Electricity Conservation Potential Review, 1988 – 2010:

The Industrial Sector

Phase I: Unconstrained Potential

Volume 1

ELECTRICITY CONSERVATION POTENTIAL
IN BC HYDRO'S SERVICE AREA

COLLABORATIVE COMMITTEE FOR
THE 1991-1994 CONSERVATION POTENTIAL REVIEW

VANCOUVER, B.C. - FEBRUARY 1993

Notes to the Reader

➡ **The results contained in this report are based on 100% changeover to the most electrically efficient technologies. Practically achievable levels are being estimated in Phase II, expected to be completed in 1994.**

One hundred per cent (100%) changeover to the most electrically efficient technologies are assumed in the target years, 2000 and 2010. Thus, these estimates do not take into account practical barriers to the availability and the adoption of electrically efficient technologies.

➡ **The estimates in this report assume a world without Power Smart, B.C.Hydro's conservation initiative.**

Thus, the electricity savings that have already been achieved through the use of Power Smart programs, and the savings expected in the future years of this initiative, have to be subtracted from the estimates contained in this report to determine what remains to be pursued.

➡ **The 1991–94 Conservation Potential Review was undertaken under the direction of a Collaborative Committee made up of representatives of the major stakeholders in B.C.Hydro's service area, plus B.C.Hydro and West Kootenay Power.**

One of a handful of collaborative processes tried in Canada, this is the first collaborative in the utility industry in the country.

➡ **This report is one of four documents which present the results of Phase I of the 1991–94 Conservation Potential Review.**

Phase I of this Review has estimated the technological, social and economic electricity conservation potential to the year 2010 for B.C.Hydro's service area. This document contains the technical report of the industrial sector by M.K. Jaccard and Associates of Vancouver. There are two other technical reports: one for the commercial sector, by Marbek Resource Consultants of Ottawa and associated firms; and one for the residential sector also by Marbek. The fourth document is a summary report written for a general audience that concisely presents the findings for each of the three sectors.

AN INTRODUCTION FROM THE COLLABORATIVE COMMITTEE

Attached is a copy of a report by M.K. Jaccard & Associates on electricity conservation potential in the industrial sector in B.C. Hydro's service area. The report was prepared as a part of Phase I of the 1991-94 Conservation Potential Review.

The Review is overseen by a Collaborative Committee composed of representatives of commercial, industrial, and residential customers and interests; environmental organizations, native peoples, local governments, B.C. Hydro and West Kootenay Power. The Committee uses a consensus approach to make decisions on the terms of reference, study methodologies, budget allocation, consultant selection, review and approval of reports, and communication of results for the Review.

In order to understand what this report covers, in particular what the results do and do not signify, it is important to understand something about the framework of its terms of reference.

Study Assumptions and Terms of Reference

The estimates of electricity conservation potential are not intended to be and do not correspond to the consultant's estimate of electricity use reductions that could be achieved in practice under any particular policy or program to implement conservation. They are estimates of the reduction in electricity use below 1988 average levels of efficiency that arise from assuming several alternative hypotheses that may never occur. The year 1988 was chosen as the base year because it is the last year in which Power Smart was not affecting the market in B.C.

These hypotheses are contained in the terms of reference and are consistent with conservation potential assessment methods used in the electricity planning literature and by other utilities. Among other purposes, they are useful as a basis for further work in achievable potential estimation, which is underway in Phase II of the Review.

These assumptions are made for the study years 2000 and 2010:

> "Technological Potential": assumes that all significant electricity-using technologies within each industry would be replaced with the most electricity-efficient versions (providing equivalent industrial services) that are in the market today or expected to be market-ready within the relevant time period. Industrial services include such processes as pumping, air compression and material conveyance.

> "Social Potential": assumes that all machines and devices either in place in 1988 or assumed under "technological potential" would be operated in the least-electricity-using way.

"Economic Potential": assumes that the least-total-cost option for providing equivalent industrial services is implemented. In assessing least-total-cost, it is assumed that all electricity is priced at the cost to the province of new electricity supply. Options considered include machines and devices replacement, retrofit* and operation in the least-electricity-using way. This is called "economic potential". The economy referred to is that of B.C. and not the individual firm.

Consideration of externality costs: In estimation of "economic potential", several different values have been assumed for the cost of new electricity supply, based on alternative assumptions about the unpriced social and environmental costs ("externality costs") associated with new electricity supply development. Specifically, the cost of new electricity supply is increased by different percentages to reflect externality costs ranging from 0% to 100% of the cost of new electricity supply. The range of percentages was specified within the terms of reference by the Collaborative Committee.

"Natural Change in Electricity Intensity": assumes that machines and devices are invested in and operated as the consultant forecasts them to be invested in and operated in the real world in 2000 or 2010, except for the assumption that Power Smart does not exist.

In all cases, conservation potential is defined as the difference between:

1) Hypothetical electricity consumption in 2000 or 2010 based on equipment and usage patterns in place in 1988 and industrial production as forecasted for 2000 or 2010, and

2) Hypothetical electricity consumption in 2000 or 2010 based on machines and devices investment and usage patterns under the assumptions above and the identical industrial production forecast to 1).

The consultants were requested by the Committee to use two specific industrial production forecasts (a "high" and a "low") for the purposes of estimating electricity conservation potentials. In other words, for each potential, there is a conservation potential estimate corresponding to the "high" production forecast and another estimate corresponding to the "low" production forecast.

* "Retrofit" is the replacement of a machine by another machine prior to the end of the economic life of the replaced machine.

Points to Note about Assumptions

Several points may be brought out with respect to the above assumptions:

- All Phase I conservation estimates exclude consideration of any savings due to Power Smart activities. 1988 was chosen as the base year for the Review since it was the last year in which the market place was not affected by Power Smart.

- The terms of reference required that in the estimation of conservation potential, there be no consideration of fuel-switching potential. In other words, the consultant was requested to constrain investment in alternative-fuel-using machines and devices to the market shares prevailing in 1988.

- Forecasts of actual market prices for electricity or alternative fuels are relevant to the analysis only in the determination of "natural change". The distinction is between the *price* of electricity (which is by definition the cost *to the consumer*) and the *cost* of new electricity supply *to B.C.* The assumption of their equality in the "economic potential" is based on social benefit-cost analysis principles.

- The consultant was requested to estimate electric *energy* conservation potential, not *capacity* savings, but to identify, where possible, situations where conservation technologies or practices would have atypical effects on peak demand.

Comments on Data and Methodology

The consultant used an industrial energy end-use model to perform the bulk of the analysis. Data and computer algorithms or procedures are the basis of any modeling exercise. There are advantages and disadvantages to a modeling approach. In this exercise, the following should be noted:

- The modeling approach allows for wide scope in terms of the number of plants or proportion of total production which may be examined. The study covered more than 98% of electricity use by B.C. Hydro's transmission rate customers (large scale industrial users). However, in gaining scope, the modeling approach will generally forgo precision, relative to plant-by-plant audits or experiments, which simply do not exist in large enough measure to be extrapolated to the whole industry. The challenge of generalizing results from individual plants to all plants is particularly great in the industrial sector, because (among many other differences), plants of different ages may contain very different processes; consequently any specific plant is relatively unlikely to represent the "average" plant.

Therefore, the results do not pertain to any single plant. However, in the absence of a sufficiently large sample of plant audits, they are of value as estimates of overall potential for the industrial sector as served by B.C. Hydro.

- The principal data deficiency is in knowledge of the mix of technologies and processes which are now in place (or were in place in the base year, 1988), in particular, their energy efficiencies. This type of information is typically obtained only through detailed plant audits, which are expensive and uncommon. The diversity mentioned above makes generalization difficult and is cited as the principal source of uncertainty in the data. The approach to sector-wide estimation of "existing" (1988) technologies and their efficiencies is described in Chapter 2.1 of the report. Recommendations for further data acquisition are included in the Report.

- **The estimates of social potential should be considered very preliminary, as this kind of research is quite new.** A great deal of judgment, as opposed to formal analysis, is necessary in this area. Many operational decisions involve trade-offs of electricity costs against other considerations, such as maintenance costs, equipment life, capital cost, reliability of operation, uniformity of product, etc. These considerations also vary from site to site.

- The modeling methodology is based primarily on minimization of "life-cycle" (present and future/whole life) costs among technologies and processes which compete to provide the same function within a plant. The model does not explicitly account for other decision variables that are known to factor into investment choices. However, these factors have been incorporated in the analysis to some extent in the "natural change" forecast through the imposition of market share constraints and differential discount rates.

Relation to Power Smart Achievements

As indicated, the consultants were asked to assume a world without Power Smart. This means the estimates in this report have to have the expected savings from Power Smart programs subtracted from them to determine what potential remains to be pursued.

The estimate of savings already achieved or expected to be achieved over the life of the Power Smart programs that existed in the spring of 1992 for the industrial sector is 1080 GWh annually in the year 2000 and 1240 GWh annually in 2010. These expected electricity savings have to be subtracted from the"economic potential" to see what remains to be targeted.

Next Steps

This report should be seen as an interim document giving the results of Phase I of the 1991-94 Conservation Potential Review. The Committee is now working on Phase II of the Review which will estimate *achievable* potential. Achievable potential is defined in the terms of reference as the reduction in electricity use resulting from the reaction of the marketplace for electricity services to different assumptions about:**

- Investment by utilities and other public or private agencies in energy conservation,
- Legislation, efficiency standards and regulations,
- Prices of electricity and competing fuels,
- Education, information and advertising programs, and
- Any other relevant factors.

Results are expected from Phase II in 1994.

An Invitation to the Reader

Modeling exercises inherently involve the use of aggregation and abstraction. They also involve the use of judgment where data is absent or incomplete. Many judgments and assumptions have had to be made by the consultants in estimating electricity conservation potential for the industrial sector. Varying some of these assumptions could produce different results.

The Collaborative Committee and B.C. Hydro staff invite the reader to match your knowledge against the assumptions made by the consultants and give us your assessment as to whether the assumptions used are acceptable or should be modified. The assumptions made in each industrial subsector are summarized at the end of each chapter. If you can take the time to review them in the areas you are intimately familiar with and give us your opinion, your views can be considered in the next phase of this work.

** An electricity service is an amenity or service supplied jointly by electricity and other components such as buildings, motors and lights. Examples of electricity services include residential space heating, commercial refrigeration, and aluminum smelting. The same electricity service can frequently be supplied with different mixes of equipment and electricity.

In addition, the consultant has identified some important data deficiencies. Information in the following areas would be appreciated:

- 1988 or present-day equipment configurations,
- 1988 or present-day market share of efficient technologies,
- Availability or efficiencies of existing and emerging technologies, and
- Information on operating load variation in motor systems.

Please direct any comments, suggestions, or questions to the Collaborative Committee at the address on the inside, front cover of this document.

The Collaborative Committee looks forward to hearing from you.

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1991-1994 ELECTRICITY CONSERVATION POTENTIAL REVIEW:

THE BRITISH COLUMBIA INDUSTRIAL SECTOR

VOLUME I

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of all Phase I reports.

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EXECUTIVE SUMMARY

TERMS OF REFERENCE

Objective

M.K. Jaccard and Associates were commissioned by B.C. Hydro and a Collaborative Committee of electricity stakeholders to:

"estimate the technological, economic and social potential for increasing electricity efficiency in B.C. industry under various assumptions of industry output, electricity cost, and industry behaviour, all of this over a 22 year forecast period including as key years: 1988, 2000 and 2010."

Definitions

To provide a framework for the efficiency estimates, the study includes estimates of frozen efficiency and natural change in electricity intensity.

* Frozen efficiency is an estimate of future electricity consumption if the average efficiencies of all installed equipment in 1988 were held constant over the 22 year period.
* Natural change in electricity intensity is a forecast of electricity consumption in a world in which demand-side management programs, such as B.C. Hydro's Power Smart, were never in place.
* Technological potential is an estimate of the reduction of electricity consumption (relative-to-frozen) that would occur if the least electricity-intensive technologies were always chosen, achieving 100% market penetration in both forecast years. It is assumed in this case, that equipment is operated and maintained using standard practice.
* Economic potential is an estimate of the reduction of electricity consumption (relative-to-frozen) that would occur if 100% penetration (in each forecast year) is achieved by those market-ready technologies whose life cycle cost is lowest at a discount rate of 8% and a cost of electricity that reflects the cost to B.C. Hydro of new electricity supply. Several different levels of environmental and social externality credits are tested in order to incorporate a wide range of estimates of the costs of unpriced environmental and social impacts associated with new supply. The economic potential also includes cost-effective changes in equipment operating and maintenance practices.
* Social potential is an estimate of the reduction of electricity consumption (relative-to-frozen) that would occur if the technologies chosen for technological potential are operated and maintained using best possible practices instead of using standard practices.

Additional Conditions

* The study is limited to the B.C. Hydro service area.

* The study focuses on end-use electricity consumption by technologies, not sales of electricity.
* Interenergy substitution at the level of end-use technologies is prevented.
* Technologies that internally produce electricity (e.g., cogeneration) are excluded from the efficiency analysis.

Electricity Use By B.C. Industry and Study Focus

Most electricity consumed by industry provides motive force. Much of this motive force is used to drive "generic" auxiliary equipment (found in most industries), such as pumps, fans and blowers, conveyers, compressors, and others. Much of this motive force is also used to drive large "process-specific" equipment, such as ore grinders in mines, saws in sawmills, and mechanical pulp refiners in pulp and paper mills. In total, these two categories of motive force account for almost 90% of electricity consumption by B.C. industry.

Other industrial uses of electricity include process heat, electrolysis, lighting, space conditioning and miscellaneous electric equipment. While the latter three usually account for no more than 10% of electricity consumption, the first two can be important depending on the industry. Electrolysis accounts for typically more than 50% of the electricity consumption in the chemical industry. Process heat is very important in metallurgy, an example being electric arc furnaces in the steel industry.

Five industries account for 90% of B.C. industry's end-use electricity consumption. These are pulp and paper (53%), mining (17%), wood products (10%), chemicals (8%), and petroleum refining (2%).

The importance of these few key industries and few key electricity end-uses established the study research focus. Analysis and data collection effort was devoted to auxiliary and process motive force equipment, especially in pulp and paper, wood products, mining and chemicals. Electrolysis in the chemical industry was also studied in detail. Collectively, this implies detailed analysis of the equipment accounting for about 80% of total end-use electricity consumption by B.C. industry.

METHOD

Disaggregating Motor Systems

Mechanical drive systems are referred to in this study as motor systems. Many motor systems, especially auxiliary systems, are comprised of several components. For example, a pumping system is comprised of an electric motor, a drive mechanism, a speed control device, a pump, and a pipe (through which fluid is pumped). Research has shown that there are often significant opportunities for efficiency improvements in each of these components, and the result in each case would be to reduce the amount of electricity consumed by the electric motor per unit of work (pumping fluid). Thus, research that focused only on installing high efficiency motors would likely miss much of the efficiency improvement potential.

In this study, motor systems are more comprehensively analyzed than in previous studies in that base stock and new technology efficiencies are estimated for all system components. This approach has the benefit of ensuring that the total efficiency potential is being estimated. However, the increase in comprehensiveness has a cost in terms of decreased accuracy. Efficiency research that focuses only on motors is well established, with much greater levels of confidence. In contrast, there is little empirical research calculating the efficiency of all components of currently installed motor systems. Instead, these efficiency estimates must be largely derived from a few plant audits, the expert opinion of plant engineers, and estimates by equipment manufacturers.

Technology Data

This study requires detailed data of existing equipment stocks in industry at a very disaggregated level. It also requires data of new technology costs and efficiencies. This type of data, especially the former, is not normally collected in a systematic manner, and must therefore be estimated via an array of techniques.

Equipment base stocks were estimated primarily through sub-contracted research by technology experts for each of the four major industry branches. The experts used "typical plant blueprints" and case study research to link the end-use electricity demand of different motor systems to the various stages of production in each industry. For example, they calculated the amount of electricity used to meet the per tonne pumping needs of a kraft batch pulp digester. This was combined with estimates of the efficiencies of the components of the pumping motor system and checked by calibrating the resulting estimate of pumping electricity demand to aggregate estimates of electricity consumption (for sub-steps of the production process, such as pulp digesting) and to B.C. Hydro sales data where appropriate. Getting this type of information was easier for major process mechanical drive equipment (ore grinders, mechanical pulp refiners, etc.) because plant managers tend to know a lot more about the efficiency of this large equipment.

These base stock efficiency data are crucial to the study. Even if the efficiency of new stocks can be determined with perfect accuracy, the study will not produce accurate estimates of percentage efficiency improvement if it lacks accuracy on the efficiencies of existing equipment.

For new technologies, data were collected from an array of secondary sources (research institutes, manufacturers, etc.) on the cost and efficiencies of all motor system components. Generally, there is a fairly high degree of agreement on the efficiencies of much of this equipment, although smaller motor system components are less well understood.

End-Use Model: ISTUM-I

The Intra-Sectoral Technology Use Model - Industry (ISTUM-I) is an end-use model of the industrial sector. Developed by Battelle Pacific Northwest Laboratories and Simon Fraser University, the model is used by B.C. Hydro for electricity demand forecasting in the industrial sector, and by Simon Fraser University for various types of energy and environmental research. ISTUM-I provides the analytical tool for the simulations required in the terms of reference of this study. The model simulates technological change as a function of changes in physical output, retirement of old equipment, and capital and operating costs of new technologies.

Process flow models were designed for the electricity intensive industries, linking major end-uses (such as pumping) to process steps (such as pulp digesting). The process flow models provided the framework for the collection and input of base stock equipment data. The model was calibrated to B.C. Hydro data for the 1988 base year.

Behavioural parameters in the model were either set in the terms of reference or taken from surveys of industry decision making. Thus, in the Frozen run equipment efficiency is fixed, in the Technological run the least-electricity equipment is always chosen, and in the Economic runs the cost-minimizing technology is always chosen. In the Natural change in electricity intensity run, the behavioural parameters are derived from industry surveys showing that discretionary investments, such as improved energy efficiency, must meet paybacks in the range of two years.

However, in some cases this approach suggested that in the Natural run (world without Power Smart) efficient motor system components would still capture most of the market (i.e., paybacks of less than two years). Additional discussion with industry survey experts suggested that the components of motor systems are often chosen only on the basis of capital cost. This would explain why more efficient units, with short paybacks, have not significantly penetrated the market in the past. On this basis, another ISTUM-I behavioural parameter - maximum market share - was adjusted to ensure that high efficiency motor system units would not capture more than 20% of the market.

Other data was input into ISTUM-I. These included:
* cost and efficiency data on new technologies (generic and process-specific);
* estimates of physical output from the electricity-intensive industries under two economic output scenarios - high and low growth (physical output forecasts resulted from a range of demographic and economic forecasts specified by the Collaborative Committee);
* breakdown of physical output among sub-products, thereby driving certain process shifts (e.g., from chemical to mechanical pulping);
* electricity price forecasts;
* environmental credits;
* estimates of efficiency improvements if equipment is operated and maintained as well as possible (best practice) instead of with standard practice.

Calculation of the technological, economic and social potential required multiple simulations with ISTUM-I:
* 1 Frozen,
* 1 Natural,
* 5 Economic (each economic run uses an electricity price with a different environmental credit: 1 - 0% credit; 2 - 15%; 3 - 30%; 4 - 60%; 5 - 100%),
* 1 Technological,
* 1 Technological / Social.

Each of these was run for the high and low output scenarios. The aggregate results are presented below. Detailed results are presented in the chapters devoted to individual industries. Even greater detail is in Volume II, where results are disaggregated by electricity end-use category and industry sub-product for all runs and all scenarios.

RESULTS

Aggregate Results

Table 1 and Table 2 summarize the study aggregate results for the B.C. industrial sector. Figure 1 and Figure 2 provide a graphic presentation of these results.

Table 1 B.C. Industry Electricity Consumption: Low (TWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	19.4	20.0	21.3	
Natural		18.7	19.3	9.3
Econ 1		12.7	13.4	37.1
Econ 3		12.5	13.2	38.0
Econ 5		12.2	12.9	39.5
Tech		12.4	13.1	38.6
Tech/Social		11.8	12.4	41.6

Table 2 B.C. Industry Electricity Consumption: High (TWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	19.4	24.8	28.4	
Natural		23.2	26.1	8.3
Econ 1		16.2	18.7	34.2
Econ 3		15.9	18.4	35.3
Econ 5		15.5	17.9	37.0
Tech		15.8	18.3	35.8
Tech/Social		14.9	17.3	39.3

Only three of the five Economic runs are shown because of the small gradient between all Economic results. As well as some technology shifts, the higher numbered Economic runs include cost-effective changes in operation and maintenance.

Both the high and low output scenarios have similar rates of percentage efficiency improvements relative to the Frozen run. The small differences are due to slight changes in the relative product mix between the two scenarios; both within and between industries. For example, the relative share of mechanical pulp may differ from the high to low scenario. Also, because both of the target years show similar percentage changes, the analysis below is limited to only the high growth scenario and the 2010 target year.

Figure 1: BC Industry Electricity

Consumption - Low Growth (TWh)

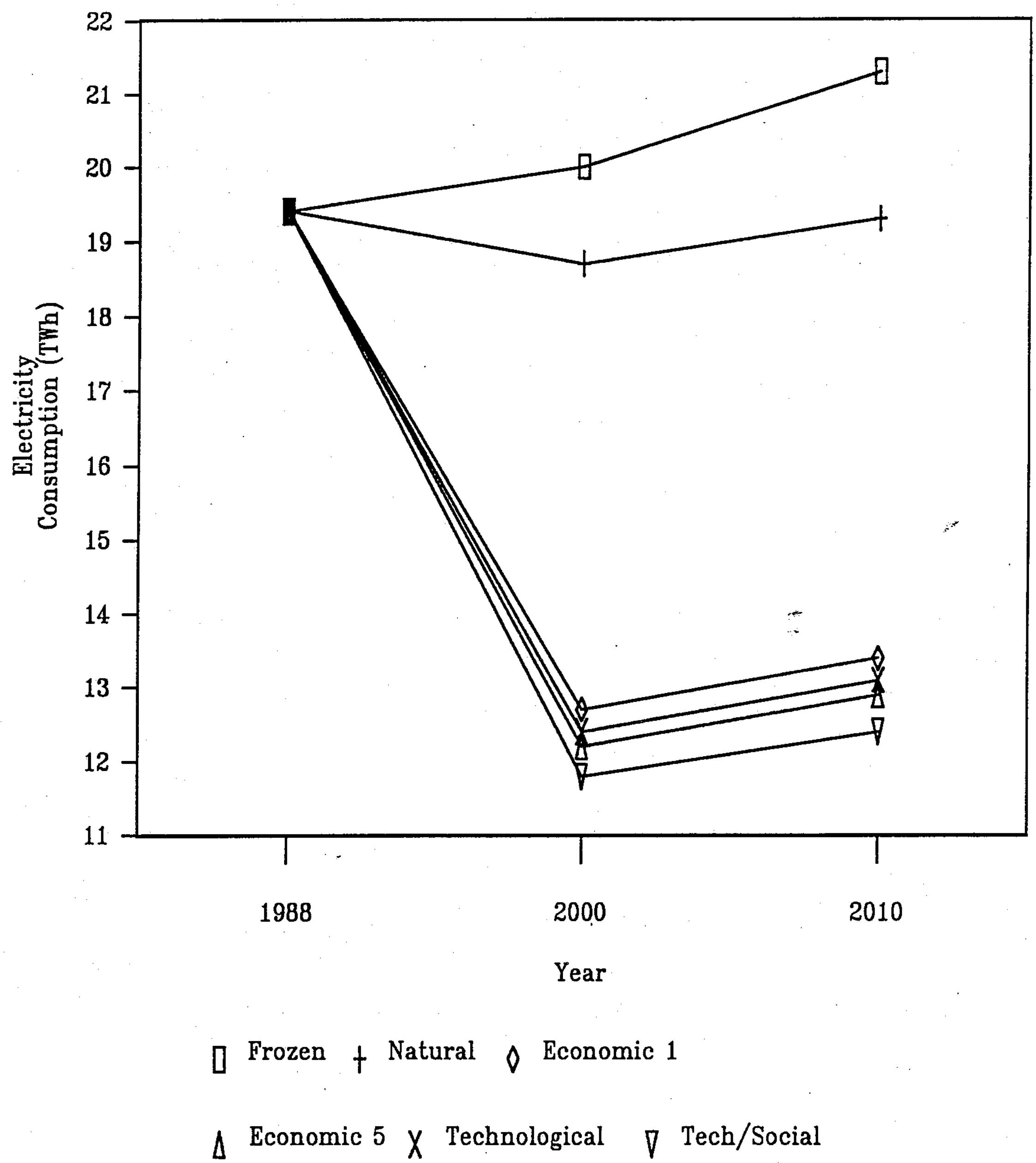
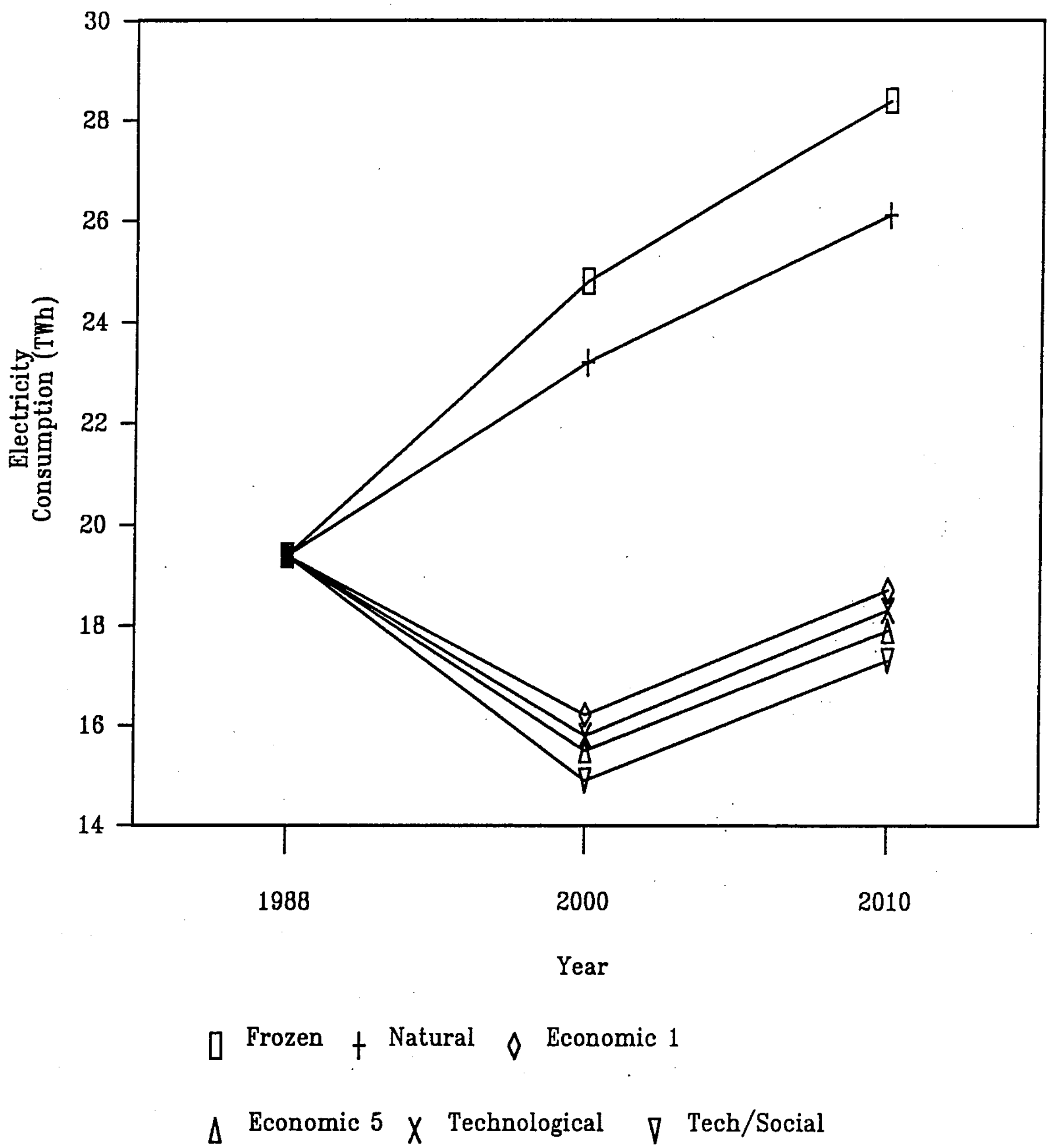


Figure 2: BC Industry Electricity Consumption - High Growth (TWh)



Analysis of Results

The analysis focuses on the estimate of technological, economic and social potential relative to the frozen run.

The Natural change in electricity intensity results in an 8% decrease in end-use electricity consumption. This is because (1) standard efficiency technologies experience a gradual efficiency improvement as old equipment is retired and replaced by new, and (2) some high efficiency technologies slowly increase their share of the total stock.

The Technological and the Economic (all runs) simulations suggest a potential for improved electricity efficiency in the range of 34% - 37%. The similarity of these results occurs because the most efficient market-ready technologies were almost all found to be economically attractive under the initial Economic run. As environmental credits are increased, the more efficient technologies continue to be the most economically attractive.

The Economic 5 run surpasses the Technological run in reducing electricity consumption. This is because the Technological run assumes standard equipment operating and maintenance practices, whereas cost-effective changes in these practices are included in the Economic run.

The Technological / Social run shows the greatest electricity saving potential. This is because it includes the least-electricity technologies and the best practices in operation and maintenance. The Technological / Social run decreases electricity consumption by about 3% more than the Technological run. This means that the aggregate Social potential (as defined in the terms of reference) is about 3%. The Social Potential is an area of considerable uncertainty in this study. Because there are few case studies from which to develop data, the empirical estimates represent an amalgamation of guesstimates by industry experts.

The aggregate results mask significant differences between industries and end-uses. Table 3 presents aggregate results by end-use for Technological relative to Frozen. These are aggregate averages, which vary depending on the assumptions and equipment types specific to each branch of industry. The results are disaggregated to show reduction in electricity demand due to technological efficiency improvements in auxiliary systems vs. demand reduction due to efficiency improvements in process technologies (technologies designed to complete a particular step in the production process). The latter are defined as improvements in end-use capacity requirements for auxiliary services, and occur because the same product can often be produced by alternative technologies with different end-use capacity requirements. Examples of these process technologies are: continuous kraft digesters in pulp and paper, primary ore crushers in mining and ring debarkers in wood products.

Table 3 Aggregate End-Use Efficiency Improvement:
Technological Relative to Frozen (High Growth - 2010)

End-Use	Auxiliary Systems Efficiency Improvement GWh Reduction	 Efficiency Improvement % Reduction	Process Technologies Efficiency Improvement GWh Reduction	 Efficiency Improvement % Reduction	Total Efficiency Improvement GWh Reduction
Machine Drive					
Pumping	1 981	30%	2 76	39%	4 557
Air Displacement	459	24%	516	27%	975
Compression	197	25%	237	30%	434
Conveyance	209	10%	293	14%	502
Other	1 476	13%	1 185	10%	2 661
Non-Machine Drive	----	----	1 046	18%	1 046

Table 4 presents the Technological potential relative to Frozen for the key electricity-intensive branches.

Table 4 Technological Relative to Frozen:
by Industry Branch (High Growth - 2010)

Branch	Technological GWh Reduction Relative to Frozen	Technological % Reduction Relative To Frozen
Pulp and Paper	6 729	42.4%
Mining	1 074	24.6%
Wood Products	570	19.3%
Chemicals	535	23.2%
Petroleum Refining	236	60.7%
Other Manufacturing	1 031	38.5%

The greatest potential for improved efficiency is found among pumping, air displacement and compression motor systems. Therefore, the pulp and paper industry, with considerable pumping, shows the greatest Technological potential, achieving a level of about 42%. The pulp and paper results are also caused by the shift from less to more electricity-efficient mechanical pulp refiners, and a reduction in pumping demand as batch chemical pulp digesters are replaced with continuous digesters.

In contrast, the Technological potential in other key branches was in the 20% to 25% range, although the reasons vary from industry to industry. In mining, electricity is primarily consumed by large process motors used for ore grinding. Because they use so much electricity, these motors have already been designed and installed with a concern for electricity efficiency. The estimate of Technological potential is 25%.

The wood products industry is dominated by process-specific machine drive equipment, such as saws, debarkers, lathes, edgers and planners. Again, this equipment does not offer the same potential for efficiency improvement as can be found with generic motor end-uses such as pumping, which is why the wood products branch only shows a Technological potential of about 20%.

Electricity consumption in the chemical industry is dominated by mature electrolysis processes, which do not have high potential for efficiency improvement. This explains why the Technological potential in this branch is 23%.

Comparison with Other Studies

The approximately 37% relative to Frozen result for Technological and Economic potential is the critical finding of this study. It is interesting to compare this with other research, even though methodologies will differ to some extent.

Table 5 summarizes some recent studies on Technological Potential. The upper part of the table presents research that focused primarily on motors and adjustable speed drives, while the lower part includes studies that have at least partly attempted a more comprehensive approach, making them better comparisons for this study.

Table 5 Studies of Technological Efficiency Potential in Industry

Focus Limited to Motors and Electronic Adjustable Speed Drives	
Barakat and Chamberlin	29% - 45%
MARBEK	15% - 20%
Electric Power Research Institute (Gellings et al.)	44%
Focus Extended to Most or All Components of Motor Systems	
Rocky Mountain Institute (Lovins et al.)	28% - 60%
Norgaard (pumps only)	70%
Larson and Nilsson (pumps and air displacement only)	50% - 65%

As Table 5 shows, studies that limit their focus to industrial motors, and the addition of adjustable speed drives (top three studies), tend to have lower estimates. Studies that examine entire motor systems (bottom three studies) tend to have higher estimates. The latter three studies have estimates similar to the finding of this study, at least for industrial pumping systems. However, they differ significantly from the aggregate results of this study. This suggests that one should be careful not to extrapolate the impressive results from an analysis of one type of auxiliary motor system to all industrial electricity consumption, or even all electricity motor system consumption. The major large process uses of motive force in industry have seen much more attention on electricity efficiency, both in equipment design and purchase. Moreover, electrolysis and process heat uses of electricity also present less opportunities for efficiency gains. As a consequence, significant additional efficiency gains will be difficult to achieve.

OVERVIEW AND RECOMMENDATIONS

Methodological Innovations

The estimation of electricity conservation potential is a field in which methodology is rapidly developing. The method applied in this study seeks to make an innovative methodological contribution in two aspects.

(1) This is the first study, to our knowledge, to estimate the base stocks and efficiency potential of all components of industrial motor systems. While some case study research has noted the importance of including all components of a motor system, previous industry-specific research on simulating aggregate electricity efficiency potential has focused only on the potential from two devices: high efficiency motors and the addition of electronic variable speed drives. The case study research shows that other components of the system can also make important contributions to efficiency improvements. In this study, not only are all components of motor systems incorporated, but they are linked to the specific production processes in each industry. Thus, changes in industrial structure and in major production processes will be reflected in the demands for different types of motor systems and in the consequent estimates of efficiency improvement potential.

(2) Almost all of the simulation and analysis of this study has been achieved with the use of a second generation end-use energy demand model, ISTUM-I. This model is used by B.C. Hydro for long run industrial electricity demand forecasting. Use of this model as the key analytical tool has several advantages for some of the broader goals of electricity efficiency research. First, equipment base stock, efficiency and cost estimates are immediately available to B.C. Hydro at the appropriate level of detail. Second, a second generation model easily allows for follow-up investigations: one can quickly rerun the model for alternative scenarios and prices. Third, a second generation end-use model can serve as a tool for integrating demand-side management and forecasting. Behavioural parameters can be adjusted in the model to match B.C. Hydro's data on consumer behaviour, and then various demand-side management initiatives (grants, pricing) can be modelled, using ISTUM-I, to test for their impacts. This latter dimension closely matches the objectives of the second phase of the

efficiency potential review being undertaken by B.C. Hydro and the Collaborative Committee.

Recommendations

1. That research be directed to case study analysis of all components of the key motor systems in industrial plants, especially in B.C.'s pulp and paper industry. This information should be gathered in a systematic way that allows extrapolation of results, from representative samples, to the estimation of specific end-uses for entire industrial branches. This will help to confirm and adjust the estimates in this study.

2. That research be undertaken to identify the most effective means of encouraging the penetration in industry of cost-effective, high efficiency motor systems. This would help to improve the confidence in the behavioural parameters of the ISTUM-I model, thereby augmenting its utility for research on the impacts of industry demand-side management programs.

CHAPTER 1

INTRODUCTION

1.1 Background

During the 1980s the electric utility industry in North America underwent profound change. At the start of the decade, electric utilities were generally focused on major capacity expansion investments; however, some utilities were beginning to recognize the economic and risk-reduction benefits of demand-side efforts to improve the efficiency with which consumers use electricity. By the end of the decade, the benefits of focusing on the demand-side had become conventional wisdom, with most utilities making significant demand-side management investments and including efficiency improvement as one of their resource options for meeting load growth. Indeed, the debate in this field has evolved from one of questioning whether demand-side management is a legitimate utility activity to one of estimating the magnitude of the technological, economic and social potential for improved electricity efficiency.

In 1991 BC Hydro established a collaborative committee comprised of consumer representatives and other stakeholders to set terms of reference and choose consultants to estimate the potential in B.C. for improved electricity efficiency. The Ottawa firm of MARBEK was granted the contract for the residential and commercial sectors. The firm of M.K. Jaccard and Associates received the contract for the industrial sector, the subject of this report. This industrial component of the total study was conducted over the period June 1991 to February 1992. Unless indicated otherwise, this research was conducted by Allan Fogwill, John Nyboer and Mark Jaccard.[1]

1.2 Objective

The primary objective of this study is to:

"assess the technological, economic and social potential for efficient use of electricity in the B.C. industrial sector over the period 1988 to 2010."

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1. Dr. Mark Jaccard is a professor in the School of Resource and Environmental Management (formerly the Natural Resources Management Program) at Simon Fraser University and principal in M.K. Jaccard and Associates. Allan Fogwill is a research associate in M.K. Jaccard and Associates and at the School of Resource and Environmental Management. John Nyboer is a Ph.D. student and research associate at the School of Resource and Environmental Management.

A precise understanding of this objective requires the establishment of study boundaries and assumptions, as well as several definitions. These are presented in sections 1.3 and 1.4.

1.3 Study Parameters and Assumptions

Time period: twenty-two years

The base year of the study is 1988. This was chosen because it represents the final year before the introduction of B.C. Hydro's Power Smart electricity efficiency program. The target years for study results are 2000 and 2010.

Geographical coverage: B.C. Hydro service area

The area covered by the study includes:

"all those industrial plants within the B.C. Hydro service area that are either (1) currently connected to the grid, or (2) have a reasonable chance of being connected to the grid over the 22 year forecast period."

Thus, plants served by West Kootenay Power and Light are excluded from the study. So too are small sawmills and mines in isolated regions far from the B.C. Hydro grid, with no chance of ever being serviced by the corporation.

Interenergy substitution: not allowed

Since the study focuses on estimating the effect of improving the efficiency of electricity use, it is necessary to isolate this effect from other developments, such as Interenergy substitution. Therefore, all scenarios in the study are:

"constrained to prevent Interenergy substitution between electricity and other energy forms, at the point of technology competition."

This distinction means, however, that Interenergy substitution could still occur if it were the result of major process or structural change. For example, a shift from chemical pulp to mechanical pulp will result in a substitution away from fossil fuels and biomass toward increased electricity. In contrast, at the technology level this assumption implies that the relative share of electric infrared dryers (relative to steam or direct natural gas) for drying fine paper will stay constant at its 1988 level throughout the forecast period.

Electricity producing technologies: excluded

If an industrial plant increased its self-generation of electricity, the result would be a decrease in sales from B.C. Hydro. However, because the focus of this study is improved efficiency of electricity use, all technologies are excluded whose net effect is to produce electricity. This includes, for example, cogeneration technologies that co-produce electricity and process steam. In those industries where self-generation does occur, it is necessary to determine the amount of electricity used by end-use technologies within the plant. This usually requires adding self-generated electricity to purchases from B.C. Hydro in order to calculate the total end-use of electricity within a plant.

Industry disaggregation: separate analysis of six branches

There is great diversity in the electricity intensity of various branches of industry in B.C. and in the relative electricity consumption of these branches. This study isolates certain branches and aggregates the rest into a category called "other".

pulp and paper
mining
wood products
chemicals
petroleum refining
other

Forecast industry output

Table 1.3.1 presents high and low forecasts of output for key branches of industry. These were provided initially by B.C. Hydro, and reviewed by the Collaborative Committee.

Forecast energy prices

Forecasts of energy prices are required estimating natural change in electricity intensity, defined below in section 1.4. Table 1.3.2 presents the forecast of energy prices used in the study, for the years 1988, 2000 and 2010. These prices were taken

Table 1.3.1 Conservation Potential Review:
Activity Forecast

Industrial Sector: Physical Output By Industry

	1988	High 2000	High 2010	Low 2000	Low 2010
Wood Products (000 m^3)					
Lumber	36 736	40420	44 764	34 370	33 670
Structural Bd	1 828	1 824	1 932	1 456	1 411
Pulp and Paper (000 t)					
chemical pulp	5 436	5 000	5 000	4 800	4 700
mechanical pulp	1 800	3 500	4 200	2 500	3 000
recycled pulp	133	380	380	250	300
newsprint/other	2 788	4 500	5 000	3 000	3 500
tissue	90	110	160	95	100
coated paper	0	170	350	0	0
Mines (t)					
Metals					
copper	353 651	435 780	481 818	223 841	185 475
molybdenum	12 497	16 508	17 377	8 481	8 066
gold (kg)	13 200	22 073	22 073	6 876	6 782
silver	431	665	665	308	287
lead	105 173	113 132	134 429	57 948	54 676
zinc	146 959	178 884	213 082	90 635	83 528
Coal (000 t)					
metallurgical	21 957	25 031	28372	23 108	24 602
thermal	3 114	4 883	6 445	4 103	4 893
Chemicals (000 t)					
Sodium chloride	139	200	225	180	200
Sodium hydroxide	265	225	225	200	175
Hydrogen peroxide	0	40	50	36	36
Petroleum Refineries(000 m^3)					
refined products	9668	10 000	10 000	8 000	8 000

(Source: B.C. Hydro, Load Forecasting Department, 1991) from the price forecast of the B.C. Ministry of Energy, Mines and Petroleum Resources, and reviewed by the Collaborative Committee.[2] They represent the market prices faced by customers.

Table 1.3.2

End-Use Energy Prices
($1990)

Energy	1989	2000	2010
Natural Gas ($/GJ)	1.99	2.24	2.74
Petroleum Coke ($/GJ)	2.47	2.80	3.10
Residual Oil ($/GJ)	3.63	5.92	7.39
Low Sulphur Coal ($/GJ)	1.42	1.56	1.72
Hog Fuel ($/GJ)	0.84	0.94	1.03
Electricity (cents/KWh)	3.31	2.90	2.90
Electricity ($/GJ)[3]	9.17	8.04	8.04

Cost of New Supply[4]

The cost of new supply[5] is the weighted incremental cost of new electricity supply to the B.C. Hydro system, discounted to the present at a rate of 8%. To incorporate the intangible externality costs of electricity provision, the Collaborative Committee for the 1991 Conservation Potential Review requested that a range of environmental and social externality credits from 0% to 100% of the incremental cost of electricity to B.C. Hydro be used. The intent of the credit is to reflect unpriced environmental and social costs associated with new supply. The Collaborative Committee wished to test the sensitivity of economic potential to the level of environmental credit used. This information is necessary for estimating economic potential, defined in section 1.4.

