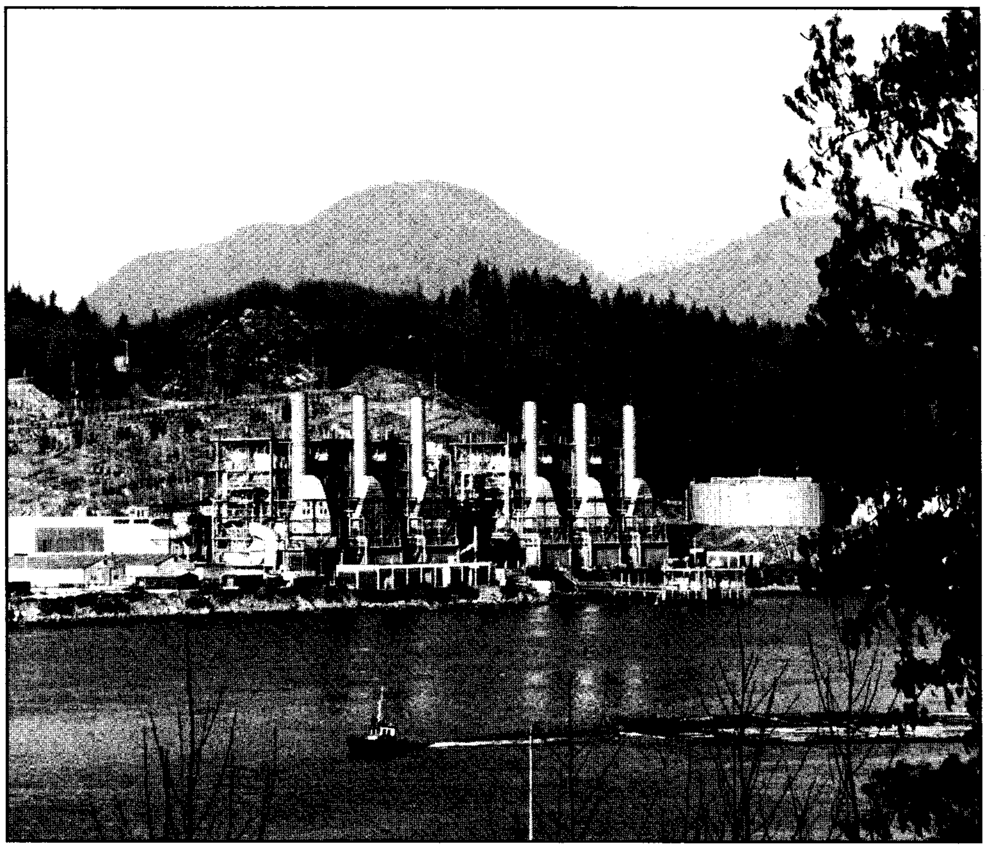
BC hydro

The Burrard Utilization Study Report



Review and Analysis of the Future Role of Burrard Thermal Generating Station

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Foreword

In April of 1991, B.C. Hydro established a multi-disciplinary project team to conduct an in-depth study of the Burrard Thermal Generating Station and to make a set of recommendations on its future. In November, 1992, the Burrard Utilization Study (BUS) Team completed its work and submitted its report to Hydro management.

A significant aspect of the BUS involved considering where and how he public should be involved in the planning process. Research on public attitudes concerning the plant identified two key points:

- the vast majority of people have limited knowledge of the plant, and
- those that do know about the plant are very interested in its future.

Hence, an important conclusion of the study was that effort would be needed to provide more information and to involve the public in meaningful consultation.

This document is part of B.C. Hydro's response to that need.

At the conclusion of the study, an independent team of business, financial, engineering and environmental experts, led by Coopers & Lybrand, was asked to review the study in detail, as a check on completeness and accuracy. The review included a check that this summary document is an accurate reflection of the complete study.

Peter D. Calder
Project Manager

Review and Analysis of the Future Role of Burrard Thermal Generating Station

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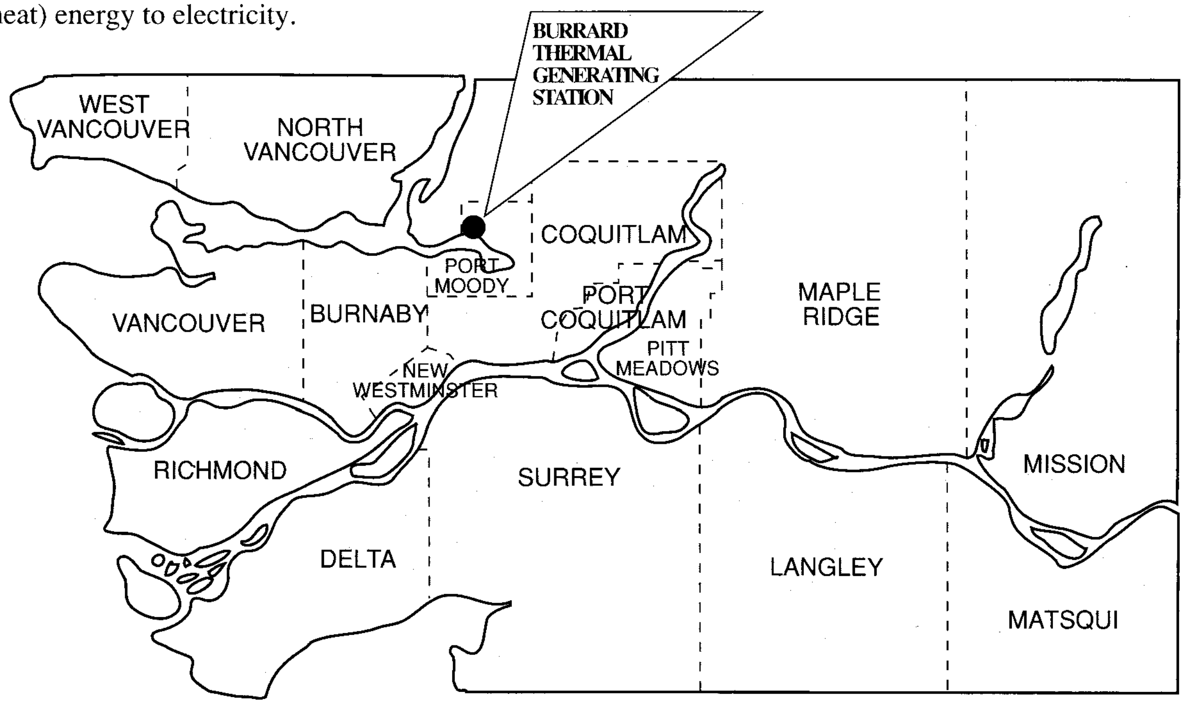
INTRODUCTION

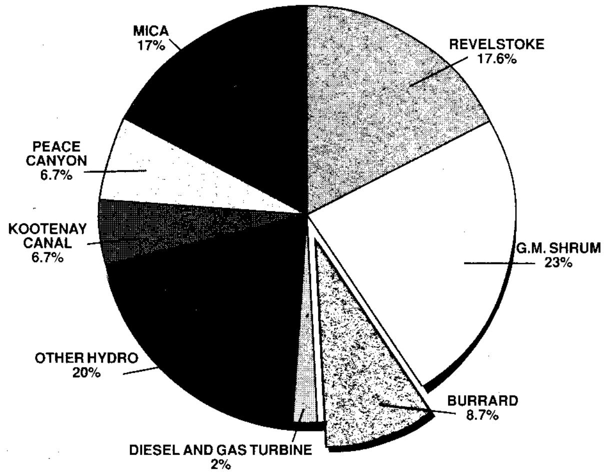
The Burrard Thermal Generating Station (Burrard) is a key part of B.C. Hydro's electricity generating system. As its name suggests, the plant is located on the shore of Burrard Inlet. Burrard generates power by converting thermal (heat) energy to electricity.



