APPENDIX II.1

OPPORTUNITIES AND TRADE-OFFS

TABLE OF CONTENTS

SECTION PAGE

TABLE OF CONTENTS (Continued)

LIST OF TABLES

1.0 INTRODUCTION

De Beers Canada Mining Inc. (De Beers) assembled an optimization team to identify and review design options that would optimize the Snap Lake Diamond Project. Through a series of desktop studies, the team examined the trade-offs between project design alternatives and the potential opportunities to apply emerging technologies. Ten trade-off and opportunity studies relating to environmental assessment were considered and are listed below:

- diesel vs. propane trade-off study;
- power reduction opportunities;
- power distribution opportunities;
- energy balance study;
- fuel cell opportunity;
- solar energy opportunities;
- wind energy opportunities;
- ore and waste rock handling study;
- explosives trade-off study; and,
- diamond sorting trade-off study.

These are preliminary studies based on available information. As the detailed design of the project progresses, project alternatives and opportunities will be re-examined. For some options (*e.g.*, wind energy opportunities), further information is desirable for a more detailed re-examination of the option.

Five trade-off and opportunity studies are contained in this appendix as examples of the economic, technical and environmental factors considered in the review of design options.

2.0 DIESEL VS. PROPANE TRADE-OFF STUDY

2.1 Introduction

Previous studies of the Snap Lake Diamond Project had assumed the exclusive use of propane fired heaters for heating of underground mine air when the ambient temperature went below freezing. This assumption did not necessarily reflect an optimized design, but was chosen primarily based on the known relatively high efficiency and low capital cost of propane-fired heaters when compared with diesel oil-fired heaters. To optimize the design, the two options were compared in further detail.

2.2 Mine Air Heating Fuel Requirements

Based on known fuel heating values and estimated heater efficiencies, it was estimated that 8.2-million litres of propane or 7.9-million litres of diesel would be required on an annual basis to fuel the mine air heating system.

2.3 Storage and Handling Requirements

Propane would be stored on site in numerous horizontal, cylindrical tanks. Depending on the actual individual tank volume (between 114,000 and 180,000 litres, depending on manufacturing and transport restrictions), between 46 and 73 tanks would be required to store the 8.2-million litre annual requirement. Propane would be pumped or trucked to the mine air heaters.

Diesel fuel would be stored in one additional 12.5-million litre steel tank, identical to the two tanks already required to store diesel for power generation and mobile equipment. Diesel fuel would be pumped or trucked to the mine air heaters.

2.4 Economic Comparison

The capital and annual operating costs for the propane option were estimated at $9.2 million and $3.5 million, respectively. Over a 20-year period, and based on an assumed 11 percent (%) discount rate, the net present value of this option is $48.1 million.

The capital and annual operating costs for the diesel option were estimated at $3.6 million and $4.3 million, respectively. Over a 20-year period and based on an assumed 11% discount rate, the net present value of this option is $49.8 million.

Since the net present values of the two options are within 5% of each other, they were considered similar. It was concluded that there was no economic difference between the two options.

2.5 Environmental Comparison

Based on air quality modelling, emissions from the combustion of propane were predicted to be lower than diesel emissions for all constituents except for NOx (oxides of nitrogen).

2.6 Logistics Comparison

Currently there is no established propane supply infrastructure (*i.e.*, storage tanks and truck fleet) in Yellowknife or Alberta that could supply Snap Lake with the annual propane requirement during the winter road period. Also, Canada's largest propane suppliers do not currently deliver such quantities in a limited access period such as the six- to eight-week winter road period. Thus, it is assumed that one or more large propane suppliers would have to set up such capability before Snap Lake could be assured of reliable annual delivery.

The supply infrastructure for diesel is well established in the Northwest Territories. Given the annual diesel supplies requirements for operations such as BHP Billiton and Diavik Diamonds Mine Inc. (over 100-million litres combined), an additional 7.9-million litres annually is not anticipated to adversely impact the supply capability.