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2. The price forecast is only used in the Natural Change in Intensity run. As noted elsewhere, (Methodology, Section 2.3 and Chapter 10, Section 10.3) a sensitivity of alternative prices on the Natural run is desirable, but not practical until further research (perhaps in Phase II of this study) has improved confidence in the model's ability to simulate investment decision making.
3. For convenience, electricity is expressed in both gigajoules (GJ) and kilowatthours (KWh). The model used in this study (ISTUM-I) operates normally in GJ. 1000 KWh = 3.6 GJ. Kilo (K) = 10^3 = Thousand. Mega (M) = 10^6 = Million. Giga (G) = 10^9 = Billion. Tera (T) = 10^{12} = Trillion. Peta (P) = 10^{15} = Quadrillion.
4. Cost of New Supply was based on special analysis by Resource Planning Department at B.C. Hydro. It is consistent with the assumptions and methodology in "The Cost of New Electricity Supply in B.C. - April, 1991 Update" (B.C. Hydro Resource Planning Department, 1991), except that Power Smart cost and savings are excluded.
5. Similar to the concept of avoided cost used by U.S. utilities.

Table 1.3.3 presents the forecast of total resource cost for the years 1988, 2000 and 2010.[6]

Table 1.3.3

Cost of New Supply
(1990 cents/KWh)

	1988	2000	2010
0% Credit	1.8	6.3	6.3
15% Credit	2.1	7.3	7.3
30% Credit	2.4	8.2	8.2
60% Credit	2.9	10.0	10.0
100% Credit	3.6	12.6	12.6

Scenarios and runs

Given its objectives, this study has two different scenarios: high and low growth. Each scenario has nine runs: 1 Frozen Efficiency, 1 Technological Potential, 1 Social Potential, 1 Natural Change in Electricity Intensity and 5 Economic Potential. This means that each branch of industry has 18 sets of results to report. The results are also to be disaggregated by electricity end-use.

1.4 Key Definitions[7]

Over a forecast period, the technological, economic and social potential for electricity consumption can only be estimated relative to a base case, frozen efficiency. An estimate of the natural change in electricity also provides an indication of how close society would get, without intervention, to the technological, economic and social potential. All of these are defined below.

6. Note that these numbers are not to be compared to the electricity prices faced by B.C. Hydro customers, for whom electricity prices are generally set at the average cost of production.
7. The following definitions are based on the Terms of Reference drafted by the B.C. Hydro Collaborative Committee.

Frozen efficiency

Frozen efficiency is defined in the following way.

> To produce a given product, all industrial technology capacity additions and replacements over the 22 year forecast period (1988 - 2010) have the same electricity intensity (electricity consumption per unit of output) as the average intensity for all the capacity that produced the same product in 1988.

This means, for example, that the electricity consumed per tonne of mechanical pulp remains constant at its 1988 industry average. However, as the relative shares of product output change within a given industry there will be a change in the industry-wide average for unit electricity production. For example, a shift from chemical to mechanical pulp will result in an increase in the aggregate ratio of electricity consumption per tonne of pulp. In a frozen efficiency forecast (1988-2010), the only cause of change in electricity demand will therefore be due to (1) changes in total output, (2) structural changes among industries (e.g. more cement, less chemicals), and (3) changes in major processes (e.g. a shift from chemical to mechanical pulp).

This definition of frozen efficiency differs from that used by MARBEK for the residential and commercial sectors. MARBEK freezes the average efficiency of only those stocks of equipment that were newly installed in the year 1988. In industry this approach is problematic because it requires many assumptions about what would have been purchased if an industry had made major investments in the previous year.

Natural Change in Electricity Intensity

> This is a forecast of how electricity consumption would evolve if there were no Power Smart program and if industry simply responded with current investment behaviour to the growth projections and energy price inputs in this study's terms of reference.

Like any demand forecast, the Natural Change in Electricity Intensity depends on the accuracy of assumptions about emerging technological options, future equipment turnover rates and industry investment behaviour. In the methodology chapter we specify the investment behaviour assumptions used to develop a forecast of natural change in electricity intensity. The technological options available at each time period for each branch of industry are specified in the chapters devoted to each branch.

Technological Potential

> Technological Potential is measured as the difference between Frozen Efficiency electricity consumption and Technological Potential electricity consumption.

The Technological Potential electricity consumption is determined by assuming that for each energy service there is 100% penetration of those market-ready technologies (in 2000 and 2010) with the lowest electricity consumption, assuming that technologies are operated and maintained using standard current practice. Thus, industry is restrained neither by cost nor by the inertia of existing equipment stocks. All equipment stocks are retired and replaced in 2000 and 2010.

Social Potential

> Social Potential is measured as the difference in electricity consumption between the Technological Potential described above and a Technological Potential in which all technologies are operated and maintained using best practice, instead of standard current practice.

The run to estimate social potential is called the Technological/Social potential. It includes correctly matching the size of equipment to the task required.

Economic Potential

> Economic Potential assumes 100% market penetration of those market-ready technologies (in 2000 and 2010) with the lowest cost when the cost of electricity is set at the cost of new supply (long run marginal cost), after application of a credit to reflect unpriced environmental and social costs of new supply development. Economic Potential is measured as the difference between the Frozen Efficiency electricity consumption and the Economic Potential electricity consumption.

It is assumed that all operation and maintenance practices which can be costed in dollar terms are included in the calculation of Economic Potential, and that all operation and maintenance practices that are cost-effective relative to the cost of new supply are assumed to occur. Environmental credits are applied by multiplying the cost of new supply by 1, 1.15, 1.3, 1.6 and 2, for a total of 5 estimates of Economic Potential. All equipment is retired in 2000 and 2010.

1.5 Analysis of Industrial Electricity Consumption

Industry Electricity End-Uses

Research into the potential for electricity conservation starts with an analysis of the major industrial end-use applications of electricity, these being motive force, electrolysis, process heat and lighting. Of these, motive force is by far the major aggregate industrial end-use. Table 1.5.1 shows a recent breakdown of industrial end-uses of electricity in the U.S. from Gellings et al. (1991).

Table 1.5.1

U.S. Industry End-Uses of Electricity
(1987 - %)

Industrial End-Use	%
Motive Force	67.5
Electrolysis	11.5
Process heat	10.0
Lighting	10.0
Other	1.0

Although the dominance of motive force is almost universal, its relative importance can vary somewhat from industry to industry depending on the character of the production process. Table 1.5.2 from Ontario Hydro (1990) provides a breakdown of electricity end-uses for those branches of Ontario industry that are also important in B.C.

Table 1.5.2

End-Uses of Electricity Among Ontario Industries
(1988 - %)

Branch	Motive Force	Electro-lysis	Process Heat	Lighting & Other
Mining	98			2
Wood products	89		3	8
Pulp & Paper	95			5
Petroleum Refining	95			5
Chemicals	66	24	5	5
All Industry	76	5	11	8

B.C. Hydro Industrial Service Area Electricity Consumption and End-Uses

In terms of electricity consumption, the B.C. Hydro service area industrial sector is dominated by a few key branches. Table 1.5.3 uses B.C. Hydro and industry data to show electricity consumption by branch.[8] Electricity sales from B.C. Hydro have been added to electricity produced at each plant (cogeneration and on-site hydro) to estimate

8. The data covers only the service area of B.C. Hydro.

the total end-use electricity consumption (i.e. the electricity consumed by in plant equipment).

Table 1.5.3

B.C. Hydro Industrial Service Area Electricity Consumption
(1988 - GWh - %)

Branch	GWh	%
Pulp & Paper	10 426	53
Mining	3 353	17
Wood Products	2 057	10
Chemicals	1 655	8
Petroleum Refining	380	2
Other	1 899	10
Total	19 770	100

As the table shows, four branches account for 88% of B.C. Hydro service area industrial electricity consumption. If this information is combined with the end-use breakdown estimates from Table 1.5.2, it is apparent that motive force is even more predominant in B.C. than in Ontario as the major industrial electricity end-use. Multiplying the electricity consumption of each B.C. Hydro service area industry branch by the Ontario motive force estimates for that branch (Table 1.5.3 by Table 1.5.2) results in a preliminary estimate that motive force represents close to 90% of the B.C. Hydro service area industrial use of electricity.[9]

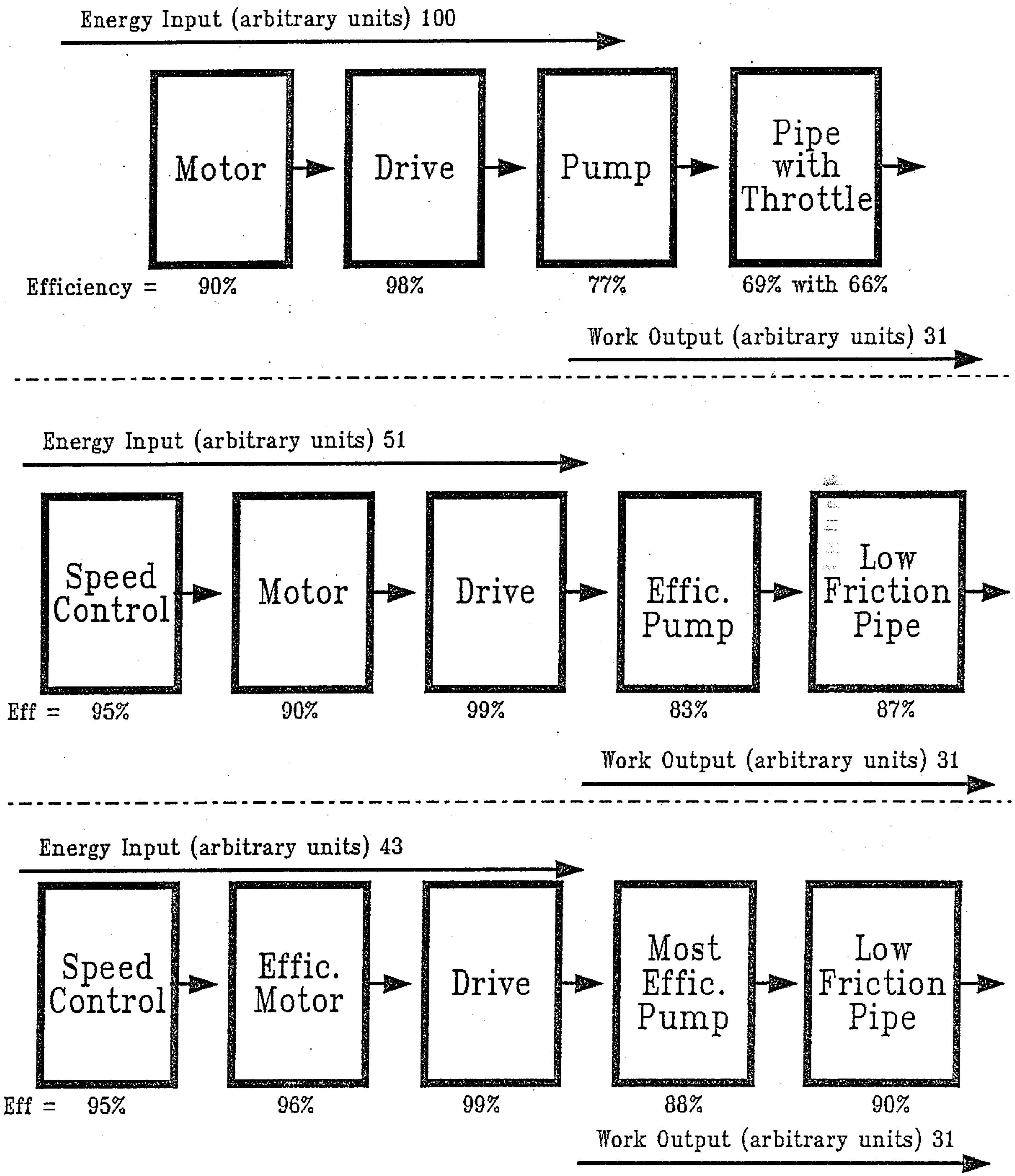
Disaggregating Motor Systems[10]

Given the importance of motive force in industrial electricity consumption, this end-use has been the principal focus of research efforts aimed at efficiency improvements (Ross, 1989). To assess total conservation potential, an electric motor must be analyzed as part of a total mechanical system, comprised of several components with varying mechanical efficiencies. This includes the motor, the equipment which it is driving - pumps, fans, blowers, conveyers, compressors, hydraulics, saws, grinders, refiners, etc. - and the other connected mechanisms - belts, axles, chains, gears, throttles, etc.

Figure 1.5.1 provides an illustrative example from Fickett et al. (1990) of how improvements in the efficiency of each component of a motor system can lead to significant cumulative effects. Moving from the top to the bottom of the figure, the

9. Combining the two tables actually gives a motive force estimate of greater than 92% of the electricity consumption; however, B.C.'s chemical industry appears to have a greater share for electrolysis and a smaller share for motive force than does Ontario's chemical industry - see Chapter 7.
10. We use interchangeably the terms motor system and mechanical system.

Figure 1.5.1 Illustrative Mechanical System Efficiency Improvements



Adapted from Fickett, et al., 1990

efficiency of a typical mechanical system is improved from 31 to 72 percent by (1) replacing each component with a more efficient unit, (2) properly sizing equipment to the required task, and (3) replacing the throttle / brake with an electronic adjustable speed drive. This example represents a reduction in electricity consumption (the energy input of the system) of 57%.

The efficiency with which mechanical systems convert electricity in order to perform some kind of mechanical task depends, therefore, on several factors.

1. Types of auxiliary equipment differ in their efficiency potentials. For example, a pump has different efficiency possibilities than a fan. Therefore, it is necessary to know within a branch of industry the relative breakdown of mechanical electricity demand among the various types of auxiliary equipment connected to electric motors.

2. Efficiency can vary from one type of motor (or auxiliary equipment) to another. Therefore, estimating the potential for improvement requires an estimate of the relative efficiencies of currently installed motors and auxiliary equipment.

3. Efficiency can also vary with the utilization rate (proportion of a year when the equipment is operated) and load factors (proportion of capacity that is used) of motors and auxiliary equipment. Thus, the information above must be augmented with estimates of the average utilization rates and load factors.

These factors imply that a study of efficiency potential requires an extensive amount of detailed information about the stocks and operating conditions of motors and auxiliary equipment inside a given plant, information which is not available in any statistical database. Scattered information from an array of secondary sources (surveys, audits, engineering blueprints, expert opinion) is required in order to construct an accurate picture of the current efficiencies of the motor systems in B.C. industry. Only then can information from technical analyses and pilot projects (such as that illustrated in Figure 1.5.1) be applied to estimate the potential for increases in industry efficiency. In the next chapter (Methodology) this process of information gathering and analysis is explained in detail.

1.6 Overview of Report Chapters

This report is organized as follows. Chapter 2 presents the study methodology, including sources and techniques for data collection and development, execution of an industry model and the determination of social potential. As noted in this introduction, analysis of motor systems is crucial to this study. Chapter 3 explains in greater detail the various types of services provided by motor systems, the technologies involved, and the kinds of efficiency gains that are possible. Chapters 4 through 8 present the explicit model assumptions and results for the five industries accounting for 90% of B.C. industrial electricity consumption. Chapter 9 explains the treatment of those industries accounting for the residual 10%. While no effort was made to simulate the production processes in these industries, surveys from elsewhere allowed for an estimate of the relative shares of motive force end-uses and other end-uses in determining electricity consumption. This was used to produce a simplified simulation of end-use service evolution as a function of average industry growth rates. Chapter 10 presents the aggregate results for all B.C. industry, compares these findings to other studies, assesses the study's limitations, and makes suggestions for the direction of future industrial sector data collection, analysis and modelling.

CHAPTER 2

METHODOLOGY

The data presented in the introductory chapter showed the importance of pulp and paper, along with just a few other branches, in B.C. industrial electricity demand. It also showed that motor systems represent about 90% of the electricity end-use. An analysis of the potential for improved electricity efficiency therefore required the following components.

1. Selection of end-use categories of electricity consumption that best characterize its use in B.C. industry. The importance of motor systems suggested the need for further disaggregation of that end-use into categories of auxiliary equipment driven by motors.

2. Estimation of 1988 base stocks (installed capacity) of equipment (technologies) associated with each of the selected end-use categories.

3. Collection of data on the efficiencies and costs of alternative sets of market-available equipment in each of the selected end-use categories for the key forecast years of 2000 and 2010.

4. Estimation of behavioural parameters (e.g., discount rate, equipment penetration rates) for those components of the study in which the researchers are asked to simulate industry investment, operation and maintenance practices.

5. Development and use of an analytical tool (a model) to simulate the evolution of technologies as a function of retirement rates, cost competition and other behavioural criteria specified in the various scenarios of the terms of reference.

2.1 Technology Data

End-Use Categories

Electricity use by industry is generally disaggregated into motive force, electrolysis, process heat, lighting and other (space conditioning, office equipment, appliances, etc.). Except in a few key industries, where electrolysis or process heat are important, industrial consumption of electricity is dominated by motive force applications. However, because the types of equipment driven by electric motors can differ significantly (in terms of mechanical efficiency and application), a further disaggregation of motive force is desirable. Categories include pumping, air displacement (fans and blowers), material conveyance, compression, hydraulics, and process specific tasks (mineral ore grinders, wood saws, mechanical pulp digesters, etc.)

Research from BC Hydro on the relative importance of motive force sub-categories in BC industry, and an assessment of data collection potential, led to the decision to disaggregate motive force into five "auxiliary" categories:

pumping
air displacement
conveyance
compression
other machine drive

Base Stock Data Requirements

A highly accurate calculation of end-use electricity consumption by BC industry would require the following information.

1. The physical quantities of liquid pumped, air displaced or compressed, material conveyed and material transformed by some direct mechanical action (pulp refined mechanically, ore pulverized by grinders, wood cut by saws, etc.). This information must be specific to unique sub-products (e.g. how much pumped liquid per tonne of mechanical pulp vs per tonne of chemical pulp), because as the relative production shares of industry sub-products change the needs for motor system end-use services can also change. Also, as processes evolve, the physical requirements for motive force services (pumping, etc.) may change per unit of final product; newer technologies tend to be more efficient in their need for these services (e.g. continuous chemical pulp digesters use less pumping than do batch chemical digesters).

2. The relative division of these physical quantities among various sizes of equipment (e.g. percentage pumped by small, medium and large pumps). This is because different sizes of mechanical systems can have different efficiencies and different costs per unit of service.

3. Both the proportion of year when equipment is operated and the proportion of capacity used, of each type of motor system (which could vary between industries and even between sub-products of the same industry). This is because efficiency and cost per unit of service varies with both of these variables.

4. The efficiency of each component in the motor system (e.g. pipe, pump, drive mechanism, electric motor). This is required to calculate the aggregate efficiency of the mechanical system in order that the total electricity input to all motor systems, when added to all other end-uses of electricity, matches the electricity sales from B.C. Hydro, after correction for self-generated electricity.

5. The relative shares in industry equipment in the base year (1988) of higher and lower efficiency motor system components for meeting each end-use service sub-category. This is needed in order to estimate the potential change if all components were of the highest possible efficiency. In other words, when calculating the effect of switching completely to the most efficient equipment it is necessary to know if 10% or 50% of existing equipment is already of that type.

Information of the type detailed above is not available from any statistics-gathering organization. Indeed, only the rarest of industrial firms would have this kind of information about its plant organized in a systematic manner. Thus, a first step of this study was to conduct an informal survey of major energy research institutes and individuals (in North America and Europe) in order to assess all approaches used to deal with this challenge in the industrial sector. The general lesson, not unexpected, was that the industrial sector has been the least well researched sector, largely because of the difficulty of dealing with its array of heterogeneous equipment stocks. The survey found the following.

1. In some jurisdictions, there have been industry-wide surveys estimating the relative base stock shares of electric motors of different efficiencies.

2. There have been case studies measuring the effect of adding electronic variable speed drives (VSDs) to motor systems; these case studies have formed the rough basis for industry-wide aggregate estimates of the electricity saving effect of VSDs.

3. However, nowhere has there as yet been a research project for the industrial sector in any country or region that attempted to provide as detailed an estimate of the base stocks and efficiency characteristics of the major types of auxiliary equipment driven by industrial motors.

This means that studies elsewhere:
(1) have not tried to assess the efficiencies of all individual components (including all auxiliary equipment) of base stock motor systems in a manner that would allow for an average aggregate estimate for all industry base stock equipment;
(2) have, therefore, had no way of totally estimating the electricity demand reduction implied by 100% penetration of the most technologically efficient equipment for all components of industry motor systems (if the average efficiency of current equipment is unknown, it is impossible to estimate how much change is implied by using only the most efficient equipment); and
(3) have been unable to accurately simulate the connection between industry product demand evolution and motor system service demands (changes in the relative importance of various sub-products - chemical vs mechanical pulp - will lead to changes in the relative importance of the sub-categories of motive force).

Thus, in this study, we seek to extend end-use research in the industrial sector by generating detailed estimates of the useful energy requirements and total motor system equipment efficiencies in the various sub-categories of motive force end-uses, disaggregated even further by major industrial sub-branch.

The method of data collection and estimation is described below.

Base Stock Estimation (1988)

The ideal data set of motor system auxiliary equipment in industry would be that which emerged from detailed plant by plant audits, including on-site measurement of current equipment efficiencies. Such an exercise is beyond the scope and budget of this study.[1] As an approximation to this end, we used the following method.

1. However, representatives from the mining industry, coordinated by Dal Scott of Highland Valley Copper, are working to conduct a mine by mine survey of auxiliary system equipment stocks throughout the province. Also, a parallel study for West

1. Process flow models were developed of the pulp and paper, mining, wood products and chemicals branches. A process flow model disaggregates an industry's production process into several key steps. An example of process steps in pulp and paper would be (1) pulp digesting, (2) pulp bleaching, (3) paper forming, and (4) paper drying. Process flow models are presented in graphic form for each of the electricity-intensive industries in their relevant chapters in this report.

2. Technical consulting firms were hired to examine the four key branches in detail. Temanex Consultants (George Ionides, Radmilla Ionides and Maria Harris) accepted responsibility for data collection in pulp and paper, chemicals and wood products, in turn sub-contracting the latter to David Mayer. John "Blue" Evans undertook the mining industry, and a considerable volunteer contribution was also provided by Dal Scott of Highland Valley Copper.

3. The consulting firms were directed to use the process flow models as a guide in constructing "blueprints" of the "typical plant" (which would not look like any particular plant) for each of the key products of an industry. For pulp and paper, these typical plants were chemical pulp, mechanical pulp and newsprint. The "typical plant blueprint" would represent a model of the entire production of one sub-product, say chemical pulp, from all plants in the B.C. Hydro service area. In addition to a breakdown of equipment stocks for each major process step, the "blueprint" would include detail on all the electric motors, classified by size of motor (six sizes - see Chapter 3), by connected auxiliary equipment (pump, fan, etc.), and by sub-step in the production process (digesting, paper forming, etc.). This data is not, therefore, derived from a primary survey of the population of equipment currently in each plant, but rather from a best guess of the mix of equipment that is likely to be there given engineering knowledge of how the "typical plant" would be designed. However, in many cases, plant-specific information was used to verify and/or adjust the data from the initial "typical plant blueprint". Figure 2.1.1 presents an example from a mechanical pulp mill of the equipment base stock data sets provided by the sub-contracting consultants.[2]

4. Survey data from B.C. and elsewhere, as well as expert judgement, were used to estimate the relative shares in 1988 of efficient and inefficient (and often several categories in between) electric motors and auxiliary equipment and market penetration of VSDs. To our knowledge, a detailed estimate for auxiliary equipment has not been attempted in any other study of this kind, yet this estimate is crucial for any attempt at gauging the full potential for technical and economic electricity efficiency improvements. Base stocks shares and relative efficiencies were also estimated for all other electricity end-use categories.

5. The information from Steps 1 - 4 generated the crucial base year data of the study. Because estimation played a key role, a subsequent verification process was required.

Kootenay Power involves detailed surveys of the key plants in that utility's service area. However, this base stock data would be especially useful if it included measurements of the mechanical efficiencies of the various components of motor systems.

2. All blueprints are presented in the appendices attached to each industry chapter.

Figure 2.1.1
Sample Mechanical Pulp Mill Motor System Base Stocks

TMP/CTMP – 1988 BASE STOCK 1,118,500 MT/YR (B.C.HYDRO SERVICE AREA)

NUMBER OF MOTORS BY SIZE – TMP/CTMP MILLS IN B.C.

PROCESS	TOTAL # MOT.	MACHINE DRIVE SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	CONVEYORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	354							45	6				
LOG HANDLING	48	3	18	3		3							
WOOD PREP.	57	3	6				9						
CHIP HANDLING	69							15	12	15		6	
CHIP SCREENING	117				6			18	84		3		
TMP PROCESS	1072	24	48	80	24		32	48	144	44	52	12	
# OF MOTORS	1717	30	72	83	30	3	41	126	246	59	55	18	

PROCESS	FANS & BLOWERS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	COMPRESSORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	PUMPING SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	51	15	93				24	24					30	12	15	6	21	12
LOG HANDLING	9							6							6			
WOOD PREP.	15	12					6	6										
CHIP HANDLING														12	9			
CHIP SCREENING			6															
TMP PROCESS	60	52	8	12				44					112	64	124	52	12	24
# OF MOTORS	135	79	107	12			30	80					142	88	154	58	33	36

INSTALLED HP BY MOTOR RATING – TMP/CTMP MILLS IN B.C.

PROCESS	TOTAL HP	MACHINE DRIVE SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	CONVEYORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	26078							71	97				
LOG HANDLING	1827	13	398	198		660							
WOOD PREP.	9665	6	90				9365						
CHIP HANDLING	3780							36	229	954		1759	
CHIP SCREENING	2876				967			49	980		396		
TMP PROCESS	304774	96	740	3500	3106		240000	200	3120	2160	9500	4200	
TOTAL INSTALLED HP:	349000	115	1228	3698	4073	660	249365	356	4426	3114	9896	5959	

PROCESS	FANS & BLOWERS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	COMPRESSORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	PUMPING SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	106	130	7211				80	229					42	222	919	791	5628	10552
LOG HANDLING	9							66							484			
WOOD PREP.	22	97					19	66										
CHIP HANDLING														77	725			
CHIP SCREENING			484															
TMP PROCESS	196	660	420	1500				980					244	732	7120	8300	3600	14400
TOTAL INSTALLED HP:	333	886	8114	1500			100	1341					286	1031	9248	9091	9228	24952

TMP/CTMP – 1988 BASE STOCK 1,118,500 MT/YR (B.C.HYDRO SERVICE AREA)

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS IN A TMP/CTMP MILL

PROCESS	TOTAL ENERGY kWh/MT	MACHINE DRIVE						CONVEYORS					
		SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kW	SIZE 6 kWh/MT	SIZE 1 kW	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kW
WATER SUPPLY & TREAT.	180							0.5	0.7				
LOG HANDLING	7	0.1	1.6	0.8		2.5							
WOOD PREP.	36	0.0	0.4				35.0						
CHIP HANDLING	22							0.2	1.4	5.7		9.9	
CHIP SCREENING	20				6.5			0.4	7.1		2.7		
TMP PROCESS	2059	0.7	5.3	25.2	20.9		1613.6	1.4	22.5	15.6	63.9	28.2	
ENERGY(kWh/MT)	2324	0.8	7.3	26.0	27.4	2.5	1648.6	2.5	31.6	21.3	66.5	38.1	

PROCESS	FANS & BLOWERS						COMPRESSORS						PUMPING					
	SIZE 1 kW	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kW	SIZE 1 kW	SIZE 2 kWh/MT	SIZE 3 kW	SIZE 4 kW	SIZE 5 kWh/MT	SIZE 6 kW	SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT
WATER SUPPLY & TREAT.	0.8	0.9	51.9				0.6	1.6					0.3	1.6	6.6	5.3	37.8	70.9
LOG HANDLING	0.0							0.3							1.9			
WOOD PREP.	0.1	0.4					0.1	0.3										
CHIP HANDLING														0.5	4.4			
CHIP SCREENING			3.5															
TMP PROCESS	1.4	4.8	3.0	10.1				7.1					1.8	5.3	51.3	55.8	24.2	96.8
ENERGY(kWh/MT)	2.3	6.1	58.5	10.1			0.7	9.2					2.1	7.3	64.2	61.1	62.0	167.8

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS IN TMP/CTMP MILLS IN B.C. (BY PROCESS & SIZE)

PROCESS	TOTAL ENERGY GWH/YR	MACHINE DRIVE						CONVEYORS					
		SIZE 1 GWh/YR	SIZE 2 GWh/YR	SIZE 3 GWh/YR	SIZE 4 GWh/YR	SIZE 5 GWh/YR	SIZE 6 GWh/YR	SIZE 1 GWh/YR	SIZE 2 GWh/YR	SIZE 3 GWh/YR	SIZE 4 GWh/YR	SIZE 5 GWh/YR	SIZE 6 GWh/YR
WATER SUPPLY & TREAT.	201							0.6	0.8				
LOG HANDLING	8	0.1	1.8	0.9		2.8							
WOOD PREP.	40	0.0	0.4				39.1						
CHIP HANDLING	25							0.2	1.5	6.4	11.0		
CHIP SCREENING	22				7.3			0.4	7.9		3.0		
TMP PROCESS	2303	0.8	6.0	28.2	23.4		1804.8	1.6	25.1	17.4	71.4	31.6	
ENERGY(GWh/YR)	2599	0.9	8.1	29.1	30.6	2.8	1843.9	2.8	35.4	23.8	85.4	31.6	

PROCESS	FANS & BLOWERS						COMPRESSORS						PUMPING					
	SIZE 1 GWh/YR	SIZE 2 GWh/YR	SIZE 3 GWh/YR	SIZE 4 GWh/YR	SIZE 5 GWh/YR	SIZE 6 GWh/YR	SIZE 1 GWh/YR	SIZE 2 GWh/YR	SIZE 3 GWh/YR	SIZE 4 GWh/YR	SIZE 5 GWh/YR	SIZE 6 GWh/YR	SIZE 1 GWh/YR	SIZE 2 GWh/YR	SIZE 3 GWh/YR	SIZE 4 GWh/YR	SIZE 5 GWh/YR	SIZE 6 GWh/YR
WATER SUPPLY & TREAT.	0.9	1.0	58.1				0.6	1.8					0.3	1.8	7.4	6.0	42.3	79.4
LOG HANDLING	0.0							0.3							2.2			
WOOD PREP.	0.1	0.4					0.1	0.3										
CHIP HANDLING														0.5	4.9			
CHIP SCREENING			3.9															
TMP PROCESS	1.6	5.3	3.4	11.3				7.9					2.0	5.9	57.4	62.4	27.1	108.3
ENERGY(GWh/YR)	2.6	6.8	65.4	11.3			0.7	10.3					2.3	8.2	71.8	68.4	69.4	187.6

Figure 2.1.1 cont'd

First, individual data estimates were usually checked from several sources. Second, the data was input into the ISTUM-I model[3] (described below) and calibrated to 1988.

Surprisingly, there were only a few cases in which data re-assessment was required; generally the model built from this bottom-up approach reproduced B.C. Hydro's sales data for each branch in 1988, with a margin of error of less than 2%.

Detailed Cost and Efficiency Data for Motor Systems

The second major data component of the study was the collection of engineering data on efficiency and cost characteristics of electric motors, VSDs and auxiliary motor system equipment.

1. An informal survey was conducted of key research institutes, technical publications, equipment marketing experts and individual researchers in order to estimate typical efficiencies and costs of various types and sizes of electric motors, VSDs and auxiliary system equipment.[4] As in the case of base stock data, information about electric motors and VSDs generally appeared more reliable than information about auxiliary equipment. This data is presented in the appendix of Chapter 3.

2. The number of components in a motor system imply a complexity beyond the limits of comprehensive analysis and modelling. For example, if a pumping system has five components (drive mechanism, motor, flow control mechanism, pump and pipe), if there are two types of pumps and two types of drive mechanisms, and if each component except the drive mechanism has three different efficiency possibilities, there are a total of 324 possible equipment combinations - and all of this is just for one of the five different motor system sizes. Thus, for this study, "packages" of motor systems were assembled which ensured that the study would probe the outer technical and economic limits entailed by the terms of reference. As a result, in most applications there would only be two or three motor system "packages", most efficient, least efficient and one of moderate efficiency.

3. The efficiency and cost data of these packages were input into an engineering end-use model for simulating the various scenarios of the terms of reference.

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3. ISTUM-I stands for the Intra-Sectoral Technology Use Model for the Industrial Sector. While the original ISTUM model was developed only for the industrial sector, versions of the model now exist for the residential, commercial and transportation sectors.
4. Some of the key electricity efficiency research institutes are (1) Lawrence Berkeley Laboratory in Berkeley California, (2) Electric Power Research Institute, (3) Rocky Mountain Institute, (4) Brookhaven National Laboratory in New York, (5) Oak Ridge National Laboratory in Tennessee, (6) Institute for Energy and Environmental Analysis at Princeton University in New Jersey, and (7) Centre for Energy and the Environment at the University of Lund, Sweden.

2.2 Model

Analysis of energy efficiency improvement does not require the construction of a formalized model. One could instead collect the base stock data, conduct a series of case studies, use assumptions to extrapolate these case study results to the entire industrial sector, then make additional assumptions about how industry will evolve in the future in order to produce an aggregate estimate of efficiency improvement. However, as soon as alternative hypotheses are proposed for any of the inputs to the exercise, a complete recalculation is required. This is why analysts turn to models to aid their attempts at policy formulation and evaluation aimed at improved energy efficiency, even if the models are relatively simple calculation devices.

Introduction to ISTUM-I

The Intra-Sectoral Technology Use Model - Industry (ISTUM-I), used in this study, is an end-use energy model of the industrial sector. This means that it focuses on the end-uses (services) of energy and on the technologies (equipment) that meet these services. By simulating the evolution of end-use service demands and of their associated technologies, an end-use model shows how energy consumption can change as a function of industry output growth and technological evolution.

The ISTUM models were initially developed in the late 1970s and early 1980s with funding from the U.S. Department of Energy. A personal computer version of the model, with important methodological changes, was developed in the mid-1980s by Joe Roop at Battelle Pacific Northwest Laboratories in Richland, Washington and Mark Jaccard at Simon Fraser University (Jaccard and Roop, 1990). This model is now used by B.C. Hydro for industrial demand forecasting. It has also been used for research and policy analysis by B.C. Gas, Canadian Energy Research Institute, B.C. Ministry of Energy, Mines and Petroleum Resources, B.C. Ministry of Environment, B.C. Science Council, Ontario Ministry of Energy, Energy Council of Canada and Canadian Department of Energy, Mines and Resources.

Conceptually, end-use models can be divided into two categories.

First generation end-use models are essentially spreadsheets which, in the industrial sector, link physical product outputs to coefficients expressing energy consumption per unit of output. These coefficients are exogenously[5] modified over the forecast period in order to reflect expert opinion on the rate of penetration of new technologies with different efficiencies. Like any spreadsheet, the model simply sums the level of energy demand in each future year. Technological evolution is only implicitly simulated by the model because the model does not keep track of vintages of equipment.

Second generation end-use models, such as ISTUM-I, explicitly simulate the evolution of equipment stocks, measured in terms of annual physical output. Thus, the model requires data on existing equipment stocks, preferably with age information, so that the model can retire and replace vintages of equipment over time. The selection of new technologies to replace retired equipment is determined by a competition based on life

5. Exogenously means calculated or set outside of the model.

cycle cost, but mitigated by other factors. New technologies may have different coefficients relating energy consumption to physical output (implying differences in energy efficiency), so that as new technologies penetrate the equipment stock the overall effect is to change aggregate energy efficiency of the industrial sector. Because minimizing life cycle cost is the overriding consideration of industrial decision-making, the model may show energy efficiency to increase or decrease over the forecast simulation period. The direction of the results depends on the characteristics of emerging technologies, and the costs of labour, capital and material inputs relative to energy inputs.

Once equipment stock data has been collected, and key parameter values set in the model, it is a relatively trivial exercise to test a wide array of alternative visions of the future. In this sense, the ISTUM-I simulation model is an exploratory model, allowing the analyst to quickly test the implications of a wide array of factors affecting industrial output, energy prices and technological evolution. Thus, while the model was useful to this study, it will also be of use to subsequent research designed to probe the effect of demand-side management programs on industrial electricity consumption.

By incorporating many of the more easy to predict aspects of industrial evolution, ISTUM-I allows the analyst to focus on those factors that are less certain. These can include:

* overall rate of growth (increasing pulp and paper sales),
* structural change (more paper, less market pulp),
* major process shifts (more mechanical, less chemical pulp),
* technological options (continuous vs batch pulp digester),
* investment behaviour (length of payback),
* factor input prices, and
* regulatory changes (new effluent or emission standards).

<u>Application and Modification of ISTUM-I for this Study</u>

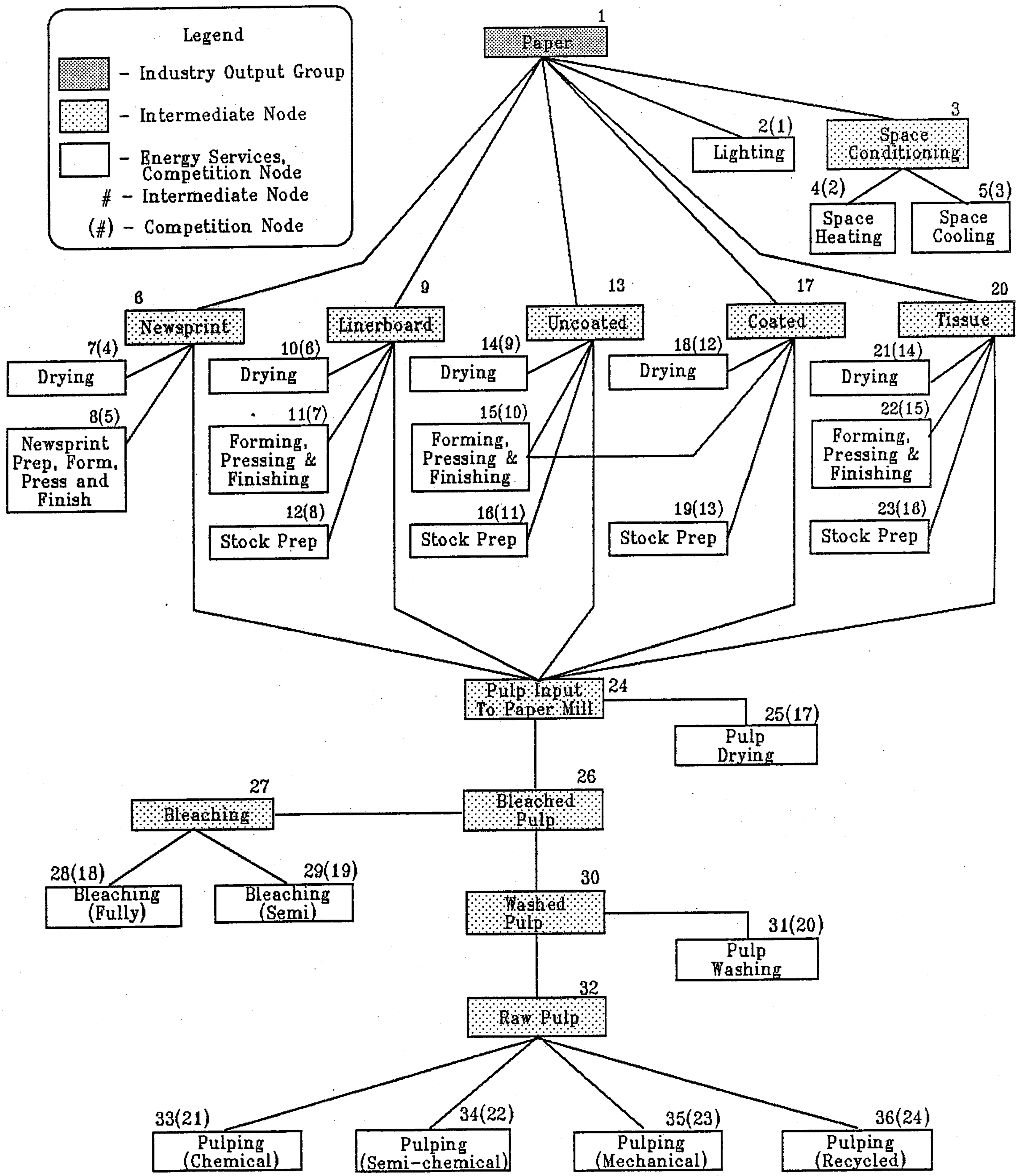
The ISTUM-I model is currently used by B.C. Hydro and has been employed for electricity demand forecasting in the past, although only in the pulp and paper industry. Use of the model in this study required completion of model development for the key electricity-consuming branches of the B.C. industrial sector.

Electricity-intensive branches each require their own unique end-use model. This involved the development of process flow models for the chemicals, wood products and mining industries, as well as the modification of the process flow model for the pulp and paper branch.

An industrial process flow model is designed using engineering information about the major process steps in the transformation of material inputs into the output products of an industry. Figure 2.2.1 provides an example from the pulp and paper branch of a process flow model. The process flow model displays a tree structure with three basic elements.

(1) Final product(s) of the industry - these are exogenously forecasted.
(2) Intermediate products - these are the material precursors of final products. For example, wet bleached pulp is the precursor to writing papers or to dried market pulp. The quantities of intermediate goods required are determined from final product volumes through fixed engineering coefficients. Allowances are made for shipments of

Figure 2.2.1 Sample Flow Model, Pulp and Paper Industry



intermediate goods outside of the study area, and the coefficients are verified against reported statistics.
(3) Technology services (competition nodes) are each associated with a set of technologies which compete in the production of intermediate or final products.

The following types of data are required for the physical flows dimension of the model.
(1) Physical production of final products in some base year, and a forecast thereof; physical production of intermediate products in the base year.
(2) Decomposition of physical production or installed capacity in the study area among technologies in a base year. This sets the initial base for the equipment retirement and investment function.
(3) Expected economic lives of equipment; future dates of first commercial availability of new technologies and sunset dates for old ones. These data are used to define stock turnover rates and the set of competing technologies in future years respectively.
(4) Consumption of purchased energy and consumption and production of self-generated energy, by fuel type in the base year. In conjunction with (2), these data will allow for calibration of the model to base year technologies and fuel shares.
(5) Technology- or fuel-related market share constraints, such as absence of natural gas supply or pollution control requirements.

Economic data are also required.
(1) Current and projected fuel prices.
(2) Capital costs, non-energy material costs (e.g. refractory linings for blast furnaces) and operation and maintenance costs of competing technologies.
(3) Assumed discount rates, which may be different for energy efficiency vs other investments.
(4) Any tax or regulatory asymmetries that will affect the costs of production among competing technologies or fuels.

Essentially, the ISTUM-I model replicates for each major industrial sector the operation of a single plant whose outputs, inputs and process technology shares are the aggregate of the plants in the study area. If it were built for a single plant, it would represent a typical model regularly used in capital decisions in the business world. However, flexibility in terms of modelling alternative assumptions for the whole study area makes it very useful as a policy analysis tool.

2.3 Behavioural Parameters

For many of the model runs required in this study, behavioural parameters are set in the terms of reference.
(1) The Frozen Efficiency run assumes that future equipment choices will mirror past choices.
(2) The Technological Potential run assumes that equipment choices are only based on minimizing electricity consumption per unit of service.
(3) The Economic Potential runs assume that equipment choices are simply based on minimizing life cycle cost using an 8% discount rate investment criteria.

However, estimating the Natural Change in Electricity Intensity involves the challenge of predicting future investment behaviour, a challenge faced by all forecasting models.[6] Also, the estimate of Social Potential involves operating and maintenance behaviour that modellers and survey researchers have almost universally ignored in the past. This affects both the Technological/ Social Potential run as well as the Economic Potential runs.