More specifically, Burrard burns natural gas to produce high pressure steam, which is then passed through steam turbines to produce electricity. In all, the plant has six units, each consisting of a boiler and turbine system. The units can be run in any combination depending on overall system requirements. The rated capacity of Burrard at full operation is 912 megawatts (MW). If that capacity were fully utilized year-round, Burrard would produce just under 8000 gigawatt-hours (GW.h) of electricity. To put that into context, Burrard could produce enough electricity to meet the equivalent needs of approximately 800,000 households.

Engineering and design work on the plant was begun in 1958, with construction beginning in 1960. The first two of the six units were brought into production in 1962 and 1963, and the remaining four units were added over the next 12 years.

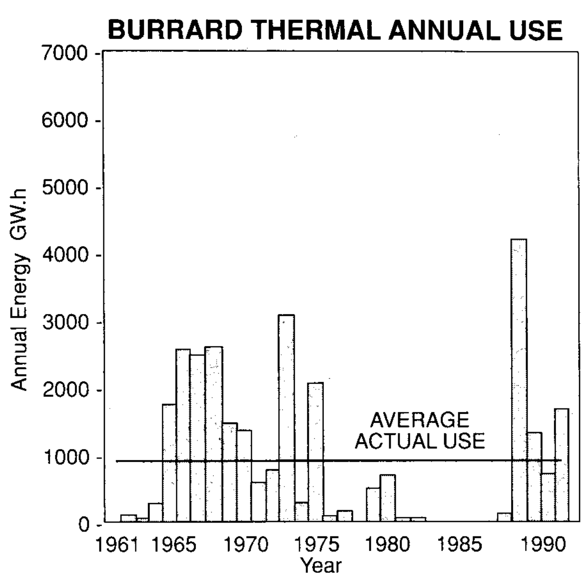
While it is true that British Columbia is largely dependent on hydroelectric capacity, this is by no means our only source of power. From an energy capability perspective, hydroelectric represents almost 90% of the total, the major components of that being the dams on the Columbia River (Mica and Revelstoke being the two biggest), and the Peace River (Shrum). After hydroelectric, the next largest source of energy is Burrard, which accounts for about 8.7% of the system. Finally, in particularly remote areas of the province where bringing in long distance transmission lines is impractical, small local B.C. Hydro diesel stations provide electricity. These, along with two gas turbine plants, make up the last 2% of Hydro's generating capability. In addition to Hydro's own supply, there are a number of Independent Power Producers (IPPs) selling to the Hydro grid.



By way of comparison, Ontario Hydro obtains about 24% of its electricity from hydroelectric sources, 22% from fossil fuels (most of which is either coal-fired or oil rather than natural gas), just over 50% from nuclear, and the remainder from other sources. In Alberta, the majority of electricity demand is served by coal-fired plants.

Burrard is expected to continue to fill a vital role in B.C. Hydro's generating system in the years to come.

As the following chart shows, there was a protracted period when a combination of events (high streamflows, declining forecast demand, high gas prices, etc.) meant that demand for



energy from Burrard was very limited. This low plant use in the early to mid-eighties, coupled with a surplus of hydroelectric energy, led to deferral of significant investment in preventive maintenance and/or equipment upgrade work.

Beginning in the late eighties, with supply and demand coming into balance, Burrard played an important role in total system supply. Looking to the future, B.C. Hydro's system planners projected a more significant reliance on Burrard production. Hence, a program was put in place in 1989 to catch up on deferred maintenance, and to begin an upgrading program on all six units as well as certain common areas of the plant.

Environmental concerns have led to a more detailed study of options for Burrard.

In parallel with this renewed focus on Burrard from a system planning perspective, there has been a marked increase concern for the environment. In the context of Burrard, concerns about air quality are of particular importance. Recent reports indicate that air quality in the Lower Mainland is becoming a serious problem, and that every effort should be made to curtail emissions of problem gases. And while the plant has always operated within its air permit levels, the question is, will current and future air quality objectives in the Lower Mainland require a more limited role for Burrard than otherwise envisioned?

To address this and other issues surrounding Burrard's future, B.C. Hydro established a multi-disciplinary project team in April 1991, to conduct the Burrard Utilization Study (BUS). The BUS team was instructed to develop a solid foundation of information and analysis and a detailed set of recommendations to senior management. The scope of work covered three key issues:

- Can the plant play a reliable and profitable role in electricity generation in British Columbia, and if so, under what operating scenario(s)?
- What options are feasible and cost-effective to deal with the air quality issue in particular, and environmental issues in general?
- Where choices exist, what are the implications of choosing one versus another?

The detailed study has been summarized in this document.

To fulfil its mandate, the BUS team looked at a wide range of issues including: the remaining useful productive life of the plant, Lower Mainland air quality, emissions reduction technologies, long term gas price and availability, and seismic stability of the plant. In all, eleven detailed back-up studies were carried out by external consultants and/or internal Hydro resources as input to the BUS. The team submitted its findings to Hydro management in November 1992.

This document is a synopsis of the key findings and recommendations contained in the BUS team's report. The document is divided into nine key sections. The first provides a "primer" on where/how Burrard fits into overall Hydro system planning. The second section is also a "primer", discussing how Burrard fits into the picture for air quality in the Lower Mainland. In combination, these two sections give the reader an increased understanding of the key issues which had to be taken into account when building the long term plan for Burrard.

The next three sections then outline the key findings of the BUS, broken out by topic area: plant capacity/availability; air quality; other environmental issues. The next two sections then layout the specific scenarios which emerge from a planning perspective, and the financial framework used to evaluate them. The final two sections then pull the study together, presenting results of the financial analysis, and the recommended forward plan.

BURRARD PLAYS AN IMPORTANT AND UNIQUE ROLE IN B.C. HYDRO'S SYSTEM

British Columbia is blessed with abundant water resources, for recreation, drinking, and electricity generation. The typical first question one is prompted to ask when presented with the reality of a large gas-fired plant in this province is, "What do we need it for?". The short answer is, to back up the hydroelectric system, particularly in periods of low stream-flows. There are some important factors that go with that answer, that also need to be understood before one can appreciate how the plan for Burrard has evolved.

