern Canadian jurisdictions. Four available studies and reports have been reviewed to provide guidance as to potential social costs for air emission impacts from different fossil fuel use.

Overall, the four studies show a wide range of estimated social costs from US thermal power generation using either oil products (diesel was not specifically examined) or natural gas, e.g., in CAN$2016, air emission impact social costs range from 3.2 cents /kW.h to 19.2 cents /kW.h for oil thermal generation and from 0.25 cents /kW.h to 13.2 cents /kW.h for natural gas thermal generation. The same studies indicate higher social costs for thermal power generation using coal, as well as for diesel fuel use in transportation.

Most of the above estimated social cost impacts from oil thermal generation in the US relate to human health impacts, and the dollar values for such impacts are very sensitive to the scale and status of the local regional population affected by such impacts. As such, these dollar cost impact estimates may have no direct application to the remote northern Canadian communities that are the focus of this review.

ATTACHMENT 1

CURRENT UTILITY FOSSIL FUEL GENERATION COSTS

Approach and Definitions

This review focuses on summarizing publicly available information on reasonably current utility costs for fossil fuel generation in specified northern communities. The factors reviewed include variable fuel costs, non-fuel operating costs, and capital related costs.

The summary overview as provided in Table 1-1 is based on publicly available documents, including recent utility General Rate Applications in Yukon, Northwest Territories and Nunavut.

NWT Communities (Inuvik, Tuktoyaktuk, Fort McPherson) – information for utility fiscal year thermal fuel costs is derived from Northwest Territories Power Corporation's (NTPC) most recent general rate application (2016/19 GRA filed in June 2016) and reflects forecasts for the 2016/17 fiscal year.

Nunavut Communities (Iqaluit, Cambridge Bay, Rankin Inlet, Baker Lake) – information for utility fiscal year thermal fuel costs is derived from Quilliq Energy Corporation's (QEC) most recent GRA (2014/15 GRA), with fuel prices updated to February 2016 actual weighted average.

Yukon Communities (Old Crow, Destruction Bay) - information for utility fiscal year thermal fuel costs is derived from ATCO Electric Yukon's (AEY) 2016-17 GRA, response to Information Request JM-AEY-8 and reflects the average fuel price for January - June 2016. AEY in its 2016-17 GRA notes that both Burwash Landing and Destruction Bay are served by three units installed in Destruction Bay [Appendix 11, page 1 of 2016-17 GRA, and also response to Information Request YEC-AEY-14a], therefore, information for Destruction Bay is used.

Estimates of utility fossil fuel cost with respect to each factor is described below (where feasible, costs are separated for diesel fuel and natural gas generation):

- **Variable Fuel Cost:** variable fuel cost has been derived by dividing community-specific fossil fuel cost per unit of volume supplied (e.g., per litre for diesel fuel, per m^3 for natural gas) by the generation plant fuel efficiency in that community.

- **Non-fuel Operating Cost:** non-fuel operating costs are utility costs that are incurred and expensed on an annual basis, including costs that may vary with actual generation and annual expense costs that do not vary materially with actual generation. InterGroup identified two factors that are related to the non-fuel operating costs of fossil fuel power generation plants:

- **Engine Overhaul Costs:** Diesel and natural gas generating engines require minor and major overhauling after certain hours of operation. Overhauls are performed periodically every few years for each thermal engine, but the cost of the overhaul is usually amortized over a number of years given their high costs. Overhaul costs are publicly available for each utility at a company/rate zone level, but not at the specific community level. In addition, public information does not enable break out of specific natural gas generation costs versus diesel generation costs. Accordingly, for the current analysis, engine overhaul cost was estimated for each utility by dividing annualized thermal overhaul costs by the company/rate zone thermal (diesel and gas) generation. This cost is then applied for each community served by this company. In the case of Yukon communities, where no such information is currently available, an average of NWT and Nunavut estimates was assumed. An approach that uses average costs will tend to overestimate costs for larger and less remote communities and underestimate costs for other communities, e.g., actual costs for the three specified NWT communities are likely materially lower than the average shown in Table 1-1.

- **Non-fuel O&M Expenses:** Fossil fuel thermal generating plant operation also includes many other types of expenses (plant operator salaries, mechanical and electrical maintenance of diesel units, maintenance of the powerhouse, etc.). Non-fuel O&M expenses related to fossil fuel generation were calculated as total thermal generation related non-fuel O&M cost (excluding overhaul) divided by generation. Again the non-fuel O&M information is only available at a company/rate zone level. In addition, public information does not enable break out of specific natural gas generation costs versus diesel generation costs. Accordingly, for the current analysis, non-fuel O&M cost for thermal generation was estimated for each utility by dividing annualized fossil fuel non-fuel O&M costs by the company/rate zone fossil fuel generation. This cost is then applied for each community served by this company. This approach using average costs will tend to overestimate costs for larger and less remote communities and underestimate costs for other communities.