Technology Competition Algorithm

The ISTUM-I model is an end-use model which combines detail on energy-using equipment with an effort to situate energy-related decisions within a broader industry decision-making framework. Thus, non-energy operating and maintenance costs of equipment are accounted for. But, more importantly, the explicit simulation of equipment choices and equipment stock evolution is based on reproducing as accurately as possible the investment decision process. If final product determines a given technology choice, the model will be constrained to ensure that result. If research shows that a slightly more expensive technology is preferred for some non-cost reason (say ease of operation, or beneficial byproduct), the model's constraints are adjusted to reflect that. Also, because investment criteria can vary between discretionary and non-discretionary investment decisions, the discount rates used to calculate technology life cycle costs vary with the type of investment, discretionary investments having significantly higher discount rates applied to them.

One of the key innovations of ISTUM-I, as a second generation end-use model, is the algorithm that it uses to simulate market share allocation between technologies competing to provide the same service. Life cycle costs of all technologies are converted from single point estimates into probability distributions, in order to reflect the variation that usually exists when technologies are produced and installed in different locations and by different firms. In this way, the results of the cost competitions between technologies are not "all or nothing."[7] If technology A is much cheaper than technology B, A will capture most of the new stock market. However, if the point estimate life cycle costs of A and B are close, they will roughly share the market. The user can change the variance of the probability distributions to reflect prior information, or to test hypotheses about the importance or unimportance of relative differences in life cycle cost in determining market shares of competing technologies.

For most technology competition simulations in this study, the model's parameters have been set up so that two technologies whose life cycle costs are within 5% of each other will each capture close to 50% of the new stock market. This function shifts as the cost difference amplifies such that a cost difference of 15% will allow the cheaper

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6. Econometric models are generally limited to only a few explanatory factors (fuel prices, output, perhaps some others) estimated from past relationships; they must use these to predict investment in a future period in which technologies and regulations may change dramatically. End-use models are rich in technological detail, but unable to statistically verify behavioural parameters; the best they can do is to incorporate paybacks and discount rate assumptions from individual surveys of industrial investment behaviour.

7. This differs from the quick technology switches that can occur with a linear programming model.

technology to capture 80% of the market and a cost difference of 20% will allow the cheaper technology to capture 95% of the market.

Forecasting the Natural Penetration of Efficient Technologies

In the Natural Change in Intensity run, the crucial issue is the estimate of the penetration rate of energy efficient equipment. Survey data of investment behaviour (Ross, 1986; Sassone and Martucci, 1985; Giffels, 1984) generally suggest that industry requires paybacks in the neighbourhood of 1.5 to 2.5 years to initiate incremental discretionary investments to improve energy efficiency.[8] However, many of the most efficient motor systems evaluated in this study had paybacks of less than two years.[9] When the model was first simulated, at discount rates set to reflect a two year payback, it was found that efficient motors captured much of the new market in the Natural run.

This unexpected result initiated a round of secondary research into historical investment behaviour, in which paybacks were calculated for investment options facing industry in the past. These suggested that some electricity efficiency investments with extremely short paybacks were neglected by industry in the past - "in the world without Power Smart". Discussions with industry and marketing representatives suggested that, especially for auxiliary equipment of motor systems, efficiency was rarely evaluated in the past; initial cost and dependability were the key decision variables.[10]

It is important to point out that a study seeking to simulate industry behaviour must be concerned with "de facto" industry discount rates, not those used in evaluating investment options. A firm may use a 30% discount rate to evaluate investment options. But if, because of a capital constraint, it then only invests in half of the options showing a positive net present value, the firm is really using a much higher de facto discount rate. Also, if the firm neglects to evaluate certain investment options, such as more efficient auxiliary equipment, it is almost impossible for a simulation model driven by life cycle cost to replicate investment behaviour. At this point, investment in efficient equipment is more likely a function of other factors, such as market acceptability, market information and perceived risk, rather than of life cycle cost.

With this consideration in mind, we discussed with experts the possibility that high efficiency motor system technologies would have climbed up the market penetration curve (from their current penetration of 0 to 20% depending on the technology) in a

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8. This means the time required for the payback (in lower electricity bills) to offset the incremental investment associated with more electricity-efficient equipment.
9. Remember that this is the incremental investment required if one is already in the process of purchasing an entire new motor system. In the case of early retrofit of all or part of a motor system, there are sunk costs. For example, if an inefficient motor is still functioning properly, industry must look at the total cost of a new efficient motor and compare this to the benefit of lower operating costs, but ignore the historic cost of the currently-installed standard motor.
10. See comments in the final chapter, Chapter 10, discussing the importance of initial cost in determining equipment selection, especially for the components of motor systems.

world without Power Smart.[11] The general consensus was that substantially higher penetration levels were unlikely to occur. It was on this basis that we decided to constrain the model, so that in the Natural run high efficiency motor system technologies were not allowed to capture more than 15 to 20% of the market, no matter how short their payback.

Others may disagree with this judgement. Fortunately, the model can easily be rerun in the future to test alternative behavioural hypotheses for simulating the Natural Change in Electricity Intensity.

Another behavioural factor affecting the results of the Natural Change in Electricity Intensity run is the selection of equipment retirement rates.[12] We assumed that retirement rates are strictly a function of equipment age, assuming a smooth age distribution for 1988 equipment base stocks. Most types of equipment have life expectancies of 20 to 30 years. In reality, research has shown that retirement rates are also a function of the rate of technological innovation (premature obsolescence) and economic activity (with higher retirement rates both during periods of very fast economic growth and deep recession).

The decision to only use time as the driving variable for equipment retirement was motivated by the extreme tenuousness of assumptions about the relationship between any of the other factors and retirement rates. To our knowledge, no empirical research has been able to estimate meaningful parameters for these relationships.

Finally, the Natural Change in Electricity Intensity run is based on only one price forecast. Because any price forecast is fraught with uncertainty, it is one component that should normally be tested by sensitivity analysis. However, because the model was unable to accurately simulate - on a strictly life cycle cost basis - the acquisition of high efficiency motor system auxiliary equipment, the model was constrained to limit penetration to slightly higher than historic levels. Simulations with alternative electricity prices should not, therefore, lead to significantly different results for the Natural Change run. Additional work on the model's parameters, to enable it to better test price responsiveness, is discussed in the recommendations of the final chapter.

Social Potential

The requirement in the study terms of reference for an estimate of social potential necessitated further assumptions lacking basis in rigorous empirical research. The estimate of Social Potential is derived from estimating the effect of operating the Technological Potential equipment set as well as possible, instead of using normal operating practice. The gains of best possible practice relative to normal are extremely difficult to estimate. We referred this issue to our sub-contractors, to our own outside experts, and to industry experts suggested by B.C. Hydro. The estimates are used to adjust the model results.

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11. This is difficult to judge. Now that demand-side management ideas are diffusing through society, marketers have found that efficiency is at least an issue in most investment choices. But it was not always like that.
12. Note that in all other runs all equipment is retired in the simulation years 2000 and 2010.

We took the definition of Social Potential to also have an impact on the equipment sizing decision, especially the general industry practice of oversizing equipment by some 10 to 25%. The oversizing issue is a difficult one. Some argue that the practice of oversizing equipment will always occur because it is a risk reduction strategy, designed to correct for possible errors (hence misinvestment) in estimating the size of equipment required. However, there is probably some electricity price level (but what?) at which the small risk of misinvestment is compensated by the energy savings from more correctly sizing equipment.

From MARBEK (1990), we assume benefits of 3% for full Social Potential improvement over Technical Potential by eliminating oversizing. In the Economic Potential, we assume that this full 3% potential is achieved at 100% environmental credit, while only 2% at 60% credit and only 1% at 30% credit. These factors have been included in Table 2.3.1 below.

Because each industry has its own unique operating environment, and each firm its own maintenance program, it is difficult to attach one unique potential electricity efficiency gain to "best practise". With the level of upkeep in each industry varying considerably, "standard practice" is a moving target.

However, some generalizations are possible. Discussions with various industry personnel suggest that the more electricity-intense the product, the more rigourous the industry maintenance schedule pertaining to electricity-using technologies, even if the technology in question is not a large user of electricity. For example, the chemicals industry generates much of its product though electrolysis. Experts suggest that its high electricity demand has prompted comprehensive industry monitoring and maintenance schedules which include careful analysis of the relatively small electricity demand of auxiliary system motors.

In conversations with various industry personnel, it was not always possible to separate issues of increased technology efficiency from overall demand reduction. For example, turning off unused auxiliary systems or lights would cause a reduction in demand but not a change in efficiency. Lubricating bearings or changing filters in fan or pump systems prevents a decrease in the technology efficiency.

Table 2.3.1 presents estimates of social potential disaggregated by end-use and industry. An industry specific discussion follows.

Table 2.3.1 Social Potential Guesstimates
(% Efficiency Improvement)

Industry

End-Use		P&P (A,C) (G,K)	Mine (B,C) (H,I)	Chem (A,C)	Wood (C,J,L)	Petrol (C)	Other (C,F)
Pump (E)	10%	10%	5%	12%	10%	10%	
Air (A,C)		5%	5%	2%	12%	5%	5%
Compress (D)		15%	15%	7%	17%	15%	15%
Convey (A,C)		5%	5%	2%	7%	5%	5%
Other Process (B)		2%	7%	2%	2%	2%	2%
Process Heat (M)		10%	0%	0%	10%	0%	10%
Lighting (M)		10%	10%	10%	10%	10%	10%
Space Conditioning (M)	5%	5%	5%	5%	5%	5%	

Note:

1. Pump, Air Displacement, Compression and Conveyance systems social potential include two components (1) improvements in oversizing and (2) efficiency improvements from better operating and maintenance practices[13].
2. Process motor system social potential is based solely on improvements in oversizing of motors.
3. Sources: A - Temanex, 1992; B - Welchman, 1992; C - Willis, 1992; D - Merrill, 1991; E - Mellis, 1991; F - Wiesehahn, 1992; G - Scott, 1991; H - Smythe, 1992; I - Ostle, 1992; J - Tucker, 1992; K - Evans, 1991; L - Mayer, 1991; M - Marbek, 1992.

13. By operating and maintenance practices we mean the following: (1) cleaning (2) oiling and lubrication (3) shutting off equipment when it is not in use, and (4) maintaining a rigourous equipment repair schedule.

Table 2.3.2 presents the estimates of social potential achieved under each set of economic parameters. An improvement in efficiency resulting from better operation and maintenance practice is dependent on economic conditions.

Table 2.3.2
Guesstimates of Social Potential for Each Simulation
(% Achievable)

Run	% of Social Potential Achieved
Frozen	0%
Natural	0%
Econ 1	0%
Econ 2	15%
Econ 3	25%
Econ 4	45%
Econ 5	70%
Technological	0%
Technological/ Social	100%

(1) Pulp and Paper

Over all, increased monitoring and maintenance in the pulp and paper industry is expected to increase efficiency in auxiliary systems, such as pumps and fans by, at most, 10%. However, in many plants maintenance schedules are already rigorous and it is estimated that, with extra care to shut down unused conveyors and fans, between 1% and 5% reduction in auxiliary system electricity demand could be expected.

(2) Chemicals

Because of the rather intense use of electricity in this industry, due to the high proportion of electrolytically- produced products, most firms in the industry conduct careful and comprehensive maintenance and upkeep. The expected gain from increased activity would be in the order of 2% or 3%.

It was suggested that the major source of efficiency loss in auxiliary systems is the result of careless technology retrofit or installation. Such additions may have introduced "dog legs" into existing piping and venting, reducing existing system efficiency. However, we do not include this in our estimate of social potential, since our Technological potential assumes optimal equipment installation. Also, our Economic potential assumes new plants that can be laid out to achieve economic optimization.

(3) Wood Products

This industry is diverse in the sense that there are many small, inefficient operations (which produce only a small share of total product) and comparatively few large operations. Energy costs are a minor component of total costs and maintenance schedules are not as rigorous as in the above industries. It is estimated that between 10% and 20% efficiency improvement in this industrial branch is possible, especially in the function of kiln fans (bearing replacement) and the maintenance of sharp blades, saws and knives for lathes, saws and chippers.

Because of the presence of significant quantities of air-borne saw dust and wood particles, the potential for efficiency gains is dependant on maintenance schedules which concentrate on lubrication and cleaning. This would include chain conveyor wear strip maintenance, reduction gear contact points and source air for compressors.

(4) Mining

Newer mines and mines with a relatively long life expectancy (greater than 10 years) tend to have more comprehensive motor maintenance and monitoring programs. Estimated improvements in equipment electricity efficiencies are low, at about 2% or 3%. Mines nearing the end of their life expectancy tend to be less rigourous and efficiencies could be improved by 10% to 15%.

Significant improvements could be obtained though proper load balance and motor sizing. Motors are purchased to match (with typical contingencies) the maximum load. This maximum load may exceed the average load by 30% to 50%. However, it is possible to reduce maximum load though the careful application of process and by monitoring. For example, even new mines oversize motors by approximately 50% in the high demand area of slurry pumping (Welchman, pers com., 1992). Yet the careful blending of rock and water and monitoring of the system could permit a reduction of maximum load (reduction of variation in load), lead to a reduced "maximum" motor demand, and provide a 6% to 8% efficiency improvement in the process.

(5) Other

In general, improvements in this category fall in the area of best possible maintenance of pump, fan and compression systems. The primary focus is to prevent leakage of fluid from the system. It is estimated that 10% improvement in pump systems would be typical, with a potential of 5% in air displacement and 15% in compression systems (Wieshahn, pers com., 1992).

CHAPTER 3

ELECTRIC MOTOR SYSTEMS

The significance of motor systems in terms of electricity consumption in industry cannot be overstated. As Table 1.5.2 indicates, motive force is the predominate end-use of electricity in most industries. The one exception to this table in B.C. industry is the chemicals industry, where the electrolysis end-use is approximately 84%.

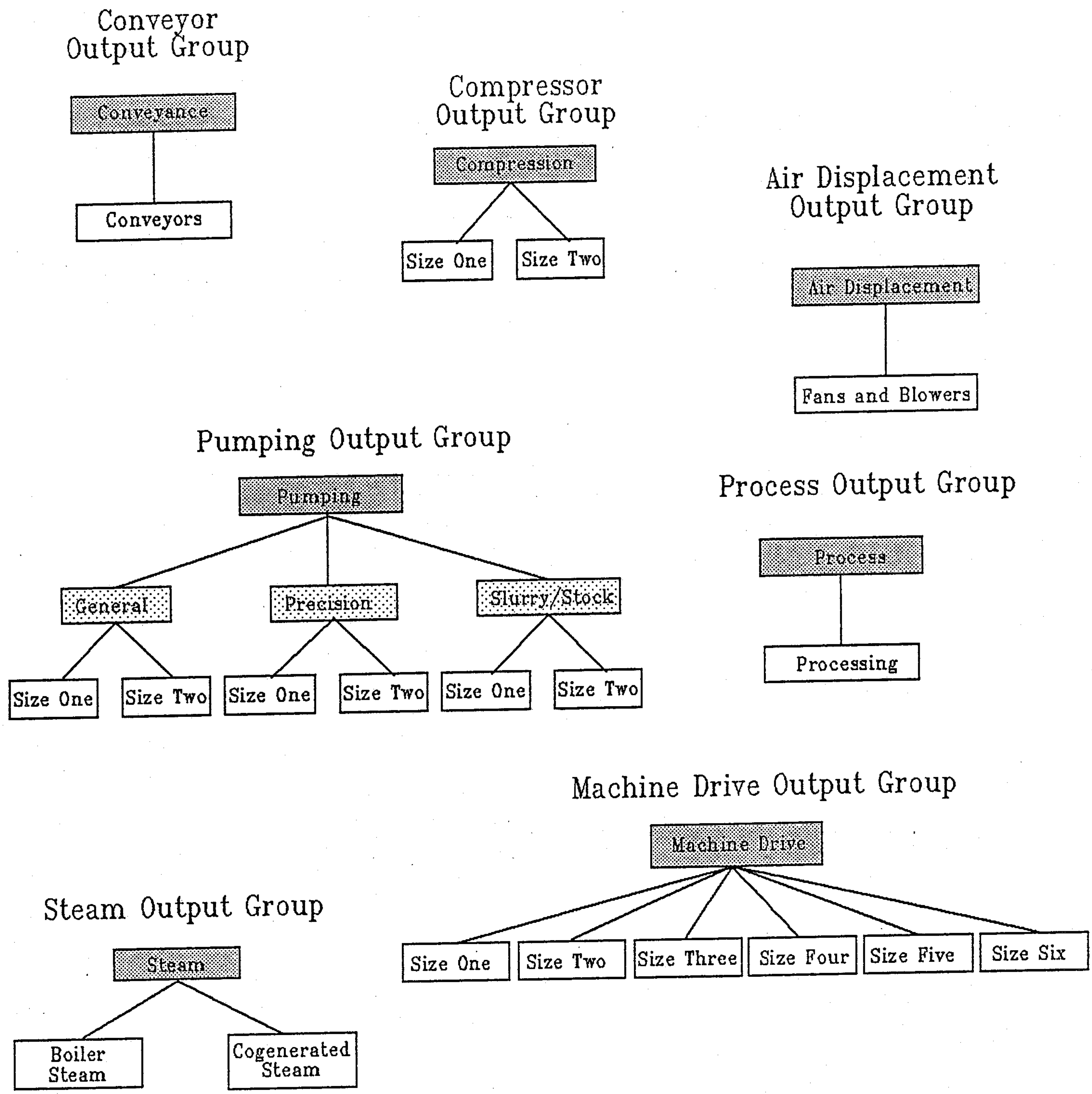
As noted in the methodology chapter, recent research into electricity efficiency in industry focuses primarily on electric motors and electronic variable speed drives, ignoring the auxiliary components that make up the balance of a motor system. Although there is substantial conservation potential associated with electric motors, the predominant potential is associated with the auxiliary equipment. For this study, five different motor systems (or motor system end-uses) were identified: (1) pumping, (2) air displacement (fans and blowers), (3) compression, (4) conveyance and (5) "other machine drive" (also called "process"). The latter machine drive category comprises all electrically-driven technologies that are unique to a given production process, hence the term "process". These would include mechanical pulpers, mineral ore grinders, wood saws, etc. Because these technologies are industry-specific, they are not dealt with in this chapter. The analysis of this chapter focuses on "generic" motor systems, that being the first four listed above.

Each of these systems plays a role in the production process in industry. Figure 3.0 is a generic flow model representation of these auxiliary systems as they appear in ISTUM-I. As the figure indicates, there are six auxiliary groups. Aside from the five listed in Chapter 2 there is one additional group called motors. Each group is used to simulate technology evolution of a specific system. Some of the groups, for example pumping, are more disaggregated reflecting the differences in end-use (between general, precision and slurry pumps) and efficiency (between large and small pumps).

In the case of the air displacement and conveyance groups, there are negligible size or end-use efficiency differences, so these two systems each have only one point of competition.

Compressor systems vary in electricity efficiency by size. Therefore, competition between different technologies must be separated by size. This disaggregation is represented by the two size competition nodes in Figure 3.0.

Figure 3.0 Flow Model: Auxiliary Systems



Pumping systems are more complex than the other three. Not only is there an efficiency difference based on size, but pumping systems can also provide different end-uses, limiting competition in some cases. Therefore, there is a further disaggregation of pump systems by technology type: general, precision and slurry/stock. These end-use distinctions will be explained in further detail in Section 3.3.

There are two competing devices represented in this group: (1) mechanical speed control devices and (2) electronic speed control devices (generally referred to as VSD - variable speed drive). Each of these devices can be attached to an electric motor to control the speed of the motor shaft.

The motor group is disaggregated by size to account for the efficiency differences of each size of motor. These efficiencies are listed in the appendix to this chapter.

Pumping, air displacement, compressing and conveyance systems (PACCS) have been represented as packages within ISTUM-I. The components of each of these systems are associated with the key end-use. For example, a pipe, throttle and speed control device are attached to a pump, and the entire package is called a pump system. In the model there are at least two types of systems: (1) the least efficient system, comprising all the least efficient components, and (2) the most efficient system, comprising all the most efficient components. The system efficiency is then a function of the efficiency of all the components within that system.

Two other factors, important in calculating efficiencies and costs, are difficult to estimate with any confidence.

First, oversizing is the general industry practice of selecting technologies that are somewhat larger than the size needed.[1] Oversizing of 10% to 40% implies that only 60% to 90% of equipment capacity is used. Reducing oversizing could affect electricity efficiency because many types of equipment experience efficiency losses when the proportion of capacity used falls below a critical level. Although it was not possible to find any way to accurately estimate the efficiency effects of better matched equipment sizing and utilization rates, a broad assumption from MARBEK (1991) that a reduction of oversizing could reduce motor system electricity consumption by 3% overall was incorporated in the analysis of Social potential and Economic potential (see Chapter 2).

Second, variability in the proportion of equipment capacity used can affect efficiency levels. Again, this is because efficiency losses are sometimes associated with low proportions of capacity utilization. We were unable to acquire estimates of the

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1. This practice is frequently justified in terms of risk reduction.

variability of use of different types of equipment. Therefore, we made assumptions of load variability for each type of equipment, which are reflected in the efficiency improvements associated with the additions of electronic variable speed drives.[2]

This chapter is structured to discuss the details of all auxiliary systems and technologies. Although motors and variable speed drives are components of pumping, air displacement, compression and conveyance systems, they have been included under separate headings. In addition to efficiency improvements of auxiliary systems the reader should be mindful that improvements in the motors that drive the systems can also provide significant efficiency potential.

3.1 Electric Motors

Although a wide variety of motor types exist, three were singled out in this study. Alternating current (AC) polyphase induction motors, alternating current synchronous motors and direct current motors represent the overwhelming majority of installed industrial capacity.

As AC induction motor speed control technology improves, and the ability to control shaft speeds develops, these motors will compete more successfully with synchronous and DC motors in areas where they could not be used in the past. Presently, the induction motor capacity dominates in the 200 hp and less range, whereas synchronous and DC motors dominate the greater than 200 hp market. Motors over 200 hp are generally custom ordered while those below 200 hp are purchased "off the shelf". However, "off the shelf" AC motors are available in capacities up to 350 hp (Marbek, 1991).

Although there are numerous types and speeds of AC induction motors, we have taken one of the common types and speeds found in industry as our representative motor. The Totally Enclosed Fan Cooled (TEFC) induction motor operating at 1800 rpm is the type represented in the efficiency tables located in the appendix.

Induction motors are also referred to as asynchronous motors because of the induction slip. This means that a motor listed at 1800 rpm is usually rotating in the 1720 to 1790 rpm range (Nadel, 1991). This slip is the main difference between

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2. If the load variability were zero, then the addition of an electronic variable speed drive would lead to substantially less efficiency improvement.

induction/asynchronous and synchronous motors. Synchronous motors are specially designed to compensate for the slip. Therefore, a synchronous motor listed at 1800 rpm will rotate at 1800 rpm.

Synchronous motors are designed for applications where constant speeds are required. The opportunity for electricity conservation with synchronous motors is limited because of their already high efficiencies and special industrial applications.

Standard efficiency (SE) and high efficiency (HE) induction motors are widely available. The difference in efficiency, listed in the appendix, is chiefly due to improved material quality and construction of the HE motor. Although there are various high or premium efficiency motors available, the high efficiency motor definition is the one currently employed by Canadian utilities offering HE motor rebate programs (Marbek, 1991). The shift from SE to HE motors provides the greatest opportunity for electricity efficiency with respect to motors. As of 1988, HE motors comprised about 10% of installed capacity (MARBEK, 1991).[3]

The efficiency of induction motors drops off sharply in the 40% to 50% load range. If a motor is operated at or below this range, then significant efficiency improvements can be gained by installing a smaller motor. This issue again relates to problems of estimating the benefits of reducing motor oversizing.

Induction motor efficiency is also affected by rewinding. Motors smaller than 20 hp are usually discarded when they fail. Motors larger than 20 hp are rewound at least once and often three or four times. In this process, the stator is baked, stripped and rewound. Sometimes this damages the stator and causes a loss of efficiency. As a general assumption, rewinding results in a 1% to 2% loss in efficiency in induction motor stock.

DC motors provide a special service to industry because of their ability to undergo continuous operation at low speeds and high torques, and their inherent ability to provide speed control. Therefore, in many large motor (> 200 hp) industrial applications, DC motors dominate. This dominance is on the decline as induction motor speed control technology improves.

DC motor systems fall under two categories: (1) motor-generators (MG) and (2) solid state (SS). The difference is not in the motor itself, but in how the direct current is generated. Motor-generator sets provide DC by using an AC motor to operate a DC

3. The assumption is that 10% of motors, in each size category, were already high efficiency in 1988. These are the motors supplying drive power to auxiliary equipment. The percentage of efficient motors for large process requirements vary from one branch to the other, a function of the types of large motors that are included in the base stocks.

generator which supplies direct current to the primary motor. Prior to the 1960s, this was the only option available, resulting in an overall electricity efficiency of 65%. The newer motor systems use solid state rectification to produce DC, increasing the efficiency rating to 85%.

Although there is significant efficiency improvement in upgrading to solid state rectification, electricity savings alone are unlikely to be a sufficient motivation unless new equipment were being purchased. Industry practice is to maintain such equipment for 30 to 40 years and only replace it if parts are no longer available. Replacing MG DC motors with solid state rectifiers or with variable speed drive AC induction motors represents the major opportunity for efficiency potential with these motors. DC motors are more expensive to purchase and maintain, but they have developed a niche in industry into which the penetration of other types of motors will be slow at best. Thus, while the market for DC motors is declining, they are still the predominant component of installed capacity in some industries. In mining, for example, electric shovels powered by DC motors are the only ones available (Welchman, pers com., 1991).

3.2 Electronic Variable Speed Drives

Electronic variable speed drives (VSD) provide motor speed control by matching shaft speed to the load requirements. A mechanical variable speed control (MSC) device, such as a v-belt or a helical gear, will take the fixed output speed from a motor and alter it to meet the load requirements. What this means is that the motor, which operates at a fixed speed, is providing shaft rotation energy unmatched to that required. VSDs change the speed of the motor so that only the required shaft rotation is produced, resulting in increased efficiency.

Constant speed applications usually have a matched motor, one that provides the required speed for that use. VSDs should be employed where load requirements vary. Because many auxiliary system end-uses are variable, these offer good opportunities for VSD applications.

Although the efficiency difference between mechanical speed controls and VSDs is not very large (85% for mechanical, 95% for VSD), the downstream benefits of adding a VSD can be significant. Auxiliary system are frequently controlled at two points: at the motor where the MSC or VSD is attached to control the shaft speed and at the pump or fan where a throttle/damper/vane is attached to control the flow speed of liquid, air, etc.[4] The downstream benefit to upgrading a system to a VSD is the replacement of not only the MSC but also the throttle/damper/vane. These MSC/throttle combinations work by holding back the material that is being moved by the auxiliary system while, at the same time, other system components continue to operate at top speed. Thus, adding a VSD improves the speed control device efficiency from 85% to 95% and eliminates the throttle component with its efficiency between 65% and 85%. The electricity efficiency potential is achieved by matching the auxiliary system output to the load requirements.

Updating a system with a VSD will provide different energy savings depending on the variability of the load. Generally, the improvement in system efficiency is in the 20% to 30% range. However, VSDs have not significantly penetrated the industrial market. Two reasons for this penetration rate are capital cost and technical problems. VSDs are two to five times more expensive than the motors themselves. VSD electricity supply must be transmitted through several transformers when attached to large motors (Scott, pers com., 1992). The transformation loss is estimated to reduce VSD efficiency from 97% to 95%. Moreover, in some instances the electromagnetic harmonics generated by VSDs interfere with the operation of other electricity consuming technologies.

3.3 Pumps

A pump displaces liquid along a piping system. Pumping systems are made up of a number of components, including motor, pump or impeller, speed control device, pipe and valve/throttle. Figure 1.5.1 in Chapter 1 indicates the energy balance of three pump configurations.[5] As the figure shows, a significant portion of the energy loss is

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4. One of the final reviewers of this study (Dougans) detected an error in the mechanical speed control assumption. This device was assumed to exist on most motor systems. Experts suggest that, in fact, the device may exist on less than half of current (1988) motor systems. For example, most pumps in pulp and paper mills are driven directly from the motor. This means that we may have underestimated by 3% to 7% the efficiency of existing motor systems. The effect would be to reduce the estimated Technical efficiency potential (relative to Frozen) in the pulp and paper branch by just over 2%. The effect on the aggregate results would be about 1%.
5. The same calculations illustrated in Figure 1.5.1 of Chapter 1, can be made with the efficiency assumptions at the end of this chapter, thereby reproducing the key motor system data inputs to the model. Thus, for example, improvements in pump efficiencies can be calculated by taking the efficiency assumptions (Appendix B) for inefficient motor system auxiliary components (mechanical variable speed control device; inefficient pump; throttle; standard pipe) and replacing these with the efficiency assumptions for efficient motor system components (electronic variable speed

due to two components: the pump itself and the throttle. Therefore, improving the efficiency of these two components is of primary concern when conducting an energy analysis.

Research and development into pump technology is focused on (1) improving impeller design to reduce friction loss and (2) material composition of the pumps to extend equipment life and reduce leakage. Because pump technology is mature, the long term improvements in efficiency will be limited to about 10% over 20 years, for both the standard and more efficient models.

Replacing the MSC and throttle with a VSD will improve the efficiency of the system by 20% to 30%. This is a significant potential for electricity conservation, given that approximately 30% of total industrial electricity demand is due to pump systems (Environmental and Energy Systems Studies, 1989). However, slurry pumping is more complex due to the increased abrasive nature of the fluid. Slurry pump systems do not use throttles to control flow. Instead, the head (height through which the fluid must be displaced) is adjusted to limit flow. Given that the study assumes an average working head of 50 feet, the difference in system efficiency between throttle flow control and head flow control was unquantifiable. The assumption was made to equate the two.

Figure 3.0 shows pump systems disaggregated by type due to their differing end-uses. In applications involving the pumping of slurries (greater than 10% solids), rotary pump systems are employed. These are particularly appropriate to the pulp and paper industry, where water removal leads to progressively higher solid concentrations in the pulp slurry.

Reciprocating pumps are used for precision applications. These pumps are employed where the quantity of the material being pumped must be strictly controlled. For example, the chemical industry uses them to move reagents.

The centrifugal pump is by far the most common and the least expensive. If an application does not call for either the reciprocating or rotary pump, then a centrifugal pump system is generally used.

Historically, pump efficiency has not been of major concern to industry. Experts suggest that pump selection has been primarily based on capital costs and reliability. This has resulted in reliable but inefficient installed capacity. The best new pumps available are from 3% to 10% better than the average new pump (Environmental and Energy Systems Studies, 1989), but industrial customers are not normally aware of the advantages of these pumps.

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drive; direct coupling; highest efficiency pump; optimally designed pipe). The differences between these total system efficiencies represents the efficiency improvement potential.

Pumping is a significant percentage of municipal electricity consumption, but it falls outside the scope of analysis of the industrial sector. Further investigation would be required to provide an indication of the efficiency potential in this case (Kober, 1991).

An innovative approach to reducing pump electricity demand involves redesigning the pumping system to take advantage of gravity. This is especially applicable to mining where there is often a wide variation in elevation between different areas of the mine site. For example, Highland Valley Copper has installed a tailings transportation system which pipes the tailings from the mill to the tailings disposal site without the requirement for pump systems (Scott, 1991).

3.4 Air Displacement Technologies

Air displacement (fan and blower) systems are major electricity consumers in the industrial sector, typically accounting for approximately 20% of demand (Environmental and Energy Systems Studies, 1991). Although the fan technology is mature, there is still room for efficiency potential by changing fan operation practice. Fan systems are composed of a speed control device (not always), a motor, a fan, a control vane or damper, and a duct system.

Fans and blowers are used to propel a gas. Fan system curves (a graphic representation of a fan system's efficiency performance) are variable. Their highest efficiency typically lies in a narrow range of operating conditions. Therefore, for best efficiency, the fan system must be well matched to the end-use requirements. In constant air flow end-uses, the largest efficiency potential can be achieved by proper matching.

Many large industrial end-uses occur under variable air flow conditions and efficiency improvements should focus on efficient flow regulation. The addition of a VSD will replace the MSC and control vane/damper (throttling device), providing efficiency improvements in the 20% range and represents the greatest potential for improved electricity efficiency.[6] Additional efficiency improvements can result from better matching the air displacement system and the flow conditions.

Fans are generally classified as one of two types: centrifugal or axial. Centrifugal fans usually generate high pressure at low speed. They are enclosed in a housing and air is

6. This is of course not possible in all cases.

forced through a duct. The fan has the appearance of a water wheel where the gas is fed in through the axis of the fan and is expelled from the impeller tips.

Three types of centrifugal fans have been represented in ISTUM-I: Backward Inclined (BI), Radial and Airfoil. The names refer to the orientation or the design of the fan impellers. Each of these fans has a different efficiency and, although they are generally interchangeable, they are designed for different end-uses. For example, radial fans are used in dirty environments where the air entrains debris. Such a fan is advantageously employed in the wood products industry due to the large amount of air-borne sawdust.

Centrifugal fan applications involve process-related end-uses, such as kiln ventilation, whereas axial fans are used for general ventilation and HVAC. Axial fans are low pressure, high speed fans designed similarly to jet engines. The air is sucked through an intake and passes over the length of the fan before it is expelled.

Axial fans fall into three categories: vaneaxial, tubeaxial and propeller. The propeller fan has no significant industrial market share and has been ignored. The other two fans have similar efficiencies and have been aggregated as one type (called vaneaxial) for this study.

Fan efficiencies are just as much a factor of their operating conditions as their inherent engineering efficiencies. However, in order to determine the efficiency potential represented by better matching air displacement systems with operating conditions, primary data collection would be required. This level of analysis is beyond the scope of this study.

Although fan technologies are mature, with no major design changes in the last 20 years, there is still room for engineered efficiency improvements. Improved impeller designs and better construction materials may achieve a 10% efficiency improvement over the next 20 years.

3.5 Material Conveyance Technologies

A conveyance system is a horizontal or inclined device for moving bulk material. Its composition is much simpler than that of a pump or air displacement system. It is composed of a belt/pulley assembly, a speed control device and a motor. Design considerations depend on the specific operating conditions and the experience of the designer but, in general, this technology is mature.

Conveyance systems account for a small portion of industrial electricity demand, typically less than 5% (based on research conducted for this study). The simple nature of conveyance systems means that electricity efficiency potential is small compared to other systems.

Four main types of conveyors exist: belt, screw, apron and chain. Each serves its own market niche. Chain conveyors, for example, are extensively used in the wood products industry where the chain(s) transport logs along a production line.

Screw conveyors are generally of smaller capacity, typically less than 500 cubic meters per hour. In the pulp and paper industry, for example, the screw conveyor is used to transport wood chips, typically over short distances.

The belt conveyor is widely used in industry. It can be set up to transport material several kilometers and can handle thousands of tonnes per hour. In mining, belt conveyors, similar to airport moving sidewalks, transport raw material from the mine site to the mill.

The apron conveyor is similar to the belt conveyor except that the sides of the conveyor are extended upward from the conveyor bottom to retain fine grained material. Because apron and belt conveyors are interchangeable, the 1988 stock of Apron conveyors have been included with belt conveyors for this study.

Conveyors are the most efficient of the four auxiliary systems studied. The inherent engineering efficiencies of the conveyors themselves range from 89 to 98%. The greatest efficiency potential is therefore centered in the speed control device attached to the conveyor (i.e., replacing mechanical speed control (MSC) with a VSD).[7]

Conveyor efficiency is dependent on operating conditions. Thus, proper maintenance is essential. The simple design of the system has remained unchanged for the last 20 years (Erikson, 1991) and is recognized as a mature technology with little improvement in efficiency expected over the next 20 years.

Presently research and development is focussed on the expanded use of automated guided vehicles (AGVs) (Kulwiec, 1985). AGVs are typically battery powered carts which move material along preset routes. Their application allows for increased flexibility in conveyor design.

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7. As noted previously, it should not be assumed that all conveyors have a mechanical control device; some conveyors are constant speed.

3.6 Compressors

A compressor is designed to increase the pressure of a gas to a useful level. Typically air is compressed from atmospheric (15 psig) to 100 psig, the most common operating pressure used in industry. Compressed air systems are comprised of a compressor, pipe system, dryer/filter unit, throttle or vane, speed control device and motor.[8]

Compressor systems are the least efficient of the auxiliary systems, averaging between 15 and 20% total system efficiency. This inefficiency is due to the compressible nature of a gas, which absorbs energy as it is compressed (some of it released as radiant heat), and due to loss of pressure from air leakage.

Compressors are similar to pumps in design. Four types are common: centrifugal, rotary screw, single acting (stage) reciprocating and double acting reciprocating.

Reciprocating compressors are generally smaller than other types of compressors (less than 200 hp) and provide more precise air pressure. Double acting compressors dominate the reciprocating compressor market because of their enhanced reliability and higher efficiency over single acting compressors. Reciprocating compressors are more expensive than centrifugal and rotary compressors but maintain a small percentage of the compressor market because of their ability to provide precise air pressures.

Rotary screw compressors dominate the market because they are reliable and cheap. Their efficiencies are not as high as centrifugal compressors but the difference is small. Rotary screw compressors can be operated in dirty and corrosive environments which gives them a greater flexibility in industrial application than centrifugal compressors.

Centrifugal compressors are similar to centrifugal fans and pumps in design. A centrifugal compressor is the most efficient type of compressor but is more limited in application than the rotary screw.

Compressor systems can be purchased as "lubrication required" or "oil free". The difference between the two options is of primary concern to industry (compressed gas must be oil free in some applications) but, in terms of energy efficiency, there is no significant difference.

The two major potential efficiency initiatives are air-leakage control and the addition of a VSD. Air-leakage control can improve efficiency by 15% but can only be achieved by improved maintenance practices.

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8. Again, not all configurations will include speed control device.

As with the other three auxiliary systems, indications are that the technology is mature. However, with improved impeller design and better material construction, a 5% improvement in compressor efficiency can be expected over the next 20 years.

One initiative to improve compressor efficiency is to link all the compressor systems in a plant. This is called automatic sequencing of compressors. In the wood products branch, for example, a bank of several compressors provide the plant with compressed air through a common distribution system. To meet the demand of the plant in a non-sequenced system, each individual compressor is modulated by setting the controls at different pressures. Thus, in times of low demand, several compressors may be found running without load when they could have been turned off. However, an automatic sequencer would modulate the system instead of the individual compressors. Sensing overall requirements, it will provide the proper control signals that will eliminate unnecessary running time and operate compressors at their most efficient ranges (Merrill, 1991).

3.7 Other Motor System Technologies

Pneumatic and hydraulic systems have not been disaggregated from the four auxiliary systems. Hydraulic systems, a sub component of pumping systems, provide some of the "muscle power" used in industrial processes. A number of case studies indicate that cost-effective efficiency improvements could be implemented with respect to these systems. However, there is not enough data available to indicate the potential energy efficiency that could be obtained. It should be noted that it could be significant because 5% to 10% of the electricity used by industry involves hydraulic systems. (Willis, pers com., 1991) However, the energy demand associated with hydraulic systems has been included in the study, typically under "pumps".

Pneumatic systems have been grouped with the air displacement systems because pneumatic systems comprise a small component of auxiliary system electricity demand. Further analysis of pneumatic systems is required to indicate the energy efficiency potential.

Synergistic interactions are not included in the estimates. A synergistic interaction occurs when the replacement of a MSC and throttle with a VSD produces electricity savings equal to the difference in efficiency, but also improves the operating conditions of all the other components and, thus, their operating efficiencies. For example, the operating efficiency of a pump may improve because it no longer has to work against the back pressure produced by the throttle. Another example describes the synergistic interaction between the lighting and HVAC system in an office building in Southern California (Larson, 1990). Improving the efficiency of the lighting system reduces the air conditioning load because less waste heat was generated. However, synergistic interaction can both decrease or increase overall system efficiency depending on the relative importance of different effects. These are extremely difficult to estimate. The general impression is that they may be largely offsetting, although the net impact could be a slight improvement in efficiency. In this study, we have not attempted to provide estimates of the direction and magnitude of synergistic interactions.

Appendices

to

Chapter 3

Electric Motor Systems

Appendix A

Electric Motor System Assumptions

1. Fifty percent of the motor stock over 25 hp has been rewound. Each motor is typically rewound 4 times with an efficiency loss of one percent per rewind. (Fleming, pers com., 1991)

2. Machine drive (MD) services are divided into five categories: (1) process MD, (2) pumping MD, (3) compression MD, (4) conveyance MD, and (5) fan and blower MD. Process MD refers to large process-specific motor applications such as ore grinders in a mine, saws in a sawmill and pulp refiners in a mechanical pulp mill.

3. DC drives are replaced by AC drives when they are retired, except in special industrial cases where there are requirements for speed and torque control at slow speeds. (Marbek Resource Consultants, 1991; Welchman, pers com., 1991)

4. Auxiliary technologies (comprising gears, pipes, throttles, pumps, compressors, fans, blowers, conveyors, etc.) are bundled together as alternative mechanical systems. For example, a high efficiency mechanical system (in which all components minimize electricity consumption) can be contrasted with a low efficiency mechanical system (in which all components are of low efficiency) and with a medium efficiency mechanical system (a typical mix of high efficiency, medium efficiency and low efficiency components).

5. The efficiency of individual components of auxiliary systems will not be changed by the addition of a variable speed drive. Thus the addition of a VSD is only assumed to improve efficiency because it replaces flow control and some speed control devices, which would otherwise reduce efficiency.

6. Market shares of existing stock of auxiliary technologies are estimated from both plant surveys and equipment manufacturer surveys. These market shares are listed in Appendix B below.

7. The existing stock auxiliary system efficiencies are estimated from expert opinion. For process drives, we have assumed that 90% of existing stock is mechanical variable speed control and the remainder is electronic variable speed control. Ninety percent of electric motor stock is allocated to standard efficiency motors and 10% to high efficiency motors. Ninety nine percent of pumping, compression, conveyance and fans and blowers existing stock is inefficient and 1% is efficient.

Appendix B

Motor Systems Engineering and Economic Data

Electric Motors

1. General

(1) Motors are divided into three groups: AC induction, AC synchronous and DC. Of the AC induction motors, we have focussed on two types; standard (STD) and high efficiency (HE). DC motor systems are also divided into two types; motor-generators units and solid state rectification.

2. Motor Efficiencies

Size	Type	HP	STD	HE
1	Induction	1 - 5	83.3	87.5
2	Induction	6 - 25	86.3	90.1
3	Induction	26 - 100	91.7	92.8
4	Induction	101 - 200	93.0	93.6
5	Induction	201 - 500	93.8	95.0
6	Induction	> 500	94.0	95.0
5/6	Synchronous	> 200	97.0	
5/6	DC MG	> 200	65.0	
5/6	DC SS	> 200	85.0	

(compiled from Marbek, 1991 and Nadel, 1991)

3. Capital and Operating Costs

(1) Capital Costs:

			Capital Costs ($1990)	
Size	Type	HP	STD	HE
1	Induction	1 - 5	337	480
2	Induction	6 - 25	956	1 276
3	Induction	26 - 100	4 779	5 690
4	Induction	101 - 200	10 543	12 170
5	Induction	201 - 500	40 000	44 000
6	Induction	> 500	128 000	138 000
5	Synchronous	201-500	48 400	
6	Synchronous	> 500	151 800	
5	DC MG	201-500	52 800	
6	DC MG	> 500	165 600	
5	DC SS	201-500	55 000	
6	DC SS	> 500	172 500	

(compiled from Marbek, 1991 and Nadel, 1991)

(2) Operating Costs for all induction motors were estimated to be 4% of the capital cost of the standard motor. Synchronous and DC motor operating costs were estimated at 10% of capital costs. However, some expert opinion indicates that synchronous motors may require less maintenance than DC motors resulting in operating costs nearer to induction motors.

Variable Speed Drives

1. General

(1) The efficiency of the variable speed drive taken from Fickett (1990) is 95%. This efficiency was held constant over the entire horsepower range of motors. VSD efficiency for motors greater than 200 hp is 97%, however, this was reduced by 2% to allow for transformer losses.