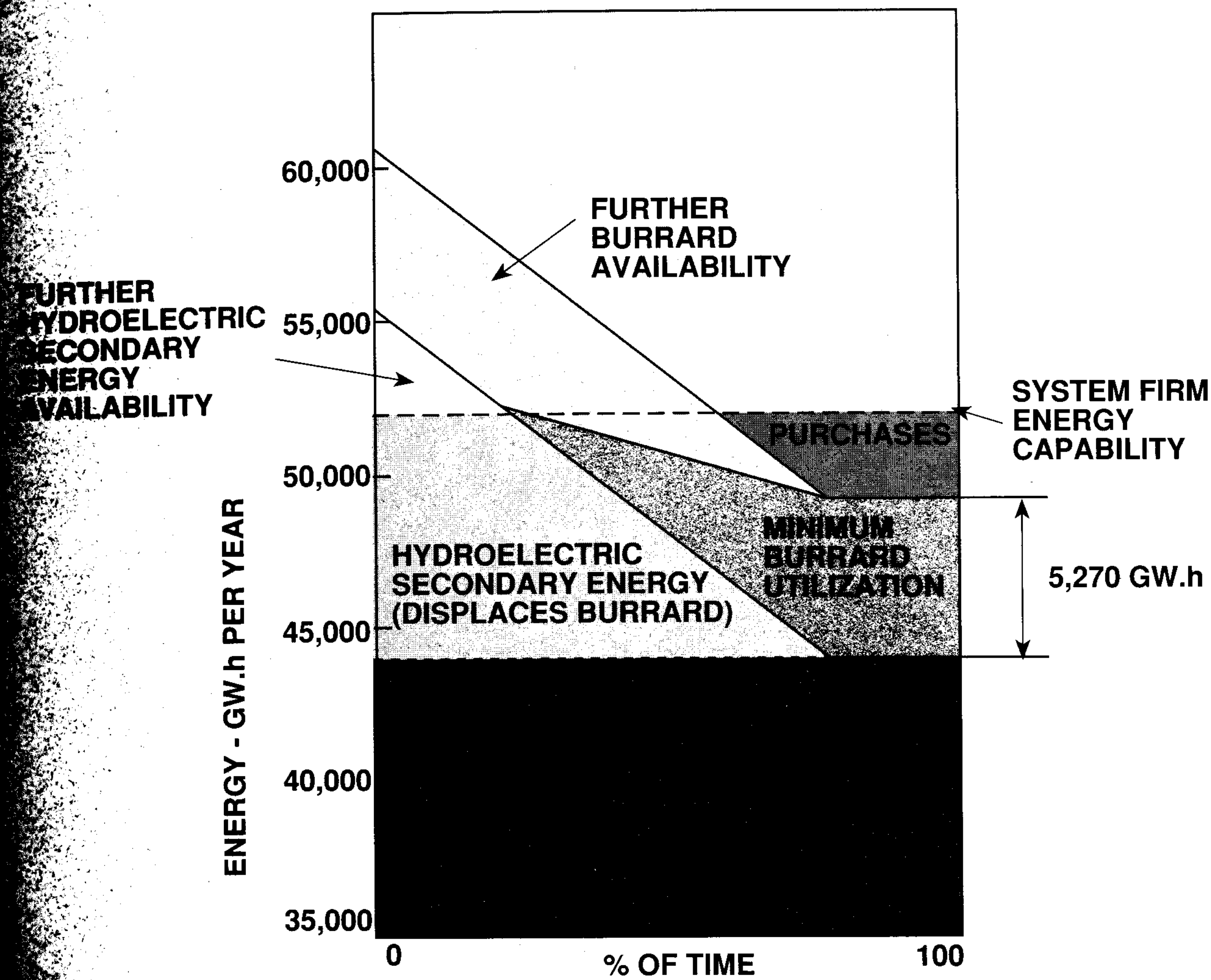
This section begins with a brief explanation of how Burrard fits into B.C. Hydro's system. It then overlays the key factors that complicate that picture, along with a discussion of how they affect Burrard.

A simplified view of Burrard in a hydroelectric system.

Eight pieces of information on the overall system set the stage for understanding Burrard's basic role.

- Hydroelectric facilities have a high capital cost, and low operating costs. Thermal plants, such as Burrard, have the opposite cost characteristics.
- The existing hydroelectric system has the capacity to meet peak provincial demand at any given moment, without Burrard operating. However, the total energy required from the system over a full year may need output from Burrard.
- The total streamflow available for electricity generation can vary dramatically from year to year, and can run below average conditions for a number of consecutive years.
- The total useable reservoir volume is huge, so that energy (in the form of stored water) can often be held over several months, and in some instances over more than one year.
- Energy supply which can be relied upon even under adverse conditions, ("firm energy"), commands a higher price than energy which may or may not be available ("secondary energy").
- For the hydroelectric system, firm energy is defined as the amount of energy that could be generated during the lowest sequence of streamflows over about five years within the last 45 years; the energy available from all water exceeding that base is classified as secondary energy.
- For Burrard, firm energy is defined as the reliable level of energy output; that is, rated plant capacity, adjusted for such factors as scheduled maintenance, equipment failures, fuel supply, etc.
- A market exists for sales of energy on a short and long term basis outside the province. The market is limited by electricity transmission capability, and varies with out-of-province demand, and availability/price of alternative energy sources.

In simple terms, then, the B.C. Hydro system can be characterized by the accompanying schematic.



The light blue area represents the hydro-electric energy available. Given the variability of streamflows, this capacity has to be shown in two-dimensions, with the horizontal axis representing cumulative probabilities (based on historical streamflow analysis). Firm hydroelectric energy, then, is that portion of total hydro energy that is available 100% of the time (shown at just under 45 000 GW.h per year). Hydro secondary energy is the triangular area, stacked on top of the firm energy, ranging from as much as about 10 000 GW.h in highest streamflow years, to zero in the lowest.

In this simplified view of the system, Burrard's capacity which entails higher marginal cost production than hydro (due primarily to purchased fuel costs) is "stacked" on top of hydro. Finally, energy purchases from other sources are stacked on top of that. In this way, we can define system-wide firm energy. And in this simplified planning world, system firm energy could be set to exactly equal domestic (British Columbia) demand. In that framework, the secondary hydro energy and Burrard capacity exceeding system firm energy would be available for energy trade purposes.

In some years, total domestic demand will be met by a combination of firm hydro, coupled with Burrard output, and some cost-effective purchased energy. When streamflows permit, the purchased energy will be phased out, and to the extent possible Burrard output will be displaced by cheaper secondary hydro. The portion of Burrard's output shown below the system firm energy line is therefore characterized as the "displaceable firm" energy Burrard contributes to the system. If that area is converted from a two-dimensional probability chart (as shown) to a single long term averaged output, we come up with the expected average demand for Burrard in its displaceable firming role.

A number of factors complicate the reality of decision making on Burrard's operation.

First, while the horizontal axis showing probability of streamflows is based on extensive analysis of historical data, we have no certainty that the past will repeat itself. And, we certainly don't know ahead of time where any single year will be on the curve.

Similarly, demand fluctuates based on population, the economy, the weather, etc. And even with the most sophisticated forecasting and analysis of future demand, the likelihood of perfectly matching capacity to demand year after year is virtually zero.

Furthermore, based on a whole range of factors affecting demand and supply conditions for B.C. Hydro's occasional electricity suppliers (e.g. IPPs) there are times when purchased electricity may have a lower marginal cost than Burrard.

Last, recognizing that additions to total system capacity often come in large increments with attendant long lead times, the system may need to build in a reasonable cushion of firm capacity above current demand levels.

So within all of these parameters, the objective is to run Burrard just enough to meet system energy requirements, balancing seasonally fluctuating gas prices, future expected demand, future stream runoff (supply), the long term but finite storage capacity of the reservoir system, etc.

While these kinds of uncertainties about the future face any business, the situation for Burrard is acute. Given its primary role to provide displaceable firm energy, Burrard is specifically positioned to be the principal focal point of the full uncertainty of the entire system.

So, it is quite possible that a decision taken with best available information today to run Burrard to meet domestic firm needs may actually contribute to trade potential in later months; unexpectedly high streamflows and/or sagging demand may produce unexpectedly high levels of (surplus) secondary hydro energy. Conversely, running Burrard today with the intention of storing water for future trade opportunities may in fact end up supporting delivery of future domestic energy requirements (due to an unexpected bump in domestic demand, or unexpectedly low streamflows).

Finally, when you add in a requirement to balance B.C. Hydro's desired service level with financial and environmental objectives (to say nothing of overall provincial energy policy objectives), the decisions on how much or little to use Burrard becomes no simple task.