- **Capital Related Fossil Fuel Thermal Generation Cost:** Construction of fossil fuel generation facilities require funding, where the cost of the facilities (e.g., generating units and related plant buildings) is allocated over the life of the assets and recovered through two components:

- **Depreciation and/or Amortization Expense:** the acquisition cost of a facility is amortized annually over the life of the asset (average life of depreciation assumed by the utilities for thermal facilities is approximately 30 years, except for NTPC where it is closer to 23 years)[1]. For the purposes of the current analysis, thermal facilities' amortization expense was divided by the generation at the company/rate zone level in order to calculate this component of the capital related cost.

[1] NTPC has substantially higher amortization rates than other northern utilities reviewed – average amortization rate of 4.3% for NTPC compared to 3.4% for QEC and 3.2% for AEY. The higher amortization rates for NTPC account for about 4 cents/kW.h higher annual cost for NTPC thermal generation facilities compared to similar QEC or AEY facilities.

- **Financing Cost:** the utility finances the construction of facilities through a combination of long-term debt and equity. The carrying cost of debt and return on equity are then added to the utility's revenue requirement. Utility's cost of debt and equity as forecast in the respective GRAs was applied to the net cost of thermal assets (i.e., gross acquisition cost less accumulated amortization) in order to calculate this component of the capital related cost. In the case of NTPC (NWT), no cost of equity is included in capital cost estimates for off-grid fossil fuel thermal generation.[2]

Review of the capital component of the fuel cost by jurisdiction indicates a higher annual cost per kW.h in the NWT communities as compared to Nunavut and Yukon communities. This difference mainly reflects variances in amortization rates (which are higher for NTPC facilities compared with QEC and AEY facilities). NTPC costs in Table 1-1 are also impacted by averaging of overall thermal capital costs across all zones, i.e., inclusion of hydro zone thermal generation tend to raise the overall NTPC average cost per kW.h (due to relatively low thermal generation per unit as well as higher return costs that include ROE).

Government Subsidies

In each Territory the territorial governments subsidize the energy costs to residential customers, either directly (through government grants) or though rate equalization measures (which reduce rates in off-grid thermal generation communities and raise rates in hydro grid served communities). These subsidies do not affect cost of generation to the utility, however, they do result in residential customers (and potentially other customers) in these communities not paying the full cost of fossil fuel generation.

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[2] Financing cost assumptions in the respective GRAs (as adopted for this analysis) are as follows:

1. NTPC – Thermal zone cost of debt of 8.29% (includes interest coverage mark-up), and ROE of 0%, for a weighted average capital cost of 4.91% (2016/17); for reference, hydro zone cost of debt of 5.53% and ROE of 8.5%, for a weighted average capital cost of 6.74%;
2. QEC – Cost of debt of 4.81%, and ROE of 9.0%, for a weighted average capital cost of 6.44% (2014/15); and
3. AEY – Cost of debt of 5.49%, and ROE of 9.35%, for a weighted average capital cost of 6.99% (2016-17 GRA, 2016 Test year).

Existing government subsidies may have an indirect impact on the social and environmental cost of diesel through distorting market signals to some extent (e.g., rate subsidies may lead to higher power consumption thus increasing the level of diesel emissions).

Descriptions and sources for each column of Table 1-1 are provided below:

- **Fossil Fuel Generation** is specific for each of the specified communities and taken directly from the utilities' rate applications.

- **Plant Fuel Efficiency** indicates how many units of electricity (kW.h) are generated per unit of fuel in that plant. These costs are specific to each of the specified communities.

- **The Fuel Prices for NWT** communities reflect the forecast price for 2016/17 fiscal year; Nunavut communities reflect weighted average fuel price per litre as of February 2016 based on QEC's March 2016 FSR application;[3] and the fuel prices for Yukon communities reflect the forecast for 2016 based on AEY 2016-17 GRA.[4] Fuel prices are community specific and include commodity, transportation and storage costs.

- **Fossil Fuel Cost Per Unit** is calculated as fuel price divided by plant fuel efficiency. Fuel prices are community specific, and include commodity, transportation and storage costs.

- **Average Overhaul Cost** is calculated as average annual cost of fossil thermal generation overhaul for the utility divided by generation (kW.h). The numbers reflect territory-wide or rate zone average as the community specific numbers are not available from public sources. NWT reflects the annual amortization of deferred overhaul costs and Nunavut reflects the average annual cost of overhaul. No information is currently available for Old Crow and Destruction Bay, and therefore an average of the NWT and Nunavut estimates is assumed ($0.04/kW.h).

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[3] See: http://www.qec.nu.ca/home/index.php?option=com_content&task=view&id=180&Itemid=0.

[4] AEY response to JM-AEY-8 during AEY's 2016-17 GRA review.

- **Non-fuel O&M Expense** is calculated as all thermal generation related O&M divided by generation at the company/rate zone level as community specific information is not publicly available. Internal checks show that the average cost in larger communities are lower than the company wide average.

- **Capital Component Cost** reflects the company level average cost based on: (a) total cost of company-wide thermal generation plant less accumulated amortization multiplied by rate of return on rate base (RORB) and divided by annual thermal generation; plus (b) annual depreciation and/or amortization expense divided by annual generation. The numbers are subject to limitations of data [for example, Old Crow uses the estimated average for AEY while the community specific data for Old Crow may show higher capital cost than shown in Table 1-1].[5]

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[5] AEY in response to YUB-YECL-15 during AEY's 2016-17 GRA review notes that complex logistics are causing an increase in capital costs in Old Crow.