2. Capital and Operating Costs

(1) Capital Costs

Size	Type	HP	Installed Capital Costs ($1990) High	Low
1	VSD	1 - 5	2 300	1 100
2	VSD	6 - 25	10 300	4 900
3	VSD	26 - 100	20 000	15 300
4	VSD	101 - 200	52 500	40 100
5	VSD	201 - 500	103 600	63 700
6	VSD	> 500	290 000	178 200

(Adapted from Marbek, 1991)

(2) Operating costs of VSDs are estimated to be 4% of capital costs.

Pump Systems

1. General

(1) Control valves or VSD used for flow adjustment but not both.

(2) Average industry head - 50 feet (Schaffer, pers com, 1991).

(3) Brake horsepower (Bhp) is 20% greater than required horsepower.

(4) Average specific gravity for all industries except mining is 1.0 (Temanex Consulting Inc, 1991), the specific gravity for mining is 1.3 (Scott, pers com., 1992)

(5) The efficiencies of the pumps will improve by 10% to the year 2010. (Mellis, pers com., 1991)

(6) Centrifugal pumps are widely used in industry. Rotary pumps are generally used to pump stock and slurries. (Krawczyk, pers com., 1991)

(7) Reciprocating pumps are used for services that require precise measurement. (Krawczyk, pers com., 1991)

2. Equipment Efficiencies

(1) Pumps

- inefficient centrifugal size 1-3	58%
- inefficient centrifugal size 4-6	72%
(Sulzer Brothers Ltd, 1989)	
- efficient centrifugal size 1-3	68%
- efficient centrifugal size 4-6	85%
(Warring, 1984)	
- rotary size 1-3	62%
- rotary size 4-6	77%
(Davidson, 1986)	
- reciprocating size 1-3	69%
- reciprocating size 4-6	85%
(Karassik, 1986)	

The efficiencies of the small size pumps are based on an efficiency of scale factor of 0.8 adapted from Warring (1984).

(2) Coupling or drive

- direct	99% (Fickett, 1990)
- V belt	85% (Fruchtbaum, 1988)
- VSD	95% (Fickett, 1990)

(3) Pipe

- standard	70%
- efficient	90%
(Fickett, 1990)	

3. Capacity Calculation Equation

Capacity = gallons per minute = q
Specific gravity = 1
Pump head = 50 ft
Bhp = (q * head * specific gravity)/(pump efficiency * 3960)

Size	1	0 - 250 gpm
	2	250 - 1 000 gpm
	3	1 000 - 5 100 gpm
	4	5 100 - 10 100 gpm
	5	10 100 - 25 400 gpm
	6	> 25 400 gpm

(Karassik, 1986)

4. Pumping Systems

Pump systems are composed of a speed and/or flow control device, a pump and a piping unit. System efficiency is determined by multiplying the component efficiencies together.

(1) Inefficient centrifugal pump system
- V-belt
- Throttle
- Inefficient centrifugal pump
- Standard pipe

(2) Medium Efficiency cent. pump system
- VSD
- Direct
- Inefficient centrifugal pump
- Efficient pipe

(3) Efficient centrifugal pump system
- VSD
- Direct
- Efficient centrifugal pump
- Efficient pipe

(4) Inefficient rotary pump system
- V-belt
- Throttle
- rotary pump
- Standard pipe

(5) Efficient rotary pump system
- VSD
- Direct
- rotary pump
- Efficient pipe

(6) Inefficient reciprocating pump system
- V-belt
- Throttle
- Reciprocating pump
- Standard pipe

(7) Efficient reciprocating pump system
- VSD
- Direct
- Reciprocating pump
- Efficient pipe

5. Market Share

All industries (estimate)

Centrifugal pumps	90%
Rotary pumps	5%
Reciprocating	5%

(Kober, pers com., 1991; Mytruk, pers com., 1991)

6. Capital and Operating Costs

(1) Capital Costs (excluding installation costs)
Centrifugal Pump - size 1-3 $5 000
- size 4-6 $20 000 (Mytruk, pers com., 1991)

Pipe capital costs equal the capital cost of a pump. (Mytruk, pers com., 1991)
Installation costs increase total capital costs by 100%. (Mytruk, pers com., 1991)
Both reciprocating and rotary pumps are 200% more expensive than centrifugal pumps. (Mellis, pers com., 1991)

(2) Operating Costs - all pump systems operating costs (excluding energy costs) are $400 annually. (Nordlund, pers com., 1991)

Air Displacement Systems

1. General

(1) Control dampers (or vanes) or VSD are used for speed/flow control but not both.

(2) Average static pressure for industry is 2.5 in. of water. (Gingras, pers com., 1991)

(3) Fan efficiencies will improve by:

centrifugal fans	- 2000 - 5%	2010 - 10%
axial fans	- 2000 - 2.5%	2010 - 5% (Maisey,pers com., 1991)

(4) Brake Horsepower (Bhp) is 20% greater than required horsepower.

(5) Axial fans are used for general ventilation. (Maisey, pers com., 1991)

(6) Drying kilns use backward inclined and axial fans. (Maisey, pers com., 1991)

2. Equipment efficiencies

(1) Fans

- backward inclined	73%
- radial	68%
- airfoil	78%
- axial	63%

(Keenan, pers com., 1991)

(2) Coupling

- direct	99%
- V-belt	85%
- VSD	95%

(3) Ducting 91%
(Cory, 1982)

(4) Control vane 75%
(Gingras, pers com., 1991)

3. Cubic feet per minute Calculation (CFM/minute)

BHP = Q (capacity)h
h = h of water in inches
Q = BHP x Eff x 6356/h

Q = CFM * 6356 * EFF
Avg. efficiency = 75%

Size	
1	4 800
2	23 800
3	95 300
4	238 300
5	556 800
6	1 493 000

(Alden, 1982)

4. Air Displacement Systems

Fan systems are composed of a speed control unit (not always), a fan, a control vane (or damper) and a duct. System efficiency is determined by multiplying the component efficiencies together.

(1) Inefficient backward inclined (BI) fan
- V-Belt
- BI Fan
- Control Vane
- Duct

(2) Efficient backward inclined fan
- VSD
- Direct couple
- BI Fan
- Duct

(3) Inefficient radial fan
- V-Belt
- Radial Fan
- Control Vane
- Duct

(4) Efficient radial fan
- VSD
- Direct couple
- Radial Fan
- Duct

(5) Inefficient airfoil fan
- V-Belt
- Airfoil Fan
- Control Vane
- Duct

(6) Efficient airfoil fan
- VSD
- Direct couple
- Airfoil Fan
- Duct

(7) Inefficient vaneaxial/tubeaxial (VA/TA) fan
- V-Belt
- VA/TA Fan
- Control Vane
- Duct

(8) Efficient vaneaxial/tubeaxial fan
- VSD
- Direct couple
- VA/TA Fan
- Duct

5. Market Share

(1) Pulp and Paper	- VA	50%
	- airfoil	25%
	- BI	25%
(older mills use radial in place of BI)		
(2) Mining	- airfoil	35%
	- radial	65%
(3) Wood Products	- radial	100%
(4) Chemicals	- VA	50%
	- BI	50%
(5) Petroleum refining	- VA	50%
	- BI	50%
(6) Other	- VA	50%
	- BI	50%

(Gingras, pers com., 1991; Maisey, pers com., 1991; Keenan, pers com., 1991)

6. Capital and Operating Costs

(1) Capital Costs

Centrifugal fan Capital costs (excluding installation costs)
- size 1-3 $5 000
- size 4-6 $20 000 (Mytruk, pers com., 1991; Kutz, 1986)

Installation costs increase total capital cost by 100%. (Mytruk, pers com., 1991) Axial fan Capital costs are 15% lower than centrifugal fan Capital costs (Nilsson, 1991; Maisey, pers com., 1991).

(2) Operating Costs - all fan operating costs (excluding energy costs) are approximately $400/yr (Nordlund, 1991).

Conveyor Systems

1. General

(1) Average length of conveyor - 250 ft. (Erikson, pers com., 1991)

(2) Average conveyor weight - 20 lbs/ft. (Erikson, pers com., 1991; Jones, pers com., 1991)

(3) Brake Horsepower (Bhp) is 20% greater than required horsepower.

(4) VSD or reducing gears (v-belts) are sometimes used to control conveyor speed.

2. Equipment Efficiencies

(1) Conveyors

- screw	96% (Environmental and Energy Systems Studies, 1989)
- belt	98%
- apron	89%
- chain	92%
(Fruchtbaum, 1988)	

(2) Coupling or drive

- worm gear (up to 60:1)	85% (Hessen, pers com., 1992)
- V belt/sheaves/helical	85% (Fruchtbaum, 1988)
- direct couple	99% (Fickett, 1990)
- VSD	95% (Fickett, 1990)

3. Tonnes per hour (Tph) capacity

Horsepower to convey material horizontally:

HP = (.004T) + (.000025TL)   T = tonnes per hour
L = length of conveyor (in feet)

Horsepower to elevate material:

HP = .001 * T * E   E = elevation (in feet)

Size	1	32 Tph
	2	162 Tph
	3	647 Tph
	4	1 618 Tph
	5	3 780 Tph
	6	10 136 Tph

(Fruchtbaum, 1988)

4. Conveyor Systems

A conveyor system is composed of a speed control device and a conveyor (some are direct drive). System efficiency is determined by multiplying the component efficiencies together.

(1) Inefficient belt conveyor
- Worm gear
- Belt

(2) Efficient belt conveyor
- VSD
- Direct couple
- Belt

(3) Inefficient screw conveyor
- Worm gear
- Screw

(4) Efficient screw conveyor
- VSD
- Direct couple
- Screw

(5) Inefficient apron conveyor
- Worm gear
- Apron

(6) Efficient apron conveyor
- VSD
- Direct couple
- Apron

(7) Inefficient chain conveyor
- Worm gear
- Chain

(8) Efficient chain conveyor
- VSD
- Direct couple
- Chain

5. Market Share

(1) Mining (90% shaft mount helical)	- belt	80%
	- chain	10%
	- screw	10%
(2) Wood Products (60% worm gear)	- chain	80%
	- belt	20%
(3) Pulp and Paper (10% worm gears)	- belt	80%
	- screw	20%
(4) Chemicals (50% worm gears)	- belt	75%
	- screw	25%

(5) Petroleum refining - none

(Brockley, pers com., 1991; Jones, pers com., 1991; Finkle, pers com., 1991; Hessen, pers com., 1992)

6. Capital and Operating Costs

(1) Capital Costs

Belt conveyor	$ 24/ft
Chain conveyor	$150/ft
Screw conveyor	$ 77/ft

(Erikson, pers com., 1991)

Installation costs increase total capital cost by 50%. (Erikson, pers com., 1991)

(2) Annual operating costs are estimated at 10% of capital costs.

Compressor Systems

1. General

(1) Control throttle (or vanes) or VSD are used for speed control but not both.

(2) Average air pressure - 100 psi. (Merrill, pers com., 1991)

(3) Compressor efficiencies will improve 5% by 2010. (Merrill, pers com., 1991)

(4) Brake Horsepower (Bhp) is 20 % greater than required horsepower. (Merrill, pers com., 1991; Krawczyk, pers com., 1991)

(5) Industry average capacity factor is 4.0 cubic feet per minute per horsepower (4.0 cfm/hp). (Merrill, pers com., 1991)

(6) Average loss of efficiency due to air leakage is 25% under standard operating conditions and 15% under best operating conditions. (Merrill, pers com., 1991)

(7) No significant energy efficiency difference between lubricated and oil free compressors (Furby, pers com., 1991).

2. Equipment efficiencies

(1) Compressors - small (sizes 1-3), large (sizes 4-6)

- small centrifugal	71%
- large centrifugal	80%
- small double acting reciprocating (recip.)	68%
- large double acting reciprocating	76%
- small rotary screw	65%
- large rotary screw	73%
- small single acting reciprocating	62%
- large single acting reciprocating	70%

(Sawchyn, pers com., 1991; Furby, pers com., 1991)

(2) Control options

- VSD	95% (Fickett, 1990)
- throttle	83% (Finkle, pers com., 1991)

CHAPTER 4

PULP AND PAPER

4.1 Description of the Production Process

Chemical pulp

Chemical pulp production, especially the Kraft method, is one of the dominant processes of the B.C. pulp and paper industry. This process uses large amounts of heat and chemicals to release the wood fibres bonded by lignin. The lignin and chemicals exit the pulping digesters in a liquor slurry which is evaporated and then burned in a recovery boiler to recover most of the chemicals for reuse. Because lignin accounts for a significant part of the mass of wood, the per tonne ratio of wood input to pulp output is low, almost two to one. Although the thermal energy requirements are substantial, this process is almost energy self-sufficient because of the energy generated (steam and sometimes electricity) in the burning of black liquor and in the disposal by combustion of wood waste (hog fuel - bark and other wood of unacceptable quality). Because the wood fibres have not been broken in the pulping process, chemical pulps are usually used for high quality and high strength papers and cardboards.

Mechanical pulp

The major alternative process is mechanical pulping. This process is much more material efficient: wood fibre is ground into pulp at a ratio of almost one to one. However, the resulting pulp and paper products are of lower quality because fibres have been broken. Variants of the mechanical process include conventional refiner mechanical pulping, stone groundwood pulping, and mechanical pulping with thermal and/or chemical pre-treatment of wood in order to improve paper quality (thermomechanical and chemi-thermomechanical). The mechanical process is not energy self-sufficient, requiring significant electricity demand by mechanical pulpers to grind wood. Much of mechanical pulp is destined for newsprint production.

In B.C. there is a general trend toward mechanical pulp production. One reason is that higher quality output is increasingly possible with thermomechanical and chemi-thermomechanical pulping. The other reason is that the greater material efficiency (yield) of the mechanical process is increasingly important as competition mounts for B.C.'s remaining wood supplies. This major trend of process evolution results in a shift from thermal energy, provided by wood and fossil fuels, to mechanical energy, provided by electricity. Other more detailed technological developments in this industry have accentuated this tendency. For example, greater use of mechanical energy, in the form of more efficient pulp and paper presses, reduces the moisture content of pre-dried pulp and paper, thereby decreasing the thermal energy requirements in the drying phase. In aggregate, this is a substitution of electricity for fossil fuels and biomass.

Approximately 40% of B.C.'s pulp production is integrated forward into paper production, with much of the remainder dried and exported as kraft market pulp. Newsprint is the predominant paper product.

4.2 Modelling the Pulp and Paper Industry

Output Forecasts

Table 4.2.1 presents the high and low output forecasts for the pulp and paper industry.

Table 4.2.1 Pulp and Paper Output Forecast
(thousands of tonnes)

	1988	2000	2010	
Chemical pulp	5436	5000	5000	High
		4800	4700	Low
Mechanical pulp	1800	3500	4200	High
		2500	3000	Low
Recycled pulp	133	380	380	High
		250	300	Low
Newsprint & other paper	2788	4500	5000	High
		3000	3500	Low
Tissue paper	90	110	160	High
		95	100	Low
Coated paper	60	170	350	High
		0	0	Low

(Source: B.C. Hydro, Load Forecasting Department, 1991)

In the high growth scenario, total pulp output is estimated to grow by 30%; chemical pulp declining slightly while mechanical pulp grows by 133% to increase its share of total pulp production from 24% to 44%. In the low growth scenario, total pulp production grows by only 9%, with chemical pulp declining by 14% and mechanical pulp increasing by 67%, increasing its share of total pulp production from 24% to 38%.

In the high growth scenario, paper production almost doubles, whereas in the low growth scenario it grows a more modest 26%.

Process Flow Model

Figure 4.2.1 presents the process flow model of the pulp and paper industry. As the diagram shows, the ISTUM-I model is cast as one large pulp and paper plant producing the combined output of the various plants in the province, and comprising the total equipment stocks of all these plants. Therefore, the single plant of this simulation model produces newsprint, linerboard, coated and uncoated paper, tissue paper, as well as market kraft pulp.

Disaggregation in the flow model only occurs where warranted to explain differences in end-use electricity demand. Thus, each type of paper has its own distinct process node for stock preparation, paper production and paper drying; each paper requires different amounts of electricity per tonne at each of these process steps.

Technologies are attached to the clear nodes in the process flow model. For example, several alternative technologies may be attached to node 28 for bleaching pulp.

Node 35 of the process flow model, mechanical pulping, includes the range of mechanical pulping technologies: stone groundwood, refiner mechanical, thermomechanical (TMP), and chemical thermomechanical (CTMP). In the simulations, market shares are constrained to some extent to reflect (1) obsolescence and (2) the potential for TMP and CTMP to compete for some furnishes with chemical pulps.

4.3 Results

Tables 4.3.1 to 4.3.4 and Figure 4.3.1 present the aggregate results for end-use electricity demand over the 22 year forecast period.

Table 4.3.1 Pulp and Paper End-use Electricity Demand:
Low
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	10 426	11 363	12 405	
Natural		10 492	11 108	10.5%
Econ 1		6 327	6 937	44.1%
Econ 3		6 239	6 844	44.8%
Econ 5		6 093	6 689	46.1%
Tech		6 146	6 761	45.5%
Tech Soc		5 874	6 471	47.8%

Figure 4.2.1 Flow Model: Pulp and Paper Industry

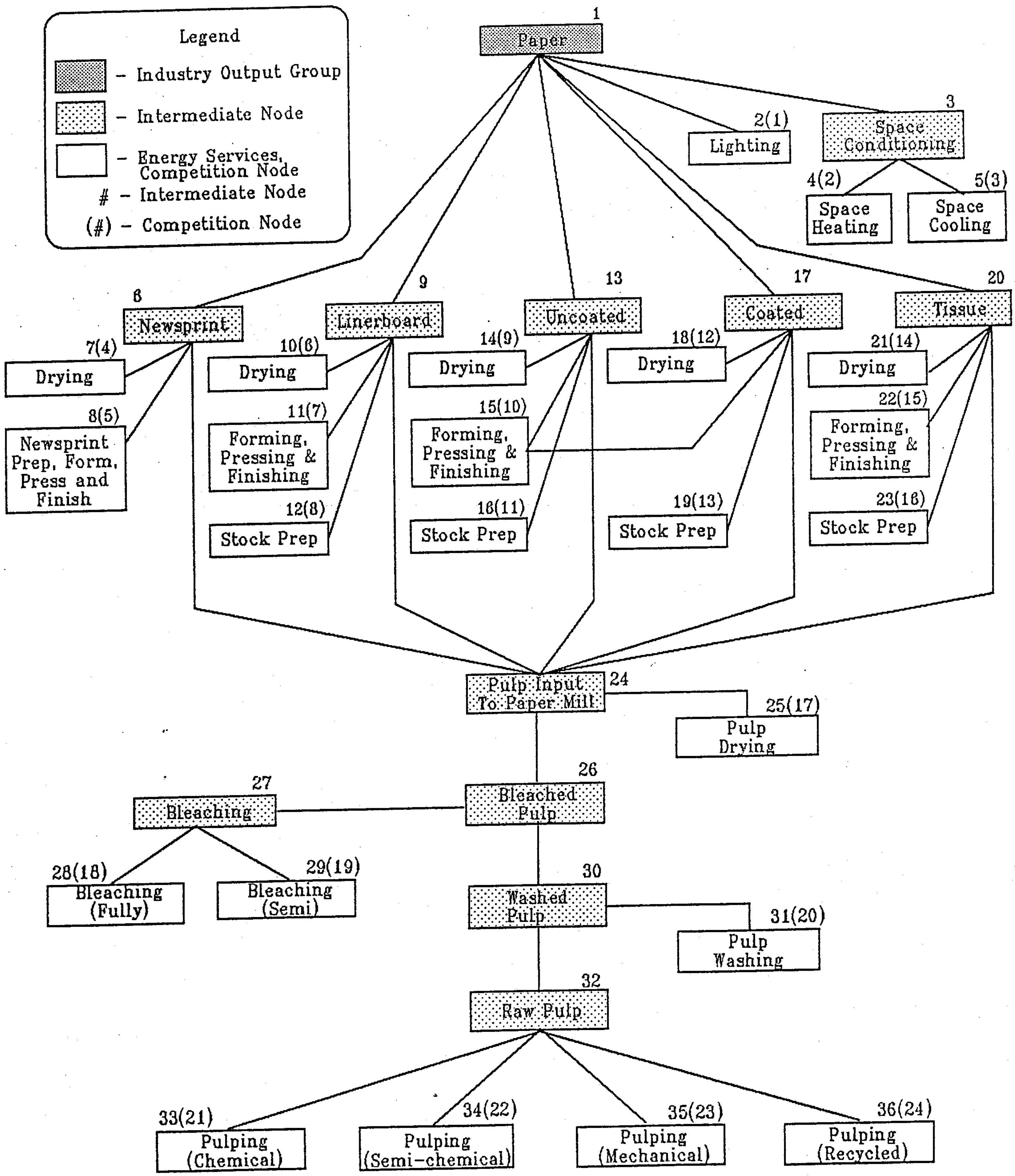

Figure 4.2.1 cont'd

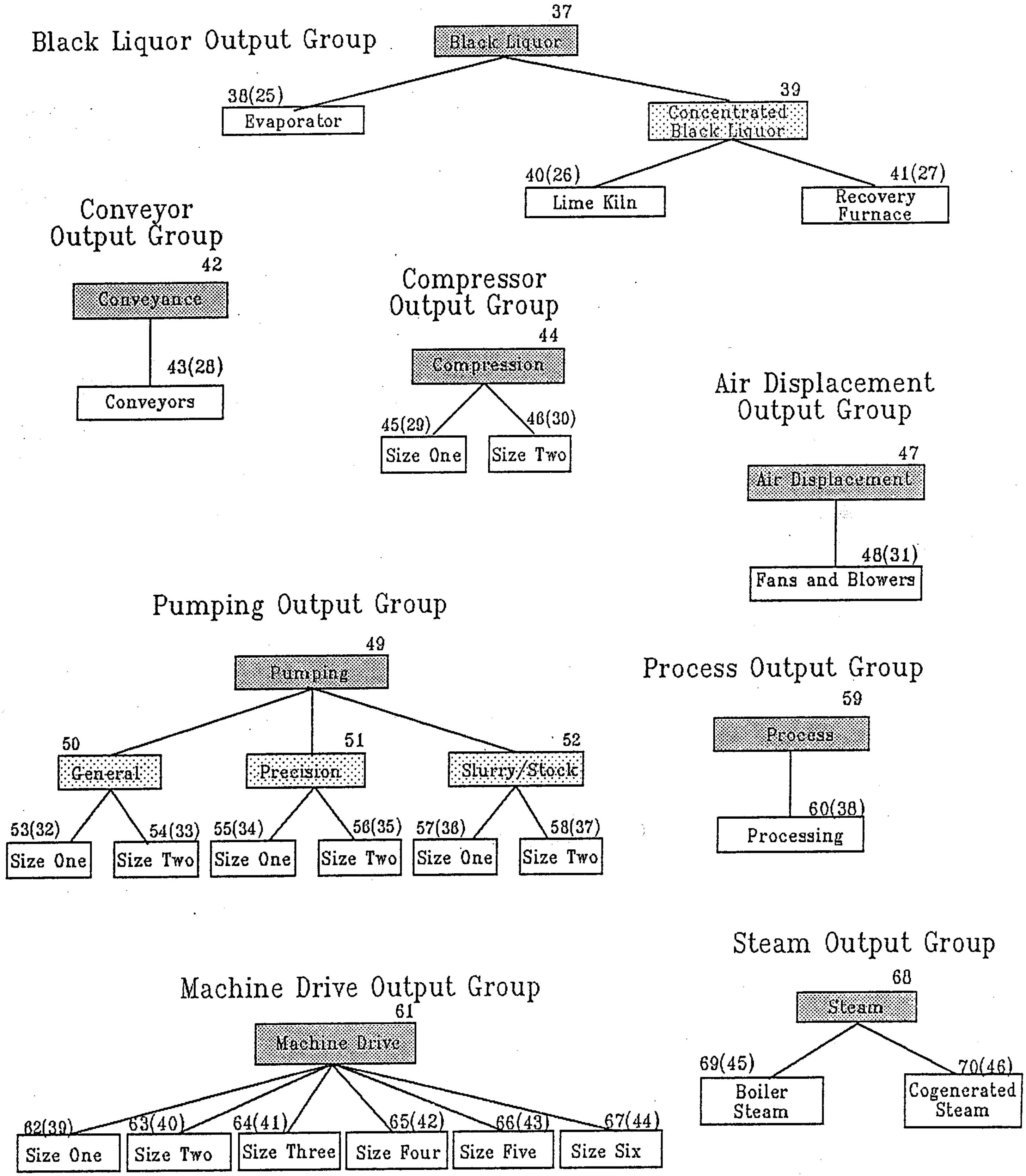

Figure 4.3.1 Pulp and Paper End-use Electricity Demand

High Growth

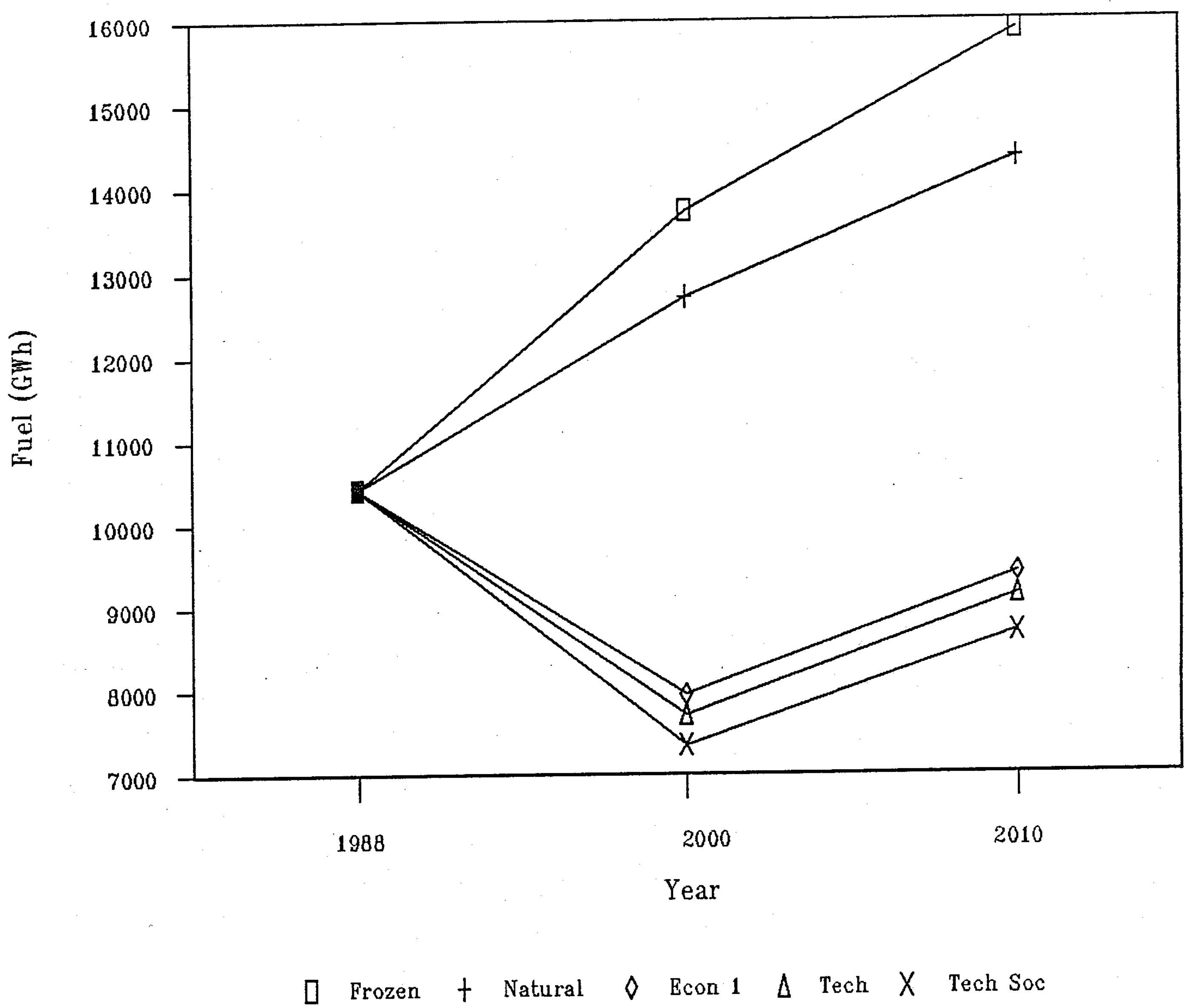

Table 4.3.2 Pulp and Paper End-use Electricity Demand:
High
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	10 426	13 728	15 882	
Natural		12 711	14 354	9.6%
Econ 1		7 952	9 408	40.8%
Econ 3		7 836	9 268	41.6%
Econ 5		7 643	9 033	43.1%
Tech		7 717	9 153	42.4%
Tech Soc		7 347	8 701	45.2%

Table 4.3.3 Pulp and Paper End-use Electricity Demand:
High Frozen Efficiency Run
(GWh)

Service	1988	2000	2010
Machine Drive	9 905	12 402	13 925
Pump	3 888	4 211	4 579
Air Displacement	1 149	1 182	1 281
Compression	212	267	299
Conveyance	501	630	701
Other	4 152	6 112	7 063
Electrolysis	0	0	0
Process Heat	0	472	973
Light	417	680	784
Other	104	173	199
Total	10 426	13 728	15 882

Table 4.3.4 Pulp and Paper End-use Electricity Demand:
High Technological Efficiency Run
(GWh)

Service	1988	2000	2010	% Reduction from Frozen in 2010
Machine Drive	9 905	6 715	7 568	45.6%
Pump	3 888	1 251	1 304	71.5%
Air Displacement	1 149	572	591	53.8%
Compression	212	116	127	57.5%
Conveyance	501	407	454	35.2%
Other	4 152	4 368	5 091	27.9%
Electrolysis	0	0	0	0.0%
Process Heat	0	472	973	0.0%
Light	417	357	411	47.6%
Other	104	173	199	0.0%
Total	10 426	7 718	9 153	42.4%

The frozen efficiency run shows a significant increase in end-use electricity demand, largely because it (like all runs) includes a significant product shift from chemical to mechanical pulp. This latter process is more electricity-intensive.

As subsequent chapters will show, pulp and paper has a high efficiency potential relative to other branches. Natural change in electricity intensity shows a 10% reduction in end-use electricity demand relative to frozen efficiency. Economic and technological potential efficiency improvements are in the range of 40-46% relative to frozen. The economic potential results are similar to the technological potential results.

The service breakdown shown in Tables 4.3.3 and 4.3.4. indicate the dominance of pumping, air displacement and process machine drive (other) in the pulp and paper industry. Pumping and air displacement are more important than process machine drive, in terms of efficiency potential in this industry. The growth from zero in 1988 of process heat use of electricity is due to the growth in production of coated paper, which requires electricity for drying.

The results for all electricity end-uses for all sub-products of each industry are presented in Volume II of this report.

4.4 Analysis and Caveats

The pulp and paper industry shows dramatic technological and economic potential for electricity efficiency improvements. The most important factor explaining this result is the dominance of motive force end-uses, especially pumping. As Chapter 3 showed, the greatest potential for efficiency improvements is in pumping, due to (1) more efficient motors, (2) adding an electronic adjustable speed drive, and (3) installing a more efficient pump and driving equipment. The overall technological efficiency improvement potential in pumping motor systems is in the range of 60% relative-to-Frozen.[1]

Another important factor in this branch is the opportunity for substitution among the major process technologies that demand motive force. First, the most electricity efficient mechanical pulping technologies (C/TMP) use 34% less electricity for machine drive requirements (grinding) than the standard technologies (stone groundwood and conventional refiner mechanical).[2] Second, the shift in chemical pulping from batch to continuous digesting decreases the end-use electricity requirement per tonne of chemical pulp output. In aggregate, the technological efficiency potential in chemical pulping is 60% relative-to-Frozen.[3]

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1. This is based on the assumption that base stock pumping systems have an aggregate mechanical efficiency in the range of 25% to 35%.
2. See Volume II. This presents all the results by sub-process and by machine drive end-use.
3. Again, Volume II shows the contributing factors in this 60% figure. It is comprised of the switch from batch to 100% continuous chemical digesters, plus improvements in motor systems efficiencies (see Chapter 10 for a summary of these effects).

Comparing Table 4.3.3 with 4.3.4, pumping end-use electricity demand decreases from 4579 GWh in the Frozen to 1174 Gwh in the Technological, a dramatic decrease of 74%. This decrease is attributable to the combined effect of the factors described in the two previous paragraphs. In part, the shift to more efficient chemical and mechanical pulping processes decreases the demand for pumping. We could call this a micro-level structural effect. At the same time, the average aggregate efficiency of pumping systems has improved by about 60%. We could call this an efficiency effect. In combination, the total demand for the pumping end-use falls by 74%.

Paper production efficiency improvement potential is smaller than chemical pulping because it requires more direct electricity as process heat. The Technological relative-to-Frozen potential for paper production is in the 42% range.

The social component of electricity efficiency potential is focused in compression (15%) and pumping (10%). The potential is not the same for all major product categories because there is a difference in the relative (to total demand) end-use requirement for pumping and compression. Chemical pulping has the greatest relative requirement for these two motor systems with a 6.4% reduction in demand for compression and 2.7% reduction for pumping, in the Technological / Social run relative to the Technological run. In aggregate, the Technological / Social run yields a 3% reduction in end-use electricity demand.

Explosion pulping is an emerging technology in the TMP/CTMP process. It involves the replacement of a TMP/CTMP pulp refiner with an explosion pulp refiner, reducing end-use electricity demand in the refining stage by 50%. However, because it is only possible to use this technology for hardwood pulping, it was constrained to a maximum 10% share of the TMP/CTMP market (Temanex, 1991). Refiner electricity demand could also be reduced 5-10% by increasing refiner rotational speed by 30% (a technology that is included in ISTUM-I).

Explosion pulping illustrates the most extreme case of the sensitivity of the study results to assumptions about technological innovation. Currently, there is a chemical barrier to the use of explosion pulping for softwood pulps. While the study terms of reference direct the researchers to make hypotheses about technologies likely to be market ready in the years 2000 and 2010, we were unable to find an industry expert willing to argue that explosion pulping will be possible for softwoods in these future time periods. However, a sensitivity analysis showed that when explosion pulping is allowed 100% penetration for all mechanical pulping, the Technological potential relative-to-Frozen for the pulp and paper industry increases from about 45% to about 60%. Clearly, this is a crucial assumption; sensitivity analysis of other assumptions in the study usually only led to incremental changes in the results.

The decline in paper production from virgin pulp is another factor reducing future demand for electricity. De-inked recycled fibre requires only 300-400 kwh/tonne for processing; a significant potential for reduction in electricity demand (Temanex, 1991).

In contrast, new paper drying technologies will increase the future demand for electricity. Linerboard impulse drying employes direct contact with a hot surface to dry the product. Using this technology would increase the electricity demand from linerboard production by 200 kwh/tonne. Infrared drying, using radiant heat, increases the electricity demand for coated paper drying by 30 kwh/tonne. Further, induction drying for newsprint would also increase electricity demand, this by 10 kwh/tonne (Temanex, 1991).

As in the other industries, the economic potential results (for all environmental credit runs) are close to the technological potential estimate. This is because almost all incremental investments in efficiency improvements are found to be cost-effective relative to the cost of B.C. Hydro's new supply.

Interenergy substitution in the pulp and paper industry is most likely to occur in the paper drying step of the production process. Steam, natural gas and direct electricity compete as the heat source for paper drying. Coated and uncoated paper use more direct electricity due to product quality constraints. Newsprint, linerboard and tissue paper could be dried using any energy source. However, because Interenergy substitution was restricted, electric drying of these paper products was excluded.

Appendices

to

Chapter 4

Pulp and Paper

Appendix A

Pulp and Paper Assumptions

Auxiliary Systems:

(1) Conveyor systems are horizontal.

(2) Load factor for pulp and paper auxiliary systems:

Process drive	.80 at .9 utilization
Pumping	.63 at .9 utilization
Fans and Blowers	.60 at .9 utilization
Conveyors	.60 at .9 utilization
Compressors	1.0 at .7 utilization

(Willis, pers com., 1991)

(3) Social Potential parameters:

a. Motor Systems

System	Potential
Pump	10%
Air Displacement	5%
Compression	15%
Conveyance	5%
Process Drive	2%
Process Heat	10%
Lighting	10%
HVAC	5%

b. Economic Runs

Run	Percentage of Potential (from above Table)
Frozen	0%
Natural	0%
Economic 1	0%
Economic 2	15%
Economic 3	25%
Economic 4	45%
Economic 5	70%
Technological	0%
Technological/ Social	100%

(Willis, pers com., 1992; Temanex, pers com., 1992; Merrill, pers com., 1991; Mellis, pers com., 1991)

Process Systems:

(1) Semi-bleached Kraft pulp will decrease to 3.4% of total Kraft pulp by the year 2000 and zero by the year 2010.

(2) All coated paper requires electricity for drying.

(3) Relative CTMP/TMP market share of TMP market pulp will remain constant.

(4) Explosion mechanical pulping is applicable to hardwood pulp only.

(5) As a percent of total paper, writing paper increases at two times the rate of newsprint and linerboard.

(6) Total paper includes newsprint, linerboard and writing (woodfree) paper.

(7) Twelve percent of mechanical pulp is sold as market pulp.

(8) Conventional Refiner Mechanical and Stone Groundwood pulps are no longer produced by 2000.

(Source: Temanex, 1991a)

Appendix B

Pulp and Paper Motor Systems Base Stocks

The following tables list the base stocks for motors in the pulp and paper branch. These are disaggregated by auxiliary system.

STONE GROUNDWOOD PULP – 1988 BASE STOCK 428,000 MT/YR

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL #MOTORS	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	148							19	3					21	6	39				10	10					13	5	6	2	9	5
LOG HANDLING	21	1	8	1		1								4							3							3			
WOOD PREP.	25	1	3				4							6	5					3	3										
CHIP HANDLING	29							6	5	6	4																4	4			
CHIP SCREENING	50				3			8	35		1					3															
SGW	451	13	19	22			14	33	41	16	19	3		41	16	5	5				14					76	43	41	30		
# OF MOTORS	724	15	30	23	3	1	18	66	84	22	24	3		72	27	47	5			13	30					89	52	54	32	9	5

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	9938							27	37					40	49	2748				31	87					16	85	350	302	2145	4021
LOG HANDLING	696	5	152	75		251								3							25							184			
WOOD PREP.	3683	2	34				3569							8	37					7	25										
CHIP HANDLING	1440							14	87	364	670																29	276			
CHIP SCREENING	1096				369			19	374		151					184															
SGW PROCESS	91132	60	299	1333			73440	137	857	816	2992	952		133	231	286	680				313					165	496	2638	5304		
TOTAL INSTALLED HP:	107986	67	485	1408	369	251	77009	196	1354	1180	3813	952		186	317	3218	680			38	450					181	610	3449	5606	2145	4021

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STONE GROUNDWOOD PULP – 1988 BASE STOCK 428,000 MT/YR

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS

PROCESS	TOTAL ENERGY	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
	kWh/MT	SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT	SIZE 1 kW	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kW	SIZE 1 kW	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kW	SIZE 1 kW	SIZE 2 kWh/MT	SIZE 3 kW	SIZE 4 kW	SIZE 5 kWh/MT	SIZE 6 kW	SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT
WATER SUPPLY & TREAT.	179							0.5	0.7					0.8	0.9	51.7				0.6	1.6					0.3	1.6	6.6	5.3	37.6	70.6
LOG HANDLING	13	0.1	2.9	1.4		4.4								0.1							0.5							3.5			
WOOD PREP.	65	0.0	0.6				62.6							0.2	0.7					0.1	0.5										
CHIP HANDLING	26							0.3	1.6	6.8	11.8																0.6	5.2			
CHIP SCREENING	20				6.5			0.3	7.0		2.6					3.5															
SGW PROCESS	1609	1.1	5.6	25.1			1289.1	2.6	16.1	15.3	52.5	16.7		2.5	4.3	5.4	11.9				5.9					3.1	9.3	49.6	93.1		
ENERGY(kWh/MT)	1912	1	9	26	6	4	1352	4	25	22	67	17		3	6	61	12			1	8					3	11	65	98	38	71

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS (BY PROCESS & SIZE)

PROCESS	TOTAL ENERGY	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
	GWH/YR	SIZE 1 GWH/Y	SIZE 2 GWH/Y	SIZE 3 GWH/Y	SIZE 4 GWH/Y	SIZE 5 GWH/Y	SIZE 6 GWH/YR	SIZE 1 GWH	SIZE 2 GWH/Y	SIZE 3 GWH/Y	SIZE 4 GWH/YR	SIZE 5 GWH/Y	SIZE 6 GWH	SIZE 1 GWH	SIZE 2 GWH/Y	SIZE 3 GWH/Y	SIZE 4 GWH/YR	SIZE 5 GWH/Y	SIZE 6 GWH	SIZE 1 GWH	SIZE 2 GWH/Y	SIZE 3 GWH	SIZE 4 GWH	SIZE 5 GWH/Y	SIZE 6 GWH	SIZE 1 GWH/Y	SIZE 2 GWH/Y	SIZE 3 GWH/YR	SIZE 4 GWH/YR	SIZE 5 GWH/YR	SIZE 6 GWH/YR
WATER SUPPLY & TREAT.	77							0.2	0.3					0.3	0.4	22.1				0.2	0.7					0.1	0.7	2.8	2.3	16.1	30.2
LOG HANDLING	5	0.0	1.2	0.6		1.9								0.0							0.2							1.5			
WOOD PREP.	28	0.0	0.3				26.8							0.1	0.3					0.1	0.2										
CHIP HANDLING	11							0.1	0.7	2.9	5.0																0.2	2.2			
CHIP SCREENING	9				2.8			0.1	3.0		1.1					1.5															
SGW PROCESS	689	0.5	2.4	10.7			551.7	1.1	6.9	6.6	22.5	7.2		1.1	1.9	2.3	5.1				2.5					1.3	4.0	21.2	39.8		
ENERGY(GWh/YR)	818	1	4	11	3	2	579	2	11	9	29	7		1	3	26	5			0	4					1	5	28	42	16	30

MARKET REFINER MECHANICAL PULP – 1988 BASE STOCK 210,000 MT/YR (B.C.HYDRO SERV

(INCLUDES DRYING AND BALE FINISHING)

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL #MOTORS	MACHINE DRIVE SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	CONVEYORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	73							9	1				
LOG HANDLING	11	1	4	1	1								
WOOD PREP.	12	1	1				2						
CHIP HANDLING	15							3	3	3		1	
CHIP SCREENING	25				1			4	18	1			
RMP PROCESS	267	6	12	20	7		8	12	36	11	13	3	
PULP DRYING	200	11	6	8	4	3		6	1	2			
BALE FINISHING	177	3	4	4				33	11			.	
# OF MOTORS	780	22	27	33	13	3	10	67	70	17	13	4	

PROCESS	FANS & BLOWERS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	COMPRESSORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	11	3	19				5	5				
LOG HANDLING	2							1				
WOOD PREP.	3	3					1	1				
CHIP HANDLING												
CHIP SCREENING			1									
RMP PROCESS	15	13	2	3				11				
PULP DRYING	4	111	3	3				4	2			
BALE FINISHING	3	111	1					3				
# OF MOTORS	38	241	26	6			6	25	2			

PROCESS	PUMPING SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	6	3	4		4	3
LOG HANDLING			1			
WOOD PREP.						
CHIP HANDLING		3	2			
CHIP SCREENING						
RMP PROCESS	28	16	31	11	3	6
PULP DRYING	5	6	8	3	8	2
BALE FINISHING	2	1	1			
# OF MOTORS	41	29	47	14	15	11

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	CONVEYORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	4676							13	17				
LOG HANDLING	327	2	71	35	118								
WOOD PREP.	1733	1	16				1680						
CHIP HANDLING	677							6	41	171		315	
CHIP SCREENING	516				173			9	176	71			
RMP PROCESS	63502	24	185	1585	875		46500	50	780	540	2375	1050	
PULP DRYING	8646	45	65	316	621	805		19	8	99			
BALE FINISHING	2228	8	34	331				51	78				
TOTAL INSTALLED HP:	71431	80	371	2267	1787	805	48180	148	1100	881	2375	1365	

PROCESS	FANS & BLOWERS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	COMPRESSORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	19	23	1293				14	41				
LOG HANDLING	2							12				
WOOD PREP.	4	17					3	12				
CHIP HANDLING												
CHIP SCREENING			87									
RMP PROCESS	49	165	105	375				245				
PULP DRYING	7	1531	124	551				78	130			
BALE FINISHING	1	1531	118					32				
TOTAL INSTALLED HP:	82	3267	1727	926			17	420	130			

PROCESS	PUMPING SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	8	40	307		1009	1892
LOG HANDLING			87			
WOOD PREP.						
CHIP HANDLING		14	130			
CHIP SCREENING						
RMP PROCESS	61	183	1780	2075	900	3600
PULP DRYING	14	96	334	419	1870	1514
BALE FINISHING		9	35			
TOTAL INSTALLED HP:	83	342	2673	2494	3779	7006

MARKET REFINER MECHANICAL PULP – 1988 BASE STOCK 210,000 MT/YR (B.C.HYDRO SERV

(INCLUDES DRYING AND BALE FINISHING)

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS

PROCESS	TOTAL ENERGY kWh/MT	MACHINE DRIVE SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	CONVEYORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
		kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kW/	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kW/
WATER SUPPLY & TREAT.	172							0.5	0.7				
LOG HANDLING	7	0.0	1.5	0.7	2.3								
WOOD PREP.	35	0.0	0.3				33.4						
CHIP HANDLING	21							0.2	1.3	5.5		9.4	
CHIP SCREENING	19				6.2			0.3	6.8	2.7			
RMP PROCESS	2289	0.9	7.1	60.8	31.3		1665.1	1.9	29.9	20.7	85.0	37.6	
PULP DRYING	317	1.7	2.5	12.1	22.2	28.8		0.7	0.3	3.8			
BALE FINISHING	85	0.3	1.3	12.7				2.0	3.0				
ENERGY(kWh/MT)	2945	3	13	86	62	29	1698	6	42	33	85	47	

PROCESS	FANS & BLOWERS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	COMPRESSORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	PUMPING SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
	kW/	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kW/	kW/	kWh/MT	kW/	kW/	kWh/MT	kW/	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT
WATER SUPPLY & TREAT.	0.7	0.9	49.6				0.5	1.6					0.3	1.5	11.8		36.1	67.7
LOG HANDLING	0.0							0.3							1.9			
WOOD PREP.	0.1	0.4					0.1	0.3										
CHIP HANDLING														0.4	4.2			
CHIP SCREENING			3.3															
RMP PROCESS	1.9	6.3	4.0	13.4				9.4					2.3	7.0	68.3	74.3	32.2	128.9
PULP DRYING	0.3	58.7	4.8	19.7				3.0	5.0				0.5	3.7	12.8	15.0	67.0	54.2
BALE FINISHING	0.0	58.7	4.5					1.2						0.3	1.3			
ENERGY(kWh/MT)	3	125	66	33			1	16	5				3	13	100	89	135	251

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS (BY PROCESS & SIZE)

PROCESS	TOTAL ENERGY GWH/YR	MACHINE DRIVE SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	CONVEYORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
		GWh/Y	GWh/Y	GWh/Y	GWh/Y	GWh/Y	GWh/YR	GWh/	GWh/Y	GWh/Y	GWh/YR	GWh/Y	GWh/
WATER SUPPLY & TREAT.	36							0.1	0.1				
LOG HANDLING	1	0.0	0.3	0.2	0.5								
WOOD PREP.	7	0.0	0.1				7.0						
CHIP HANDLING	4							0.0	0.3	1.1		2.0	
CHIP SCREENING	4				1.3			0.1	1.4	0.6			
RMP PROCESS	481	0.2	1.5	12.8	6.6		349.7	0.4	6.3	4.4	17.9	7.9	
PULP DRYING	67	0.4	0.5	2.5	4.7	6.1		0.2	0.1	0.8			
BALE FINISHING	18	0.1	0.3	2.7				0.4	0.6				
ENERGY(GWh/YR)	618	1	3	18	13	6	357	1	9	7	18	10	

PROCESS	FANS & BLOWERS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	COMPRESSORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	PUMPING SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
	GWh/	GWh/Y	GWh/Y	GWh/YR	GWh/Y	GWh/	GWh/	GWh/Y	GWh/	GWh/	GWh/Y	GWh/	GWh/Y	GWh/Y	GWh/YR	GWh/YR	GWh/YR	GWh/YR
WATER SUPPLY & TREAT.	0.2	0.2	10.4				0.1	0.3					0.1	0.3	2.5		7.6	14.2
LOG HANDLING	0.0							0.1							0.4			
WOOD PREP.	0.0	0.1					0.0	0.1										
CHIP HANDLING														0.1	0.9			
CHIP SCREENING			0.7															
RMP PROCESS	0.4	1.3	0.8	2.8				2.0					0.5	1.5	14.3	15.6	6.8	27.1
PULP DRYING	0.1	12.3	1.0	4.1				0.6	1.0				0.1	0.8	2.7	3.2	14.1	11.4
BALE FINISHING	0.0	12.3	1.0					0.3						0.1	0.3			
ENERGY(GWh/YR)	1	26	14	7			0	3	1				1	3	21	19	28	53

TEMANEX CONSULTING INC.