ARD'S TIONSHIP TO LOWER AND AIR QUALITY BE FULLY RSTOOD

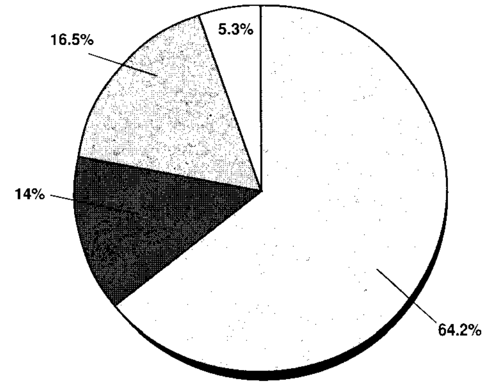
ality in the Lower Mainland has an important issue for everyone. Recent and expected future trends on the d regulatory fronts at the federal, l and local government level point to ly stringent standards for air emis- The federal government's Green Plan a goal of 40% reduction in key air s by 2005. The Greater Vancouver al District (GVRD), which has local ng authority for Burrard, has released a ion paper which sets a more aggressive of 50% reduction by 2000.

majority of attention to Lower Mainland lity focuses on ground level ozone. In oncentrations, ozone causes adverse on human health and vegetation. While ocess which produces ground level ozone fully understood, scientists do know that gen Oxides (NOx) and Volatile Organic pounds (VOCs) are its precursors; particu- on warm, sunny days, NOx and VOCs act with ultra-violet light to form ozone in lower atmosphere.

this context, it is important to have some erstanding of Burrard's role in the overall shed, focusing on NOx emissions in particu- . Discussions of this kind can take many rms, ranging from relative shares of total issions, to parts per cubic metre, to compari- ons with other like facilities, etc. This section erefore presents information from a number of fferent perspectives, in an attempt to produce complete picture.

Looking first at total airshed emissions, the most striking fact to note is that automobiles are y far the largest source of NOx emissions in the Lower Mainland. However, there are significant challenges facing the regulators on this front: the technology to further reduce vehicle emissions is not yet readily available; we are dealing with hundreds of thousands of individual sources as opposed to one "large" one; and people's reliance on their automobiles is hard to dampen.

LOWER MAINLAND AIRSHED NITROGEN OXIDE SOURCES



- **On-Road Mobile Sources** (Cars, trucks, buses)
- **Off-Road Mobile Sources** (Planes, trains, ships, etc.)
- **Point Sources** (Burrard, refineries, factories)
- **Area Sources** (Domestic furnaces, water heaters, etc.)

Not surprisingly, then, increased attention turns to more easily identifiable single point sources of offending emissions, even if their share of the total emissions is lower. Also, technology for the control of emissions from industrial point sources such as Burrard is more advanced, so this sector may be asked to contri–bute disproportionately to the reduction require-ments of NOx and VOCs.

Burrard's share of total NOx output is brack-eted by a range of figures. When running at full capacity, NOx emissions may contribute up to 6% of the daily airshed total. And of course, on days when Burrard is not needed at all, its share of total daily emissions is zero. On an annual basis, using an average energy output for Burrard of about 30% of capacity, its total contribution would fall into the 2% range of total NOx. It should also be noted that demand for Burrard generation typically tends to be highest in the summer months, when ozone formation is of particular concern.

Switching to another perspective, the following table shows Burrard's NOx output in terms of a range of service needs of an average household.

Household Need	Weight of NOx (in kg / year)
Garbage Disposal	0.4
Home heating (natural gas)	4.0
Home electricity supplied entirely by Burrard	4.0
Operating 2 cars	68.0

Based on these consumption patterns, even if NOx output from Burrard were totally eliminated, this gain to the airshed would be wiped out by adding 20,000 dwellings to our base. Since the average projected growth rate for the Lower Mainland is about 20,000 households per year, this means we are adding the equivalent air emissions of one new Burrard plant every year.

Shifting our focus from one of comparing Burrard to the Lower Mainland airshed, we can look at the plant's emissions in terms of how they compare to similar plants in other jurisdictions. By volume, Burrard's emissions of NOx account for less that 0.01% of its total emissions. And recent modifications to combustion practices have achieved a 40% reduction in NOx emissions per unit of energy produced. Burrard is among the lowest emitters of NOx when compared to other steam turbine fossil fuelled plants in North America.

The plant has consistently performed within limits specified in its existing permits (currently set at 170 mg of NOx per cubic meter of emissions).

As a final perspective on this issue, the BUS team hired Concord Environmental, a national consulting firm specializing in air quality, to assess Burrard's role in overall air quality in the Lower Mainland. This perspective is particularly important in light of the fact that some regulators have already tabled the idea of imposing a substantially higher reduction target on Burrard than the overall average of 50%.

The Concord study produced three key findings. First, Burrard's contribution to peak NOx concentrations in the eastern Burrard Inlet area (where the plant is located) does not cause federal guidelines to be exceeded in the nearby communities, even in combination with NOx from other emitters. Historical data do not show any correlation between Burrard operation and air quality at any of the Lower Mainland air quality monitoring stations. There is no basis on which to conclude that Burrard's contribution to ground level ozone formation is either any greater or any less than its contribution to the region's overall emission inventory of all sources of NOx. Finally, the airshed modelling and resulting scientific information necessary to make optimal decisions is not available for the Lower Mainland airshed. In particular, the relative importance of VOCs (none produced at Burrard) and NOx as contributors to ground-level ozone is not well understood.

To summarize the air quality issue, considerable pressure is mounting to reduce NOx emissions throughout the Lower Mainland. And while Burrard's past and current performance has been good, it is reasonable to expect that the plant will be required to make a substantial contribution to improved air quality through reductions in NOx output, regardless of any increased demand for its energy.

Two key questions

This section on air quality and the preceding one on energy system planning set up two key questions: is the physical plant capable of producing the desired levels of output, and can this be accomplished while simultaneously achieving the needed reductions in NOx emissions? These two issues are addressed sequentially in the next two sections of this document.

LANT IS A BLE LONG TERM CE OF ELECTRICITY

tion presents the BUS team's find- issue of Burrard availability for in three stages. First, what kind of ability could be counted on, and at of output? Second, for how many this capability be relied upon? And at extent might earthquake risk affect rs to the previous two questions?

ng 1992, the BUS team hired Monenco onduct a review of existing maintenance de plans for Burrard, carry out an inspection of the plant, and review records.

result of their study, Monenco con- that the work contemplated in the main- plan developed and implemented in necessary, and consistent with other practices at similar plants. As of today, ficant portion of the planned work has mpleted according to schedule, but a cant backlog of maintenance work still s to be completed; the 1989 plan scoped rogram that would carry through 1995.

e Monenco review also compared Burrard nsAlta's Wabamun 3, a sister unit, which ves an operating factor of between 80% 0%. On the basis of these findings it was luded that once the Burrard maintenance ram is complete, an annual availability or of 85% can be achieved for the plant. ther words, an allowance of 15% for total n-time for ongoing preventive maintenance and for equipment failure is reasonable. So, B.C. Hydro's system planners can count on output (if needed) from Burrard at levels in the 6600 GW.h per year range, providing that an adequate fuel supply is available

On the basis of those estimates, the system planning process yielded average long term demand forecasts for Burrard in the range of 2900 to 3700 GW.h per year. The Monenco team assessed the plant life in the context of those forecasts, and concluded that Burrard could be economically and reliably operated for another 25 years at those average levels. And, with retirement and replacement of major components as needed, the plant life could be extended indefinitely.

The remaining question for the BUS team in terms of plant reliability was whether Burrard could be expected to withstand an earthquake. A seismic study was undertaken, which produced the following key findings. The plant was built in conformance with the seismic code at the time of construction. However, investment would be needed to bring Burrard to current earthquake standards. In the event of an earthquake of the magnitude defined by codes now current, wide-spread equipment failures and some failures of buildings could occur. The costs of upgrading the key shortcomings are of a far smaller magnitude than the anticipated repair costs in the event of any substantial quake damage.

Overall, the BUS concluded that subject to some investment in unit upgrades and to address key seismic issues, Burrard represents a reliable long term source of electricity supply for B.C. Hydro. And, under assurance of reliable output, average demand for output over the long term would be significant.