2.7 Operations and Safety Comparison

The handling of propane on site would introduce additional operational and safety requirements. For example, extensive training for operation and maintenance of propane systems and delivery trucks, increased spares inventory for propane distribution equipment, additional safety procedures and supplies, and additional regulatory requirements and inspections may be required. The operation and maintenance of a propane storage and handling system clearly introduces more safety hazards (primarily explosion) to site personnel and equipment when compared to diesel.

Storage and handling of diesel fuel on site would be required regardless of mine air heating fuel type. Therefore, using diesel for mine air heating would not introduce additional operational or safety requirements.

2.8 Conclusion and Recommendation

The environmental advantages of propane (*i.e.*, lower overall emissions), make it the preferred option for mine air heating when compared with diesel fuel. When comparing the two fuel options from logistical, operational and safety perspectives; however, there are substantial disadvantages associated with propane use. It is recommended that diesel be used for mine air heating fuel.

3.0 POWER REDUCTION

3.1 Introduction

The operating costs and emissions associated with combustion of diesel fuel for electrical power generation for the Snap Lake Diamond Project will be significant. The investigation and implementation of all feasible power reduction measures is therefore warranted. This study is a preliminary identification of the potential sources of power reduction. The feasibility of additional sources of power reduction identified in the final project design will be examined.

3.2 Power Generation

The overall efficiency of diesel generator sets will be optimized in the final selection and configuration of the power plant. Increased efficiency of the generator sets will minimize fuel consumption through the following measures:

- determination of optimal loading configuration of the power plant to obtain highest diesel engine fuel efficiency;
- consideration of diesel engines for burning alternate fuels such as refined oil (emissions must be studied carefully in this case; certain diesel engines are more conducive to burning alternate fuels);
- optimization of lubrication oil to minimize friction losses;
- consideration of the technology of using power cells for magnetic fluid treatment to increase combustion efficiency (preliminary results indicate potential for up to 20% greater efficiency);
- recovery of engine waste heat (from coolant, exhaust and oil) for use as building heating (common practice in northern installations);
- consideration of fuel additives for fuel consumption improvement;
- use of generator manufacturers with proven northern experience; and,
- consideration for comprehensive vendor support for ongoing maintenance requirements. The expertise of vendor support services will be important to the ongoing optimal efficiency of the power plant.

The power plant will also be equipped with an automated power management system, which will monitor and manage the power system to increase efficiency.

3.3 Heat Recovery

Waste heat may be used to heat buildings or water in the process plant. All sources of waste heat will be examined and, if deemed practical, will be implemented in the final design. The primary source of waste heat is the power plant generators (as identified above). However, it may be feasible to recover waste heat from several other sources. To date, four potential sources of waste heat have been identified:

- de-humidification exhaust fans in the process plant;
- any warm effluent pipes (*e.g.*, water treatment plant discharge, laundry washing outflow, *etc.*);
- building exhausts (*e.g.*, kitchen, laundry dryers, *etc.*); and,
- incinerators.

3.4 Electrical and Control Systems and Components

Four systems and components identified as potential sources of significant power reduction will be implemented in the final design. High-efficiency electric motors can reduce motor power consumption by up to 12%. While more expensive than conventional motors, their payback is estimated to be approximately two years. Variable frequency drives or adjustable speed drives (ASDs) installed on mechanical equipment subject to varying demand, such as fans and pumps, can reduce motor power consumption by 45% to 60%. While more expensive than conventional motor starters, their payback is estimated to be less than two years. Efficient lighting fixtures (*e.g.*, high pressure sodium lighting, metal halides for exterior and interior plant lighting, T-8 fluorescent lamps for office lighting, light emitting diode exit lights and compact florescent) will be installed instead of incandescent lights. Lighting system controls (*e.g.*, dimmer controls, photocell controls for all exterior lighting, or occupancy sensors for meeting rooms, washrooms, storage areas and low traffic areas) will be installed instead of manual controls.

3.5 Mechanical Systems and Components

Optimization of mechanical systems will also minimize power requirements. Five designs and system features are currently being considered for inclusion in the final design:

- optimized compressed air systems, including ASDs, leak detection and overall compressor system monitoring;
- automated building heating, ventilation and air conditioning controls;
- solar heating or intake air (examined in the solar energy study);
- ozone laundry systems that reduce requirements for electricity, laundry chemicals and water; and,
- advanced electric commercial cooking technologies.