Table 1-1: Summary Utility Fossil Fuel Generation Costs for Selected NWT, Nunavut and Yukon Off-Grid Communities

Territory	Reference Year	Community	Fossil Fuel Generation (MWh)	Plant efficiency (kWh/l); (kWh/m3)	Fuel Price ($/l); ($/m3)	Fossil Fuel Cost per Unit of Generation ($/kWh)	Non Fuel Operating Costs: Average Overhaul Cost ($/kWh)	Non Fuel Operating Costs: Non-fuel O&M ($/kWh)	Capital Component ($/kWh)	Total Utility Costs ($/kWh)
NWT	2016/17	Inuvik - Diesel	16,996	3.59	1.17	0.33	0.05	0.12	0.15	0.64
	2016/16	Inuvik - Natural Gas	11,330	3.34	0.89	0.27	0.05	0.12	0.15	0.58
	2016/17	Tuktoyaktuk-Diesel	4,142	3.69	1.08	0.29	0.05	0.12	0.15	0.61
	2016/17	Fort McPherson-Diesel	3,424	3.59	1.23	0.34	0.05	0.12	0.15	0.66
Nunavut	2014/15	Iqaluit-Diesel	60,741	3.82	1.11	0.29	0.03	0.09	0.09	0.50
	2014/15	Cambridge Bay-Diesel	10,267	3.69	1.08	0.29	0.03	0.09	0.09	0.50
	2014/15	Rankin Inlet-Diesel	17,625	3.77	1.06	0.28	0.03	0.09	0.09	0.49
	2014/15	Baker Lake-Diesel	9,518	3.86	1.06	0.27	0.03	0.09	0.09	0.48
Yukon	2015	Old Crow-Diesel	2,264	3.30	1.79	0.54	0.04	0.08	0.10	0.76
	2015	Destruction Bay-Diesel	1,789	3.54	0.69	0.19	0.04	0.08	0.10	0.41

ATTACHMENT 2

FUEL PRICE FORMATION IN THE NORTHERN TERRITORIES AND POTENTIAL NEAR TERM FUTURE ADDITIONAL UTILITY FOSSIL FUEL GENERATION COSTS

This Attachment reviews publicly available documents to analyze the following direct factors (other than normal inflation) that may increase thermal generation utility costs in the northern communities in the near future [5-10 years] beyond the current costs described in Attachment 1:

- Fuel price formation in the Northern Territories.
- Diesel capital costs for plant expansion or replacement.
- GHG emission price impact on future utility diesel cost.

Current Fuel Price Formation

"Fuel price" in this review is the cost of fuel delivered to the northern community's thermal generation. It includes basic commodity prices (e.g., market prices for oil or natural gas), processing cost to provide the specific fuel (e.g., refinery cost for diesel fuel, liquefaction costs for LNG), transportation from processing centers to the northern community, storage costs at the community, and any taxes applicable to the fuel.

Overall, a large portion (e.g., 50% or more) of the delivered fossil fuel cost for each northern community is separate from the basic commodity prices.

Accordingly, delivered fossil fuel prices for these communities in the next 5 to 10 years will be affected by changes in basic commodity prices (which remain potentially volatile), changes in refining or processing costs, changes in transportation costs, and changes in taxes applicable to the fuel.

These notes do not address potential future changes in basic commodity prices (which are forecast to increase - but remain volatile and uncertain as to timing and degrees of increase), or potential future changes in refining or processing costs and/or haul distances required to transport these fuels to the northern communities (e.g., LNG haul costs would be materially reduced if LNG processing facilities in future are established closer to the northern communities).

Analysis below does review potential impacts of current northern government fuel purchasing policies. Subsequent analysis examined potential impacts on delivered fuel prices from new taxes related to GHG emissions.

Review of diesel fuel prices in the Northern Territories, Yukon and Nunavut indicates that with the exception of Yukon they do not vary notably by community. Similar fuel price levels by community in the Northwest Territories and Nunavut may suggest that fuel prices are being subsidized by each territory's respective government. A review of the fuel price formation for the utilities servicing each of the reviewed northern communities is provided below – however, this does not indicate evidence of such subsidization.

Northwest Territories Power Corporation

Until December 1, 2005, NTPC purchased fuel required for power generation through a variety of options - it tendered all its fuel requirements; purchased fuel required for power generation from the Petroleum Product Division (PPD) of the GNWT through local purchase orders; entered into commodity swap options; and entered separate contracts for certain communities.[6]

In December 1, 2005, NTPC entered a Fuel Management Services Agreement with the PPD. By entering this Agreement, the PPD became responsible for all activities related to the procurement, transportation and storage of fuel, as well as operation and maintenance of tank farms. The PPD includes the Corporation's fuel requirements as part of its annual fuel purchases and as part of its regular operations, and arranges for shipment of fuel via truck or barge, manages and coordinates the delivery and off-loading of fuel, and maintains and monitors fuel storage (although the Corporation retains ownership of its tank farms). The Corporation only purchases its actual fuel requirements from the PPD at the point of consumption, i.e., for the fuel taken from fuel storage tanks.