THERE ARE VIABLE OPTIONS FOR BRINGING BURRARD NOx EMISSIONS IN LINE WITH PUBLIC TARGETS

The six boilers at the plant were supplied by the same manufacturer, but over a 15 year period. Thus, they are all similar, but not identical. Except for Unit #6, installed in 1975, Burrard was designed without specific pollution control equipment. Notwithstanding, the plant has consistently operated within permitted maximum NOx emissions, and recent adjustments in boiler operations have resulted in a 40% reduction in NOx.

The question is, what additional steps can be taken to further reduce NOx in anticipation of tighter standards for the future? This question was put to a joint consulting team of ABB Combustion Services Division Canada and Mitsubishi Canada, who reported back to the BUS team in April 1992.

The team evaluated eight alternative technologies to reduce NOx. The study focused on one unit (Unit #4), and given the similarity of the six units, the findings are considered to be valid for all units. A conservative approach was taken, in that actual test data were used to assess NOx reduction potential, rather than relying on the unit's original design parameters.

This study concluded that all eight tech–nologies were practical, but Selective Catalytic Reduction (SCR) provided the best possible solution. It produced emission reductions as great or greater than the other technologies, and at the best cost.

From a baseline emissions level of 125 parts per million (ppm), SCR can be expected to achieve an 80% reduction, to 25 ppm. Anticipated costs for SCR are in the range of a one-time $12 million investment per unit, with increased operating cost of $1 million per year.

Satisfied that a viable option exists to achieve target emissions reductions through installation of existing technology, the BUS team turned its attention to reviewing whether there were yet more efficient means to achieve the desire end result.

The first avenue considered builds upon the recommendations of the Canadian Council of Ministers of the Environment, which recommended that emission trading be considered within a plant. For Burrard, this would provide the option for upgrading some units to a higher standard than the average required, and then using these preferentially. Other units would not be upgraded, (or to a lower performance standard) and would be used to a minimum. This combination of emissions trading (still within the plant) and preferential loading led to a broader line of enquiry.

If a regional "bubble" for emissions trading was established, then Burrard would not be constrained to implementing only the most cost-effective on-site technologies to achieve targeted reductions. Off-site mitigation options could be investigated.

A number of discussion papers and preliminary forays into off-site mitigation have recently come forward. The kinds of options which can be considered include (but are not restricted to):

- vanpooling, through which incentives are directed at commuters to travel in seven-plus passenger vans, who would otherwise travel in low occupancy vehicles;
- purchase and scrapping of old high-polluting vehicles;
- direct investment in transit or bicycle paths to reduce vehicle use; and

waste heat from the boilers for other district heating, reducing emissions from furnaces.

es of strategies may prove to be yet ical than SCR in terms of cost per uction. This is particularly true when options are compared to SCR installa- Burrard units under a preferential ime. For example, if SCR were say, three units, the vast majority of output from Burrard would be able to d with "SCR-installed units". Install- the fourth unit, which would be run ittently, would have the same front- bout $12 million), but this would have tized over much lower use of the unit; per effective tonne of reduction in NOx much higher than for the first three ts. So even if off-site options seem effective than on-site SCR for the first cales may tip the other way as more SCR units are installed.

off-site mitigation strategies appear to n added avenue to achieve the most ctive reductions, the idea is not without awbacks. To begin with, the infrastruc- mplement the system (e.g. regulations, ystem, accounting, etc.) is not in place.

Also, the opportunities for such emission mitigation are uncertain, as are the associated costs, benefits and risks. This is not to say that the benefits are necessarily in question, but rather that they may be hard to track and quantify precisely. For example, if vanpooling is valued only for its NOx reduction, then the value of such other bonuses such as less non-renewable fuel being burned, less carbon dioxide emissions, and less congestion on the streets are being ignored.

There are also problems in tracking the actual increase in benefits, and assessing the duration of the improvement. For example, if an old car is purchased and taken off the road, we need to factor in the short and long term response of the individual whose car was purchased; did they buy a new car, switch to transit, move out of the province anyway, etc.?

In summary, then, the BUS concluded that off-site mitigation is an attractive option to consider for the future. We do not yet have all the answers we need to supplant installation of SCR on at least the first unit with off-site alternatives, but further study and research should be ongoing to establish the information base we need to make appropriate future trade-off decisions.

OTHER ENVIRONMENTAL ISSUES AT THE PLANT HAVE ALSO BEEN ADDRESSED

Although the BUS, and this document, have paid particular attention to NOx emissions, there are other environmental issues surrounding Burrard that merit some review. These are: carbon dioxide emissions; noise from plant operations; liquid effluents; and the asbestos remaining in the plant. Each is touched upon briefly in the following comments.

Consideration was given to carbon dioxide reduction options in the context of the discussions on global warming.

There is no-one who has still not heard of potential global warming, said to be caused by a buildup of "greenhouse gases" in the upper atmosphere. The scientific and public debate carries on as to whether the phenomenon is real or not, but most people agree that we had better pay close attention to the steady growth in volumes of carbon dioxide (CO2) emissions, if for no other reason than "just in case".

As with NOx emissions, though, options for CO2 reduction at Burrard should be first viewed from a system perspective. Ninety per cent of B.C. Hydro's energy is generated from hydro-electric sources, where there is no room for CO2 reduction (we are already at zero). Burrard represents the bulk of the remaining capacity, and since it is gas fired as opposed to either coal or oil, the opportunity facing most other utilities of switching to the cleaner burning natural gas is not available.

The remaining option which offers the potential to make any substantial eduction in CO2 emissions at Burrard is therefore to convert to combined cycle generating technology.

Combined cycle generation involves putting a gas turbine "in front" of a steam turbine; a significant amount of the gas' energy value is first converted directly to electricity, with the waste heat from this turbine used to generate steam which is then utilized in more conventional steam turbine technology. By extracting more total energy from each unit of gas, a better CO2 performance is achieved; less gas is burned to produce the needed power.

If a brand new plant was being considered, combined cycle would be a strong candidate for the plant's configuration. The issue for the BUS is, since we already have a plant in place with a significant number of productive years ahead, when if ever does it make sense to retrofit?

The evaluation of plant options (presented later in this report) therefore included a set of runs to assess the implications of switching to combined cycle.

There is some sensitivity to both noise levels and general aesthetics for residents in close proximity to the plant.

Some public concern about noise from plant operation has been expressed occasionally, primarily when the plant first came into service, after which some noise abatement measures were implemented. Although none of the immediately surrounding lands to Burrard were contemplated for residential use, if those lands were to be developed, the noise factor may again need to be addressed.

Although noise studies were not undertaken as part of the BUS, there may be an opportunity to combine further noise abatement measures with measures to enhance the appearance of the south face of the plant (facing the opposite shore) to blend more with the surroundings and baffle the noise coming from the plant.

cooling system was wed.

was designed with a once-through salt ing system. Cooling water is drawn in rd Inlet, continuously chlorinated to ssel growth, and discharged back into

eral environmental concerns from gh cooling systems are related to the es of water used and the potential aquatic life from physical, chemical al stresses of actually passing through . There is also some concern that the evels and temperature of the effluent versely affect the aquatic life in the area g the discharge point of the system.

d has consistently operated within its e permit, which was last reviewed and by the Ministry of Environment in 1990. uent studies done in 1991 and 1992 show entrations of residual chlorine are permitted discharge limits, but the rate of s slow and the plume occurs over a wide f the eastern end of the Inlet. Hence, the al chlorine levels are near the toxicity old of sensitive fish species.

C. Hydro began a program to minimize ine use at the plant in 1992. The program des improved monitoring and control of ine injection, a mussel control study, and tigation of dechlorination techniques. This ram is consistent with the draft "Environ- tal Code of Practice for Steam Electric wer Generation - Operations Phase" developed by Environment Canada in consultation with the Canadian Electrical Association, and with recommendations of the Burrard Inlet Environmental Improvements - Action Plan (BIEAP).