3.6 Conclusion and Recommendation

Several sources of potential energy conservation have been identified, most of which will be considered in the final, detailed project design. This includes diesel generation optimization, power plant management system, waste heat recovery, and electrical and mechanical system design and selection. All means of power reduction will be examined during detailed design and will be implemented where practical.

4.0 ENERGY BALANCE

4.1 Introduction

The Snap Lake Diamond Project will require a significant amount of energy for heating of buildings, water and mine air. The primary source of this energy will be diesel fuel. Diesel fuel will be used to operate diesel generators from which waste heat can be extracted and used to heat other facilities, and burned directly to heat process water, glycol (for building heat) and mine air. There will be many sources of waste heat, for example, diesel generator engine coolant and exhaust stacks, building exhausts or compressors. To minimize the consumption of diesel fuel and its associated emissions, a preliminary energy balance was performed.

The energy balance for site-wide heating is presented in this study. The balance was conducted to provide four types of information:

- total annual gross energy required for heating;
- net heating required assuming waste heat could be recovered from the power plant;
- viability of alternate waste heat sources for further reduction of total fuel consumption; and,
- optimized distribution of available recovered waste heat to minimize fuel consumption.

4.2 Site Energy Requirements

The first step in the energy balance was to identify the total energy required to heat buildings, water, and mine air. Based on the current proposed design and on-site monthly ambient temperature data, the total energy required for heating was estimated as 12.6-million litres of diesel per year (Table II.1-1).

Table II.1-1
Annual Heating Energy Requirements

Description	Annual Heating Energy Required (litres of diesel)
Building and domestic water heating	3,900,000
Process water heating	800,000
Mine air heating	7,900,000
Total	**12,600,000**

4.3 Waste Energy Recovery

4.3.1 Power Plant Generators

The largest source of available waste heat will be the diesel engines in the power plant. Recovery of waste heat from the power plant will provide approximately 60% of the total building, domestic and process water heating requirements, or about 110,000-gigaJoules (2.8-million litres of diesel).

The heat balance indicated that generator waste heat will provide 100% of building and water heating requirements between ambient temperatures of approximately –17°C and –2°C. Waste heat from the generators (from engine coolant and exhaust stacks) will be transferred to a glycol circulation system for building heating.

Below this range, the balance of the heat requirement will be supplied by diesel-fired auxiliary glycol boilers. Above –2°C, there will be surplus waste heat available, during which heated glycol will be pumped to the mine air intake raises, where the heat will be transferred to the intake air in glycol-air heat exchangers. Preheating of intake air via waste heat is expected to reduce diesel consumption by approximately 1.5-million litres per year.

4.3.2 Other Waste Energy Sources

Recovering waste heat from any source requires capital investment in recovery equipment, with feasibility being determined by payback period associated with reduced diesel consumption (typically assumed to be within three to four years). In addition to the power plant, other sources of waste heat were evaluated to determine the economic feasibility of recovery. It was determined that heat could be economically recovered from mine compressors, ore dryers, plant electric motors and accommodations complex exhausts. This heat recovery would save an estimated 1.3-million litres of diesel annually.

There are other potential sources of waste heat recovery such as, the effluent from the water treatment plant, exhausts from the process plant and service complex and mine air exhaust. However, they have not been included in the energy balance nor in the capital and operating cost estimates because the payback period was greater than four years or, there was insufficient technical information for feasibility determination. These sources will be re-examined during final project design to confirm their feasibility.

There are still further options for waste heat recovery such as, small compressors, incinerators or small building exhausts. However, the capital and operating costs savings associated with heat recovery from these sources were considered insignificant at this coarse level of study.

4.4 Conclusion and Recommendation

The preliminary energy balance indicates that there are substantial economic and environmental advantages associated with recovering waste heat from the power plant generators and from several other sources. Waste heat recovery will reduce emissions and will reduce total diesel fuel consumption by an estimated 5.6 million litres per year, which is approximately 44% of the total annual heat requirement.