The fuel cost is made up of the following:

- Landed cost of fuel (Edmonton rack rate, same for all communities);
- Delivery charges (varies by community, but appears to be clustered by location proximity);
- Fuel services charge (set at a same fixed price for all communities); and
- Fuel tax of $0.031/litre (same for all communities).

[6] See: Source: NTPC IR responses to BR-4 from July 23, 2001 (2001/03 Phase I GRA); BR-7 from Feb 16, 2007, TGC-50 from Feb 16, 2007 (2006/08 Phase I GRA).

The only component of the total fuel price which varies by community is the delivery charge. The forecast delivery charge from NTPC's 2006/08 GRA application ranged from $0.0642/liter in Yellowknife to $0.3919/litre in Colville Lake – the difference of approximately $0.36/ litre. The difference between Yellowknife and Colville Lake forecast fuel price for the 2016/17 test year is $0.34/litre, which is in line with the delivery charge difference.

The delivery charges appear to be clustered by location proximity – in the 2006/08 GRA delivery charge was $0.2116/litre for Inuvik, $0.2249/litre for Tuktoyaktuk, and $0.2293/litre for Fort McPherson. In addition, review of NTPC's fuel price forecast from 2000/01, i.e., the period when NTPC purchased its fuel directly, indicates that Inuvik, Tuktoyaktuk and Ft McPherson fuel prices are all within $0.03/litre difference to each other.

As such, the GNWT does not appear to directly subsidize fuel prices to NTPC by taking over fuel management services.

However, in accordance with Clause 4 of the Fuel Management Services Agreement, the GNWT is responsible for any fuel spill caused by the GNWT under the Agreement. As such, by entering the Agreement with the GNWT, NTPC transferred future fuel spill risks to the government.

The variance between actual and forecast fuel prices are refunded to, or recovered from, customers through the Fuel Stabilization Rider [FSR].

Qulliq Energy Corporation

The Petroleum Products Division of the Government of Nunavut is responsible for the purchase, transportation, storage and distribution of all petroleum products in Nunavut, including the fuel required for QEC's operations.[7]

[7] No details with respect to fuel purchase arrangements can be provided, as a copy of a written agreement between the Government of Nunavut and QEC with respect to fuel purchases was not publicly available.

The fuel price varies significantly between sealift season, where a bulk purchase is available, and the rest of the year, when only nominated purchase is available.

Some communities have enough storage capacity for the annual volume of fuel required (e.g., Cambridge Bay), and their prices would generally be lower reflecting largely bulk fuel purchases.[8] However, bigger communities like Iqaluit do not have such capacity, and from time to time would need to purchase at nominated fuel prices which are notably higher than bulk fuel prices. This pushes their average fuel price higher than bulk purchase only communities.

The Government of Nunavut offers fuel subsidies to the general public through programs like Senior Fuel Subsidy and Fuel Tax Rebate to Harvesters, Outfitters, and Tour Operators. However, it does not appear that the government offers any subsidy to QEC for fuel purchases other than possibly transferring to QEC any volume discount it receives through its bulk purchase of fuel.

The variance between actual and forecast fuel prices are refunded to, or recovered from, customers through the Fuel Stabilization Rider [FSR].

Yukon

In contrast to NWT and Nunavut, in Yukon the fuel for electricity generation is purchased directly by the utilities. The communities reviewed in this document are served by AEY. AEY purchases fuel on an ongoing basis for each of the five isolated diesel plants. AEY conducts a diesel fuel tendering process in which a vendor is selected to be the provider of diesel fuel.[9]

Similar to NWT and Nunavut, the variance between actual and forecast fuel prices are refunded to, or recovered from, customers through a fuel price flow through rider [Rider F].

[8] In 2013/14 fiscal year, fuel prices for Iqaluit were approximately $0.98/L for bulk delivery and approximately $1.16/L for nominated fuel (or 18% difference in fuel prices). Source: QEC's response to URRC-QEC-1, dated January 10, 2014 (Table 1).

[9] AEY 2016/17 GRA, page 4-1.

Diesel Capital Cost for Plant Expansion or Replacement

The capital component of the price illustrated in Table 1-1 is based on the current cost of plant in service for the communities where a company-wide estimate is used. This may underestimate the future capital cost per unit as diesel plants in most of the northern communities are aged and the cost reflects significantly amortized values [although the capital costs also include some new plant costs, like new diesel plant construction in Iqaluit in 2014 and Old Crow in 2015].

As an illustration of this point, for example, it is understood that AEY completed a plant expansion project in Old Crow at a cost of $4.6 million plus installation of 400 kW unit at a cost of $0.612 million.[10] The annual amortization and return on rate base for this new unit would be about $0.490 million [assuming 40 year amortization and 2016/17 GRA proposed return on rate base]. This is about 22 cents/kW.h for the capital cost component compared to 10 cents/kW.h included in Table 1-1.[11]

Potential New Fuel Taxes for GHG Emissions

Studies are being conducted for northern utilities (e.g., Yukon Energy) on lifecycle assessments of total GHG emissions (kg CO_2e [carbon dioxide equivalent]) during construction and operation (including emissions related to the fuel supply chain outside northern communities) related to various resource options, including diesel and natural gas (LNG) thermal generation. Two publicly released studies are noted below for Yukon with respect to the lifecycle GHG emissions estimate per unit of power generation.