While it is not practical to stop using chlorine in the plant's effluent, ongoing efforts to reduce chlorine use and minimize residual chlorine in the cooling water effluent are continuing.

Plans have been set in place to deal with the remaining asbestos in the plant.

Burrard has a significant amount of insulating asbestos throughout the plant. Containment (encapsulation) has been proceeding to an increasing degree since the 1970s. The plant has developed an abatement plan under which first priority area asbestos would be removed by about 1995, at a cost of approximately $7 million. This would remove and replace friable asbestos from the turbine house and workshops, which represent the primary work areas, as well as from the areas where weathering damage is most acute. Plans for second priority asbestos would follow at a cost of about $8 million, and low priority areas would only be remedied if further deterioration in the asbestos takes place.

The Monenco Engineering team which conducted the plant life assessment study also reviewed the asbestos program, and commented that the plan for Burrard is at least as comprehensive as that carried out by other utilities.

THE FINDINGS TO THIS POINT YIELDED A NUMBER OF GENERIC OPTIONS FOR EVALUATION

With the background research completed, the long term options for Burrard began to crystallize along two lines: alternative operating regimes, overlaid with alternatives for dealing with emissions.

Three basic options were identified for the operating regime:

❍ **shutdown** - what if the plant was decommissioned altogether;
❍ **supply displaceable firm energy role** - continuation of current practices;
❍ **full base load** - running at full output (to maximize total electricity).

As to options for emissions reduction, three prime candidates emerged:

❍ **SCR** - installing SCR on all six units over time;
❍ **Maximum off-site with SCR** - SCR on the first four units, along with maximum off-site mitigation;
❍ **Partial Repowering** - SCR on the first three units, and repowering the other half of the plant to combined cycle once the plant's useful life has shortened.

To develop forecasts of plant use under any/all of above scenarios, assumptions needed to be made on permit terms. The issue here is, notwithstanding a full supply/demand balance analysis for the total system, would Burrard output be constrained due to permit restrictions?

At the time of publishing the BUS, the current GVRD position appeared to encompass three key elements: individual permits for each unit; mandatory curtailment during peak ozone periods (summer); and relatively short term permits (no longer than three years).

The BUS team concluded that each of these positions, in combination or on their own, were sub-optimal. In the case of separate permits for each unit, this constrains cost-effective planning for emissions reduction. The most cost-effective solutions are not necessarily found by equal application of a given technology to all operating units; preferential loading of units, proper scheduling of preventative maintenance, etc. are all hampered by limiting each unit's output (presumably to a flat one-sixth of total).

The arguments against mandatory curtailment in the peak ozone periods are twofold. First, as per the Concord Environmental study findings, it is not at all clear that Burrard's operation can be linked to the specific problem in the first place; until we know if such a linkage even exists, does it make sense to impose additional restrictions on one source of emissions that is not contemplated for any other in the Lower Mainland? Second, from a pure economics perspective, the summer period is when B.C. Hydro system demand for Burrard is the highest.

As to the duration of permits, the case for long term permitting is an economic one. The costs for installing SCR are significant, and hence the utility must be given some confidence that the plant can be operated for a sufficient period to offer a chance to recapture that investment for effective capacity planning.

A review of current practices and emerging trends in other districts, including the regulatory body for the Los Angeles airshed (the SCAQMD) shows an increasing trend towards setting "bubble" permits for total sites rather than for individual stacks. Permits are typically ified in terms of maximum emissions per of energy produced, and/or total tonnage pecified time period. The CCME discus- paper on emissions trading also advocates thin plant emissions trading".

And, a perpetual GVRD air permit would be istent with Ministry of Environment prac- elsewhere in the province.

Hence, the BUS financial analysis is predicated on a modification to the GVRD's apparent position, to move more in line with other jurisdictions. Put another way, the analysis has been performed on the basis that the regulator will specify limits on Burrard in terms of "how much", but B.C. Hydro will have flexibility in both capital and operating decisions to figure out "how to do it".

A COMPREHENSIVE FINANCIAL ANALYSIS FRAMEWORK WAS DEVELOPED TO ASSESS THE OPTIONS

The approach used to evaluate the alternative options for Burrard followed a four-step process. The various operating regimes were run through a system planning model used to establish annual generation profiles for Burrard under each.

The planning model information was then used in conjunction with a financial model to develop the dollar value of each scenario. The planning model also provided cost information that was used to validate the results. Finally, the environmental benefits/impacts of each option were quantified, and included in the final ranking of options.

The remainder of this section of the document provides added detail on that process. Those readers already familiar with the process, and/or those who have limited interest in method, can skip past this discussion with little risk.

B.C. Hydro has a sophisticated model (the Resource Planning Model) which can simulate a range of streamflow scenarios by year, fluctuations in demand, production costs, export pricing and demand, gas prices, etc. Support for the input assumptions came from current and ongoing analysis done by Hydro on domestic demand, export markets, etc. This information was supplemented by key studies focused particularly on Burrard (e.g. a study of long term trends in natural gas supply and pricing).

The model then produces annual demand balances for each major group of generating plants in the system, consistent with these input assumptions. Annual average generation levels for Burrard were produced going out 25 years, for all the scenarios (Displaceable Firm Energy with SCR, Partial Repowering, Full Base-load, etc.).

A financial analysis model built specifically for this project then took the key financial assumptions from the Resource Planning Model (gas prices, export prices, etc.) and the annual demand profiles for each option, and produced 25 years of operating statements for each option. The projections were run in constant dollars, and the annual results were brought back to a single dollar value using a Net Present Value (NPV) approach.

As a validation procedure on the financial analysis, information from the Resource Planning Model was used to examine the cost of each scenario. Total system costs for each of the scenarios that included Burrard were compared with the total system costs under a scenario that excluded Burrard. The value of Burrard was thus estimated as the absolute difference in costs. Rather than looking at the financial results for Burrard in isolation, then, this "avoided cost" approach looks at the total B.C. Hydro system.

At the conclusion of this step, results from the financial model and the avoided cost approach were compared for each option. In all cases, the results coming from the two approaches were consistent in terms of the relative rankings amongst the options. Furthermore, the actual dollar spreads between the financial model and the avoided cost model could be fully reconciled for each option. In short, both valuation approaches support the identical conclusions on the attractiveness of the alternatives. For brevity and simplicity, then, the presentation of findings (in the next section) will be limited to the financial model approach. The last step in the process involved bringing the non-financial aspects into the evaluation on a consistent basis, and in particular, the environmental "goodness" of each option.

A point system was developed, which subjectively scored each option on two overall criteria: financial results; and environmental results. So, each option was first scored on a scale from 1 to 10 in terms of its relative financial performance

10 being the highest possible score). These were relatively easy to assign, as they derived directly from the NPV results.

a similar way, scores were assigned to each for environmental results (again on a scale 1 to 10). This scoring was somewhat more ective, and incorporated information on total emissions, total CO_2 emissions, and other ent discharges.

he financial score and environmental score then aggregated to produce a total point for each option. The aggregation was first done using an 85% importance weighting on the financial score and a 15% importance weighting on the environmental score (this apparently low regard for environmental outcomes was justified on the basis that each option had to meet minimum NOx targets to even be considered in the first place). Having said that, just as a check on the final outcomes, a second aggregation was performed giving equal weighting to both financial and environmental scores (50/50). Here again, the validity check produced identical ranking of options, so the next section will only presen results based upon the initial 85/15 weightings.