5.0 SOLAR ENERGY

5.1 Introduction

A diesel-generation power plant is currently planned as the source of primary power for the Snap Lake Diamond Project. Diesel power generation was selected for its proven technology, reliability, economics, and suitability for a remote mining operation. The operating cost associated with diesel fuel consumption for power generation will be substantial, estimated to be over $15 million annually.

In the interest of reducing emissions and operating costs, the technical and economic feasibility of various alternative sources of power generation was examined, including wind, solar and hydrogen fuel cells. These sources were all considered as supplemental power sources. The diesel generator plant would be the primary power source because reliable, non-fluctuating, continuous power is required for critical operation loads. The alternative sources, if viable, would serve to reduce the demand on the primary diesel plant, thereby reducing diesel fuel consumption.

This document summarizes the examination of solar energy as an alternate source of power to supplement the primary, diesel power plant.

5.2 Solar Energy

5.2.1 Solar Power Generation

Solar energy would power low voltage sources via photovoltaic (PV) cells that convert solar energy to direct current (DC) electricity. DC electricity would be used to supplement the low-voltage power distribution system (after conversion to alternating current by an inverter) or to power DC-powered equipment directly.

5.2.2 Solar Air Heating

Solar air heating involves the pre-heating of fresh air prior to distribution to buildings or the mine. Pre-heating of air reduces the energy needed to bring the air to suitable temperature. At Snap Lake, fresh air varies from –50 degrees Celsius (°C) to 20°C and must be heated to 20°C to 22°C for most buildings on site.

An example of solar air heating technology is Solarwall, developed by Conserval Engineering. Solarwall systems have been installed in many cold-climate locations, including Fort Smith and Yellowknife.

5.3 Feasibility

5.3.1 Solar Power Generation

According to the United States Department of Energy's Photovoltaics Program, current PV technology is reported to be 7% to 17% efficient in converting solar energy into electrical energy. Based on available solar radiation data gathered at the Snap Lake area, it was estimated that a PV cell bank of 1,000 metres squared in area would produce over 100,000-kilowatt hours (kWh) per year. The total expected power plant demand is approximately 85-million kWh per year. In this example, a solar energy bank would therefore generate less than half a percent reduction in total diesel consumption and would not significantly reduce associated emissions. Emissions savings would accrue through an annual reduction in diesel consumption of approximately 37,000 litres, approximately one tenth of one percent of annual diesel fuel consumption for power generation. This size of fuel bank would cost over $1 million to design and construct, and would save less than $20,000 per year in diesel fuel costs.

5.3.2 Solar Air Heating

Preliminary estimates of the technical feasibility of solar air heating were made by utilizing information from Conserval Engineering and solar radiation data from Snap Lake. For example, on a typical day in May, solar air heating could pre-heat air temperature by approximately 8°C to 10°C. However, in January, the solar energy available may be insufficient to produce any appreciable temperature rise. Further building and heating design details are required to fully assess the feasibility of solar air heating technology at Snap Lake.

5.4 Environmental Considerations

The benefit of solar energy in either application is the reduction in emissions associated with reduction of diesel consumption for power generation.

The potential environmental concerns related to use of PV cells are vegetation loss under the cell banks, and the creation of shelter-space for wildlife under the cell banks, which may increase the potential for wildlife-human interaction on the site.

There are no environmental concerns related to solar air heating.

5.5 Conclusion and Recommendation

Solar power generation is technically feasible. However, PV cells appear to provide only limited solar power generation and the resultant reduction in total diesel fuel consumption and associated emissions are very small. Therefore, on this scale, solar power generation offers no economic benefits and minor environmental benefits.

Solar air heating appears technically feasible and has the potential to provide some environmental benefits economically. It should be investigated further once detailed design of buildings and heating systems commences.

6.0 WIND ENERGY

6.1 Introduction

Diesel fuel consumption for power generation represents a substantial contribution to the operating cost and overall emissions of the Snap Lake Diamond Project. The feasibility of wind power as a supplemental power source that would reduce the demand on the primary diesel plant and provide savings in diesel fuel consumption and emissions was examined.

This document summarizes the examination of wind power as an alternate source of power to supplement the primary, diesel power plant.