- ICF International conducted a study in 2013 on Yukon power plant fuel life cycle.[12] The study estimated total GHG emissions of 694.8 tonnes/GW.h of energy output for diesel, and 679.5 tonnes/GW.h of energy output for natural gas.

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[10] AEY 2016-17 GRA, Schedule 9.2, page 1 of 6. Cost for Plant Expansion and Unit 4 addition.

[11] AEY response to CW-YECL-33(c) [Attachment 1, page 2] during review of AEY's 2013-15 GRA shows that for Old Crow the structures and improvements are amortized over 40 years, prime movers over 25 years and other generation equipment over 35-40 years. For simplicity it is assumed over 40 years. The 22 cents/kW.h estimated as $0.490 million/year [$0.130 million amortization and $0.360 million return at WACC of 6.99%] divided by 2,264 MW.h total generation shown in Table 1-1.

[12] ICF International, Yukon Power Plant Fuel Life Cycle Analysis, Final Report, 2013.

- Pembina Institute also conducted a study of a life cycle emissions inventory in 2013.[13] This study presented GHG emissions estimates from power generation for several scenarios. The study found that life cycle GHG emissions for new diesel engines would be 884 tonnes/GW.h for 100-year lifetime, and 980 tonnes/GW.h for 20-year lifetime. For the existing diesel engines, however, the study estimated GHG emissions at 1,005 tonnes/GW.h. GHG emissions for natural gas were estimated at 688 tonnes/GW.h for a 100-year lifetime, and 906 tonnes/GW.h for a 20-year lifetime.

Without detailed review of publicly available information, the following assessment of potential new carbon taxes for fossil fuels assumes that overall GHGs for each GW.h energy output approximate 1,000 tonnes for diesel fuel use and 750 tonnes for LNG use.[14]

With the widely discussed proposed price on carbon dioxide pollution by the federal government at $10 /tonne as a starting price and an increase to $50/tonne by 2022, the impact of such a new carbon tax would be in the range of $10,000 to $50,000/ GW.h of fossil fuel diesel energy generation.[15]

[13] Pembina Institute, LNG for Yukon Energy Power Generation, 2013.

[14] These assumed numbers are adopted simply to provide an indication of potential cost impacts of new taxes on lifecycle GHG emissions from diesel or natural gas generation, based on Global Warming Potential (GWP) for 100 year time horizons, which is widely used.

[15] For example, http://www.cbc.ca/news/politics/canada-trudeau-climate-change-1.3788825 [accessed on October 18, 2016].

The current practice in some of the Canadian jurisdictions is to charge different prices for carbon dioxide. For example, BC imposes $30/tonne of CO_2 equivalent which is translated into tax rates for each specific type of fuel. For diesel it is about 7.67 cents/litre [or about 2 cents/kW.h using the average fuel efficiency for the reviewed communities in Table 2-1] due to the higher carbon content of the fuel, while the tax on natural gas is 5.70 cents/ litre [or about 1.5 cents/kW.h]. [16]The floor price for Quebec Cap and Trade was set at $10/tonne in 2012 and subject to increases annually by 5% plus inflation.[17]

Table 2-1 illustrates the GHG emission cost of fossil fuel, using carbon price based on $10/tonne and $50/tonne price options.

Table 2-1: Estimated GHG Emission Cost of Fuel Generation

Territory	Community	Fossil Fuel Generation (MWh)	Total Utility Current Costs ($/kWh)	Potential Impact of GHG Cost			
				GHG Cost based on $10/tonne[2]		GHG Cost based on $50/tonne[2]	
				($/kWh)	% impact	($/kWh)	% impact
NWT	Inuvik-Diesel	16,996	0.64	0.01	1.6%	0.05	7.8%
	Inuvik-Natural gas	11,330	0.58	0.01	1.3%	0.04	6.5%
	Tuktoyaktuk-Diesel	4,142	0.61	0.01	1.7%	0.05	8.3%
	Fort McPherson-Diesel	3,424	0.66	0.01	1.5%	0.05	7.6%
Nunavut	Iqaluit-Diesel	60,741	0.50	0.01	2.0%	0.05	10.0%
	Cambridge Bay-Diesel	10,267	0.50	0.01	2.0%	0.05	10.0%
	Rankin Inlet-Diesel	17,625	0.49	0.01	2.0%	0.05	10.2%
	Baker Lake-Diesel	9,518	0.48	0.01	2.1%	0.05	10.4%
Yukon	Old Crow-Diesel	2,264	0.76	0.01	1.3%	0.05	6.6%
	Destruction Bay-Diesel	1,789	0.41	0.01	2.4%	0.05	12.1%

Notes:
1. Assumes total GHG emissions (kg CO2e [carbon dioxide equivalent]) from all sources for each GW.h energy output at 1,000 tonnes for diesel, and 750 tonees for natural gas (LNG). Assumed carbon pricing based on recent federal government proposals for a starting price of $10/tonned increasing to $50/tonne by 2022.
http://yukonutilitiesboard.yk.ca/pdf/YEC_LNG_Application/YEC_LNG_Part_3_Update_Filing_Appendices.Mar_27__2014.pdf

[16] Available in http://www.fin.gov.bc.ca/tbs/tp/climate/A4.htm [accessed on October 19, 2016].