TMP/CTMP – 1988 BASE STOCK 1,118,500 MT/YR (B.C.HYDRO SERVICE AREA)

NUMBER OF MOTORS BY SIZE – TMP/CTMP MILLS IN B.C.

PROCESS	TOTAL # MOT.	MACHINE DRIVE SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	CONVEYORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	354							45	6				
LOG HANDLING	48	3	18	3		3							
WOOD PREP.	57	3	6				9						
CHIP HANDLING	69							15	12	15		6	
CHIP SCREENING	117				6			18	84		3		
TMP PROCESS	1072	24	48	80	24		32	48	144	44	52	12	
# OF MOTORS	1717	30	72	83	30	3	41	126	246	59	55	18	

PROCESS	FANS & BLOWERS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	COMPRESSORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	PUMPING SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	51	15	93				24	24					30	12	15	6	21	12
LOG HANDLING	9							6							6			
WOOD PREP.	15	12					6	6										
CHIP HANDLING														12	9			
CHIP SCREENING			6															
TMP PROCESS	60	52	8	12				44					112	64	124	52	12	24
# OF MOTORS	135	79	107	12			30	80					142	88	154	58	33	36

INSTALLED HP BY MOTOR RATING – TMP/CTMP MILLS IN B.C.

PROCESS	TOTAL HP	MACHINE DRIVE SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	CONVEYORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	26078							71	97				
LOG HANDLING	1827	13	398	198		660							
WOOD PREP.	9665	6	90				9365						
CHIP HANDLING	3780							36	229	954		1759	
CHIP SCREENING	2876				967			49	980		396		
TMP PROCESS	304774	96	740	3500	3106		240000	200	3120	2160	9500	4200	
TOTAL INSTALLED HP:	349000	115	1228	3698	4073	660	249365	356	4426	3114	9896	5959	

PROCESS	FANS & BLOWERS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	COMPRESSORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	PUMPING SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	106	130	7211				80	229					42	222	919	791	5628	10552
LOG HANDLING	9							66							484			
WOOD PREP.	22	97					19	66										
CHIP HANDLING														77	725			
CHIP SCREENING			484															
TMP PROCESS	196	660	420	1500				980					244	732	7120	8300	3600	14400
TOTAL INSTALLED HP:	333	886	8114	1500			100	1341					286	1031	9248	9091	9228	24952

TEMANEX CONSULTING INC.

TMP/CTMP – 1988 BASE STOCK 1,118,500 MT/YR (B.C.HYDRO SERVICE AREA)

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS IN A TMP/CTMP MILL

PROCESS	TOTAL ENERGY kWh/MT	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
		kWh/MT	kWh/MT	kWh/MT	kWh/MT	kW	kWh/MT	kW	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kW	kW	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kW	kW	kWh/MT	kW	kW	kWh/MT	kW	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT
WATER SUPPLY & TREAT.	180							0.5	0.7					0.8	0.9	51.9				0.6	1.6					0.3	1.6	6.6	5.3	37.8	70.9
LOG HANDLING	7	0.1	1.6	0.8		2.5								0.0							0.3							1.9			
WOOD PREP.	36	0.0	0.4				35.0							0.1	0.4					0.1	0.3										
CHIP HANDLING	22							0.2	1.4	5.7		9.9															0.5	4.4			
CHIP SCREENING	20				6.5			0.4	7.1		2.7					3.5															
TMP PROCESS	2059	0.7	5.3	25.2	20.9		1613.6	1.4	22.5	15.6	63.9	28.2		1.4	4.8	3.0	10.1				7.1					1.8	5.3	51.3	55.8	24.2	96.8
ENERGY(kWh/MT)	2324	0.8	7.3	26.0	27.4	2.5	1648.6	2.5	31.6	21.3	66.5	38.1		2.3	6.1	58.5	10.1			0.7	9.2					2.1	7.3	64.2	61.1	62.0	167.8

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS IN TMP/CTMP MILLS IN B.C. (BY PROCESS & SIZE)

PROCESS	TOTAL ENERGY GWH/YR	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
		GWH/Y	GWH/Y	GWH/Y	GWH/Y	GWH	GWH/YR	GWH	GWH/Y	GWH/Y	GWH/YR	GWH/Y	GWH	GWH	GWH/Y	GWH/Y	GWH/YR	GWH/Y	GWH	GWH	GWH/Y	GWH	GWH	GWH/Y	GWH	GWH/Y	GWH/Y	GWH/YR	GWH/YR	GWH/YR	GWH/YR
WATER SUPPLY & TREAT.	201							0.6	0.8					0.9	1.0	58.1				0.6	1.8					0.3	1.8	7.4	6.0	42.3	79.4
LOG HANDLING	8	0.1	1.8	0.9		2.8								0.0							0.3							2.2			
WOOD PREP.	40	0.0	0.4				39.1							0.1	0.4					0.1	0.3										
CHIP HANDLING	25							0.2	1.5	6.4	11.0																0.5	4.9			
CHIP SCREENING	22				7.3			0.4	7.9		3.0					3.9															
TMP PROCESS	2303	0.8	6.0	28.2	23.4		1804.8	1.6	25.1	17.4	71.4	31.6		1.6	5.3	3.4	11.3				7.9					2.0	5.9	57.4	62.4	27.1	108.3
ENERGY(GWh/YR)	2599	0.9	8.1	29.1	30.6	2.8	1843.9	2.8	35.4	23.8	85.4	31.6		2.6	6.8	65.4	11.3			0.7	10.3					2.3	8.2	71.8	68.4	69.4	187.6

MARKET TMP/CTMP – 1988 BASE STOCK 255,000 MT/YR (B.C.HYDRO SERVICE AREA)

(INCLUDES DRYING AND BALE FINISHING)

NUMBER OF MOTORS BY SIZE – TMP/CTMP MILLS IN B.C.

PROCESS	TOTAL #MOTORS	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	90							11	2					13	4	23				6	6					8	3	4	2	5	3
LOG HANDLING	14	1	5	1		1								2							2							2			
WOOD PREP.	16	1	2				2							4	3					2	2										
CHIP HANDLING	18							4	3	4	2																3	2			
CHIP SCREENING	30				2			4	21	1						2															
TMP PROCESS	206	5	10	16	5		6	39		9	2	2		12	10	2	2				9					22	13	25	10	2	5
PULP DRYING	238	14	8	10	4	3		6	1	2				5	134	3	2	2			5	2				6	7	9	4	9	2
BALE FINISHING	213	3	5	5				40	13					3	134	2					3					2	1	2			
# OF MOTORS	825	24	30	32	11	4	8	104	40	16	4	2		39	285	32	4	2		8	27	2				38	27	44	16	16	10

INSTALLED HP BY MOTOR RATING – TMP/CTMP MILLS IN B.C.

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	5978							16	22					24	30	1653				18	52					10	51	211	181	1290	2419
LOG HANDLING	419	3	91	45		151								2							15							111			
WOOD PREP.	2216	1	21				2147							5	22					4	15										
CHIP HANDLING	866							8	52	219	403																18	166			
CHIP SCREENING	669				222			11	225	100						111															
TMP PROCESS	68311	19	147	1265	698		56600	80		623	431	838		39	132	84	299				195					48	146	1420	1656	718	2873
PULP DRYING	11054	57	83	404	794	1029		24	10	126				10	1957	158	222	484			100	166				18	122	427	536	2390	1935
BALE FINISHING	2850	11	43	423				65	100					2	1957	151					41					1	11	44			
TOTAL INSTALLED HP:	78458	91	385	2138	1714	1180	58747	205	410	1068	834	838		82	4099	2157	521	484		23	419	166				77	348	2380	2374	4398	7227

MARKET TMP/CTMP – 1988 BASE STOCK 255,000 MT/YR (B.C.HYDRO SERVICE AREA)

(INCLUDES DRYING AND BALE FINISHING)

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS IN A TMP/CTMP MILL

Units: TOTAL ENERGY kWh/MT; size columns kWh/MT

PROCESS	TOTAL ENERGY kWh/MT	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	183							0.5	0.7					0.8	1.0	52.8				0.6	1.7					0.3	1.6	6.7	5.4	38.5	72.2
LOG HANDLING	7	0.1	1.6	0.8		2.5								0.0							0.3							2.0			
WOOD PREP.	37	0.0	0.4				35.6							0.1	0.4					0.1	0.3										
CHIP HANDLING	22							0.2	1.4	5.8	10.0																0.5	4.4			
CHIP SCREENING	21				6.6			0.4	7.2	3.2						3.5															
TMP PROCESS	2047	0.6	4.7	40.4	20.8		1688.9	2.6		19.9	12.9	25.0		1.2	4.2	2.7	8.9				6.2					1.5	4.7	45.4	49.4	21.4	85.7
PULP DRYING	338	1.8	2.7	12.9	23.7	30.7		0.8	0.3	4.0				0.3	62.6	5.1	6.6	14.4			3.2	5.3				0.6	3.9	13.7	16.0	71.3	57.7
BALE FINISHING	91	0.3	1.4	13.5				2.1	3.2					0.1	62.6	4.8					1.3					0.0	0.4	1.4			
ENERGY(kWh/MT)	2746	3	11	68	51	33	1725	7	13	33	23	25		3	131	69	16	14		1	13	5				2	11	74	71	131	216

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS IN TMP/CTMP MILLS IN B.C. (BY PROCESS & SIZE)

Units: TOTAL ENERGY GWH/YR; size columns GWh/YR

PROCESS	TOTAL ENERGY GWH/YR	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	47							0.1	0.2					0.2	0.2	13.5				0.2	0.4					0.1	0.4	1.7	1.4	9.8	18.4
LOG HANDLING	2	0.0	0.4	0.2		0.6								0.0							0.1							0.5			
WOOD PREP.	9	0.0	0.1				9.1							0.0	0.1					0.0	0.1										
CHIP HANDLING	6							0.1	0.4	1.5	2.6																0.1	1.1			
CHIP SCREENING	5				1.7			0.1	1.8	0.8						0.9															
TMP PROCESS	522	0.2	1.2	10.3	5.3		430.7	0.7		5.1	3.3	6.4		0.3	1.1	0.7	2.3				1.6					0.4	1.2	11.6	12.6	5.5	21.9
PULP DRYING	86	0.5	0.7	3.3	6.0	7.8		0.2	0.1	1.0				0.1	16.0	1.3	1.7	3.7			0.8	1.4				0.2	1.0	3.5	4.1	18.2	14.7
BALE FINISHING	23	0.1	0.3	3.5				0.5	0.8					0.0	16.0	1.2					0.3					0.0	0.1	0.4			
ENERGY(GWh/YR)	700	1	3	17	13	8	440	2	3	8	6	6		1	33	18	4	4		0	3	1				1	3	19	18	33	55

TEMANEX CONSULTING INC.

UNBLEACHED KRAFT - 1988 BASE STOCK 700,000 MT/YR (B.C. HYDRO SERVICE AREA)

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL #MOTOR	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE	SIZE 5	SIZE	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUP.& TREAT	236							30	4					34	10	62				16	16					20	8	10	4	14	8
LOG HANDL.& STOR.	32	2	12	2		2								6							4							4			
WOOD PREPARATIO	38	2	4				6							10	8					4	4										
CHIP HANDLING	46							10	8	10		4															8	6			
CHIP SCREENING	78				4			12	56		2					4															
DIGESTING	147	2	2	5	4			24	2	8				24	8							2				12	18	22	4	4	6
WASHING & SCREEN	212	14	12	20		6		4	10	14	6	6		16	10	2	2					4				10	10	30	10	22	4
EVAPORATORS	74																										16	42	12	4	
CHEMICALS RECOV.	224		14					24	6					130				6	2		6					10	6	16	4		
RECAUSTICIZING	147	10	14	12				10						16		3				4	8					16	24	20	8		2
LIME BURNING	48	2				2		8	14	2				8	8	4															
# OF MOTORS	1282	32	58	39	8	10	6	122	100	34	8	10		244	44	75	2	6	2	24	38	6				68	90	150	42	44	20

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE (HP)	SIZE 5 (HP)	SIZE (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUP.& TREAT	17810							49	66					72	89	4924				55	156					29	152	628	540	3843	7206
LOG HANDL.& STOR.	1248	9	272	135		450								6							45							330			
WOOD PREPARATIO	6601	4	62				6396							15	66					13	45										
CHIP HANDLING	2581							24	156	652		1201															53	495			
CHIP SCREENING	1964				661			33	670		270					330															
DIGESTING	10689	3	23	450	793			108	47	471				62	48							90				20	326	1853	540	1081	4774
WASHING & SCREEN	18604	44	165	961		1561		16	188	784	811	1441		74	111	111	270					132				28	116	1703	1531	6155	2402
EVAPORATORS	6741																										222	3336	1982	1201	
CHEMICALS RECOV.	6331		357					101	89					329				1832	1501		50					15	146	1372	540		
RECAUSTICIZING	4966	26	179	420				24						46		225				13	99					45	435	1051	1201		1201
LIME BURNING	1346	3				751		20	201	135				9	95	132															
INSTALLED HP:	78881	89	1057	1967	1453	2762	6396	374	1416	2042	1081	2642		614	408	5723	270	1832	1501	81	395	222				137	1449	10768	6336	12281	15584

TEMANEX CONSULTING INC.

UNBLEACHED KRAFT - 1988 BASE STOCK 700,000 MT/YR (B.C. HYDRO SERVICE AREA)

KWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS IN A KRAFT MILL (BY PROCESS & SIZE)

PROCESS	ENERGY kWh/MT	MACHINE DRIVE SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	CONVEYORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUP.& TREAT	182							0.5	0.7				
LOG HANDL.& STOR.	7	0.1	1.6	0.8		2.5							
WOOD PREPARATIO	37	0.0	0.4				35.4						
CHIP HANDLING	22							0.2	1.4	5.8	10.0		
CHIP SCREENING	20				6.6			0.4	7.1		2.7		
DIGESTING	109	0.0	0.2	4.8	7.9			1.2	0.5	5.0			
WASHING & SCREEN	188	0.5	1.8	10.3		15.5		0.2	2.0	8.4	8.1	14.4	
EVAPORATORS	70												
CHEMICALS RECOV.	65		3.8					1.1	0.9				
RECAUSTICIZING	51	0.3	1.9	4.5				0.3					
LIME BURNING	14	0.0				7.5		0.2	2.1	1.4			
TOTAL kWh/T	765	0.9	9.7	20.3	14.5	25.5	35.4	4.0	14.8	20.6	20.7	14.4	

PROCESS	FANS & BLOWERS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	COMPRESSORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	PUMPING SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUP.& TREAT	0.8	0.9	52.5				0.6	1.7					0.3	1.6	6.7	5.4	38.3	71.8
LOG HANDL.& STOR.	0.0							0.3							2.0			
WOOD PREPARATIO	0.1	0.4					0.1	0.3										
CHIP HANDLING														0.5	4.4			
CHIP SCREENING			3.5															
DIGESTING	0.7	0.5							1.0				0.2	3.5	19.8	5.4	10.8	47.5
WASHING & SCREEN	0.8	1.2	1.2	2.7					1.4				0.3	1.2	18.2	15.2	61.3	23.9
EVAPORATORS														2.4	35.6	19.7	12.0	
CHEMICALS RECOV.	3.5				18.2	14.9		0.5					0.2	1.6	14.6	5.4		
RECAUSTICIZING	0.5		2.4				0.1	1.1					0.5	4.6	11.2	12.0		12.0
LIME BURNING	0.1	1.0	1.4															
TOTAL kWh/T	6.4	4.0	61.1	2.7	18.2	14.9	0.8	3.8	2.4				1.5	15.4	112.4	63.1	122.3	155.2

(GWh/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS IN KRAFT MILLS IN B.C. (BY PROCESS & SIZE)

PROCESS	ENERGY GWh	MACHINE DRIVE SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	CONVEYORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUP.& TREAT	127							0.4	0.5				
LOG HANDL.& STOR.	5	0.0	1.1	0.6		1.7							
WOOD PREPARATIO	26	0.0	0.3				24.8						
CHIP HANDLING	16							0.2	1.0	4.1	7.0		
CHIP SCREENING	14				4.6			0.2	5.0		1.9		
DIGESTING	76	0.0	0.2	3.4	5.5			0.8	0.3	3.5			
WASHING & SCREEN	132	0.3	1.2	7.2		10.9		0.1	1.4	5.9	5.7	10.0	
EVAPORATORS	49												
CHEMICALS RECOV.	45		2.7					0.8	0.7				
RECAUSTICIZING	36	0.2	1.3	3.1				0.2					
LIME BURNING	10	0.0				5.2		0.2	1.5	1.0			
TOTAL GWh/YR	535	0.6	6.8	14.2	10.1	17.9	24.8	2.8	10.4	14.4	14.5	10.0	

PROCESS	FANS & BLOWERS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	COMPRESSORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	PUMPING SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUP.& TREAT	0.5	0.7	36.8				0.4	1.2					0.2	1.1	4.7	3.8	26.8	50.2
LOG HANDL.& STOR.	0.0							0.2							1.4			
WOOD PREPARATIO	0.1	0.3					0.1	0.2										
CHIP HANDLING														0.3	3.1			
CHIP SCREENING			2.5															
DIGESTING	0.5	0.4							0.7				0.1	2.4	13.8	3.8	7.5	33.3
WASHING & SCREEN	0.6	0.8	0.8	1.9					1.0				0.2	0.9	12.7	10.7	42.9	16.7
EVAPORATORS														1.7	24.9	13.8	8.4	
CHEMICALS RECOV.	2.5				12.8	10.5		0.4					0.1	1.1	10.2	3.8		
RECAUSTICIZING	0.3		1.7				0.1	0.7					0.3	3.3	7.8	8.4		8.4
LIME BURNING	0.1	0.7	1.0															
TOTAL GWh/YR	4.5	2.8	42.7	1.9	12.8	10.5	0.6	2.6	1.7				1.0	10.8	78.7	44.2	85.6	108.6

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW•UTILIZATION FACTOR/TONNES OF FINAL PRODUCT•MOTOR POWER FACTOR)

SEMI BLEACHED KRAFT - 1988 BASE STOCK 383,000 MT/YR (B.C. HYDRO SERVICE AREA)

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
	#MOTOR	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUP.& TREAT	118							15	2					17	5	31				8	8					10	4	5	2	7	4
LOG HANDL.& STOR.	16	1	6	1		1								3							2							2			
WOOD PREPARATIO	19	1	2				3							5	4					2	2										
CHIP HANDLING	24							5	4	5	3																4	3			
CHIP SCREENING	40				3			6	28		1					2															
DIGESTING	74	1	1	3	2			12	1	4				12	4							1				6	9	11	2	2	3
WASHING & SCREEN.	105	7	6	10		3		2	5	7	2	3		8	5	1	1					2				5	5	15	5	11	2
BLEACHING	79	7	4	11		3		2						8	3		2			1	3		1			3	16	8	2	3	2
EVAPORATORS	37																										8	21	6	2	
CHEMICALS RECOV.	112		7					12	3					65				3	1		3					5	3	8	2		
RECAUSTICIZING	74	5	7	6				5						8		2				2	4					8	12	10	4		1
LIME BURNING	24	1				1		4	7	1				4	4	2															
# OF MOTORS	722	23	33	31	5	8	3	63	50	17	6	3		130	25	38	3	3	1	13	22	3	1			37	61	83	23	25	12

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
	HP	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUP.& TREAT	8905							24	33					36	44	2462				27	78					14	76	314	270	1922	3603
LOG HANDL.& STOR.	624	5	136	68		225								3							23							165			
WOOD PREPARATIO	3300	2	31				3198							8	33					7	23										
CHIP HANDLING	1291							12	78	326	601																26	248			
CHIP SCREENING	982				330			17	335		135					165															
DIGESTING	5345	2	11	225	396			54	23	236				31	24							45				10	163	926	270	540	2387
WASHING & SCREEN.	9302	22	83	480		781		8	94	392	405	721		37	56	56	135					66				14	58	851	766	3078	1201
BLEACHING	5584	24	58	525		841		4						27	31		338			3	57		188			9	254	465	360	1197	1201
EVAPORATORS	3371																										111	1668	991	601	
CHEMICALS RECOV.	3166		179					50	44					164				916	751		25					8	73	686	270		
RECAUSTICIZING	2483	13	89	210				12						23		113				7	50					23	218	525	601		601
LIME BURNING	673	2				375		10	101	68				5	47	66															
INSTALLED HP:	45025	69	587	1509	727	2222	3198	191	708	1021	1141	721		334	235	2862	473	916	751	44	254	111	188			78	979	5849	3528	7338	8993

SEMI BLEACHED KRAFT – 1988 BASE STOCK 383,000 MT/YR (B.C. HYDRO SERVICE AREA)

KWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS IN A KRAFT MILL (BY PROCESS & SIZE)

PROCESS	ENERGY	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
	KWh/MT	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUP.& TREAT	179							0.5	0.7					0.8	0.9	51.8				0.6	1.6					0.3	1.6	6.6	5.3	37.7	70.8
LOG HANDL.& STOR.	7	0.1	1.6	0.8		2.5								0.0							0.3							1.9			
WOOD PREPARATIO	36	0.0	0.4				34.9							0.1	0.4					0.1	0.3										
CHIP HANDLING	22							0.2	1.4	5.7	9.8																0.5	4.3			
CHIP SCREENING	20				6.5			0.4	7.0		2.7					3.5															
DIGESTING	107	0.0	0.2	4.7	7.8			1.1	0.5	5.0				0.7	0.5							0.9				0.2	3.4	19.5	5.3	10.6	46.9
WASHING & SCREEN	186	0.5	1.7	10.1		15.3		0.2	2.0	8.2	8.0	14.2		0.8	1.2	1.2	2.7					1.4				0.3	1.2	17.9	15.0	60.4	23.6
BLEACHING	112	0.5	1.2	11.1		16.5		0.1						0.6	0.7		6.6			0.1	1.2		3.7			0.2	5.4	9.8	7.1	23.5	23.6
EVAPORATORS	69																										2.3	35.1	19.5	11.8	
CHEMICALS RECOV.	64		3.8					1.1	0.9					3.5				18.0	14.7		0.5					0.2	1.5	14.4	5.3		
RECAUSTICIZING	51	0.3	1.9	4.4				0.2						0.5		2.4				0.1	1.0					0.5	4.6	11.1	11.8		11.8
LIME BURNING	14	0.0				7.4		0.2	2.1	1.4				0.1	1.0	1.4															
TOTAL kWh/T	866	1.4	10.8	31.1	14.3	41.7	34.9	4.0	14.6	20.3	20.4	14.2		6.9	4.6	60.2	9.3	18.0	14.7	0.9	4.9	2.3	3.7			1.6	20.5	120.6	69.3	144.1	176.6

(GWh/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS IN KRAFT MILLS IN B.C. (BY PROCESS & SIZE)

PROCESS	ENERGY	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
	GWh	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUP.& TREAT	69							0.2	0.3					0.3	0.4	19.8				0.2	0.6					0.1	0.6	2.5	2.0	14.5	27.1
LOG HANDL.& STOR.	3	0.0	0.6	0.3		0.9								0.0							0.1							0.7			
WOOD PREPARATIO	14	0.0	0.1				13.4							0.0	0.1					0.0	0.1										
CHIP HANDLING	8							0.1	0.5	2.2	3.8																0.2	1.7			
CHIP SCREENING	8				2.5			0.1	2.7		1.0					1.3															
DIGESTING	41	0.0	0.1	1.8	3.0			0.4	0.2	1.9				0.3	0.2							0.4				0.1	1.3	7.5	2.0	4.1	18.0
WASHING & SCREEN	71	0.2	0.7	3.9		5.9		0.1	0.8	3.2	3.0	5.4		0.3	0.4	0.4	1.0					0.5				0.1	0.5	6.9	5.8	23.1	9.0
BLEACHING	43	0.2	0.5	4.2		6.3		0.0						0.2	0.2		2.5			0.0	0.5		1.4			0.1	2.1	3.8	2.7	9.0	9.0
EVAPORATORS	26																										0.9	13.4	7.5	4.5	
CHEMICALS RECOV.	24		1.4					0.4	0.4					1.3				6.9	5.6		0.2					0.1	0.6	5.5	2.0		
RECAUSTICIZING	19	0.1	0.7	1.7				0.1						0.2		0.9				0.1	0.4					0.2	1.8	4.2	4.5		4.5
LIME BURNING	5	0.0				2.8		0.1	0.8	0.5				0.0	0.4	0.5															
TOTAL GWh/YR	332	0.5	4.1	11.9	5.5	16.0	13.4	1.5	5.6	7.8	7.8	5.4		2.7	1.8	23.1	3.6	6.9	5.6	0.3	1.9	0.9	1.4			0.6	7.9	46.2	26.5	55.2	67.6

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

FULLY BLEACHED KRAFT – 1988 BASE STOCK 4,060,500 MT/YR (B.C. HYDRO SERVICE AREA)

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL #MOTOR	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUP.& TREAT	1298							165	22					187	55	341				88	88					110	44	55	22	77	44
LOG HANDL.& STOR.	176	11	66	11		11								33							22							22			
WOOD PREPARATIO	209	11	22				33							55	44					22	22										
CHIP HANDLING	253							55	44	55		22															44	33			
CHIP SCREENING	429				22			66	308		11					22															
DIGESTING	805	11	11	24	22			132	11	44				132	44							11				66	99	121	22	22	33
WASHING & SCREEN	1166	77	66	110		33		22	55	77	33	33		88	55	11	11					22				55	55	165	55	121	22
BLEACHING	1723	143	88	231		66		44						176	44	11	55			22	55	11		11		77	352	187	40	66	44
PULP DRYING	3485	198	110	143	64	44		99	11	33				77	1958	44	22	33			77	33				88	99	132	55	132	33
BALE FINISHING	3091	44	66	77				583	187					44	1958		22				44					33	11	22			
EVAPORATORS	407																										88	231	66	22	
CHEMICALS RECOV.	1232		77					132	33					715				33	11		33					55	33	88	22		
RECAUSTICIZING	803	55	77	66				55						88			11			22	44					88	132	110	44		11
LIME BURNING	264	11				11		44	77	11				44	44	22															
# OF MOTORS	15341	561	583	662	108	165	33	1397	748	220	44	55		1639	4202	451	121	66	11	154	385	77		11		572	957	1166	326	440	187

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUP.& TREAT	94692							259	351					385	471	26183				292	830					153	806	3337	2874	20435	38316
LOG HANDL.& STOR.	6634	48	1445	718		2395								33							239							1756			
WOOD PREPARATIO	35095	21	327				34006							81	351					70	239										
CHIP HANDLING	13724							129	830	3464		6386															279	2634			
CHIP SCREENING	10443				3512			177	3560		1437					1756															
DIGESTING	56835	18	120	2395	4215			575	247	2507				330	255							479				106	1732	9850	2874	5747	25385
WASHING & SCREEN	98917	235	878	5109		8302		83	998	4167	4311	7663		393	591	591	1437					702				148	615	9052	8142	32729	12772
BLEACHING	118738	512	1237	11176		17881		81						572	351	295	7184			70	854	351		3991		198	5412	9898	7663	25464	25544
PULP DRYING	175099	910	1319	6402	12581	16300		378	160	1996				151	31004	2507	3512	7663			1581	2634				292	1940	6769	8493	37853	30653
BALE FINISHING	45143	168	679	6705				1031	1589					30	31004		2395				655					10	176	702			
EVAPORATORS	35842																										1181	17737	10537	6386	
CHEMICALS RECOV.	33664		1900					535	471					1748				9739	7983		263					81	774	7296	2874		
RECAUSTICIZING	26403	137	950	2235				126						246			1197			70	527					239	2315	5588	6386		6386
LIME BURNING	7157	18				3991		107	1070	718				48	503	702															
INSTALLED HP:	758386	2066	8854	34740	20308	48869	34006	3482	9276	12852	5747	14049		4015	64531	32034	15726	17402	7983	503	5189	4167		3991		1229	15231	74621	49843	128615	139056

TEMANEX CONSULTING INC.

FULLY BLEACHED KRAFT – 1988 BASE STOCK 4,060,500 MT/YR (B.C. HYDRO SERVICE AREA)

KWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS IN A KRAFT MILL (BY PROCESS & SIZE)

PROCESS	ENERGY kWh/MT	MACHINE DRIVE SIZE 1	MACHINE DRIVE SIZE 2	MACHINE DRIVE SIZE 3	MACHINE DRIVE SIZE 4	MACHINE DRIVE SIZE 5	MACHINE DRIVE SIZE 6	CONVEYORS SIZE 1	CONVEYORS SIZE 2	CONVEYORS SIZE 3	CONVEYORS SIZE 4	CONVEYORS SIZE 5	CONVEYORS SIZE 6
WATER SUP.& TREAT	180							0.5	0.7				
LOG HANDL.& STOR.	7	0.1	1.6	0.8		2.5							
WOOD PREPARATIO	36	0.0	0.4				35.0						
CHIP HANDLING	32							0.2	1.4	5.7	9.9	9.9	
CHIP SCREENING	20				6.5			0.4	7.1		2.7		
DIGESTING	108	0.0	0.2	4.8	7.8			1.1	0.5	5.0			
WASHING & SCREEN	186	0.5	1.7	10.1		15.4		0.2	2.0	8.3	8.0	14.2	
BLEACHING	224	1.0	2.5	22.2		33.1		0.2					
PULP DRYING	332	1.8	2.6	12.7	23.3	30.2		0.8	0.3	4.0			
BALE FINISHING	94	0.3	1.3	13.3				2.0	3.2				
EVAPORATORS	69												
CHEMICALS RECOV.	64		3.8					1.1	0.9				
RECAUSTICIZING	53	0.3	1.9	4.4				0.3					
LIME BURNING	14	0.0				7.4		0.2	2.1	1.4			
TOTAL kWh/T	1418	4.0	16.0	68.3	37.6	88.5	35.0	6.9	18.1	24.4	20.5	24.0	

PROCESS	FANS & BLOWERS SIZE 1	FANS & BLOWERS SIZE 2	FANS & BLOWERS SIZE 3	FANS & BLOWERS SIZE 4	FANS & BLOWERS SIZE 5	FANS & BLOWERS SIZE 6	COMPRESSORS SIZE 1	COMPRESSORS SIZE 2	COMPRESSORS SIZE 3	COMPRESSORS SIZE 4	COMPRESSORS SIZE 5	COMPRESSORS SIZE 6	PUMPING SIZE 1	PUMPING SIZE 2	PUMPING SIZE 3	PUMPING SIZE 4	PUMPING SIZE 5	PUMPING SIZE 6
WATER SUP.& TREAT	0.8	0.9	52.0				0.6	1.6					0.3	1.6	6.6	5.3	37.8	71.0
LOG HANDL.& STOR.	0.0							0.3							1.9			
WOOD PREPARATIO	0.1	0.4					0.1	0.3										
CHIP HANDLING														0.5	4.4			
CHIP SCREENING			3.5															
DIGESTING	0.7	0.5							1.0				0.2	3.4	19.5	5.3	10.6	47.0
WASHING & SCREEN	0.8	1.2	1.2	2.7					1.4				0.3	1.2	18.0	15.1	60.6	23.7
BLEACHING	1.1	0.7	0.6	13.3			0.1	1.7	0.7		7.4		0.4	10.7	19.6	14.2	47.2	47.3
PULP DRYING	0.3	61.5	5.0	6.5	14.2			3.1	5.2				0.6	3.8	13.4	15.7	70.1	56.8
BALE FINISHING	0.1	61.5	4.8	4.4				1.3					0.0	0.3	1.4			
EVAPORATORS														2.3	35.2	19.5	11.8	
CHEMICALS RECOV.	3.5				18.0	14.8		0.5					0.2	1.5	14.5	5.3		
RECAUSTICIZING	0.5		2.4	2.2			0.1	1.0					0.5	4.6	11.1	11.8		11.8
LIME BURNING	0.1	1.0	1.4															
TOTAL kWh/T	7.9	127.7	70.7	29.1	32.2	14.8	0.9	9.9	8.3		7.4		2.4	30.1	145.6	92.3	238.2	257.5

(GWh/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS IN KRAFT MILLS IN B.C. (BY PROCESS & SIZE)

PROCESS	ENERGY GWh	MACHINE DRIVE SIZE 1	MACHINE DRIVE SIZE 2	MACHINE DRIVE SIZE 3	MACHINE DRIVE SIZE 4	MACHINE DRIVE SIZE 5	MACHINE DRIVE SIZE 6	CONVEYORS SIZE 1	CONVEYORS SIZE 2	CONVEYORS SIZE 3	CONVEYORS SIZE 4	CONVEYORS SIZE 5	CONVEYORS SIZE 6
WATER SUP.& TREAT	730							2.1	2.8				
LOG HANDL.& STOR.	29	0.2	6.5	3.2		10.0							
WOOD PREPARATIO	147	0.1	1.5				142.1						
CHIP HANDLING	129							0.9	5.6	23.3	40.0	40.0	
CHIP SCREENING	81				26.4			1.4	28.7		10.8		
DIGESTING	437	0.1	1.0	19.3	31.7			4.6	2.0	20.2			
WASHING & SCREEN	756	1.9	7.1	41.2		62.4		0.7	8.0	33.6	32.4	57.6	
BLEACHING	910	4.1	10.0	90.0		134.5		0.7					
PULP DRYING	1348	7.3	10.6	51.6	94.6	122.6		3.0	1.3	16.1			
BALE FINISHING	382	1.4	5.5	54.0				8.3	12.8				
EVAPORATORS	280												
CHEMICALS RECOV.	260		15.3					4.3	3.8				
RECAUSTICIZING	215	1.1	7.7	18.0				1.0					
LIME BURNING	56	0.1				30.0		0.9	8.6	5.8			
TOTAL GWh/YR	5760	16.4	65.0	277.3	152.7	359.5	142.1	27.9	73.6	98.9	83.2	97.6	

PROCESS	FANS & BLOWERS SIZE 1	FANS & BLOWERS SIZE 2	FANS & BLOWERS SIZE 3	FANS & BLOWERS SIZE 4	FANS & BLOWERS SIZE 5	FANS & BLOWERS SIZE 6	COMPRESSORS SIZE 1	COMPRESSORS SIZE 2	COMPRESSORS SIZE 3	COMPRESSORS SIZE 4	COMPRESSORS SIZE 5	COMPRESSORS SIZE 6	PUMPING SIZE 1	PUMPING SIZE 2	PUMPING SIZE 3	PUMPING SIZE 4	PUMPING SIZE 5	PUMPING SIZE 6
WATER SUP.& TREAT	3.1	3.8	211.0				2.4	6.7					1.2	6.5	26.9	21.6	153.7	288.1
LOG HANDL.& STOR.	0.1							1.1							7.9			
WOOD PREPARATIO	0.4	1.6					0.3	1.1										
CHIP HANDLING														1.9	17.7			
CHIP SCREENING			14.1															
DIGESTING	2.7	2.1							3.9				0.9	14.0	79.4	21.6	43.2	190.9
WASHING & SCREEN	3.2	4.8	4.8	10.8					5.7				1.2	5.0	72.9	61.2	246.1	96.0
BLEACHING	4.6	2.8	2.4	54.0			0.6	6.9	2.8		30.0		1.6	43.6	79.7	57.6	191.5	192.1
PULP DRYING	1.2	249.8	20.2	26.4	57.6			12.7	21.2				2.4	15.6	54.5	63.9	284.6	230.5
BALE FINISHING	0.2	249.8	19.3	18.0				5.3					0.1	1.4	5.7			
EVAPORATORS														9.5	142.9	79.2	48.0	
CHEMICALS RECOV.	14.1				73.2	60.0		2.1					0.7	6.2	58.8	21.6		
RECAUSTICIZING	2.0		9.6	9.0			0.6	4.2					1.9	18.7	45.0	48.0		48.0
LIME BURNING	0.4	4.1	5.7															
TOTAL GWh/YR	31.9	518.7	287.0	118.3	130.9	60.0	3.8	40.1	33.6		30.0		9.9	122.3	591.4	374.8	967.2	1045.7

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW•UTILIZATION FACTOR/TONNES OF FINAL PRODUCT•MOTOR POWER FACTOR)

TEMANEX CONSULTING INC.

SEMICHEMICAL PULP – 1988 BASE STOCK 100,000 MT/YR

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL #MOTORS	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
WATER SUPPLY & TREAT.	32							4	1					5	1	8				2	2					3	1	2		2	1
LOG HANDLING	9	1	3	2										1							1							1			
WOOD PREP.	6	1	1				1							1						1	1										
CHIP HANDLING	6							1	1	1	1																1	1			
CHIP SCREENING	14			1				2	9	1						1															
DIGESTING & REF.	22	2		1	1		1	3	1	1					1						1					2	2	3	2		1
WASHING & SCR.	27	2	1	2	1			1	1	2	1			2	1	2					1					1	1	4	1	3	
EVAPORATORS	9																										2	5	2		
CHEMICAL RECOVERY	30		2					3	1					16				2			1					1	1	3			
RECAUSTICIZING	20	1	2	1				1						2		1				1	2					2	3	3	1		
LIME BURNING	9	1		1				1	2	1				1	2																
# OF MOTORS	184	8	9	8	2		2	16	16	6	2			28	5	12		2		4	9					9	11	22	6	5	2

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
WATER SUPPLY & TREAT.	2282							3	17					4	12	645				7	20					4	20	150		500	900
LOG HANDLING	155	1	51	55										1							7							40			
WOOD PREP.	826	1	8				800							2	8					1	6										
CHIP HANDLING	330							3	20	85	150																7	65			
CHIP SCREENING	252			85				4	83	35						40															
DIGESTING & REF.	7247	4		50	101		6000	12	6	53				7	6						10					2	36	207	220		533
WASHING & SCR.	2276	5	20	120	195			2	23	200	180			9	14	60					17					3	15	212	201	1000	
EVAPORATORS	867																										27	400	440		
CHEMICAL RECOVERY	780		50					12	10					41				400			7					2	18	240			
RECAUSTICIZING	622	3	22	52				3	1					6		28				2	14					6	55	280	150		
LIME BURNING	183	1		100				2	25	26				1	28																
TOTAL INSTALLED HP:	15820	15	151	462	296		6800	41	190	399	330			71	68	773		400		10	81					17	178	1594	1011	1500	1433

TEMANEX CONSULTING INC.