THE FINANCIAL ANALYSIS SHOWS THAT BURRARD ADDS SUBSTANTIAL VALUE TO THE SYSTEM

This section presents the results of the financial analysis in four parts: a brief overview of key assumptions; results of the base runs; sensitivity analysis; and options for fine tuning the results.

The assumptions are consistent with the research developed by the BUS team.

All of the assumptions used as inputs to the analysis are directly supported by the various background studies prepared by the BUS team and/or its external consultants (e.g. capital costs for seismic upgrades from the internal seismic study, capital and operating costs for each SCR unit installed from the Monenco study, etc.)

Some of the key values are noted in the following table.

Key Values

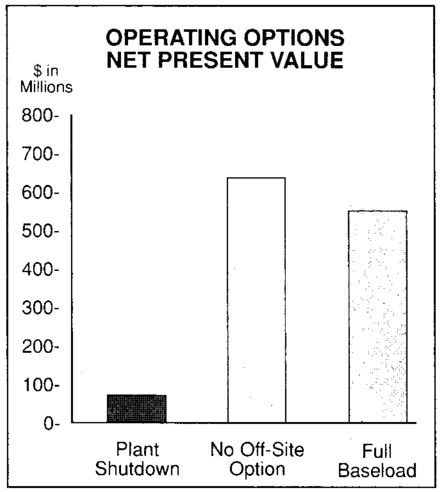
Available Energy	
Current maximum plant annual energy output	5270 GW.h
Future maximum annual output (after maintenance upgrade and permitting)	6480 GW.h
Fuel Costs	
Natural gas fuel cost (current average)	1.6 cents/KW.h
Average gas price increase (net of inflation)	3.5% year
Capital Costs	
Supply and installation of SCR (with $1 million operation)	$13 million/unit
Repowering with combined cycle units	$450 million
Replacement of voltage control	$70 million
Emission Abatement Costs	
Average cost of on-site NOx abatement	$6,000/tonne
Average cost of off-site NOx reduction	$2,500/tonne
Total off-site abatement cost for average current CO^2 emissions	$56 million
Electric Prices	
Firm energy (bulk transmission customer rate)	3.2¢/kW.h
Long term (beyond next 3 years) revenue increase (net of inflation)	.5%/year
Secondary energy (average non-firm export price)	2.1¢/kW.h
Emission Levels	
Allowable NOx emissions (based on current permit)	0.53 tonnes/GW.h
Allowable maximum NOx emissions (based on current permit)	13.2 tonnes/day
Current NOx emissions (estimated actual)	0.48 tonnes/GW.h
Current maximum NOx emissions (estimated actual)	12 tonnes/day

As noted previously, assumptions have been made that Burrard is operating under a permit regime which does not constrain production below effective capacity. Similarly, the base runs also assume that Hydro is able to sell energy from its system into the spot market for energy trade when the demand conditions (price and volume) are attractive relative to forecasted availability of secondary energy in the system.

The results support a displaceable firm energy role, with SCR installation on at least the first units.

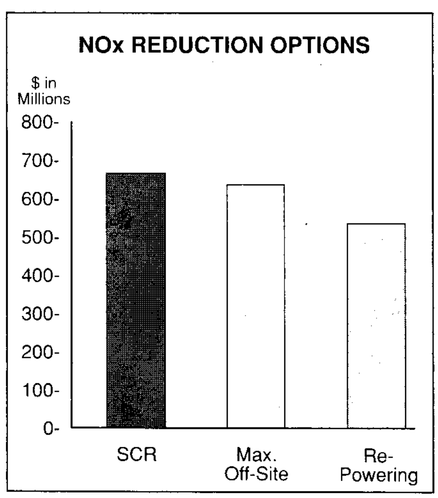
To avoid "option overload", the results from the financial analysis are presented in a three layers. The first examines the financial merits of the three operating scenarios; the data show that operating Burrard in a displaceable firm energy role is clearly superior to either shut-down on the one extreme, or full base load on the other. Within that narrowed focus, the next series of numbers presents the relative merits of the three emissions reduction options; here, the results are less clear on the long term strategy, but clearly support the financial feasibility of putting SCR on at least one unit as a start. Finally, to round out the picture, the results of the point scoring system used to bring environmental issues into the analysis are presented; this suggests a narrowing of the gap between the three emissions management options, but without a change in their rank order.

The following bar chart shows the Net Present Value (NPV) results for the three operating options. Under the shutdown scenario, Burrard still produces some value for the system, by fulfilling an essential service of providing voltage stabilization (which is entirely separate from generating additional electricity). Notwithstanding, these data show an unambiguous value for Burrard in an operating mode as opposed to full shutdown.



The data also suggest that continuing to run in a displaceable firm energy role is superior to full base loading, by a spread of almost $200 million. This outcome makes sense, in that a base loading scenario means that Burrard is being run a some constant output level, even in times when gas prices are unfavourable and/or when there is ample secondary hydroelectric energy available (which we know has lower marginal costs of production). Being able to leave Burrard idle under those conditions (the displaceable regime) must result in lower costs, and hence higher total value.

On the basis of strong indications that the displaceable firm energy role makes most sense from an operating perspective, attention could be turned to assessing the relative merits of the three options for dealing with emissions. The next chart shows the results of those runs.



For these runs, the selection of the "best" financial option is much less clear. The scenario involving installation of SCR on the first four units, along with aggressive pursuit of off-site mitigation opportunities ("Maximum Off-site") has the highest NPV, at $644 million. However, the NPV of installing SCR on all six units ("SCR"), is a mere $11 million lower, or a difference of less than 2%.

The Partial Repowering option, involving SCR on the first three units and conversion of the remaining half of the plant to combined cycle at some later date, has an NPV about $100 million below Maximum Off-site, but at $538 million, this option is still quite attractive.

The unambiguous conclusion is that SCR represents an attractive starting off point for dealing simultaneously with environmental concerns while providing substantial financial value to the B.C. Hydro system. Pursuing a strategy to begin with SCR gives some time flexibility to further monitor unfolding events on the economic and regulatory front, to make a final determination on the relative merits of each of the three options for full mitigation.

The following table presents results of the subjective scoring exercise, bringing the environmental attractiveness of each option into the picture. The point scores for financial outcomes are in direct proportion to the NPVs for each option.

The environmental point scores come from an analysis of the NOx emissions, CO2 emissions, and effluent discharge. The Maximum Off-site and SCR options score virtually identically, in that the off-site activities are set to a level which essentially mitigates the equivalent amounts of all three effluents that could be achieved on-site. The Partial Repowering option scores higher than either of the other two, primarily due to the reductions in CO2 levels and NOx levels per unit of energy that come with this technology.

In the end, the gap between the three options narrows somewhat, but the ordinal ranking of the options remains the same. When the point scores are combined on a 50/50 weighting (instead of the 85/15 weighting favouring financial results), the gap between the options gets yet tighter still, but again with no change in the order.

The clear conclusion is that operating Burrard under a displaceable firm energy role, with SCR is the best option. Once the SCR program is begun, however, it may well be that the latter units could have either off-site mitigation or partial repowering substituted for SCR, depending on the prevailing conditions.

	SCR	MAX off-site	Re Powering
Financial Scores	6.2	6.3	5.2
Environmental Score	5.8	5.8	6.2
TOTAL - 85/15 split	6.1	6.2	5.4
TOTAL - 50/50 split	6.0	6.05	5.7

A number of "what if" sensitivity tests were conducted to assess the reliability of these findings.

To gain confidence in the findings to this point, a number of sensitivity tests were run on the key assumptions. The following table summar–izes the various runs conducted, showing the nature of the sensitivity test and the financial impact.

And, there are a range of alternative assumptions that could easily add substantial value to the plant, either on their own or in combination.