[17] http://www.mddelcc.gouv.qc.ca/changements/carbone/documents-spede/q&a.pdf [accessed on October 19, 2016].

ATTACHMENT 3

REVIEW OF OTHER FOSSIL FUEL GENERATION COSTS - SOCIAL COSTS EXTERNAL TO UTILITY GENERATION COSTS

Approach and Definitions

In addition to the direct utility costs related to the fossil fuel electricity generation, as reviewed in Attachments 1 and 2, there are also other impacts, or indirect social costs, imposed by installation and running of fossil fuel generation units. Social costs may include direct and indirect impact to health and well−being of populations, impact to animals and plants, and climate change. Social costs are not limited to the communities wherein the thermal generation occurs, e.g., GHG emissions related to fossil thermal generation can impact climate globally.

Preliminary review has not revealed any defined guidelines regarding the determination of relevant social costs related to thermal generation in northern Canadian jurisdictions. Four available studies and reports have been reviewed to provide guidance as to potential social costs for air emission impacts from different fossil fuels use (see Table 3-1 for an overview comparison of air emission cost impacts as provided by these four studies).

Overall, the four studies show a wide range of estimated social costs from US thermal power generation using either oil products (diesel was not specifically examined) or natural gas, e.g., in CAN$2016, air emission impact social costs range from 3.2 cents/kW.h to 19.2 cents/kW.h for oil thermal generation and from 0.25 cents/kW.h to 13.2 cents/kW.h for natural gas thermal generation. Most of these social cost impacts from oil thermal generation relate to human health impacts, and the dollar values for such impacts are very sensitive to the scale and status of the local regional population affected by such impacts, i.e., as such, these dollar cost impacts may have no direct application to the remote northern Canadian communities that are the focus of this review.

Review of Specific Studies

Initial review focused on a recent monetized health and social cost of fossil fuel air emissions as calculated by a US researcher, D. T. Shindell in 2015.[18] The Shindell analysis is a detailed and technical paper, which builds upon the Social Cost of Carbon framework and extends it to a broader range of pollutants and impacts. The paper estimates impacts of emissions on health and climate related to 11 factors, including baseline mortality projections, fertilization on agriculture/malnutrition, climate sensitivity, carbon-cycle response to non-CO_2 forcing, and others. Social costs include both health and cost of environmental impacts from air emissions, and specifically from GHG emissions.

- The results indicate social and health costs for diesel used in transportation at USD $4.80 /US gallon or CAN$1.98 /litre of diesel escalated to 2016$ at recent exchange rates.[19]

    - If it is assumed that transportation uses are a proxy for thermal generation uses, based on diesel fuel requirements per kW.h for northern communities as reviewed in Attachment 1 (Table 1-1), a social cost of $1.98/litre equals between 51 and 60 cents/kW.h.[20]

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[18] D. T. Shindell, The Social Cost of Atmospheric Release, 2015

[19] Escalated for 2007$ to 2016$ at 2%/ year and converted to CAN$ using Bank of Canada October 18, 2016 exchange rate of $1.31 CAD/$1 USD http://www.bankofcanada.ca/rates/exchange/daily-converter/ [accessed on October 18, 2016].

[20] Reflects range of fuel efficiency from 3.30 kW.h/litre (Old Crow, Yukon) to 3.86 kW.h/litre (Baker Lake, Nunavut).

    - As reviewed in Table 3-1, by far the major element of this social cost derives from human health impacts from non-CO_2 air emissions, and only 16% of this cost impact relates to CO_2 emissions.[21]

- Table 3-1 shows Shindell study estimates of overall social cost impact (CAN$2016) from coal and natural gas use in power generation at 37.6 cents/kW.h and 13.2 cents/kW.h respectively. This study did not estimate social costs from oil use in power generation.

    - As shown in Table 3-1 from other studies, oil use in power generation consistently has lower health and climate cost impacts than coal use in power generation.

    - Based on the Shindell study estimated air emission social costs for coal use in power generation, which exceed similar Shindell study cost impacts from diesel use in transportation, it is reasonable to conclude that diesel use in transportation is not a good indicator of diesel air emission impacts in power generation (due to differences in technology and efficiencies).

    - As noted in the Shindell study, social costs from air emissions from fossil fuel use in power generation can vary widely depending on actual technologies used (e.g., age of facilities) and actual fuels used.

The second study reviewed is by Muller et al.[22] This study measures only the externalities from air pollution and omits other external effects that take place through water, soils, noise, and other media. The pollutants tracked in this study include sulfur dioxide, nitrogen oxides, two measures of particulate matter ($PM_{2.5}$ and PM_{10}), ammonia, volatile organic compounds, and carbon dioxide emissions from the electric power generation sector.

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[21] Personal communication from Dr. Shindell.

[22] Muller N, Mendelsohn R, Nordhaus W (2011) Environmental accounting for pollution in the United States, The American Economic Review 101:5 1649-1675;

- The study uses an integrated assessment model, which first calculates the total damages from the 2002 levels of emissions across the U.S. Numerical experiments, undertaken by adding one ton to baseline emissions from each source. This calculation captures the effects of secondary pollutants and pollution interaction effects. The study then repeats this process for the remaining 10,000 sources in the U.S. and for each of the six primary pollutants listed above. Multiplying the shadow price times the quantity of emissions by industry yields the Gross External Damages (GEDs) caused by that source.