6.2 Wind Power Generation

Wind turbines generate electrical power via generators driven by turbine blades. The size and height of turbines is normally dictated by the power capacity required, local wind regime and space available. Wind turbines can generally operate in a wind speed range of 16 to 80 kilometres per hour (km/h), according to the American Wind Energy Association. National Resources Canada provides guidelines for wind turbine effectiveness at varying annual average wind speeds (Table II.1-2).

Table II.1-2
National Resources Canada Guidelines for Wind Turbine Effectiveness

Average Annual Wind Speed	Wind Regime
0 - 15 km/h	no good
18 km/h	poor
22 km/h	moderate
25 km/h	good
29 km/h or greater	excellent

Note: km/h = kilometres per hour.

Wind turbines can be applied as either a stand-alone power generating facility, or more commonly, as a supplemental generation to a primary facility (*i.e.*, a “hybrid” arrangement). In a hybrid arrangement, the wind turbines operate whenever wind speed is within operating range to reduce the demand on the primary plant. In the case of Snap Lake, a diesel-wind hybrid plant would be the most suitable.

6.3 Technical Feasibility

6.3.1 Cold Temperature Operation

Wind turbines would need to operate reliably at temperatures as low as –50°C if they are to be successful at Snap Lake. Wind turbines have been installed at several cold-climate locations, the most relevant of which are installations in Antarctica, Alaska, and Vermont. These facilities are currently in operation but technical difficulties associated with reliability of materials and components at very low temperatures are reportedly common.

The cold-climate installations are generally considered experimental and are typically funded by governments and/or consortiums. They do not use economic feasibility as criteria for successful operation. These facilities are successful at producing electric power and valuable research information and they do reduce diesel consumption and emissions. However, any reduction of operating costs will not amortize the capital investment over a reasonable period of time.

6.3.2 Site Wind Regime

Several sources of wind data were examined to determine the technical viability of wind turbines at Snap Lake. These include the Canadian Meteorological Centre, Environment Canada, National Aeronautic Space Agency Weather Satellite data and a wind monitoring station installed at Snap Lake in March 1998. These sources indicate that an average, annual wind speed of 10 to 20 km/h could be expected at Snap Lake. Recognized limitations of the data are: (1) the Snap Lake monitoring station has been in place less than three years and (2) most wind data is typically measured about 10 m from ground level.

If Snap Lake has an average, annual wind speed approximating 10 to 12 km/h, effective wind turbine operation would not be technically feasible (Table II.1-4).

6.4 Economic Feasibility

For illustrative purposes, it was estimated that, based on the available wind data and the current proposed diesel power plant design, a 1.0-megawatt (MW) wind turbine plant (ten 100-kilowatt turbines) would cost approximately $3.3 million to design and build at Snap Lake. The wind turbine plant would reduce diesel consumption by less than 130,000 litres per year and would save approximately $70,000 year in diesel fuel costs. A 2.0-MW plant would save approximately double the amount of fuel and costs as the 1.0-MW plant and would cost $5 million to build. In both cases, the period for payback of capital cost is not economically attractive.

6.5 Environmental Considerations

The benefit of wind power as supplemental power generation is the reduction in diesel consumption and the emissions associated with reduction of diesel consumption.

Potential environmental concerns that would require investigation include the physical hazard to birds, the impact of noise on local wildlife, and the requirement for permanent access roads to the turbines, resulting in vegetation and habitat loss.

6.6 Conclusion and Recommendation

Based on the current design of wind turbines and the available wind data at Snap Lake, wind turbines are not considered technically or economically feasible at Snap Lake at this time. It is recommended, however, that local wind conditions continue to be measured at the site to better determine actual, long-term site conditions so that the application of wind turbines at site can be re- investigated. In addition, the long-term, reliable, turbine performance in Arctic conditions would be investigated further.

7.0 UNITS AND ACRONYMS

UNITS

%	Percent
°C	degrees Celsius
km/h	kilometres per hour
kWh	kilowatt hours
MW	Megawatt

Acronyms

ASD	adjustable speed drives
DC	direct current
De Beers	De Beers Canada Mining Inc.
NOx	oxides of nitrogen
PV	Photovoltaic