Three of the "what ifs" require some explanation, as their meaning may not be immediately clear from the titles. First, the basic analysis was undertaken under a capital expansion plan which added capacity with what could be characterized as ample lead times ahead of growing demand. The "what if" scenario around lower energy margin scenarios examined what would happen if additional system capacity were added with less cautious lead times. Under this scenario, more energy is typically required from Burrard since its buffering capacity is called into play in more years (i.e. the total hydro-electric secondary energy margins are squeezed more tightly). It is no wonder, therefore, that under this scenario

Sensitivity Analysis
($ millions)

Base Case	$ 633	$ 633
	Variance From Base Case	
	Positive Impacts	Negative Impacts
High Gas Prices		-185
Low Gas Prices	+100	
Low Energy Margin	+393	
10% Higher Operating Costs		-35
85% Plant Availability	+ 85	
Alternative Costs of Unserved Load		-85
$5,000/tonne NOx offsite cost		-7
Combined Best (Worst) Case	+574	-302
Adjusted Best (Worst) Case	$1,207	$338

The table shows that higher gas prices and/or higher capital and operating costs (other than gas purchases) have a negative impact on value. Even if the individual adverse "what ifs" are combined, however, the cumulative negative impact is comfortably less than the base case NPV. In short, these tests add confidence to the conclusion that operating Burrard has substantial value over a shutdown scenario.

the NPVs are much higher. The second "what if" that needs comment is the test on an 85% plant availability factor. Notwithstanding that the study on plant life and reliability suggested that an 85% level could be achieved, the base runs were performed under an intentionally conservative assumption of 70% availability. Obviously, increased equipment availability allows for more output from Burrard in years when it is required, and hence yields higher value.

The third "what if" requiring comment deals with an alternative assumption on the cost associated with the Load Not Served. The load not served concept is designed to capture the system costs of not meeting total demand in any period with conventional capacity. The volume of unserved load is highest under the shutdown option, and hence any change in the assumed price for unserved load affects the options unequally. The question is, to what extent would a much lower unit cost assumption on unserved load reduce the gap between the values of the operating options and the shutdown case? As the table shows, the lower cost assumption reduces the value of Burrard in operating mode by $85 million (as compared to shutdown), but by no means closes the gap altogether.

Overall, then, there is potential for substantial additional value to the plant above the base case. Under some scenarios, an NPV in the $1 billion range is possible. And even under the cumulative worst case, operating the plant still has significant additional value over shutdown.

The values for Burrard may be improved with some added "fine tuning" of the plan.

One of the most significant determinants of Burrard's value to the B.C. Hydro system is the price of the gas it burns. Obviously, higher gas prices mean higher costs per unit of energy produced, and hence lower profit margins. In addition, higher gas prices change the decision on when to run the plant; at the margin, there is some gas price threshold in every situation above which other sources of energy become more economical (e.g. purchased energy). Thus, not only are margins reduced, but so is Burrard operation.

Current and recent past Hydro practices for purchasing gas supply and price have always tried to strike a balance between some future contracting (to reduce risk) and maintaining maximum flexibility to operate or not (as system requirements dictate).

B.C. Hydro uses a "portfolio" approach for gas contracting. In other words, Hydro uses a mix of different vehicles for securing gas for Burrard, including some "spot" and "seasonal" gas purchases, some portion of demand being served by longer term supply and price contracts. Hydro continuously monitors emerging options in the gas industry to best match fuel requirements for Burrard with fuel supply options offered by the industry. This is an ongoing and dynamic requirement.

THE STUDY CONCLUSIONS, RECOMMENDATIONS AND FORWARD ACTION PLAN FOR BURRARD ARE CLEAR

The BUS has produced seven key conclusions on the future potential for Burrard.

- Burrard contributes substantial value to the system.
- The optimal role is providing displaceable firm energy, to back up the system's hydro-electric energy capability.
- To justify the substantial investment required, and to allow for the most efficient solutions to emissions issues, a long term permit applied to the plant as a whole (rather than stack by stack), is critical.
- B.C. Hydro is committed to doing its share to reduce air emissions in the Lower Mainland, but more needs to be done to understand where and how Burrard fits into the overall equation.
- SCR can effectively deal with NOx emission issues, at least as a starting point, and potentially as a technology to be applied to additional units.
- Particularly with preferential loading of units, off-site mitigation appears to be worth more serious study as a complement to SCR.
- Combined cycle technology should be periodically reviewed to assess if/when the timing is right for repowering some portion of the plant.

Key Initiatives

In light of these findings, an action plan for implementation can take shape, involving a number of key initiatives.

1. Proceed with the key aspects of the maintenance/ upgrade program, to ensure plant availability (as per the "maintenance backlog" list, the seismic improvements, etc.) targeting 85% plant availability.

A number of specific work plans have been set in place to deal with a range of physical plant needs. The financial sensitivity tests show that a move from a 70% availability factor to 85% would add literally millions of dollars of value to the system. Given the findings of the Monenco team, it appears that achieving that availability factor is comfortably within Hydro's grasp.

2. Pursue permitting on a long-term, plant-wide basis.

B.C. Hydro must make a substantial investment to do its share to reduce emissions in the Lower Mainland. The company is committed to that program, so long as it can be reasonably assured of the opportunity to recapture that investment. The prevailing views on regulatory options argue convincingly for flexible permit regimes, which allow companies to identify and pursue the most cost-efficient methods for achieving stated environmental goals.

3. In support of the previous objective, take a series of unilateral actions which support improving air quality.

B.C. Hydro can take some meaningful steps on its own to further our collective aim of improv-ing air quality. To begin with, by committing to a 50% reduction in total air emissions by the year 2000, the company demonstrates its dedication and leadership in air quality management. This can be supported by some important activities that will generate better information for regulatory decision-making: a contribution of $1 million to a Lower Mainland airshed modelling program; and installation of continuous stack monitoring technology for NOx and CO2 on each unit.

4. Install SCR on one unit, as a demonstration project that makes a meaningful first step to dramatic reduction in total NOx emissions.

The technical research and financial modelling support SCR technology as an effective approach to achieving target NOx emissions. B.C. Hydro should initiate the necessary design and installation program to have SCR operational on one unit by 1995, subject to appropriate long term licensing.

5. Continue to investigate and monitor off-site mitigation and combined cycle technology as alternatives to SCR.

Having said that SCR is the logical place to begin, the analysis also suggests that as market conditions and regulatory regimes unfold, off-site mitigation and/or combined cycle technology may provide even better alternatives in the future. Hence, B.C. Hydro should move forward on two parallel fronts in addition to putting SCR on one unit: in cooperation with the GVRD and the Provincial Government, explore a regulatory regime and specific opportunities for off-site mitigation; and continue to monitor and assess the merits of combined cycle technology under emerging market conditions.

6. Take steps to manage specific other environmental issues, such as chlorine minimization, asbestos removal, and noise/aesthetic impacts.

These issues have been identified as important environmental concerns, albeit far less critical than air quality management. B.C. Hydro has specific, detailed plans in place to deal with the chlorine and asbestos issues. Implementation in both areas should continue. On the noise/visual impacts issue, little has been done in the recent past. A review could be undertaken to determine if some type of cladding should be put on the south face of the plant to simultaneously reduce noise and improve sight lines from across the inlet.

7. Monitor emerging options to gas contracting.

Hydro will continue to monitor emerging options for contracting gas for Burrard to optimally match the fuel supply to the long term role of the plant.

In Conclusion . . .

Aggressive implementation of this seven-point program will serve two important objectives. It will ensure that Burrard can provide maximum value to the B.C. Hydro system, helping to provide low cost reliable energy to the province. And, it will do so while ensuring that Burrard makes a substantial contribution to attainment of environmental objectives in the Lower Mainland.

For more information
about the Burrard
Utilization Study please
telephone our toll-free
information line
1-800-663-1377