- Using this approach, the study arrives at an average social cost of US oil thermal power generation (US$2000 for GED/kW.h) of 1.79 cents/kW.h including CO_2 emissions, and 1.26 cents/ kW.h excluding CO_2 emissions (i.e., only reflecting sulfur dioxide, nitrogen oxides, two measures of particulate matter ($PM_{2.5}$ and PM_{10}), ammonia, and volatile organic compounds). The study notes that these cost estimates are in 2000 prices, and assume a CO_2 climate impact value of $7.4 / ton. Updating these numbers to the 2016 prices using the annual inflation assumption of 2% and exchange rate of CAD1.31/USD1, the social cost of diesel is estimated at 3.2 cents/kW.h including CO_2 emissions, and 2.3 cents / kW.h excluding CO_2 emissions. This suggests that CO_2 emission costs for climate impacts are approximately 1 cent/kW.h, which appears reasonable and is consistent with estimates presented in Table 2-1. This study's non-CO_2 oil thermal power generation air emission cost impacts, however, are much lower than the estimates in the Shindell study and the Machol and Rizk study.

- The study also provides US thermal power generation air emission cost impacts from natural gas and from coal. Table 3-1 indicates these costs in CAD$2016 at 0.81 cents/kW.h for natural gas and 4.59 cents/kW.h for coal.

The third study reviewed is by the National Research Council (NRC).[23] This study evaluated effects from thermal power generation in the US related to air emissions of particulate matter (PM), sulfur dioxide (SO_2), and oxides of nitrogen (NO_x), which form criteria pollutants.[24]

- The NRC studied energy technologies that constitute the largest portion of the U.S. energy system or that represent energy sources showing substantial increases (>20%) in consumption over the past several years. The study evaluated each of these technologies over their entire life cycles – from fuel extraction to energy production, distribution, and use to disposal of waste products – and considered the external effects at each stage.

- The method started with estimates of burdens (such as air-pollutant emissions and water-pollutant discharges). Using mathematical models, the study then estimated these burdens' resultant ambient concentrations as well the ensuing exposures. The exposures were then associated with consequent effects, to which the study attached monetary values in order to produce damage estimates.

- With respect to the electricity industry, the study focused mainly on coal and natural gas, which the study notes together account for nearly 70% of the US electricity generation sources. As such, it does not provide social cost estimate for diesel fuel. However, comparison of the results of this study to the Muller et al. study results for coal and natural gas allow review of consistency between the findings of the two studies.

[23] National Research Council (2010) Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, The National Academies Press, Washington.

[24] Criteria pollutants, also known as "common pollutants" are identified by the U.S. Environmental Protection Agency (EPA), pursuant to the Clean Air Act, as ambient pollutants that come from numerous and diverse sources and that are considered to be harmful to public health and the environment and to cause property damage.

- The NRC study arrives at the social cost of coal thermal generation air emissions (excluding CO_2 emission impacts) of 3.2 cents/kW.h in 2007 cents (US$) compared to 2.07 cents/kW.h in the Muller et al. study (excluding CO_2 impacts, and inflated to 2007 cents for comparison).[25] With respect to the social cost of natural gas thermal generation air emissions, the NRC study arrives at 0.16 cents/kW.h in 2007 cents (US$) compared to 0.11 cents/kW.h in the Muller et al. study. As such, in both cases the NRC study arrives at somewhat higher cost estimates than the Muller et al. study; however, both studies arrive at significantly different cost estimates than the Shindell study or the Machol and Rizk study (reviewed below).

The fourth study reviewed in Table 3-1 is by Machol and Rizk (2013).[26] This study provides an estimate of the economic value of air quality-caused health impacts resulting from the use of fossil fuels for power generation in the U.S. by source type and by state, but does not include climate cost impacts. The study analyzes the same common pollutants analyzed in the NRC and Muller et al. studies, i.e., particulate matter (PM), sulfur dioxide (SO_2), and oxides of nitrogen (NO_x).

- The study argues that Muller et al., as well as the NRC studies do not examine the health impact variation at the state or plant level. This study shows a wide variation in health impact costs per kW.h for thermal power generation in different US states, reflecting variances in technologies (age of facilities) as well as fossil fuel mix.

- The Machol and Rizk study notes that its analysis should not be used to determine absolute values for local impacts of individual plants. The study notes that figures presented in the study will tend to overestimate the impacts in rural areas and underestimate the impacts in urban areas (in part highlighting the extent to which health impact cost per kW.h are sensitive to the population scale and status that is impacted by the plant's air emissions in its area of regional impact).

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[25] Despite projected increases in damages per ton of pollutant resulting mainly from population and income growth—average damages per kW.h from coal plants (weighted by electricity generation) are estimated in the NRC study to be 1.7 cents per kW.h in 2030 as compared with 3.2 cents/kW.h in 2005. This decrease derives from the assumption that SO_2 emissions per MW.h will fall by 64% and that NO_x and PM emissions per MW.h will each fall by approximately 50%.