SEMICHEMICAL PULP – 1988 BASE STOCK 100,000 MT/YR

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS

PROCESS	TOTAL ENERGY kWh/MT	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT	SIZE 1 kWh	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh	SIZE 1 kWh	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT	SIZE 1 kWh	SIZE 2 kWh/MT	SIZE 3 kWh	SIZE 4 kWh	SIZE 5 kWh/MT	SIZE 6 kWh	SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT
WATER SUPPLY & TREAT.	176							0.2	1.4					0.3	1.0	52.0				0.6	1.6					0.3	1.6	12.1		37.6	67.7
LOG HANDLING	7	0.0	2.3	2.5										0.0							0.3							1.8			
WOOD PREP.	35	0.0	0.4				33.4							0.1	0.4					0.0	0.3										
CHIP HANDLING	21							0.2	1.3	5.7	9.4																0.5	4.4			
CHIP SCREENING	20			6.9				0.3	7.1	2.8						3.2															
DIGESTING & REF.	547	0.3		4.1	7.6		451.4	1.0	0.5	4.2				0.6	0.5						0.8					0.2	2.9	16.7	16.5		40.1
WASHING & SCR.	175	0.4	1.6	9.7	14.7			0.2	1.9	16.1	13.5			0.7	1.1	4.8					1.4					0.2	1.2	17.1	15.1	75.2	
EVAPORATORS	68																										2.2	32.2	33.1		
CHEMICAL RECOVERY	61		4.0					1.0	0.8					3.3				30.1			0.6					0.2	1.5	19.3			
RECAUSTICIZING	49	0.2	1.8	4.2				0.2	0.1					0.5		2.3				0.2	1.1					0.5	4.4	22.6	11.3		
LIME BURNING	15	0.1		8.1				0.2	2.0	2.1				0.1	2.3																
ENERGY(kWh/MT)	1174	1	10	35	22		485	3	15	31	23			6	5	62		30		1	6					1	14	126	76	113	108

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS (BY PROCESS & SIZE)

PROCESS	TOTAL ENERGY GWH/YR	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 GWH/Y	SIZE 2 GWH/Y	SIZE 3 GWH/Y	SIZE 4 GWH/Y	SIZE 5 GWH/YR	SIZE 6 GWH/YR	SIZE 1 GWH	SIZE 2 GWH/Y	SIZE 3 GWH/Y	SIZE 4 GWH/YR	SIZE 5 GWH/Y	SIZE 6 GWH	SIZE 1 GWH	SIZE 2 GWH/Y	SIZE 3 GWH/Y	SIZE 4 GWH/YR	SIZE 5 GWH/Y	SIZE 6 GWH/Y	SIZE 1 GWH	SIZE 2 GWH/Y	SIZE 3 GWH	SIZE 4 GWH	SIZE 5 GWH/Y	SIZE 6 GWH	SIZE 1 GWH/Y	SIZE 2 GWH/Y	SIZE 3 GWH/YR	SIZE 4 GWH/YR	SIZE 5 GWH/YR	SIZE 6 GWH/YR
WATER SUPPLY & TREAT.	17.6							0.0	0.1					0.0	0.1	5.2				0.1	0.2					0.0	0.2	1.2		3.8	6.8
LOG HANDLING	0.7	0.0	0.2	0.2										0.0							0.0							0.2			
WOOD PREP.	3.5	0.0	0.0				3.3							0.0	0.0					0.0	0.0										
CHIP HANDLING	2.1							0.0	0.1	0.6	0.9																0.0	0.4			
CHIP SCREENING	2.0			0.7				0.0	0.7	0.3						0.3															
DIGESTING & REF.	54.7	0.0		0.4	0.8		45.1	0.1	0.0	0.4				0.1	0.0						0.1					0.0	0.3	1.7	1.7		4.0
WASHING & SCR.	17.5	0.0	0.2	1.0	1.5			0.0	0.2	1.6	1.4			0.1	0.1	0.5					0.1					0.0	0.1	1.7	1.5	7.5	
EVAPORATORS	6.8																										0.2	3.2	3.3		
CHEMICAL RECOVERY	6.1		0.4					0.1	0.1					0.3				3.0			0.1					0.0	0.1	1.9			
RECAUSTICIZING	4.9	0.0	0.2	0.4				0.0	0.0					0.0		0.2				0.0	0.1					0.0	0.4	2.3	1.1		
LIME BURNING	1.5	0.0		0.8				0.0	0.2	0.2				0.0	0.2																
ENERGY(GWh/YR)	117.4	0	1	4	2		48	0	2	3	2			1	1	6		3		0	1					0	1	13	8	11	11

TEMANEX CONSULTING INC.

NEWSPRINT – 1988 BASE STOCK 1,915000 MT/YR (B.C.HYDRO SERVICE AREA)

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL # MOT.	MACHINE DRIVE						CONVEYORS					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
CLEANING & SCREENING	273	28	28	77									
FORMING	28			7			21						
PRESSING	34					6	28						
DRYING	14						14						
CALENDERING	13					6	7						
AUXILIARY SYSTEMS	1414							35	21				
WINDING AND PACKAGING	448	77	28	7				49	21				
# OF MOTORS	2224	105	56	91		12	70	84	42				

PROCESS	FANS & BLOWERS						COMPRESSORS						PUMPING					
	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
CLEANING & SCREENING	7												35	42	56			
FORMING																		
PRESSING																		
DRYING																		
CALENDERING																		
AUXILIARY SYSTEMS	98	126	49	105	14		21	126			28		175	350	119		112	35
WINDING AND PACKAGING	63	21	7				21	21						70	63			
# OF MOTORS	168	147	56	105	14		42	147			28		210	462	238		112	35

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
CLEANING & SCREENING	10824	69	692	4844									
FORMING	14070			494			13575						
PRESSING	17134					1318	15816						
DRYING	7908						7908						
CALENDERING	4613					1318	3295						
AUXILIARY SYSTEMS	88135							152	152				
WINDING AND PACKAGING	5035	132	217	231				132	250				
TOTAL INSTALLED HP:	147718	201	909	5569		2636	40594	283	402				

PROCESS	FANS & BLOWERS						COMPRESSORS						PUMPING					
	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
CLEANING & SCREENING	16												63	626	4514			
FORMING																		
PRESSING																		
DRYING																		
CALENDERING																		
AUXILIARY SYSTEMS	178	1865	2353	11697	3295		72	1898			6590		600	4534	6148		28831	19770
WINDING AND PACKAGING	132	297	395				99	185						989	1977			
TOTAL INSTALLED HP:	326	2162	2748	11697	3295		171	2082			6590		662	6148	12640		28831	19770

NEWSPRINT – 1988 BASE STOCK 1,915000 MT/YR (B.C.HYDRO SERVICE AREA)

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS IN A NEWSPRINT MILL

PROCESS	TOTAL ENERGY kWh/MT	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
		kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT
CLEANING & SCREENING	45.5	0.3	2.9	20.4										0.1												0.3	2.6	19.0			
FORMING	55.4			2.1			53.3																								
PRESSING	67.3					5.2	62.1																								
DRYING	31.0						31.0																								
CALENDERING	18.1					5.2	12.9																								
AUXILIARY SYSTEMS	351.1							0.6	0.6					0.7	7.8	9.9	45.9	12.9		0.3	8.0			25.9		2.5	19.1	25.9		113.2	77.6
WINDING AND PACKAGING	21.2	0.6	0.9	1.0				0.6	1.1					0.6	1.2	1.7				0.4	0.8						4.2	8.3			
ENERGY(kWh/MT)	589.6	0.8	3.8	23.4		10.3	159.4	1.2	1.7					1.4	9.1	11.6	45.9	12.9		0.7	8.8			25.9		2.8	25.9	53.2		113.2	77.6

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS IN NEWSPRINT MILLS IN B.C. (BY PROCESS & SIZE)

PROCESS	TOTAL ENERGY GWH/YR	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
		GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR	GWh/YR
CLEANING & SCREENING	87.2	0.6	5.6	39.0										0.1												0.5	5.0	36.4			
FORMING	106.1			4.0			102.1																								
PRESSING	128.8					9.9	118.9																								
DRYING	59.5						59.5																								
CALENDERING	34.7					9.9	24.8																								
AUXILIARY SYSTEMS	672.3							1.2	1.2					1.4	15.0	19.0	88.0	24.8		0.6	15.3			49.5		4.8	36.5	49.5		216.8	148.6
WINDING AND PACKAGING	40.6	1.1	1.8	1.9				1.1	2.0					1.1	2.4	3.2				0.8	1.5						8.0	15.9			
ENERGY(GWh/YR)	1129.1	1.6	7.3	44.9		19.8	305.2	2.3	3.2					2.6	17.4	22.1	88.0	24.8		1.4	16.8			49.5		5.3	49.5	101.8		216.8	148.6

TEMANEX CONSULTING INC.

UNTREATED LINERBOARD – 1988 BASE STOCK 700,000 MT/YR

NUMBER OF MOTORS BY SIZE .

PROCESS	TOTAL #MOTORS	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
REFINING & BEATING	48	6		9	3	3	6																			3		15	3		
CLEANING & SCR.	117	12	12	33										3												15	18	24			
FORMING	16			14	2																										
PRESSING	12			8	4																										
DRYING & CAL.	18		2	10	6																										
AUX. SYSTEMS	363							10	6					28	36	14	30	4		6	36			8		50	50	34	45	6	
WINDING & PACK	177	9	8	4				28	5					27	3	1				9	3						30	45	5		
# OF MOTORS	751	27	22	78	15	3	6	38	11					58	39	15	30	4		15	39			8		68	98	118	53	6	

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
REFINING & BEATING	11155	7		600	375	1500	7200																			3		1020	450		
CLEANING & SCR.	3958	25	253	1771										6												23	229	1651			
FORMING	1170			870	300																										
PRESSING	1330			530	800																										
DRYING & CAL.	1340		40	400	900																										
AUX. SYSTEMS	22536							46	45					54	565	750	3000	1000		22	575			2000		181	688	1860	8750	3000	
WINDING & PACK	3654	17	60	200				80	60					59	45	60				45	28						450	1800	750		
TOTAL INSTALLED HP:	45143	49	353	4371	2375	1500	7200	126	105					119	610	810	3000	1000		67	603			2000		207	1367	6331	9950	3000	

TEMANEX CONSULTING INC.

UNTREATED LINERBOARD – 1988 BASE STOCK 700,000 MT/YR

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS

PROCESS	TOTAL ENERGY kWh/MT	MACHINE DRIVE SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT	CONVEYORS SIZE 1 kW	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kW
REFINING & BEATING	121	0.1		6.9	4.0	16.1	77.3						
CLEANING & SCR.	46	0.3	2.9	20.4									
FORMING	13			10.0	3.2								
PRESSING	15			6.1	8.6								
DRYING & CAL.	15		0.5	4.6	9.7								
AUX. SYSTEMS	246							0.5	0.5				
WINDING & PACK.	41	0.2	0.7	2.3				0.9	0.7				
ENERGY(kWh/MT)	497	1	4	50	26	16	77	1	1				

PROCESS	FANS & BLOWERS SIZE 1 kW	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kW	COMPRESSORS SIZE 1 kW	SIZE 2 kWh/MT	SIZE 3 kW	SIZE 4 kW	SIZE 5 kWh/MT	SIZE 6 kW
REFINING & BEATING												
CLEANING & SCR.	0.1											
FORMING												
PRESSING												
DRYING & CAL.												
AUX. SYSTEMS	0.6	6.5	8.6	32.2	10.7		0.3	6.6			21.5	
WINDING & PACK.	0.7	0.5	0.7				0.5	0.3				
ENERGY(kWh/MT)	1	7	9	32	11		1	7			21	

PROCESS	PUMPING SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT
REFINING & BEATING	0.0		11.7	4.8		
CLEANING & SCR.	0.3	2.6	19.0			
FORMING						
PRESSING						
DRYING & CAL.						
AUX. SYSTEMS	2.1	7.9	21.4	94.0	32.2	
WINDING & PACK.		5.2	20.7	8.1		
ENERGY(kWh/MT)	2	16	73	107	32	

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW•UTILIZATION FACTOR/TONNES OF FINAL PRODUCT•MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS (BY PROCESS & SIZE)

PROCESS	TOTAL ENERGY GWH/YR	MACHINE DRIVE SIZE 1 GWH/Y	SIZE 2 GWH/Y	SIZE 3 GWH/Y	SIZE 4 GWH/Y	SIZE 5 GWH/Y	SIZE 6 GWH/YR	CONVEYORS SIZE 1 GWH	SIZE 2 GWH/Y	SIZE 3 GWH/Y	SIZE 4 GWH/YR	SIZE 5 GWH/Y	SIZE 6 GWH
REFINING & BEATING	84.8	0.1		4.8	2.8	11.3	54.1						
CLEANING & SCR.	31.9	0.2	2.0	14.3									
FORMING	9.3			7.0	2.3								
PRESSING	10.3			4.3	6.0								
DRYING & CAL.	10.3		0.3	3.2	6.8								
AUX. SYSTEMS	172.0							0.4	0.4				
WINDING & PACK.	29.0	0.1	0.5	1.6				0.6	0.5				
ENERGY(GWH/YR)	347.6	0.4	2.8	35.2	17.9	11.3	54.1	1.0	0.8				

PROCESS	FANS & BLOWERS SIZE 1 GWH	SIZE 2 GWH/Y	SIZE 3 GWH/Y	SIZE 4 GWH/YR	SIZE 5 GWH/Y	SIZE 6 GWH	COMPRESSORS SIZE 1 GWH	SIZE 2 GWH/Y	SIZE 3 GWH	SIZE 4 GWH	SIZE 5 GWH/Y	SIZE 6 GWH
REFINING & BEATING												
CLEANING & SCR.	0.0											
FORMING												
PRESSING												
DRYING & CAL.												
AUX. SYSTEMS	0.4	4.6	6.0	22.6	7.5		0.2	4.6			15.0	
WINDING & PACK.	0.5	0.4	0.5				0.4	0.2				
ENERGY(GWH/YR)	1.0	4.9	6.5	22.6	7.5		0.5	4.9			15.0	

PROCESS	PUMPING SIZE 1 GWH/Y	SIZE 2 GWH/Y	SIZE 3 GWH/YR	SIZE 4 GWH/YR	SIZE 5 GWH/YR	SIZE 6 GWH/YR
REFINING & BEATING	0.0		8.2	3.4		
CLEANING & SCR.	0.2	1.8	13.3			
FORMING						
PRESSING						
DRYING & CAL.						
AUX. SYSTEMS	1.5	5.5	15.0	65.8	22.6	
WINDING & PACK.		3.6	14.5	5.6		
ENERGY(GWH/YR)	1.7	11.0	51.0	74.8	22.6	

UNCOATED WOODFREE – 1988 BASE STOCK 135,000 MT/YR

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL #MOTORS	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
REFINING & BEATING	16	2		3	1	1	2																			1		5	1		
CLEANING & SCR.	20	2	2	6										1												3	3	4			
FORMING	8			8																											
PRESSING	6			4	2																										
DRYING & CAL.	12		1	10	1																										
AUX. SYSTEMS	144							5	3					14	10	4	5	2		3	18			2		13	50	7	6	2	
WINDING & PACK.	42	8	1	1				7						6	3	1				3	2						10				
# OF MOTORS	248	12	4	32	4	1	2	12	3					21	13	5	5	2		6	20			2		17	63	16	7	2	

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
REFINING & BEATING	3318	2		200	125	500	2000																			1		340	150		
CLEANING & SCR.	764	5	49	342										1												4	44	319			
FORMING	525			525																											
PRESSING	515			265	250																										
DRYING & CAL.	701		20	580	101																										
AUX. SYSTEMS	5460							23	23					27	160	225	525	500		11	288			500		45	688	370	1075	1000	
WINDING & PACK.	368	16	8	20				20						16	45	60				15	18						150				
TOTAL INSTALLED HP:	11651	23	77	1932	476	500	2000	43	23					44	205	285	525	500		26	306			500		50	882	1029	1225	1000	

TEMANEX CONSULTING INC.

UNCOATED WOODFREE – 1988 BASE STOCK 135,000 MT/YR

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS

PROCESS	TOTAL ENERGY	MACHINE DRIVE						CONVEYORS					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kW	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kW
REFINING & BEATING	187	0.1		11.9	7.0	27.9	111.4						
CLEANING & SCR.	46	0.3	2.9	20.4									
FORMING	31			31.3									
PRESSING	30			15.8	13.9								
DRYING & CAL.	41		1.2	34.6	5.6								
AUX. SYSTEMS	312							1.4	1.4				
WINDING & PACK.	22	1.0	0.5	1.2				1.2					
ENERGY(kWh/MT)	669	1	5	115	27	28	111	3	1				

PROCESS	FANS & BLOWERS						COMPRESSORS						PUMPING					
	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
	kW	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kW	kW	kWh/MT	kW	kW	kWh/MT	kW	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT	kWh/MT
REFINING & BEATING													0.1		20.3	8.4		
CLEANING & SCR.	0.1												0.3	2.6	19.0			
FORMING																		
PRESSING																		
DRYING & CAL.																		
AUX. SYSTEMS	1.6	9.5	13.4	29.2	27.9		0.7	17.2			27.9		2.7	41.1	22.1	59.9	55.7	
WINDING & PACK.	1.0	2.7	3.6				0.9	1.1						9.0				
ENERGY(kWh/MT)	3	12	17	29	28		2	18			28		3	53	61	68	56	

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS (BY PROCESS & SIZE)

PROCESS	TOTAL ENERGY	MACHINE DRIVE						CONVEYORS					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
	GWH/YR	GWH/Y	GWH/Y	GWH/Y	GWH/Y	GWH/Y	GWH/YR	GWH	GWH/Y	GWH/Y	GWH/YR	GWH/Y	GWH
REFINING & BEATING	25.2	0.0		1.6	0.9	3.8	15.0						
CLEANING & SCR.	6.2	0.0	0.4	2.8									
FORMING	4.2			4.2									
PRESSING	4.0			2.1	1.9								
DRYING & CAL.	5.6		0.2	4.7	0.8								
AUX. SYSTEMS	42.1							0.2	0.2				
WINDING & PACK.	3.0	0.1	0.1	0.2				0.2					
ENERGY(GWH/YR)	90.3	0.2	0.6	15.6	3.6	3.8	15.0	0.3	0.2				

PROCESS	FANS & BLOWERS						COMPRESSORS						PUMPING					
	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
	GWH	GWH/Y	GWH/Y	GWH/YR	GWH/Y	GWH	GWH	GWH/Y	GWH	GWH	GWH/Y	GWH	GWH/Y	GWH/Y	GWH/YR	GWH/YR	GWH/YR	GWH/YR
REFINING & BEATING													0.0		2.7	1.1		
CLEANING & SCR.	0.0												0.0	0.4	2.6			
FORMING																		
PRESSING																		
DRYING & CAL.																		
AUX. SYSTEMS	0.2	1.3	1.8	3.9	3.8		0.1	2.3			3.8		0.4	5.5	3.0	8.1	7.5	
WINDING & PACK.	0.1	0.4	0.5				0.1	0.1						1.2				
ENERGY(GWH/YR)	0.4	1.7	2.3	3.9	3.8		0.2	2.5			3.8		0.4	7.1	8.3	9.2	7.5	

TISSUE – 1988 BASE STOCK 90,000 MT/YR

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL #MOTORS	MACHINE DRIVE SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
REFINING & BEATING	28	4		8			4
CLEANING & SCR.	32	8	16				
FORMING	16			4		12	
PRESSING	16			16			
DRYING	4					4	
AUX. SYSTEMS	117						
WINDING & PACK.	118	16	4	4			
# OF MOTORS	331	28	20	32		16	4

PROCESS	CONVEYORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	FANS & BLOWERS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
REFINING & BEATING												
CLEANING & SCR.												
FORMING												
PRESSING												
DRYING												
AUX. SYSTEMS	4	4					8	8	4	3		
WINDING & PACK.	12	6					24	20	4			
# OF MOTORS	16	10					32	28	8	3		

PROCESS	COMPRESSORS SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	PUMPING SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
REFINING & BEATING												
CLEANING & SCR.							4		8			
FORMING							4	4				
PRESSING												
DRYING												
AUX. SYSTEMS	4	12	4				8	50	4	4		
WINDING & PACK.	4	4						12	8			
# OF MOTORS	8	16	4				16	66	20	4		

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
REFINING & BEATING	5309	5		600			4000
CLEANING & SCR.	540	16	440				
FORMING	3480			280		3200	
PRESSING	1200			1200			
DRYING & CAL.	1800					1800	
AUX. SYSTEMS	3002						
WINDING & PACK.	920	64	60	120			
TOTAL INSTALLED HP:	16251	85	500	2200		5000	4000

PROCESS	CONVEYORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	FANS & BLOWERS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
REFINING & BEATING												
CLEANING & SCR.												
FORMING												
PRESSING												
DRYING & CAL.												
AUX. SYSTEMS	20	30					12	100	200	400		
WINDING & PACK.	20	38					20	45	60			
TOTAL INSTALLED HP:	40	68					32	145	260	400		

PROCESS	COMPRESSORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	PUMPING SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
REFINING & BEATING												
CLEANING & SCR.							4		700			
FORMING							4	80				
PRESSING												
DRYING & CAL.												
AUX. SYSTEMS	12	200	400				40	688	400	500		
WINDING & PACK.	15	28						150	300			
TOTAL INSTALLED HP:	27	228	400				48	918	1400	500		

TEMANEX CONSULTING INC.

TISSUE – 1988 BASE STOCK 90,000 MT/YR

kWh/MT ENERGY PER METRIC TONNE OF FINISHED PRODUCT CONSUMED BY MOTORS

PROCESS	TOTAL ENERGY kWh/MT	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT	SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT	SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT	SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT	SIZE 1 kWh/MT	SIZE 2 kWh/MT	SIZE 3 kWh/MT	SIZE 4 kWh/MT	SIZE 5 kWh/MT	SIZE 6 kWh/MT
REFINING & BEATING	452	0.4		53.7			334.3																			0.4		62.7			
CLEANING & SCR.	48	1.4	39.4																							0.4	7.2				
FORMING	293			25.1		267.5																									
PRESSING	107			107.5																											
DRYING & CAL.	150					150.5																									
AUX. SYSTEMS	263							1.8	2.7					1.1	9.0	17.9	33.4			1.1	17.9	35.8				3.6	61.6	35.8	41.8		
WINDING & PACK.	29	2.0	1.9	3.8				0.6	1.2					0.6	1.4	1.9				0.5	0.9						4.8	9.6			
ENERGY(kWh/MT)	1343	4	41	190		418	334	2	4					2	10	20	33			2	19	36				4	74	108	42		

(ENERGY PER METRIC TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

(GWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS (BY PROCESS & SIZE)

PROCESS	TOTAL ENERGY GWH/YR	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 GWH/YR	SIZE 2 GWH/YR	SIZE 3 GWH/YR	SIZE 4 GWH/YR	SIZE 5 GWH/YR	SIZE 6 GWH/YR	SIZE 1 GWH/YR	SIZE 2 GWH/YR	SIZE 3 GWH/YR	SIZE 4 GWH/YR	SIZE 5 GWH/YR	SIZE 6 GWH/YR	SIZE 1 GWH/YR	SIZE 2 GWH/YR	SIZE 3 GWH/YR	SIZE 4 GWH/YR	SIZE 5 GWH/YR	SIZE 6 GWH/YR	SIZE 1 GWH/YR	SIZE 2 GWH/YR	SIZE 3 GWH/YR	SIZE 4 GWH/YR	SIZE 5 GWH/YR	SIZE 6 GWH/YR	SIZE 1 GWH/YR	SIZE 2 GWH/YR	SIZE 3 GWH/YR	SIZE 4 GWH/YR	SIZE 5 GWH/YR	SIZE 6 GWH/YR
REFINING & BEATING	40.6	0.0		4.8			30.1																			0.0		5.6			
CLEANING & SCR.	4.4	0.1	3.5																							0.0	0.6				
FORMING	26.3			2.3		24.1																									
PRESSING	9.7			9.7																											
DRYING & CAL.	13.5					13.5																									
AUX. SYSTEMS	23.7							0.2	0.2					0.1	0.8	1.6	3.0			0.1	1.6	3.2				0.3	5.5	3.2	3.8		
WINDING & PACK.	2.6	0.2	0.2	0.3				0.1	0.1					0.1	0.1	0.2				0.0	0.1						0.4	0.9			
ENERGY(GWH/YR)	120.9	0.4	3.7	17.1		37.6	30.1	0.2	0.4					0.2	0.9	1.8	3.0			0.1	1.7	3.2				0.4	6.6	9.7	3.8		

Appendix C

Pulp and Paper Process Technologies

ISTUM-I Code	Technology Description
Chemical Digesters	
KR BA	Kraft batch digester
KR BA CC	Kraft batch digester with computer control and secondary effluent treatment
KR BA BH	Kraft batch digester with blow heat recovery
KR BA ALL	Kraft batch digester with CC and BH and secondary effluent treatment
KR CO	Kraft continuous digester
KR CO CC	Kraft continuous digester with computer control and secondary effluent treatment
NS BA	Neutral sulphite batch digester
NS BA CC	Neutral sulphite batch digester with computer control and secondary effluent treatment
NS BA BH	Neutral sulphite batch digester with blow heat recovery
NS BA ALL	Neutral sulphite batch digester with CC and BH and secondary effluent treatment
NS CO	Neutral sulphite continuous digester
NS CO CC	Neutral sulphite continuous digester with computer control and secondary effluent treatment
Mechanical Grinders/Refiners	
TMP I	Size one TMP refiner
TMP I SVR	Size one TMP refiner with small electric vapour recompression
GRO	Stone groundwood grinder
RMP	Refiner mechanical pulp
TMP II	Size two TMP refiner
TMP IIHSR	Size two TMP refiner with high speed refiner
TMP IILVR	Size two TMP refiner with large electric vapour recompression
TMP IIVRHS	Size two TMP refiner with electric vapour recompression and high speed refiner
C/TMP EXPL	Explosion C/TMP refiner for hardwood pulps only
Washers	
WA CONV	Drum washer
WA HI-EFF	Diffusion washer
Recycled Paper Refiner	
RECYCLED	Recycled pulp technologies
Bleaching Technologies	
CEDED C	Chlorine conventional full bleach
CEDED C/C	Chlorine conventional full bleach with computer control
CEDED D	Chlorine displacement full bleach

CEDED D/C	Chlorine displacement full bleach with computer control
ODED C	Oxygen conventional full bleach
ODED C/C	Oxygen conventional full bleach with computer control
ODED D	Oxygen displacement full bleach
ODED D/C	Oxygen displacement full bleach with computer control
ODE C	Oxygen conventional semi bleach
ODE C/C	Oxygen conventional semi bleach with computer control
ODE D	Oxygen displacement semi bleach
ODE D/C	Oxygen displacement semi bleach with computer control
CEH C	Chlorine conventional semi bleach
CEH C/C	Chlorine conventional semi bleach with computer control
CEH D	Chlorine displacement semi bleach
CEH D/C	Chlorine displacement semi bleach with computer control

Refining and Screening

L REF	Linerboard conical refining and screening
L REF EFF	Efficient linerboard disc refining and screening
UN REF	Uncoated woodfree conical refining and screening
UN REF EFF	Efficient uncoated woodfree disc refining and screening
CT REF	Coated woodfree conical refining and screening
CT REF EFF	Efficient coated woodfree disc refining and screening
TI REF	Tissue paper conical refining and screening
TI REF EFF	Efficient tissue paper disc refining and screening

Forming, Pressing, Finishing

F/P NW	Newspaper form, press, finish & refine/screen
F/P NW I	Newspaper form, press, induction heat finish & refine/screen
F/PEN NW	Newspaper form, extended nip press, finish & refine/screen
F/PEN NW I	Newspaper form, extended nip press, induction heat finish & refine/screen
FEF/P NW	Newspaper efficient form, press, finish & refine/screen
FEF/P NW I	Newspaper efficient form, press, induction heat finish & refine/screen
FEF/PEN NW	Newspaper efficient form, extended nip press, finish and refine/screen
FEF/PEN NW I	Newspaper efficient form, extended nip press, induction heat finish and refine/screen
F/P LB	Linerboard form, press, finish
F/PEN LB	Linerboard form, extended nip press, finish
FEF/P LB	Linerboard efficient form, press, finish
FEF/PEN LB	Linerboard efficient form, press, finish
F/P WF	Woodfree form, press, finish
F/PEN WF	Woodfree form, extended nip press, finish
FEF/P WF	Woodfree efficient form, press, finish
FEF/PEN WF	Woodfree efficient form, press, finish
F/P TI	Tissue form, press, finish
F/PEN TI	Tissue form, extended nip press, finish
FEF/P TI	Tissue efficient form, press, finish
FEF/PEN TI	Tissue efficient form, press, finish

Paper Products Drying

DRI/ST	Paper dryer steam size I
DRI/STCC	Paper dryer steam size I with computer control
DRI/STVR	Paper dryer steam size I with small electric vapour recompression

DRII/EL	Paper dryer electric size II with computer control
DRII/ST	Paper dryer steam size II
DRII/STCC	Paper dryer steam size II with computer control
DRII/STVR	Paper dryer steam size II with large electric vapour recompression
DRII/STAL	Paper dryer steam size II with CC and VR
DR LB/NG	Linerboard dryer natural gas
DR LB/NGC	Linerboard dryer natural gas with computer control
DR LB/NGX	Linerboard dryer natural gas HXCS tissue dryer
DR LB/NGA	Linerboard dryer natural gas CC and HXCS
DR LB/IMPL	Linerboard dryer electric impulse drying
DR TI/NG	Tissue dryer natural gas
DR TI/NGC	Tissue dryer natural gas with computer control
DR TI/NGX	Tissue dryer natural gas HXCS tissue dryer
DR TI/NGA	Tissue dryer natural gas CC and HXCS
DR UCP/NG	Uncoated paper dryer natural gas
DR UCP/NGC	Uncoated paper dryer natural gas with computer control
DR UCP/EL	Uncoated paper dryer electric
DR CP/NG	Coated paper dryer natural gas
DR CP/NGC	Coated paper dryer natural gas with computer control
DR CP/EL	Coated paper dryer electric
DR CP/IF	Coated paper dryer infrared radiation
Recovery Boilers	
TOM RE II	Tomlinson recovery furnace - cogeneration @ 900 psig
TOM RE III	Tomlinson recovery furnace - cogeneration @ 1250 psig
TOM RE IV	Tomlinson recovery furnace - cogeneration @ 1500 psig
TOM RE CC	Tomlinson recovery furnace with computer control
TOM RE CO	Tomlinson recovery furnace with computer control & cogeneration, 600 psig
PYR RE CC	Pyrolysis recovery furnace with computer control
PYR RE CO	Pyrolysis recovery furnace with computer control & cogeneration
Pulp Dryers	
PU DR ST	Pulp dryer steam
PU DR STV	Pulp dryer steam with electric vapour recompression
PU DR NG	Pulp dryer natural gas
Lime Kilns	
LK NG	Conventional lime kiln natural gas
LK DI	Conventional lime kiln diesel
LK BI	Conventional lime kiln biomass
LK RE	Conventional lime kiln refined petroleum products
LK CO	Conventional lime kiln coal
LK/W/NG	Lime kiln with flash dryer natural gas
LK/W/DI	Lime kiln with flash dryer diesel
LK/W/BI	Lime kiln with flash dryer biomass
LK/W/RE	Lime kiln with flash dryer refined petroleum products
LK/W/CO	Lime kiln with flash dryer coal
Evaporators	
EVA I	Evaporators--size I
EVA I CC	Evaporators--size I with computer control
EVA I VR	Evaporators--size I small electric vapour recompression
EVA I AL	Evaporators--size I with CC and VR

EVA II	Evaporators--size II
EVA II CC	Evaporators--size II with computer control
EVA II VR	Evaporators--size II large electric vapour recompression
EVA II AL	Evaporators--size II with CC and VR

Boilers

B HF I	Boiler hog fuel @ 600 psig
COG HF I	Cogeneration hog fuel steam turbine @ 600 psig
B HF II	Boiler hog fuel @ 900 psig
COG HF II	Cogeneration hog fuel steam turbine @ 900 psig
B HF III	Boiler hog fuel @ 1250 psig
CO HF III	Cogeneration hog fuel steam turbine @ 1250 psig
B HF IV	Boiler hog fuel @ 1500 psig
COG HF IV	Cogeneration hog fuel steam turbine @ 1500 psig
B LSR I	Boiler low sulfur residual @ 600 psig
COG LSR I	Cogeneration low sulfur residual steam turbine @ 600 psig
B DI	Boiler distillate
B DI	Boiler distillate steam turbine-cogeneration
B NG I	Boiler natural gas @ 600 psig
COG NG I	Cogeneration natural gas steam turbine @ 600 psig
B NG II	Boiler natural gas @ 900 psig
COG NG II	Cogeneration natural gas steam turbine @ 900 psig
B NG III	Boiler natural gas @ 1250 psig
CO NG III	Cogeneration natural gas steam turbine @ 1250 psig
B NG IV	Boiler natural gas @ 1500 psig
COG NG IV	Cogeneration natural gas steam turbine @ 1500 psig
B LSR II	Boiler low sulfur residual @ 900 psig
CO LSR II	Cogeneration low sulfur residual steam turbine @ 900 psig
B LSR III	Boiler low sulfur residual @ 1250 psig
CO LS III	Cogeneration low sulfur residual steam turbine 1250 psig
B LSR IV	Boiler low sulfur residual @ 1500 psig
CO LSR IV	Cogeneration low sulfur residual steam turbine 1500 psig
CO RD	Cogeneration residual diesel turbine
CO PFB GT	Cogeneration/pressurized fluidized bed - gas turbine

CHAPTER 5

MINING

5.1 Description of Production Process

Mine Types

The many different commodities mined in B.C. can be organized into three categories.

1. Primary metals - gold, silver, copper, zinc, lead, molybdenum, etc. There are an estimated 22 major primary metal mines currently operating in the province (MEMPR, 1991).

2. Coal. There are presently eight coal mining operations in B.C.

3. Industrial minerals - limestone, sand and gravel, gypsum, silica, granite, asbestos, diatomaceous earth, etc.

Our analysis has focused on the first two types of mines as they account for over 99% of the electricity consumed by the mining industry in 1988.

Mines are typically categorized as either open-pit or underground. While the general production processes that occur in both categories are about the same, specific aspects of the mining technologies can differ significantly. For example, underground mining must be concerned with air quality control in the mine shaft (cooling, heating, ventilation). On a per tonne of ore basis, an underground mine is more electricity intensive than an open-pit mine. In British Columbia, approximately 3% of metal mining is underground.

In the mining industry there are two distinct phases of production: the extraction and transportation of raw material (ore, coal, etc.) from the mine site to a mill and the preparation of raw materials for shipment. For example, raw copper ore is moved from the mine site to a mill where the metal is concentrated and shipped. Coal is moved from the open pit mine to be washed and cleaned prior to loading on trains.

Transport

Movement of the raw material from mine site to the mill site generally requires some sort of loader or shovel and a system of transport trucks or a conveyor systems. The trucks, loaders and some of the shovels run on diesel fuel (diesel or diesel-electric motors). Conveyor systems and some of the larger shovels utilize cheaper electricity from the local grid. Their presence on-site is obviously related to the availability of electrical power.

Numerous energy saving programs are on the horizon. Automated trucks, increased use of conveyor systems and more efficient motors are some technologies which may reduce the total future energy demand in the mining industry. These technologies may be already on hand or in preliminary planning stages.

Underground mines present other energy loads such as ventilation, heating (natural gas, propane), hoists, and lighting.

Materials preparation

Raw ore containing metal showings is transported to a crusher to be ground into smaller chunks. Primary crushing can be located at the mine site or the mill. Significant energy savings can be realized if in-pit crushing is used (Scott, 1991). This crushed ore is then transported to a mill or concentrator, where the ore can undergo further crushing and milling. In the milling process grinding mills reduce the size of the ore particles in preparation for the separation process.

The milled ore is introduced to a separator where the specific gravity is slightly higher than waste rock. When the ore is added, the mixture is agitated and air is bubbled through it. For multi-metal ores the addition of chemical reagents can selectively separate different metals causing them to float to the surface. The froths are skimmed off, separated, thickened and filtered producing a metal concentrates ranging from 20% to 70% primary metal.

Energy demand is met by two energy carriers: diesel fuel and electricity. Although other types of fuel are used in different mine based activities (eg: company trucks run on gasoline or natural gas, space heating requires natural gas or propane), none of them is of major consequence.

Motors account for 95% of electricity demand and of that the large grinding motors consume over 70%. Grinding the ore is the most energy intensive step in the production process. Common practice in the past has been to install custom made AC synchronous and DC motors ranging in size up to 13500 hp.

Coal mining is similar to metal mining as the objective is to extract the ore, process it and then ship it to the end-user. The major difference is that extensive grinding is not required in coal mining. The raw ore is crushed and milled but not to the same degree of fineness that metal operations require. Once the ore is crushed it is washed and cleaned to remove the ash. Typically ash content ranges from 20 to 34% (Evans, 1991).

The waste stream in coal mining, upwards of 34% of raw material, is much smaller than in metal mining where the waste stream accounts for more than 80% of mined material. This combined with the reduced grinding requirements means that coal mining is less energy intensive at 17.5 Kwh/tonne of raw ore than metal mining which consumes 23.2 Kwh/tonne.

5.2 Modelling the Mining Industry

Output Forecast

Table 5.2.1 presents the high and low output forecasts for the B.C. mining industry.

Table 5.2.1 Mining Output Forecast
(thousands of tonnes)

	1988	2000	2010	
Copper	354	436	482	High
		224	185	Low
Molybdenum	12.5	16.5	17.4	High
		8.5	8.1	Low
Silver	.4	.7	.7	High
		.3	.3	Low
Lead	105	113	134	High
		58	55	Low
Zinc	147	179	213	High
		91	84	Low
Coal	22	25	28	High
Metallurgical	23	25	Low	
Coal	3	5	6	High
Thermal		4	5	Low

(Source: B.C. Hydro Load Forecasting Department, 1991)

In the high growth scenario total mining output is estimated to grow by 37%. In the low growth scenario metal mine output declines by 47% while coal production increases by 20%. The net effect in the low growth scenario is a shift towards the less energy intensive coal mining process resulting in lower electricity demand.

Process Flow Model

Figure 5.2.1 presents the process flow model of the mining industry. As the diagram shows, the ISTUM-I model is cast as one large mine producing the combined output of the various mines in the province, and comprising the total equipment stock of all these mines. Therefore, the single mine of this simulation produces all metal and coal products.

The entire process is defined by three primary activities: raw product, size reduction and ore concentration. In the raw product node, extraction and ore transportation are represented. Extraction includes removing the overburden and separating the material from the pit walls. Transportation involves trucks and conveyors which move the ore from the mine site to the mill.

Figure 5.2.1 Flow Model: Mining Industry

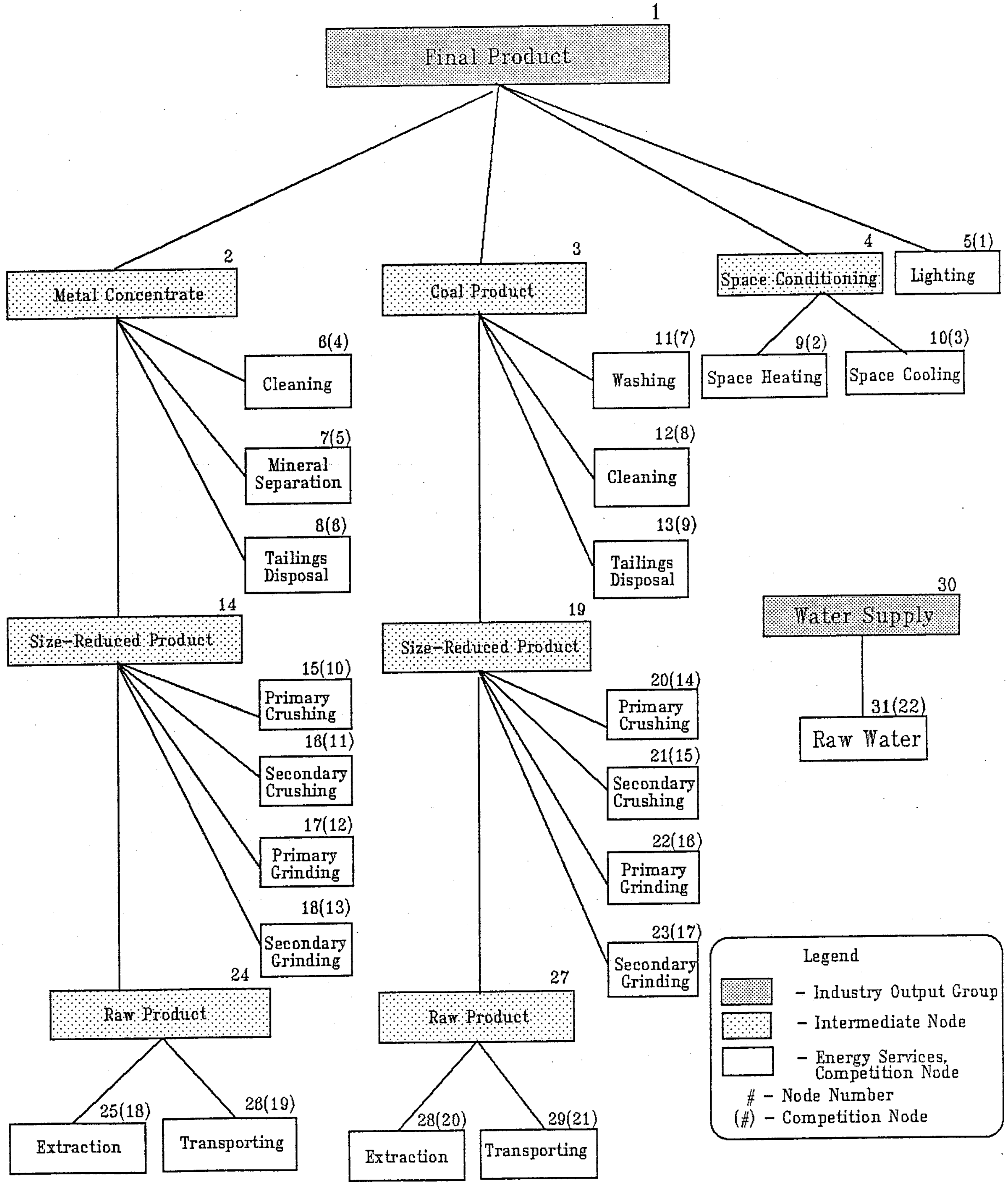
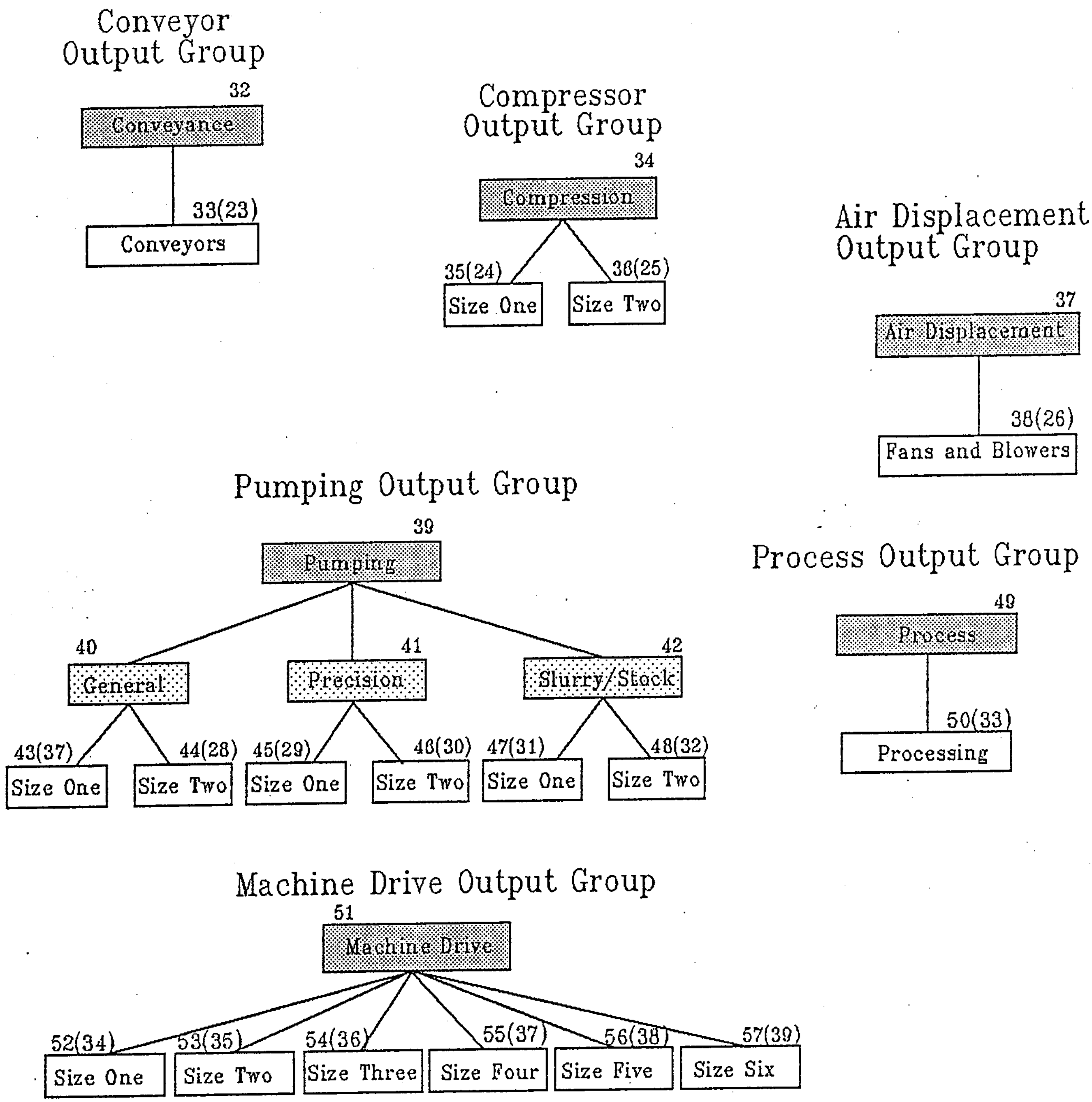


Figure 5.2.1 cont'd



In the size reduction process, crushing and grinding are employed to prepare the ore for separation. Although the model shows primary crushing under size reduction, normally located in the mill, it does not necessarily mean that primary crushing is located at the mill. At Highland Valley Copper, for example, primary crushing is conducted in the pit (Scott, 1991).