[26] Machol B, Rizk S (2013) Economic Value of U.S. Fossil Fuel Electricity Health Impacts, Environment International 52 (2013) 75-80.

- The study notes that the estimate of the economic value of health impacts by Muller et al., and NRC studies was significantly lower than estimated in this study, "likely driven by large differences in the air modeling".[27] This study notes that Muller et al. and the NRC studies both use a source-receptor (SR) model that does not account for nonlinearities resulting from photochemical reactions.

- The study argues that its approach provides a new independent estimate that improves upon the previous SR model estimates and provides more thorough analysis of variance between sources and states.

- The study estimates an average economic value of health impacts in the US from thermal power generation (US$2010) at 13 cents/kW.h for oil, 2 cents/kW.h for natural gas, and 32 cents/kW.h for coal.[28]

- At the assumed exchange rate of CAD1.31/USD1 and escalation at 2% /year from 2010$ to 2016$, the average social health cost of air emissions from thermal power generation in the US using fossil fuel (excluding impacts from CO_2 emissions) equal 19.18 cents/kW.h from oil and 2.95 cents/kW.h from natural gas based on the Machol and Rizk study. Compared with the Shindell study estimates, the Machol and Rizk study cost estimates for health impacts are higher for coal power generation and lower for natural gas power generation.

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[27] Machol B, Rizk S (2013) Economic Value of U.S. Fossil Fuel Electricity Health Impacts, p.80.

[28] Machol B, Rizk S (2013) Economic Value of U.S. Fossil Fuel Electricity Health Impacts, p.78.

Table 3-1: Comparison of Estimated Social Costs from Fossil Fuel Air Emissions (2016$CAD)

All in CAD $, 2016 dollars	D. T. Shindell (2015) - Climate & Health Impacts from wide range of air emission pollutants			Muller et al. (2011) - Climate & Health Impacts from specific air emission pollutants			NRC (2007) - Health and non-climate impacts from specific air emission pollutants		Machol and Rizk (2013) - Health Impacts (US national average) from specific air emission pollutants		
	Diesel for Transport	Natural Gas for Thermal Generation	Coal for Thermal Generation	Oil for Thermal Generation	Natural Gas for Thermal Generation	Coal for Thermal Generation	Natural Gas for Thermal Generation	Coal for Thermal Generation	Oil for Thermal Generation	Natural Gas for Thermal Generation	Coal for Thermal Generation
Total Social Cost, cents/kW.h	55.15	13.15	37.57	3.22	0.81	4.59	0.25	5.01	19.18	2.95	47.21
CO2, cents/kW.h	8.62			0.95	0.63	1.42	n/a	n/a	n/a	n/a	n/a
CO2 % of total social	16%			30%	78%	31%	n/a	n/a	n/a	n/a	n/a
Other (patriculate matter & ozone precursors) cents/kW.h	46.53			2.27	0.18	3.17	0.25	5.01	19.18	2.95	47.21
Other % of total social	84%			70%	22%	69%	100%	100%	100%	100%	100%
Total Social Cost includes impact from	carbon dioxide (CO_2), sulfur dioxide (SO_2), BC, nitrogen dioxide (NO_2), nitrogen oxides (NO_x), organic carbon (OC), ammonia (NH_3), methane (CH_4), carbon monoxide (CO)			carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), two measures of particulate matter ($PM_{2.5}$ and PM_{10}), ammonia (NH_3), volatile organic compounds (VOC)			particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide (SO_2), nitrogen oxides (NO_x)		particulate matter ($PM_{2.5}$) and $PM_{2.5}$ precursors (sulfur dioxide (SO_2), nitrogen oxides (NO_x))		

Notes:

1. The estimates from D. T. Shindell (part 4) at 3% discount rate are converted from 2007$ to 2016$ using 2% inflation rate and converted from US dollars to Canadian dollars using exchange rate of $1.31CAD/$1US. Health impacts tend to dominate compared with climate damages. Cost impacts reflect average activities (e.g., major variances for different aged coal technologies and/or activity regions).

2. The estimates from Muller et al. (Table 2) for impacts in the US are inflated from 2000$ to 2016$ using 2% inflation rate and converted from US dollars to Canadian dollars using exchange rate of $1.31CAD/$1US. CO_2 emission cost impacts assume $7.4/ton of CO_2 (US$2000).

3. The average estimates from NRC (Tables 2-9 and 2-15) for the US are inflated from 2007$ to 2016$ using 2% inflation rate and converted from US dollars to Canadian dollars using exchange rate of $1.31CAD/$1US. Wide variances are noted around the mean value estimates for coal and natural gas plant emissions. The NRC document did not provide estimate for CO_2 air emission impacts.

4. The average estimates from Machol and Risk (Figure 1) are inflated from 2010$ to 2016$ using 2% inflation rate and converted from US dollars to Canadian dollars using exchange rate of $1.31CAD/$1US. This study provided a range for national average health impacts of +/-40% for coal generation and +/-46% for oil generation (no material range provided for natural gas generation). The study also showed wide variances in health impact values for thermal generation in different US states, reflecting variances in technologies (e.g., age of plants) and fossil fuel mix.