Product concentration involves cleaning and separating the waste rock from the ore, and then ejecting the waste rock. Although the technologies are different for metal and coal mining, the objective, to increase the concentration of the desired product is the same.

Technologies are attached to the clear nodes in the process flow model. For example, several alternative technologies can be attached to node 17, for primary grinding of raw metal ore.

Disaggregation at the process technology level in the flow model only occurs where warranted to explain differences in end-use electricity demand of the technologies. Each mine type has its own distinct process nodes reflecting the different amounts of end-use electricity per tonne of ore required at each process step. However, there was no disaggregation of the process technologies because their efficiency differences are insignificant (Evans, 1991).

5.3 Results

Table 5.3.1 and Table 5.3.2 present the aggregate results for end-use electricity demand over the 22 year forecast period.

Table 5.3.1 Mining End-Use Electricity Demand: Low (GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	3 185	2 338	2 281	
Natural		2 229	2 129	6.6%
Econ 1		1 727	1 658	27.3%
Econ 3		1 693	1 625	28.7%
Econ 5		1 636	1 570	31.2%
Tech		1 718	1 650	27.7%
Tech Soc		1 593	1 529	33.0%

Figure 5.3.1 Mining End-use Electricity Demand

High Growth

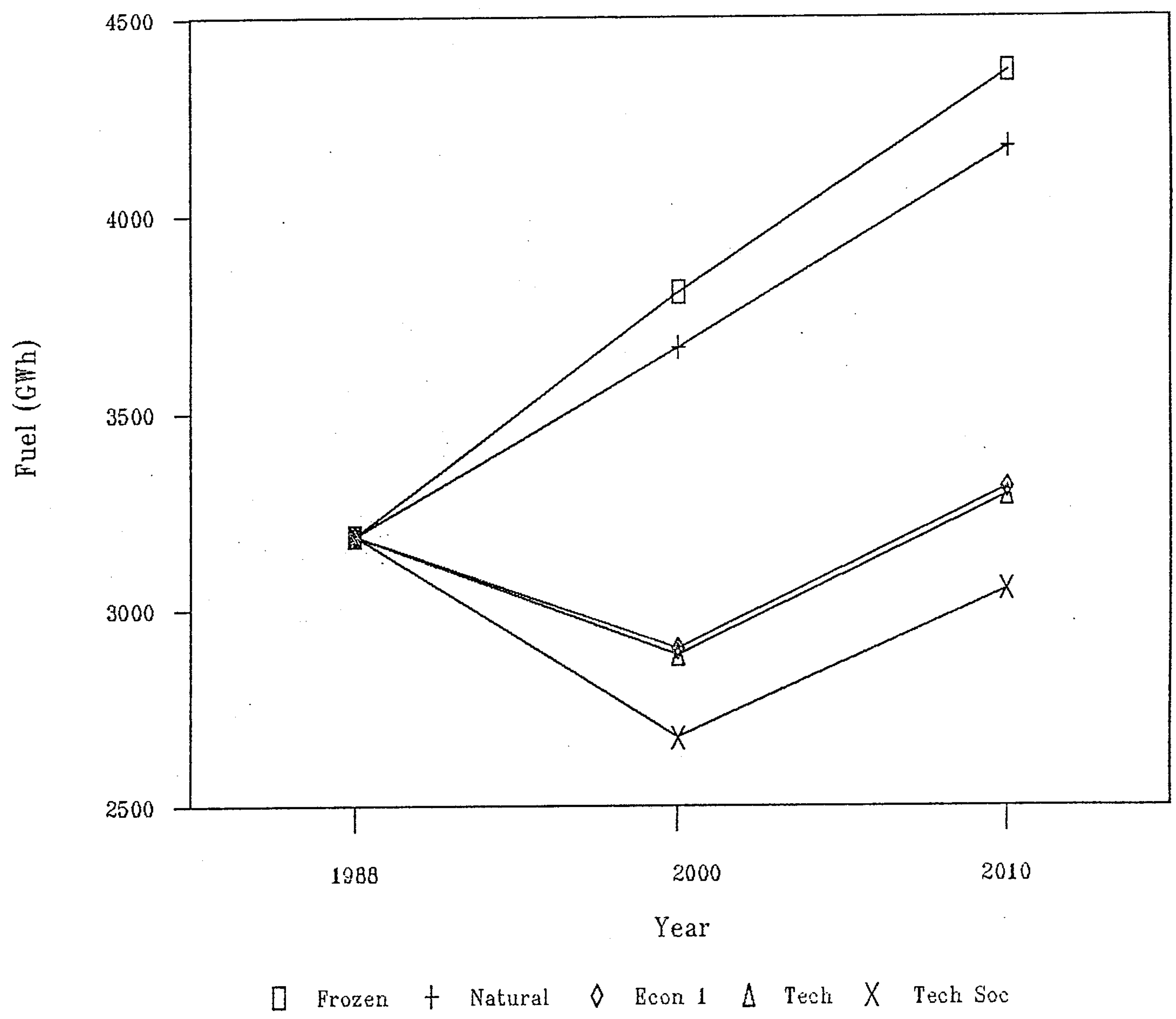


Table 5.3.2 Mining End-Use Electricity Demand: High
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	3 184	3 806	4 364	
Natural		3 665	4 170	4.4%
Econ 1		2 899	3 307	24.2%
Econ 3		2 841	3 242	25.7%
Econ 5		2 745	3 132	28.2%
Tech		2 883	3 289	24.6%
Tech Soc		2 674	3 051	30.1%

Table 5.3.3 Mining End-Use Electricity Demand:
High Frozen Efficiency Run
(GWh)

Service	1988	2000	2010
Machine Drive	3 025	3 615	4 142
Pump	422	504	580
Air Displacement	148	176	204
Compression	53	63	73
Conveyance	67	80	92
Other	2 333	2 791	3 191
Electrolysis	0	0	0
Process Heat	0	0	0
Light	143	172	200
Other	16	19	22
Total	3 184	3 806	4 364

Table 5.3.4 Mining End-Use Electricity Demand:
High Technological Efficiency Run
(GWh)

Service	1988	2000	2010	% Reduction from Frozen in 2010
Machine Drive	3 025	2 774	3 163	23.6%
Pump	422	187	205	64.6%
Air Displacement	148	99	110	46.1%
Compression	53	32	35	52.1%
Conveyance	67	62	72	1.3%
Other	2 333	2 395	2 741	14.1%
Electrolysis	0	0	0	0.0%
Process Heat	0	0	0	0.0%
Light	143	90	104	48.0%
Other	16	19	22	0.0%
Total	3 184	2 883	3 290	24.6%

In both the high and low growth scenarios, the results are similar. However, the low growth scenario actually shows a slightly greater percentage efficiency improvement in the economic and technological runs. This is because the relative shares of coal and metal mines differ between high and low growth scenarios.

Social potential is incorporated into economic run number 5 and the technological/social. The results show that by including a social component to electricity conservation an economic/social set of parameters can realize a greater conservation potential than a technological fix alone.
Note that efficiency improvements in natural and other runs are considerably less than in pulp and paper.

Tables 5.4.3 and 5.4.4 list the end-use breakdown of different energy services. In the mining industry end-use energy requirements are dominated by other (process machine drive) and pumping.

5.4 Analysis and Caveats

The mining industry shows a significant technological and economic potential for electricity conservation, over 24% in both the high and low growth scenario cases. The most important factor explaining this smaller conservation potential compared to pulp and paper is the dominance of large grinding motors. These large motors (over 1000 hp) are designed with efficiency in mind so the conservation potential for this technology is small. Efficiency improvements in the order of 1 or 2% are possible.

The conservation potential identified is primarily due to improvements in auxiliary systems. Pumping, air displacement and compression efficiency improvements, similar in magnitude to those in the pulp and paper industry, are realized. However, slurry pump efficiency improvements are not as extensive as in pulp and paper because the abrasive nature of the slurry means that throttles are not used (Scott, 1992). Mining electricity conservation potential differs from pulp and paper due to the larger more efficient motor stock used by the mining industry.

The difference in efficiency potential between the high and low output forecasts is due to different relative product shares. The relative share of coal mining is higher in the low output scenario than in the high output scenario. Coal mining has a slightly greater conservation potential than metal mining because coal mining uses fewer large motors. The economic and technological conservation potentials for coal mining is approximately 37% while the potential for metal mining is approximately 20%.

The economic results closely match the technological because almost all efficiency improvements are cost effective using the total resource cost test with no environmental adder.

Interenergy substitution has been restricted in this study but it will effect the future demand for end-use electricity. Diesel and electricity are the energy sources which compete in mining. This occurs in two steps in the production process (1) raw material extraction and (2) material transport.

In raw material extraction shovels are used to scoop up the ore and place it into trucks. These shovels can consume either diesel fuel, in a diesel/electric shovel or direct electricity but no market shifts between the two process technologies was allowed.

In the material transportation step diesel/electric trucks compete with conveyor systems to move raw ore from the mine site to the mill. Interenergy substitution was restricted by not allowing a market shift between these two technologies. However, expert opinion indicates a market shift towards conveyance of raw ore is probable.

Discussion with mining experts reveals three trends in mining technology. First is the elimination of truck haulage in favour of conveyance. This change anticipates improvements in blasting practices which may reduce average lump size in the initial rock breaking operation. The resulting increase in electricity demand would be approximately 3 kwh/tonne milled (Evans, 1991).

Second, there is increased interest in incorporating a rock sorting unit between primary crushing and the subsequent secondary crushing and grinding. The removal of a portion of the waste rock would not make a significant impact on electricity demand since demand would increase in the process which includes the rock sorter but decrease in the secondary crushing and grinding steps. However, the inclusion of a rock sorter may increase mine life and thus electricity demand (Evans, 1991).

Third, there is a trend towards on site metal production. This would have a considerable impact on electricity demanded by the mining industry in the order of 3 kwh/Kg of copper metal produced.

The results in tables 5.3.1 and 5.3.2 take into account three important assumptions. The first is that the percentage of underground mining in British Columbia will remain constant over the forecast period. As underground mining is the most energy intensive mining activity changes in the amount of underground mining may have a significant impact on the results.

The second assumption holds that the average hardness of ore bearing material will not change. This means that the energy required to grind a tonne of ore will not fluctuate on the basis of the ore being harder or softer. Since grinding is the most significant single energy consuming process step, this assumption will have important ramifications on future electricity demand.

Finally, as the richer ore bodies are depleted the concentration of metal with respect to host rock will decline. Again this will effect the grinding stage more so than the other process steps. A poorer ore concentration means grinding more material to get the same amount of metal concentrate. The assumption we have made is that the average ore concentration will not change over the 20 year forecast.

Appendices

to

Chapter 5

Mining Industry

Appendix A

Mining Industry Assumptions

Auxiliary Systems:

(1) Conveyor systems in pit and mill inclined at 15 degrees. (Fruchtbaum, 1991)

(2) Load factor for mining auxiliary systems:

Process drive	.90 at .9 utilization
Pumping	.70 at .9 utilization
Fans and Blowers	.70 at .9 utilization
Conveyors	.70 at .9 utilization
Compressors	1.0 at .7 utilization

(Willis, 1991; Scott, 1992)

(3) Social Potential parameters:

a. Motor Systems

System	Potential
Pump	10%
Air Displacement	5%
Compression	15%
Conveyance	5%
Process Drive	7%
Process Heat	10%
Lighting	10%
HVAC	5%

b. Economic Runs

Run	Percentage of Potential (from above Table)
Frozen	0%
Natural	0%
Economic 1	0%
Economic 2	15%
Economic 3	25%
Economic 4	45%
Economic 5	70%
Technological	0%
Technological/ Social	100%

(Welchman, 1992; Willis, 1992; Scott, 1992; Evans, 1991; Temanex, 1992; Merrill, 1991; Mellis, 1991)

Appendix B

Mining Industry Motor Systems Base Stocks

The following tables list the base stocks for motors in the mining branch. These are disaggregated by auxiliary system.

Electrical Energy Demand - Open Pit Mine Processing 3.3 Million Tonnes per Year (2.2 Million Tonnes Clean Coal) at Strip Ratio 6 BCM/ Tonne Clean Coal

MOTOR FUNCTION		MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
MOTOR SIZE		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1 Number of Motors																															
	Totals																														
Mine Drainage	2																										2				
Drill and Blast	3					3															4										
Load and Transport	40				8	16								8	4						1										
Raw Coal Breaking	13	2	1	1	1				6	1										1		1									
Raw Coal Tansfer	16	5			1				1			1		5	1					2		1	1			5	7	9	7	1	
Coal Washing	134	39	16	16					3	1				15	9	3			1							5	1	10			
Drying and Load Out	62	17	2						4	3		2		13	1	3											4	6	4	1	
Reclaim Water	15																			1		1					1	5		1	
Fresh Water System	8																			1		1				2	7				
Shops/W'house/Office	78	56												3	1	7															
Totals	372	119		17	10	19			14	5		3		44	16	13			1	5	5	4	1			12	22	29	11	3	

MOTOR FUNCTION		MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
MOTOR SIZE		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
2. Installed kW by Motor Rating																															
	Totals																														
Mine Drainage	31																										31				
Drill and Blast	1119					1119																									
Load and Transport	7299				1194	5968								17	60						60										
Raw Coal Breaking	223	7	19	22	93				45	30											7										
Raw Coal Tansfer	512	4			75				8			373		4	7					4		37									
Coal Washing	2534	69	239	448					37	37				56	100	97				7		56	118			17	104	298	653	298	
Drying and Load Out	2070	21	22						37										1678							3	11	299			
Reclaim Water	1030																										60	224	373	373	
Fresh Water System	608																										11	224		373	
Shops/W'house/Office	618	70												2	15	293				3		60					170				
Totals	16144	171	280	470	1362	7087			127	67		373		79	182	395			1678	14	67	153	118			20	357	1044	1026	1044	

MOTOR FUNCTION			MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
MOTOR SIZE			1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
3. kW Consumed by Motor Rating																																
(Installed x 0.94 x F)	(F)	Totals																														
Mine Drainage	25%	6																										6				
Drill and Blast	25%	265					265																									
Load and Transport	25%	1729				283	1414								4	14						14										
Raw Coal Breaking	50%	103	3	9	10	44				20	14											3										
Raw Coal Tansfer	50%	254	2			37				4			187		1	3					2		18									
Coal Washing	100%	2499	65	226	424					35	35				53	95	92				6		53	112			16	99	282	619	282	
Drying and Load Out	80%	1568	16	16						28										1272							2	8	226			
Reclaim Water	50%	483																										28	106	177	177	
Fresh Water System	50%	288																										5	106		177	
Shops/W'house/Office	50%	291	33												1	7	141				1		28					80				
Lighting		350																														
Totals		7841	119	251	434	364	1679			87	49		187		59	119	233			1272	9	17	99	112			18	226	720	796	636	

MOTOR FUNCTION		MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
MOTOR SIZE		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
4. kWH per Tonne Processed																															
	Totals																														
Mine Drainage	0.01																										0.1				
Drill and Blast	0.6					0.6																									
Load and Transport	3.9				0.64	3.19								0	0						0										
Raw Coal Breaking	0.24	0	0	0	0.1				0.1	0											0										
Raw Coal Tansfer	0.56				0.08				c			0.4			0							0									
Coal Washing	5.62	0.2	0.5	1					0.1	0.1				0.1	0.2	0.2				0		0.1	0.3			0	0.2	0.64	1.39	0.64	
Drying and Load Out	3.54	0	0						0.1										2.87								0	0.51			
Reclaim Water	1.1																										0.1	0.24	0.4	0.4	
Fresh Water System	0.65																										0	0.24		0.4	
Shops/W'house/Office	0.66	0.1													0	0.3						0.1					0.1				
Lighting	0.8																														
Totals	17.68	0.3	0.6	1	0.82	3.79			0.2	0.1		0.4		0.1	0.3	0.5			2.87	0	0	0.2	0.3			0	0.5	1.63	1.79	1.44	

Electrical Energy Demand - Open Pit Porphyry Copper Mine - Normal Milling Capacity 60000 Tonnes per day - Annual Throughput Capacity 21 million Tonnes

MOTOR FUNCTION		MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
MOTOR SIZE		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1. Number of Motors by Size																															
Mine Drainage and Ventilation	11																											5		6	
Drill and Blast	6																														
ROM Load and Transport	3				6		3																								
Primary Crushing	16	1		1	3		1							4	1	1											4				
Crushed Ore Transfer & Storage	65	3	8	6	1			4	20	3	4		5	6		1					1	1					4				
Fine Crush and Grind	181	11	1	10	7	9	12							13	38						5		2			17	23	23	6	4	
Min'l Sep. & Conc. Hldg	247	27	15	34	36	7	1							1	4						1			2		57	38	22	2		2
Tail Disposal & Reclaim Water	33																											4	17	2	10
Fresh Water System	10																											6	4		
Shops/W'house/Office	2																														
Total Number of Motors	576	42	26	51	53	16	17	4	20	3	4		5	24	43	2					7	1	2	2		74	69	58	29	12	12

MOTOR FUNCTION		MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
MOTOR SIZE		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
2. Installed kW by Motor Rating																															
Mine Drainage and Ventilation	1634																											231		1343	
Drill and Blast	918				918																										
ROM Load and Transport	2400						2400																								
Primary Crushing	1072	1		45	372		522							8	6	45					6	37					30				
Crushed Ore Transfer & Storage	7111	9	67	222	143			15	218	89	561		5670	6		45											39				
Fine Crush and Grind	66356	41	5	511	775	2536	59188							25	477						24		238			17	225	735	894	1592	
Min'l Sep. & Conc. Hldg	19996	40	186	3299	5320	2057	4894							4	37						6			746		118	398	625	373		89
Tail Disposal & Reclaim Water	9347																											150	2193	446	655
Fresh Water System	820																											374	446		
Shops/W'house/Office	30		30																												
Total Installed kW	109714	91	309	4077	7534	5593	66004	16	218	89	561		5670	43	520	90					36	37	298	746		135	670	2238	3906	3381	745
Heat and Light	1916																														

MOTOR FUNCTION		MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
MOTOR SIZE		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
3. kW Consumed by Motor Rating																															
Mine Drainage and Ventilation	724																											123		601	
Drill and Blast	580				580																										
ROM Load and Transport	2526						2526																								
Primary Crushing	471	1		2	75		327																								
Crushed Ore Tansfer & Storage	3979	8	43	84	14			15	149	72	411		3123	7	4	37						8					10				
Fine Crush and Grind	59669	25	1	259	692	1102	55175							3		42					5		63			17	126	326	400	1336	
Min'l Sep. & Conc. Hdlg	15396	13	122	1734	4508	1988	4684							13	355						1	1	334			33	169	293	333		850
Tail Disposal & Reclaim Water	4095													4	30													14	948	200	2933
Fresh Water System	372																											170	202		
Shops/W'house/Office	3		3																												
Total kW Consumed by Motors	89042	49	169	2079	6259	2970	62712	15	149	72	411		3123	27	389	79					6	8	397			50	334	926	1893	2137	3783
Heat & Light	957																														

MOTOR FUNCTION		MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
MOTOR SIZE		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
4. kWH per Tonne Milled (at 92% Availability=21x10^6 T/hr																															
Mine Drainage and Ventilation	0.28																											0.05		0.23	
Drill and Blast	0.2				0.2																										
ROM Load and Transport	0.97						0.97																								
Primary Crushing	0.18				0.03		0.12																								
Crushed Ore Tansfer & Storage	1.53		0.02	0.04					0.06	0.03	0.16		1.2			0.03															
Fine Crush and Grind	23.09	0.01		0.1	0.27	0.42	21.18									0.02							0.03			0.01	0.05	0.13	0.15	0.51	
Min'l Sep. & Conc. Hdlg	5.91		0.05	0.67	1.89	0.72	1.8								0.14								0.13			0.01	0.07	0.11	0.13		0.33
Tail Disposal & Reclaim Water	1.57														0.01														0.37	0.08	1.12
Fresh Water System	0.14																											0.06	0.08		
Shops/W'house/Office																															
Total kWH per Tonne Milled	33.78	0.01	0.07	0.81	2.83	1.14	24.07		0.06	0.03	0.16		1.2		0.15	0.05							0.16			0.32	0.12	0.35	0.73	0.82	1.45
Heat & Light	0.34																														

Appendix C

Mining Industry Process Technologies

ISTUM-I Code	Description of Technologies
Coal Mining	
EXTRACTION	Shovels, drills and loaders
PRIM CRUSH	Primary and secondary crushing mill
TRANSFER	Conveyor transport from mine to mill
WASH/MILL	Primary and secondary grinder with wash cycle
DRY/CLEAN	Coal cleaner/dryer with tailings disposal
WATER SUPPLY	Reclamation and fresh water for coal washing
Metal Mining	
M/EXTRACT	Shovels, drills and loaders
M/CRUSH	Primary and secondary crushers
M/TRANSFER	Conveyor transport from mine to mill
M/MILL	Primary and secondary grinders
M/MIN SEP	Mineral separator
M/CLEAN	Concentrate cleaning, tailings transport and raw water

CHAPTER 6

WOOD PRODUCTS

6.1 Description of Production Process

In 1988, approximately 230 sawmills, 16 plywood plants and 22 planer mills were in operation in the B.C. lumber products industry. The sawmill and planing constituent accounted for over 80% of the total electrical energy consumption in the industry and approximately 10% of all purchased electricity in the industrial sector in B.C. Most of this energy is apportioned to mechanical drive to run the various conveyors, lathes and saws in the mills. Kilning of wet lumber consumes a large quantity of natural gas as well as some hog fuel with relatively small amounts of electricity used to dry specialty woods and remanufactured products (Temanex, 1991c) . Lighting, space heating and cooling and other demands consume approximately 14% of the electricity used in this branch.

There is significant variation in lumber mill size. Small operations are typically much less efficient than the larger mills since the larger mills can afford to incorporate computer control and more efficient technologies that increase raw timber utilization. With the present turn-down in the industry, many of these smaller, inefficient operations have already or are expected to close.

Because the processes used to make plywood and structural board vary significantly from the production of finished lumber, the industry is best thought of as having 2 sub-branches:

i) structural board - includes plywood, oriented strand board (OSB), panel board, wafer board and particle board.

ii) finished lumber - includes dimension lumber, large structural timbers and reconstituted wood products (parallam, oriented strand products, and the like)

In each of these sub-branches, a value-added component called "specialty products" is included. Here milled wood and special order products are manufactured.

Also included in each sub-branch is a miscellaneous component to capture numerous functions including blade and knife sharpening, saw sharpening and machine upkeep.

Mills

The major functional process in lumber and structural board mills is mechanical drive. Motors drive debarkers, veneer peelers and various saws, lathes, chippers, shapers and sanders.

All logs are debarked using mechanical debarking processes. Though hydraulic debarking was once used (especially for large diameter old growth logs), presently there is very little of this in B.C. (Temanex, pers com., 1991c). After debarking, the raw timber goes through one of three streams of processes which are generally motor-driven, to produce OSB, plywood products or finished lumber products.

6.2 Modelling the Wood Products Industry

Output Forecast

Table 6.2.1 Wood Products Output Forecast
(thousands of cubic metres)

	1988	2000	2010	
Lumber	36 736	40 420	44 764	High
		34 370	33 670	Low
Structural Board	1 828	1 824	1 932	High
		1 456	1 411	Low

(Source: B.C. Hydro Load Forecasting Department, 1991)

Considering the present down-turn in the wood products industry, as well as changes in demand for product type, it is difficult to predict the future demand for lumber. One possible issue is the concern by the European community for parasitic nematodes in green lumber.[1] Because of this, the EEC may in the future require that all coastal lumber be kiln dried; this could cause economic ruin for many mills (Temanex, pers com., 1991c). Large scale drying requirements using radio frequency (RF) drying could boost electricity demand, but this lies outside of the terms of reference of this report because this would be energy substitution.

The high growth scenario shows nearly 22% increase in finished lumber products and less than 6% increase in panel products.. The low growth scenario shows output declining by approximately 9% and 23% respectively.

As in the pulp and paper industry, there is increased emphasis on value-added products. The shift to such products increases energy intensity per unit output. For example, OSB is expected to rise from 15% to 40% of the panel products market and specialty products are expected to increase from 10% to 20% over the forecasted time period.

Process Flow Model

Figure 6.2.1 presents the process flow model of the wood products branch. Like the other branches, ISTUM-I displays the industry as if it were one large plant with three

1. To our knowledge, no nematodes have ever been found in B.C. coastal lumber.

Figure 6.2.1 Flow Model: Wood Products Industry

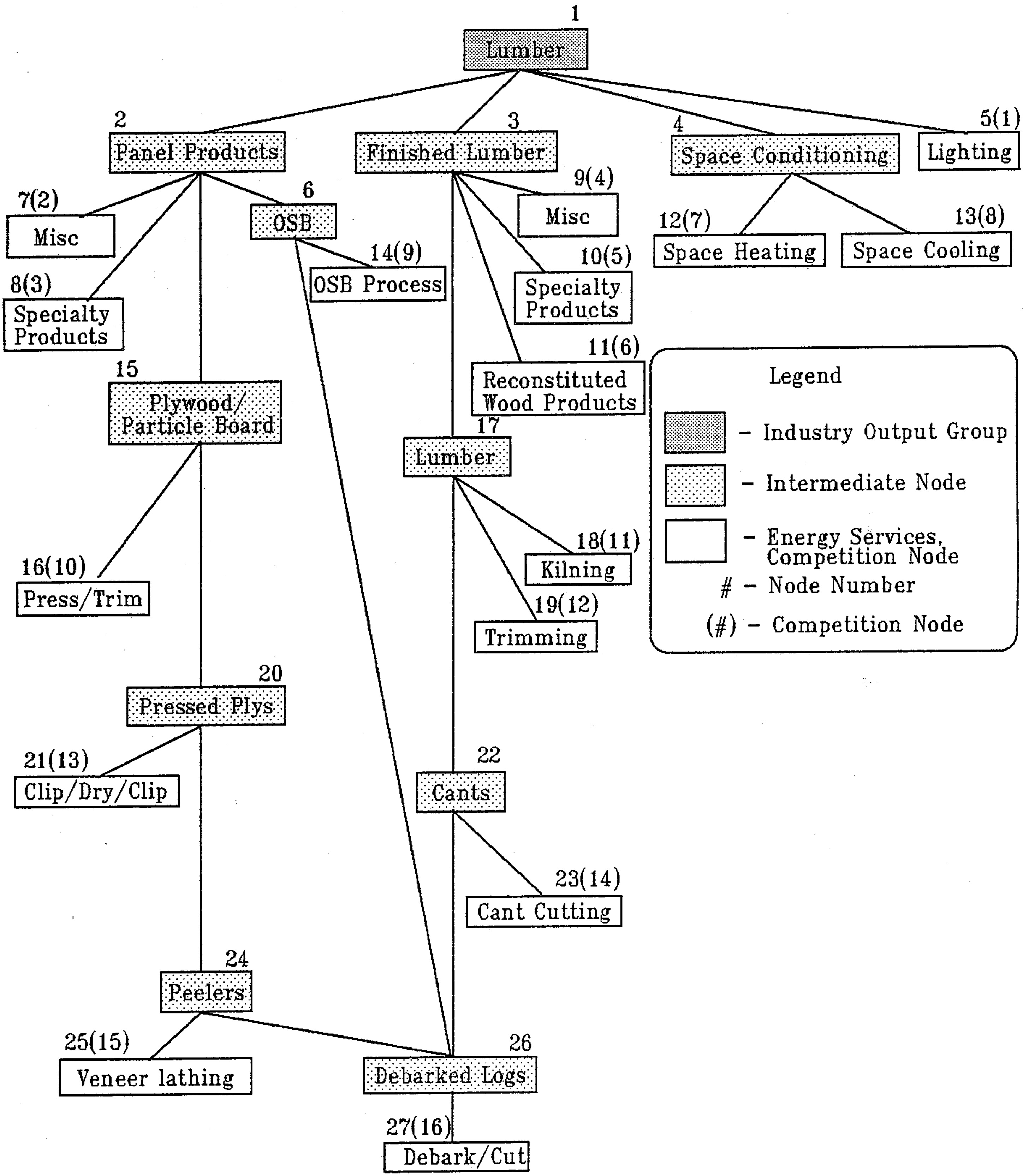
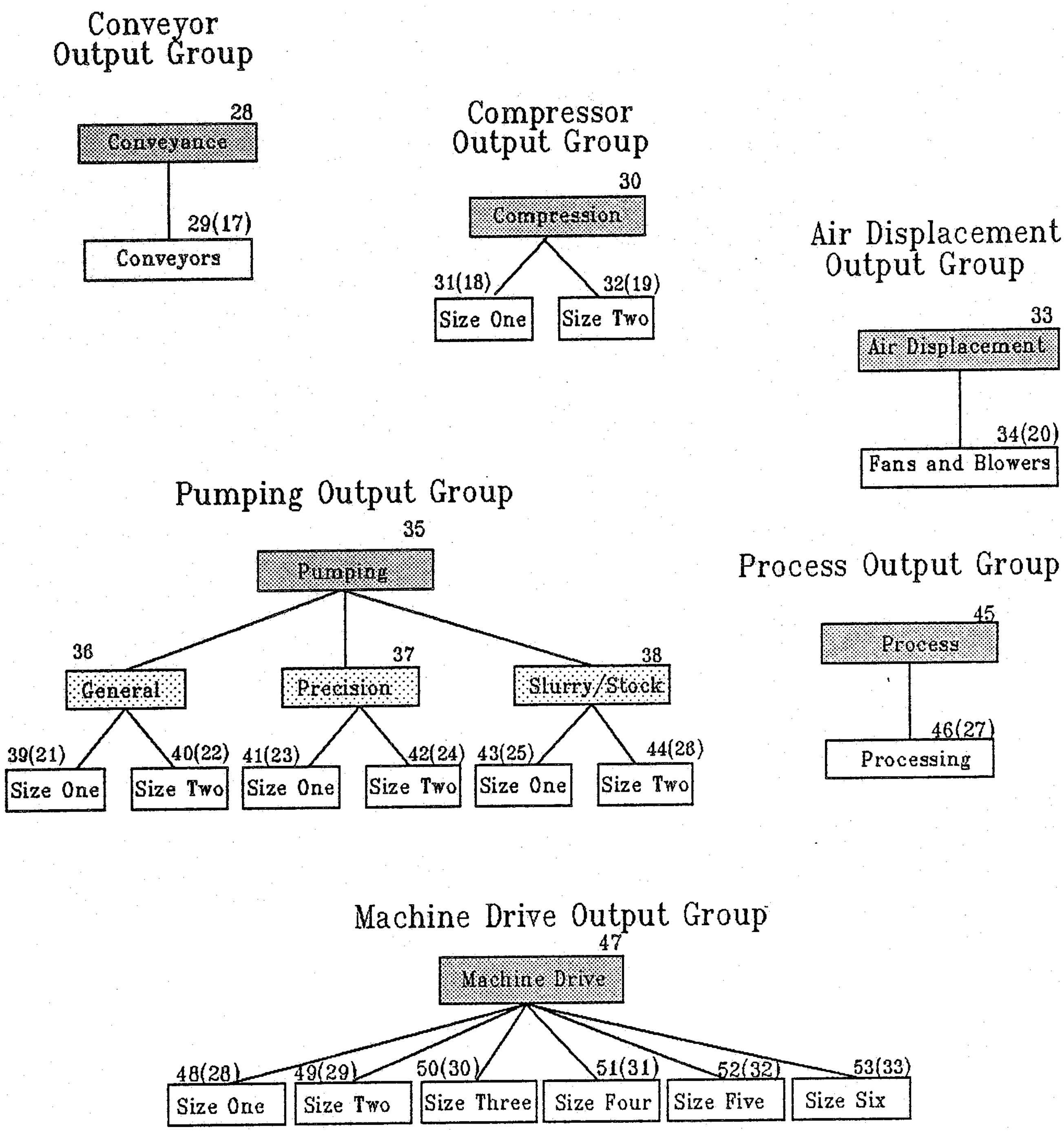


Figure 6.2.1 cont'd



steams, two of which (plywood/particle board and OSB products) are considered under the Panel Products intermediate node.

All raw logs are debarked and separated to enter one of the three streams. At a few of the nodes, certain products are exported, increasing the production at that node. For example, 5% of all veneers leave the province (and thus our 'single' plant) and never enters the next 'clip/dry/clip' node.

"Miscellaneous" electricity demand is distinguished from "Other" electricity use in that the electricity used here is specific to the production of the product (knife and saw sharpening, etc) rather than general use (office heating and lighting, computer, appliances, etc.).

6.3 Results

Table 6.3.1 and Table 6.3.2 present the aggregate results for electricity demand over the 22 year forecast period. Figure 6.3.1 provides a graphic representation of these results. Table 6.3.3 and 6.3.4 present the demand of the various end-uses in frozen and technological runs of the high growth scenario.

Table 6.3.1 Wood Products End-use Electricity Demand: Low (GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	2 057	2 223	2 222	
Natural		2 154	2 120	4.6
Econ 1		1 905	1 896	14.7
Econ 3		1 871	1 863	16.2
Econ 5		1 803	1 795	19.2
Tech		1 803	1 794	19.2
Tech/Social		1 677	1 671	24.8

Figure 6.3.1 Wood Products End-use Electricity Demand

High Growth

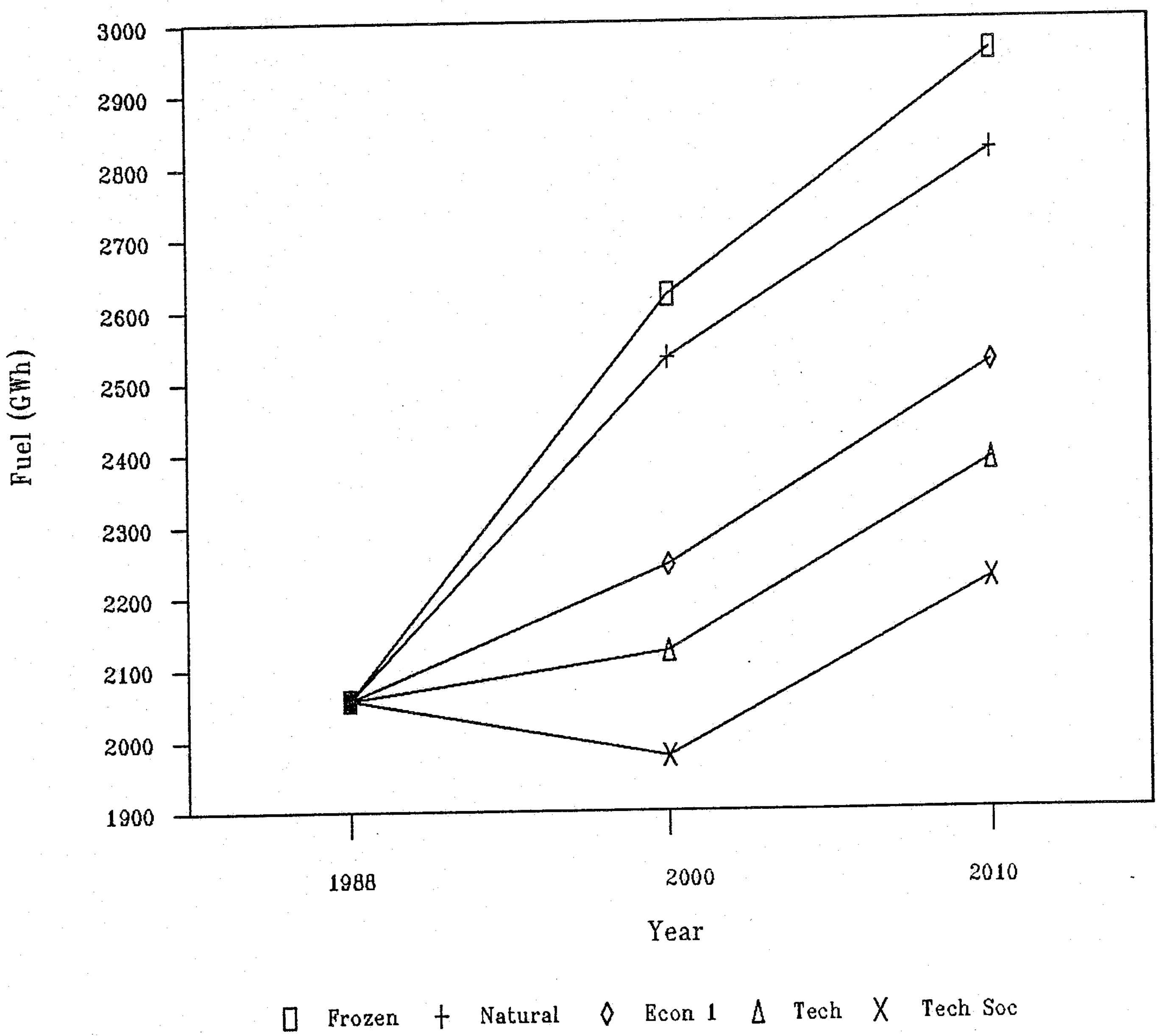


Table 6.3.2 Wood Products End-use Electricity Demand: High
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	2 057	2 621	2 958	
Natural		2 533	2 821	4.7
Econ 1		2 245	2 524	14.7
Econ 3		2 206	2 480	16.2
Econ 5		2 125	2 389	19.2
Tech		2 125	2 388	19.3
Tech/Social		1 977	2 224	24.8

Table 6.3.3 Wood Products End-use Electricity Demand:
High, Frozen Efficiency Run
(GWh)

	1988	2000	2010
Machine Drive	1 286	1 601	1 830
Pump	12	12	20
Air Displacement	183	243	271
Compress	14	16	18
Convey	337	429	496
Other	740	901	1 026
Electrolysis	0	0	0
Process Heat	503	730	808
Light	247	267	295
Other	21	23	26
Total	2 057	2 621	2 958

Table 6.3.4 Wood Products End-use Electricity Demand:
High, Technological Efficiency Run
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Machine Drive	1 286	1 209	1 375	24.8%
Pump	12	4	7	65.0%
Air Displacement	183	134	143	47.2%
Compress	14	6	6	66.7%
Convey	337	366	422	14.9%
Other	740	698	796	22.4%
Electrolysis	0	0	0	0.0%
Process Heat	503	730	808	0.0%
Light	247	163	180	39.0%
Other	21	23	26	0.0%
Total	2 057	2 125	2 388	19.3%

With a Technological potential (relative-to-Frozen) of less than 20% wood products has one of the lowest potentials for electricity efficiency improvement among the industrial branches that are modelled.

Airborne sawdust and scattered shavings of the typical sawmill environment provide a less-than-good environment for motors and their attached auxiliary systems. Consequently. the social potential for this industrial branch is the highest of all branches. A 12% efficiency improvement in pumping and air displacement units was used, with a potential 17% improvement in compressors, a 7 percent improvement in conveyors and a 2% improvement in oversizing of process motors (see Chapter 3).

6.4 Analysis and Caveats

The dominant use in this industry is "other machine drive": saws, debarkers, lathes, planers, sanders and the like. Because these types of equipment are only connected to direct drives, the potential efficiencies gains are small relative to, for example, a pumping system with components of very low efficiency. This explains the lower efficiency improvement potential in this industry relative to pulp and paper.

The relatively large gap between economic and technological potential, graphically represented in Figure 6.3.1, is due to the high capital cost of new technologies . Capital intensive technologies (such as biodegradable debarking and automated systems) can reduce electricity consumption but do not penetrate the market, even when a 100% credit is applied to the marginal price of new electricity.

As was mentioned above, there is a shift to value added products in this industry. Thus, the per-unit electricity demand (electricity intensity) increases more rapidly than the growth in industry output. Even in the low growth scenario, which shows a decline in output, demand for electricity is increasing in frozen and natural runs.

Appendices

To

Chapter 6

Wood Products

Appendix A

Wood Products Assumptions

Auxiliary systems:

1. Conveyor systems are inclined at 7.5%. (Kahuska, 1991).

2. Technology stocks used in in-plant transport of materials (type of conveyor system, chip movement) maintain base year shares. Thus, although chain conveyors are not the most efficient mode of conveyance, they maintain their 1988 market share.

2. Load factor for wood products auxiliary systems:

Process drive	.70 at .5 utilization
Pumping	.60 at .5 utilization
Fans and Blowers	.60 at .5 utilization
Conveyors	.60 at .5 utilization
Compressors	1.00 at .5 utilization

(Willis, pers com., 1991)

3. Social Potential parameters:

a. Motor Systems

System	Potential
Pump	12%
Air Displacement	12%
Compression	17%
Conveyance	7%
Process Drive	2%
Process Heat	10%
Lighting	10%
HVAC	5%

b. Economic Runs

Run	Percentage of Potential (from above Table)
Frozen	0%
Natural	0%
Economic 1	0%
Economic 2	15%
Economic 3	25%
Economic 4	45%
Economic 5	70%
Technological	0%
Technological/ Social	100%

(Welchman, pers com., 1992; Willis, pers com., 1992; Scott, pers com., 1992; Evans, pers com., 1991; Temanex, pers com., 1992; Merrill, pers com., 1991; Mellis, pers com., 1991)

Process Systems:

1. Certain remanufactured wood products, such as oriented strand dimension lumber, are assumed to compete with regular dimension lumber for the existing market share. Other products such as Parallam and PSL 300 are assumed to carve out there own market share (competing with beams of materials such as steel).

2. OSB and other structural panel board products are assumed to replace plywood products.

3. Both saw mills and veneer/plywood plants operate 2 shifts per day (16 hrs), 240 days per year.

4. Computer controlled and monitored systems, typical of larger mills, were assumed to composed 90% of the base stock. The goal of these systems is not to decrease energy consumption but to increase utilization of raw materials by producing value added product. Some of the extra handling, sawing and resawing may actually increase the load, but the total effects were estimated as resulting in 5% electricity savings (Mayer, 1991).

5. The market share of steam drive systems and mechanical drive systems is assumed to remain constant over the period.

Appendix B

Wood Products Motor Systems Base Stock

The following pages contain a listing of the base stock of motors in the wood products branch. These numbers were derived from a sample sawmill and sample plywood plant and extrapolated to encompass the output of the B.C. wood products industry and are disaggregated by auxiliary system.

SUMMARY

SAMPLE SAWMILL – 1988 BASE STOCK 120 MMfbm (MILLION BOARD FEET)

OPERATING TIME: 240 DAYS/YR, 16 hrs/day

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL # MOT.	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
LOG PREPARATION	16		4		2				10																						
PRIMARY PROCESS	54		8		10	1		4	28		1					2															
FINISHING	68	4			2	1		4	12						45																
SPECIALTY PROCESSING	12		4	2					6																						
MISCELLANEOUS	57	10	30						14						1							2									
# OF MOTORS	207	14	46	2	14	2		8	70		1				46	2						2									

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
LOG PREPARATION	650		100		300				250																						
PRIMARY PROCESS	3120		200		1500	450		20	700		150					100															
FINISHING	1690	20			300	300		20	300						750																
SPECIALTY PROCESSING	450		100	200					150																						
MISCELLANEOUS	975	50	450						350						25							100									
TOTAL INSTALLED HP:	6885	70	850	200	2100	750		40	1750		150				775	100						100									

kWh/Mfbm: ENERGY PER THOUSAND BOARD FEET OF FINISHED PRODUCT CONSUMED BY MOTORS IN A SAWMILLS

PROCESS	TOTAL ENERGY	MACHINE DRIVE						CONVEYORS					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
		kWh/Mfbm						kWh/Mfbm					
LOG PREPARATION	14		2.2		6.5				5.1				
PRIMARY PROCESS	68		2.4		32.6	9.7		0.4	16.6		3.6		
FINISHING	40	0.4			7.2	6.5		0.5	6.1				
SPECIALTY PROCESSING	10		2.3	4.6					3.2				
MISCELLANEOUS	14	0.1	3.2						9.0				
ENERGY(kWh/MFBM)	146	0.5	10.1	4.6	45.2	16.1		0.9	40.0		3.6		

PROCESS	FANS & BLOWERS						COMPRESSORS						PUMPING					
	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
	kWh/Mfbm						kWh/Mfbm						kWh/Mfbm					
LOG PREPARATION																		
PRIMARY PROCESS			2.6															
FINISHING		19.2																
SPECIALTY PROCESSING																		
MISCELLANEOUS		0.6							1.3									
ENERGY(kWh/MFBM)		19.8	2.6						1.3									

(ENERGY PER 1000 BOARD FEET COMPUTED AS:INSTALLED kW*LOAD FACTOR*UTILIZATION FACTOR/Mfbm OF FINAL PRODUCT*MOTOR POWER FACTOR)
LOAD FACTOR ASSUMED TO BE 75%

(MWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS IN A SAMPLE SAWMILL PRODUCING 120 MMfbm
(BY PROCESS AND SIZE)

PROCESS	TOTAL ENERGY MWH/YR	MACHINE DRIVE						CONVEYORS					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
		MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR
LOG PREPARATION	1649		260		774				614				
PRIMARY PROCESS	8135		292		3911	1160		48	1988		430		
FINISHING	4770	43			859	774		55	737				
SPECIALTY PROCESSING	1212		276	552					384				
MISCELLANEOUS	1704	16	384						1074				
ENERGY(MWh/YR)	17471	59	1212	552	5544	1934		103	4798		430		

PROCESS	FANS & BLOWERS						COMPRESSORS						PUMPING					
	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR	MWH/YR
LOG PREPARATION																		
PRIMARY PROCESS			307															
FINISHING		2302																
SPECIALTY PROCESSING																		
MISCELLANEOUS		77							154									
ENERGY(MWh/YR)		2378	307						154									

SUMMARY

SAMPLE PLYWOOD MILL – TOTAL ANNUAL PRODUCTION 150,000,000 SQUARE FEET

OPERATING TIME: 240 DAYS/YR, 16 hrs/day

****Mill actually operates 3 shifts a day, but in the third shift wood is only dried using natural gas.*

NUMBER OF MOTORS BY SIZE

PROCESS	TOTAL # MOT.	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
LOG PREPARATION	33	6	4		2				12	9																					
PRIMARY PROCESS	84	6	4	2		2			51						10																
FINISHING	7	2	1						3																			9			
SPECIALTY PROCESSING	7	2						3	2																	1					
MISCELLANEOUS	67	31	29	2				1							2												2				
# OF MOTORS	198	47	38	4	2	2		4	68	9					12											1	2	9			

INSTALLED HP BY MOTOR RATING

PROCESS	TOTAL HP	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
LOG PREPARATION	1080	30	100		300				200	450																					
PRIMARY PROCESS	3305	30	100	100		900			1475						250																
FINISHING	107	6	25						75																			450			
SPECIALTY PROCESSING	75	10						15	50																	1					
MISCELLANEOUS	1025	155	665	100				5							50												50				
TOTAL INSTALLED HP:	5592	231	890	200	300	900		20	1800	450					300											1	50	450			

SUMMARY

SAMPLE PLYWOOD MILL – TOTAL ANNUAL PRODUCTION 150,000,000 SQUARE FEET

OPERATING TIME: 240 DAYS/YR, 16 hrs/day

****Mill actually operates 3 shifts a day, but in the third shift wood is only dried using natural gas.*

kWh/1000 ft2 ENERGY PER THOUSAND SQUARE FEET OF FINISHED PRODUCT CONSUMED BY MOTORS IN A PLYWOOD MILL

PROCESS	TOTAL ENERGY kWh/ 1000 ft2	MACHINE DRIVE (kWh/1000 square feet)						CONVEYORS (kWh/1000 square feet)						FANS & BLOWERS (kWh/1000 square feet)						COMPRESSORS (kWh/1000 square feet)						PUMPING (kWh/1000 square feet)					
		SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6
LOG PREPARATION	12	0.1	1.6		4.6				4.6	0.6																					
PRIMARY PROCESS	48	0.1	1.0	0.4		13.8			21.4						4.1													6.8			
FINISHING	1	0.0	0.5						0.2																						
SPECIALTY PROCESSING	0	0.1						0.1	0.2																						
MISCELLANEOUS	9	0.4	4.4	2.0				0.1							1.0												1.0				
ENERGY(kWh/1000 BOARD F	69	1	7	2	5	14		0	26	1					5												1	7			

(ENERGY PER 1000 FT2 COMPUTED AS:INSTALLED kW*LOAD FACTOR*UTILIZATION FACTOR/1000 FT2 OF FINAL PRODUCT*MOTOR POWER FACTOR)
LOAD FACTOR ASSUMED TO BE 75%

(MWH/YR) TOTAL ANNUAL ENERGY CONSUMED BY MOTORS IN A SAMPLE PLYWOOD MILL PRODUCING 150,000,000 ft2/yr

PROCESS	TOTAL ENERGY MWH/YR	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
		SIZE 1 MWH/YR	SIZE 2 MWH/Y	SIZE 3 MWH/Y	SIZE 4 MWH/Y	SIZE 5 MWH/Y	SIZE 6 MWH/YR	SIZE 1 MWH/	SIZE 2 MWH/Y	SIZE 3 MWH/Y	SIZE 4 MWH/YR	SIZE 5 MWH/Y	SIZE 6 MWH/	SIZE 1 MWH/	SIZE 2 MWH/Y	SIZE 3 MWH/Y	SIZE 4 MWH/YR	SIZE 5 MWH/Y	SIZE 6 MWH/	SIZE 1 MWH/	SIZE 2 MWH/Y	SIZE 3 MWH/	SIZE 4 MWH/	SIZE 5 MWH/Y	SIZE 6 MWH/	SIZE 1 MWH/Y	SIZE 2 MWH/Y	SIZE 3 MWH/YR	SIZE 4 MWH/YR	SIZE 5 MWH/YR	SIZE 6 MWH/Y
LOG PREPARATION	1725	15	240		690				690	90																					
PRIMARY PROCESS	7140	15	150	60		2070			3210						615													1020			
FINISHING	93	2	69						23																						
SPECIALTY PROCESSING	54	15						9	30																						
MISCELLANEOUS	1485	60	660	300				15							150											150	150				
ENERGY(MWH/YR)	10497	107	1119	360	690	2070		24	3953	90					765											150	150	1020			

TEMANEX CONSULTING INC.

Appendix C

Wood Products Process Technologies

ISTUM-I Code	Technology Description
Debarking Technologies	
DEB RI CUT	Ring style mechanical debarker/cutter
DEB RO CUT	Rosser-head mechanical debarker/cutter
DEB BI CUT	Biodegradable debarker/cutter
Primary Preparation Technologies	
PRIM SAW	Primary sawing: canter, headrig (chip-n-saw), gang, edger
PRIM S CC	Primary sawing as above, w/ computer control
PRIM ABR	Primary sawing w/ abrasive water jet, zero kerfsaw
PRIM LAS	Primary sawing w/ laser saw, zero kerf
Finishing Technologies	
FTRIMMER	Finish trimmer
TRIM CC	Finish trimmer with computer control
Miscellaneous Lumber Technologies	
FLUM MISC	Finished lumber miscellaneous and mill maintenance
Specialized Lumber Products Technologies	
FLUM SPEC	Finished lumber specialty technologies
FLUM S ACC	Finished lumber specialty technologies w/ auto computer numeric control
Reconstituted Wood Products Technologies	
REC WOOD	Reconstituted wood products, OS derivatives
Kiln Technologies	
KILN/P NG	Natural gas kiln and finish planer
KILN/P HF	Hog fuel kiln and finish planer
KILN/P EL	Electric kiln and finish planer
KILN DEH	Dehumidifying kiln and finish planer
KILN RFM	Radio frequency/microwave kiln and finish planer
Lathe Technologies	
LATHE	Veneer lathe
LATHE CC	Lathe with computer control

Clip/Dry/Clip Technologies

C/D/C NG	Clip/dry/clip process of veneer preparation, natural gas drier
C/D/C HF	Clip/dry/clip, hog fuel drier
C/D/C EL	Clip/dry/clip , electric drier

Press and Trim Technologies

PRESS/TRIM	Composer, hot/cold plywood press and trim

Oriented Strand Board Technologies

OSB TECH	Process for generating OSB products
OSB R1	OSB process using uniform radio wave drying
OSB R2	OSB process using press-platen containing radio wave elements

Miscellaneous Panel Products Technologies

PAN MISC	Panel products miscellaneous and maintenance

Specialized Panel Products Technologies

PAN SPEC	Specialty technologies for panel products
PAN S ACC	Panel specialty techs w/ auto computer numeric control

CHAPTER 7

CHEMICAL PRODUCTS

7.1 Description of Production Process

The chemicals industry includes the production of both inorganic and organic chemicals. Inorganic chemical production accounts for over 96% of the electricity consumed in this industrial branch while organic chemical production is about 4% (methanol/ammonia production is considered organic). Of the over 200 chemical accounts on B.C. Hydro's grid, the firms incorporated into the model account for 95% of demand in this branch.

Inorganic chemicals produced in the province include chlorine and caustic (also known as sodium hydroxide, co-produced with chlorine in the same process), sodium chlorate, hydrogen peroxide and oxygen. Most of these chemicals are generated to meet the demand of the pulp and paper industry. Thus, any shift in demand for digestion or bleaching chemicals in pulp and paper production would be reflected in this industry.

Two major chemical processes, the chlor-alkali and sodium chlorate processes, require significant amounts of electricity in electrolytic cells. These processes are relatively mature, and little improvement in their function or efficiency is expected. Because they dominate the industry (in terms of electricity demand), B.C. chemical production electricity demands are based more on electrolysis (83%) than on motive force (15%).[1]

Ammonia and methanol are produced concurrently in one plant in B.C. (Ocelot in Kitimat). Methanol production utilizes natural gas as a feed stock. In the methanol process, significant quantities of hydrogen are released, captured and attached to condensed atmospheric nitrogen to produce ammonia. The process involves the use of pumps and large compressors (refrigeration is included in this later service type).

Chatterton Chemicals produced phenolic compounds (organic chemicals) and were included in the study until it was announced in early January, 1992, that they would close their doors. The specific product type and quantity was unknown. Only estimates of motor stock in 1988 along with billing statistics were available. Calibration of the model included Chatterton's electricity consumption.

Presently liquid oxygen is generated on site or is purchased from Alberta or Washington. Estimates for specific production plants designed to meet the market demand were included in the model. Compression and refrigeration (included with compression) requirements capture the major portion of electricity demand.

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1. The remainder is allocated to light, heat and miscellaneous uses.

7.2 Modelling the Chemicals Industry

Output Forecast

Table 7.2.1 presents the output forecast for the chemicals industry.

Table 7.2.1 Chemicals Output Forecast
(thousands of tonnes/year)

	1988	2000	2010	
Sodium chlorate	139	200	225	High
		180	200	Low
Sodium hydroxide	265	225	225	High
		175	200	Low
Hydrogen peroxide	0	40	50	High
		36	36	Low
Alcohol/ ammonia	700	700	700	High
		700	700	Low
Oxygen	0	35	70	High
		35	70	Low

(Source: B.C. Hydro Load Forecasting Department, 1991)

An activity forecast was not provided for the later two products of this industrial branch. Consultants in the area and further contact with B.C. Hydro provided estimates of their output. Since they are relatively small components of the total electricity picture and are not as closely related to the pulp and paper industry (the source of the variability in production in the other chemicals), there was no difference postulated between high and low scenarios.

As was mentioned, chemical demand in the pulp and paper industry drives production. The recent shift from chlorine to non-chlorine based bleaching agents will have a significant effect on the demand for the major chemical products in the industry, chlorine and sodium chlorate (the precursor to the bleaching agent, chlorine dioxide). It is difficult to forecast the demand for these chemicals since the demand for B.C. chemical pulp (the most significant type of bleached pulp) is not increasing and recent government policies require the reduction and eventual elimination of chlorine compounds from pulp mill effluents. The shift will be to alternative bleaching agents such as hydrogen peroxide, oxygen and ozone. None of these requires electrolytic processes in their production.

Process Flow Model

There is typically only one major component to each of the chemical processes modelled in ISTUM-I. There are various technologies that can fulfill the requirement of chemical production but each of these uses approximately the same amount of auxiliary services. For example, there are three technologies which can generate chlorine and caustic in the chlor-alkali process but each of them requires the same amount of pumping, conveyance and compression to make the product ready for shipment. Thus, no further disaggregation is required.

There are processes which generate two saleable products (chlorine and caustic, chlorine dioxide and caustic). ISTUM-I included these co-products as output products in much the same way as the model can tally emissions. In this way, a record of the output of each chemical was generated and the model constrained so that the demand for the particular product (in this case, caustic) was not exceeded. See Section 7.4 for further discussion.

7.3 Results

Table 7.3.1 and 7.3.2 present the aggregate results for electricity demand over the 22 year forecast period. Figure 7.3.1 provides a graphic representation of these results. Table 7.3.3 and 7.3.4 present the demand of the various end-uses in frozen and technological runs of the high growth scenario.

Table 7.3.1 Chemicals End-use Electricity Demand: Low
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	1 644	1 950	2 020	
Natural		1 813	1 836	9.1
Econ 1		1 505	1 551	23.2
Econ 3		1 502	1 548	23.4
Econ 5		1 497	1 543	23.6
Tech		1 490	1 536	23.9
Tech/Social		1 481	1 528	24.4

Figure 7.2.1

Flow Model: Chemicals Industry

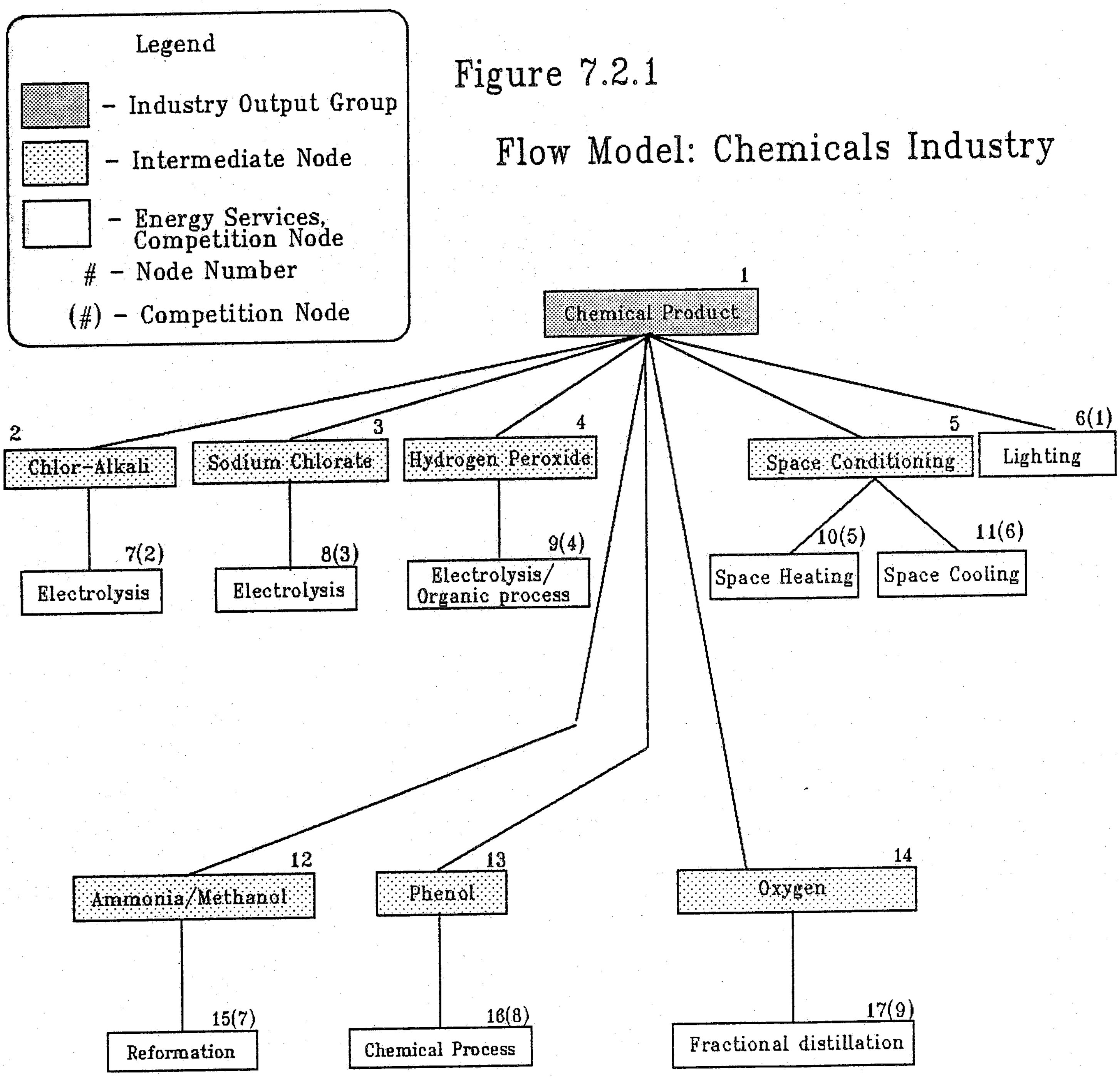

Figure 7.2.1 cont'd

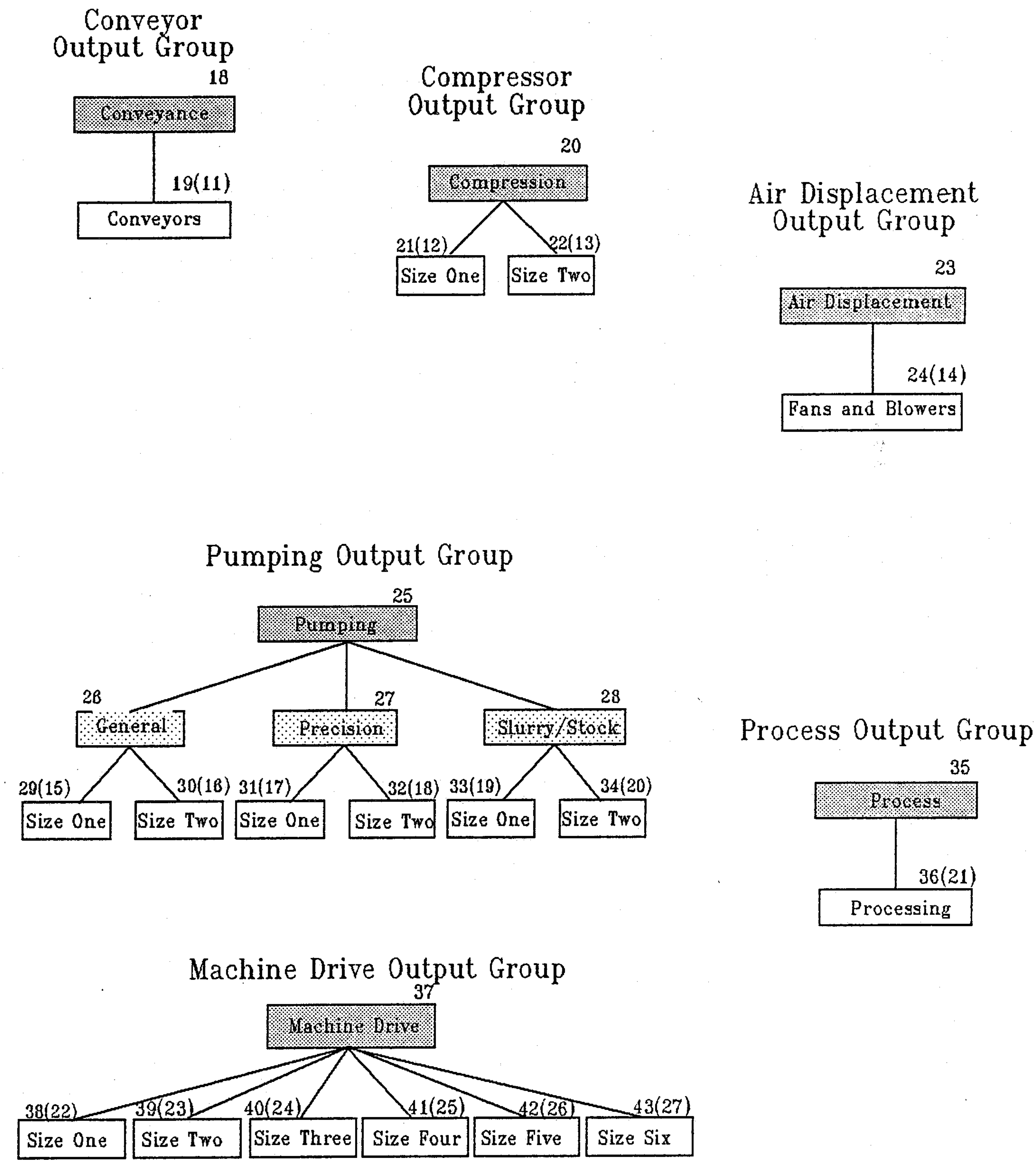

Figure 7.3.1 Chemical Products End-use Electricity Demand

High Growth

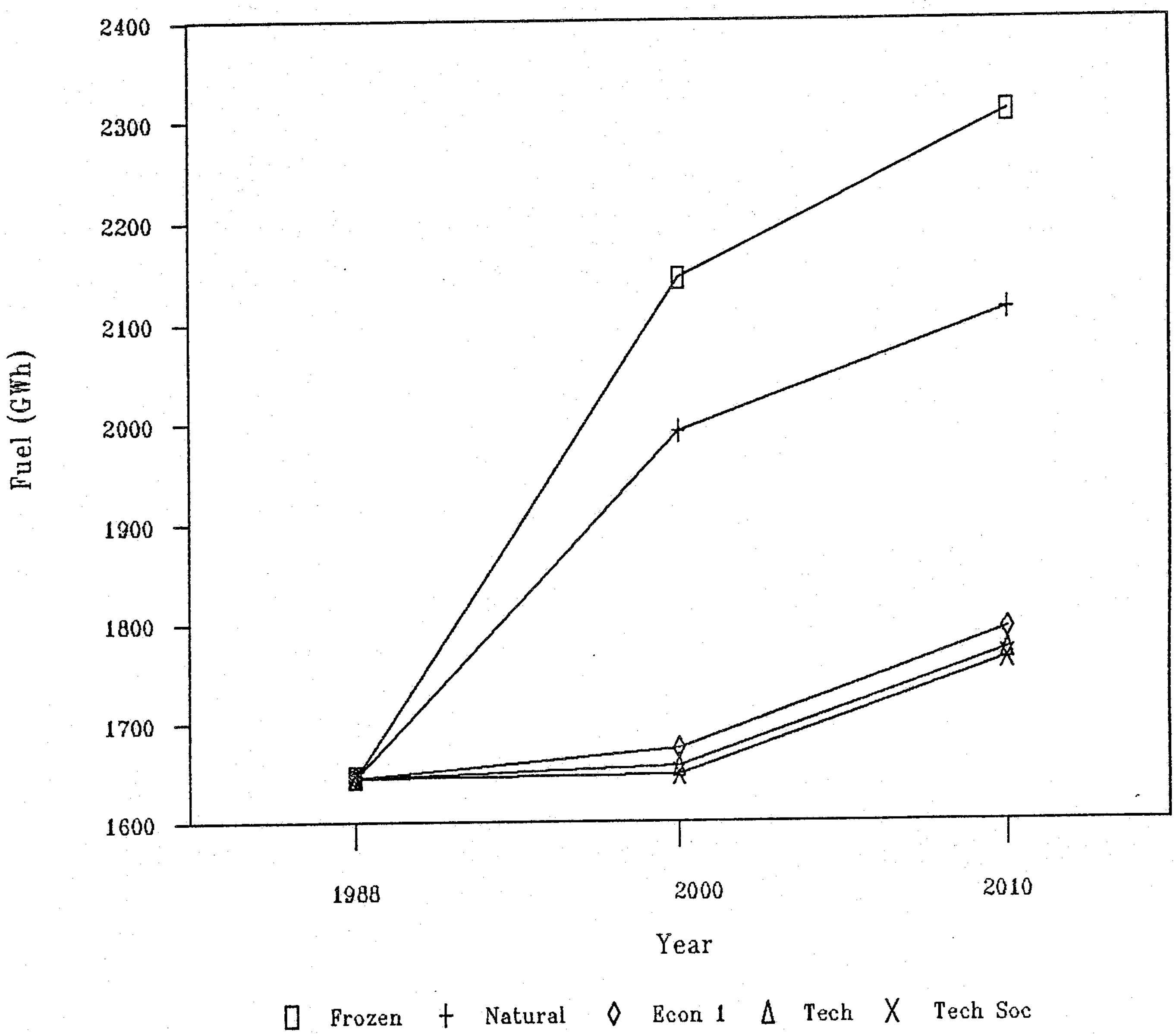

Table 7.3.2 Chemicals End-use Electricity Demand: High
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	1 644	2 144	2 308	
Natural		1 992	2 113	8.5
Econ 1		1 673	1 793	22.3
Econ 3		1 670	1 789	22.5
Econ 5		1 668	1 783	22.7
Tech		1 657	1 773	23.2
Tech/Social		1 648	1 764	23.6

Table 7.3.3 Chemical Products End-use Electricity Demand:
High, Frozen Efficiency Run
(GWh)

	1988	2000	2010
Machine Drive	258	309	338
Pump	129	146	156
Air Displacement	6	6	6
Compress	98	132	151
Convey	3	4	5
Other	23	20	21
Electrolysis	1 362	1 800	1 934
Process Heat	0	0	0
Light	12	17	18
Other	12	17	18
Total	1 644	2 144	2 308

Table 7.3.4 Chemical Products End-use Electricity Demand:
High, Technological Efficiency Run
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Machine Drive	258	134	139	58.9%
Pump	129	49	49	68.6%
Air Displacement	6	4	4	33.3%
Compress	98	59	64	57.6%
Convey	3	4	4	20.0%
Other	23	18	19	9.5%
Electrolysis	1 362	1 497	1 605	17.0%
Process Heat	0	0	0	0.0%
Light	12	9	9	50.0%
Other	12	17	18	0.0%
Total	1 644	1 657	1 773	23.2%

This industrial branch shows low potential electricity efficiency gains relative to pulp and paper.

The already relatively high level of maintenance and monitoring in this industry supports the notion that potential efficiency gain from increased rigour in maintenance and monitoring schedules is small. Recall that the social efficiency potential in this industry, as described in Chapter 3, includes a 5% improvement in pumps, a 2% improvement in fans, conveyors, and process motor drive oversizing and a 7% improvement in compressors. This results in an overall efficiency improvement of approximately 3%.

7.4 Analysis and Caveats

As was mentioned in the introduction to this chapter, the major electricity use is in the electrolytic processes which generate chlorine and caustic, and sodium chlorate. These mature technologies do not have great potential for efficiency improvement. Consequently, the chemicals branch has a low efficiency potential relative to pulp and paper.

This is not to say that there are no gains to be made. The B.C. chlor-alkali industry was, in 1988, dependant on outdated mercury and diaphragm electrolytic cells.[2] Switching to newer membrane cells permits a saving of 500-600 kWh/tonne.(Temanex, 1991)

A second potential electrolytic saving occurs in the production of sodium chlorate. In 1988, 58% of sodium chlorate was produced using less-efficient graphite cells. Switching these to metal cells could reduce consumption of electricity by 2000 kWh/tonne. (Temanex, 1991)

There are also new membrane technologies available for the production of hydrogen peroxide. The process is a bipolar membrane-based separation which requires a considerable amount of electricity but has the benefit of generating caustic (sodium hydroxide) as a co-product. The penetration of this technology affects demand for pumping, compression and conveyance, because, when compared to competing hydrogen peroxide technologies, significantly more of these services are required.

A second new hydrogen peroxide process depends on the availability of methyl-benzyl-alcohol and is known as the ARCO process. In terms of electricity consumption per unit of peroxide produced, this process is the most efficient.

Among motor systems, the potential for efficiency improvement in compression, the major service requirement in this industry, is high. This explains most of the observed efficiency gains.

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2. Mercury cells are electrolytically more efficient than diaphragm cells but require a number of emission control devices to prevent release of mercury to the environment. The net effect is that electricity demanded by these two technologies per unit output is the same. (Temanex, 1991)

In the Technological Run, demand reduction in pumping, conveyance and compression systems (see Volume II, Chemical Products) are, in part, the result of not allowing any penetration of the bipolar membrane process for hydrogen peroxide production, mentioned above. The alternative processes in hydrogen peroxide generation do not require as much of these auxiliary services as the bipolar process, for this run. The penetration of this technology in the other runs results in an increase in demand for these auxiliary services.

A second factor causing a significant reduction in the above mentioned auxiliary services is the complete capture of the hydrogen peroxide production by the newer, more efficient, liquid phase oxidation of methyl-benzyl-alcohol, or the ARCO process. This process does not penetrate the market in economic runs due to its significantly higher operating and maintenance costs. It is better suited to sites where petrochemical plants are in operation (e.g., Alberta). It is doubtful that this process would ever make inroads in B.C. (Temanex, 1991)

An interesting modelling problem arose in the attempt to simulate caustic production. Some alternative methods to produce caustic are much less energy-intense than the present chlor-alkali process because they do not involve electrolysis. The reason caustic has historically been generated electrolytically is because chlorine, once the desired product, is also generated. At present, the demand for chlorine and caustic is approximately in balance with the output of the production process (which is chemically defined at 1.12 tonnes of caustic for each tonne of chlorine). A decline in the demand of chlorine does not cause a decline in the demand for caustic since these products are used in two different aspects of the pulping process. Because the study was constrained to follow demand for sodium hydroxide (activity forecast), technologies which reduce demand due to better recovery and recycling were not considered viable. Secondly, alternative processes that could generate caustic require different fuels, eliminating, for the most part, electricity demand.[3] These technologies could not be competed with the present ones since interenergy substitution was not permitted.

There were several questions, posed by our sub-consultants and others who were given access to the activity forecast and to our initial assumptions, regarding the mix of chemical outputs based on the demand for alternatives to the bleaching process. In the end, we used the agreed-upon activity forecast with the additions of ammonia/methanol and oxygen.

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3 Production of one metric electrochemical unit (MECU) of chlorine and caustic (one tonne chlorine and 1.12 tonnes caustic) requires roughly 2800 KWh in total. If we apportion roughly half of this to the production of caustic, then these new alternative process, in effect, use no electricity.

Appendices

To

Chapter 7

Chemical Products

Appendix A

Chemical Products Assumptions

Auxiliary systems:

1. Conveyor systems are not inclined.
2. Refrigeration is captured under compression.
3. Oxygen production is based on compression and a small amount of pumping.
4. The penetration of efficient auxiliary systems is 10%
5. Load factor for chemical products auxiliary systems:

Process drive	.80 at .9 utilization
Pumping	.60 at .9 utilization
Fans and Blowers	.60 at .9 utilization
Conveyors	.60 at .9 utilization
Compressors	1.0 at .7 utilization

(Willis, pers com., 1991)

6. Social Potential parameters:

   a. Motor Systems

System	Potential
Pump	5%
Air Displacement	2%
Compression	7%
Conveyance	2%
Process Drive	2%
Lighting	10%
HVAC	5%

b. Economic Runs

Run	Percentage of Potential (from above Table)
Frozen	0%
Natural	0%
Econ 1	0%
Econ 2	15%
Econ 3	25%
Econ 4	45%
Econ 5	70%
Technological	0%
Technological/ Social	100%

(Welchman, pers com., 1992; Willis, pers com., 1992; Scott, pers com., 1992; Evans, pers com., 1991; Temanex, pers com., 1992; Merrill, pers com., 1991; Mellis, pers com., 1991)

Process Systems

1. Recapture of mercury in mercury-based chlor-alkali cells is counted as electricity used for electrolysis.

2. All sodium chlorate is shipped crystallized and dried beginning in 1992.

3. Sodium chlorate bipolar membrane process will not enter the market because chlorine-based compounds used in pulp bleaching will soon fall out of demand and the technology is not yet considered viable in the industry (expected date of viability is 2000).

Appendix B

Chemical Products Motor Systems Base Stock

The following pages contain a listing of the base stock of motors in the chemical products branch. They are disaggregated by auxiliary system.

CHLOR-ALKALI – 1988 BASE STOCK 237,000 MECU/YR

(MECU=METRIC ELECTROCHEMICAL UNIT=1 TONNE OF CHLORINE + 1.12 TONNES OF CAUSTIC SODA)

OPERATIONS: 350 days/yr, 24hrs/day

Machine Drive Type	MACHINE DRIVE SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	CONVEYORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	FANS & BLOWERS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
TOTAL INSTALLED HP	410	477		4765			280						349					
# OF MOTORS	213	24		24			95						47					
ENERGY KWh/MECU	12.4	14.4		134.4			8.4						10.6					

Machine Drive Type	COMPRESSORS SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	PUMPING SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
TOTAL INSTALLED HP			4448				1819	1112	1557			
# OF MOTORS			47				593	166	47			
ENERGY KWh/MECU			134.4				55.0	33.6	47.0			

450 kWh/MECU *TOTAL ENERGY CONSUMED BY MOTORS IN THE PROCESS*

2600 kWh/MECU *ADD AVERAGE ELECTROLYTIC POWER CONSUMPTION* ← Avg.

3050 kWh/MECU *ELECTRICITY CONSUMPTION PER MECU OF THE FINISHED PRODUCT*

722921 MWH/YR TOTAL ANNUAL ELECTRICITY CONSUMPTION BY CHLOR-ALKALI INDUSTRY IN B.C.

(ENERGY CONSUMED BY MOTORS COMPUTED AS:
INSTALLED kW*LOAD FACTOR/MECU OF FINAL PRODUCT*MOTOR POWER FACTOR)
LOAD FACTOR ASSUMED TO BE 80%

TEMANEX CONSULTING INC.

PETROCHEMICALS – CHATTERTON PETROCHEMICAL CORPORATION

1988 BASE STOCK NOT AVAILABLE

OPERATIONS: 350 days/yr, 24hrs/day

Machine Drive Type	MACHINE DRIVE Size 1 (HP)	Size 2 (HP)	Size 3 (HP)	Size 4 (HP)	Size 5 (HP)	Size 6 (HP)
centrifuge			30			
			30			
			30			
mixer	5.0					
	3.0					
drum flaker	3.0					
dryer		7.5				
densifier		15.0				
granulator		15.0				
bagger		5.5				
flaker	1.0					
	5.0					
mixer	1.5	7.5				
		25.0				
		15.0				
bagger		5.5				
TOTAL INSTALLED HP	19	96	90			
# OF MOTORS	6	8	3			
ENERGY KWh/TONNE						

Machine Drive Type	CONVEYORS Size 1 (HP)	Size 2 (HP)	Size 3 (HP)	Size 4 (HP)	Size 5 (HP)	Size 6 (HP)
centrifuge	2	15				
	2					
	2					
mixer	2					
	2					
drum flaker	1					
dryer	3					
densifier	1					
granulator	1					
bagger	1					
flaker	1					
	1					
mixer	1					
	5					
	1					
bagger	5					
	2					
	2					
	1					
TOTAL INSTALLED HP	32	15				
# OF MOTORS	19	1				
ENERGY KWh/TONNE						

Machine Drive Type	FANS & BLOWERS Size 1 (HP)	Size 2 (HP)	Size 3 (HP)	Size 4 (HP)	Size 5 (HP)	Size 6 (HP)
centrifuge	3	20	30			
	2	15	40			
	5	10	26			
mixer	1	25	75			
	2	15	75			
drum flaker	5	15	75			
dryer	1	15	75			
densifier	5	15				
granulator	5	15				
bagger	5	15				
flaker	1	15				
	1	15				
mixer	1					
	1					
	5					
bagger	1					
	5					
TOTAL INSTALLED HP	47	190	396			
# OF MOTORS	17	12	7			
ENERGY KWh/TONNE						

Machine Drive Type	COMPRESSORS Size 1 (HP)	Size 2 (HP)	Size 3 (HP)	Size 4 (HP)	Size 5 (HP)	Size 6 (HP)
centrifuge	5		60	200	300	600
	5		50		300	600
			60		450	
mixer			60			
TOTAL INSTALLED HP	10		230	200	1050	1200
# OF MOTORS	2		4	1	3	2
ENERGY KWh/TONNE						

Machine Drive Type	PUMPING Size 1 (HP)	Size 2 (HP)	Size 3 (HP)	Size 4 (HP)	Size 5 (HP)	Size 6 (HP)
centrifuge	6*0.3	20*7.5	50	150		
	11*0.5	22*10	50	150		
	4*0.8	19*15	40	150		
mixer	10*1	8*20	40	150		
	16*1.5	5*25	40	150		
drum flaker	16*2			200		
dryer	38*3			200		
densifier	27*5			200		
granulator				200		
TOTAL INSTALLED HP	333	941	220	1550		
# OF MOTORS	129	74	5	9		
ENERGY KWh/TONNE						

TOTAL ENERGY CONSUMED BY MOTORS IN THE PROCESS UNKNOWN

6618 INSTALLED HP

(ENERGY PER TONNE COMPUTED AS:INSTALLED kW*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

TEMANEX CONSULTING INC.

METHANOL & AMMONIA PLANT – OCELOT CHEMICALS INC.,KITIMAT – MOTORS

1988 BASE STOCK 700,000 MT/YR

	CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING						PUMP UTIL.
	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5	SIZE 6	
	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(HP)	(%)
Plant Operatos								20		150							300	4500			25*40HP		500		100
359 days/Yr								20		150								4000					500		100
24 hrs/day								20		150								4000					500		100
								20		150								2500					500		100
								20		150													300		100
								20															300		100
								20															400		100
								20															250		100
								20															250		100
								20															250		100
								20															450		10
								20															450		10
								20															450		10
								20															450		10
								20														200			5
																						200			5
TOTAL INSTALLED HP:								300		750							300	15000			960	400	5550		
# OF MOTORS								15		5							1	4			25	2	14		
ENERGY kWh/TONNE								3.0		6.9							2.8	137.7			9.4	0.2	37.4		

197.4 (kWh/MT) *(ENERGY PER METRIC TONNE COMPUTED AS:*
*INSTALLED kW*LOAD FACTOR*UTILIZATION FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)*
(LOAD FACTOR 75%)

138146 (MWh) *TOTAL ANNUAL ENERGY CONSUMED BY MOTORS*

HYDROGEN PEROXIDE PLANT – CAPACITY 41,000 TONNES/YR (FMC–PRINCE GEORGE)

OPERATIONS: 350 days/yr, 24hrs/day

1988 BASE STOCK 0 TONNES/YR

MACHINE DRIVE

Machine Drive Type	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
agitators	0.5	10.0				
	0.5	10.0				
TOTAL INSTALLED HP:	1	20				
	2	2				
ENERGY KWh/TONNE	0.2	3.1				

CONVEYORS

Machine Drive Type	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
agitators						
TOTAL INSTALLED HP:						
ENERGY KWh/TONNE						

FANS & BLOWERS

Machine Drive Type	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
agitators	1.5	25	70			
	5.0		70			
			70			
TOTAL INSTALLED HP:	7	25	210			
	2	1	3			
ENERGY KWh/TONNE	0.9	3.8	32.1			

COMPRESSORS

Machine Drive Type	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
agitators				150	200	1500
				150		1500
				150		1500
				150		
				150		
				150		
				150		
TOTAL INSTALLED HP:				1050	200	4500
				7	1	3
ENERGY KWh/TONNE				160.5	28.5	642.0

PUMPING

Machine Drive Type	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
agitators	2.0	7.5	40	150	400	
	5.0	7.7	40	125	400	
	5.0	7.5	40	125	400	
	5.0	7.5			325	
	1.5	7.5			325	
	0.5	20.0			350	
	0.5	20.0			350	
	0.5	25.0			250	
	5.0	25.0			250	
	3.0	7.5			350	
	5.0	10.0			350	
	5.0	7.5				
	5.0	7.5				
	0.5	7.5				
	0.5	10.0				
	0.5	10.0				
	0.3	10.0				
	0.5	20.0				
	5.0	20.0				
	5.0	7.5				
	1.0	7.5				
	1.0	10.0				
	5.0	25.0				
	2.0	10.0				
	1.0	15.0				
	1.5	15.0				
	0.5					
TOTAL INSTALLED HP:	67	328	120	400	3750	
	27	26	3	3	11	
ENERGY KWh/TONNE	9.6	50.1	18.3	61.1	535.0	

1545.4 kWh/T TOTAL ENERGY CONSUMED BY MOTORS IN THE PROCESS

(ENERGY PER TONNE COMPUTED AS:INSTALLED kW*LOAD FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

TEMANEX CONSULTING INC.

SODIUM CHLORATE – 1988 BASE STOCK 123,000 T/YR

OPERATIONS: 350 days/yr, 24hrs/day

Machine Drive Type	MACHINE DRIVE						CONVEYORS						FANS & BLOWERS						COMPRESSORS						PUMPING					
	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)	SIZE 1 (HP)	SIZE 2 (HP)	SIZE 3 (HP)	SIZE 4 (HP)	SIZE 5 (HP)	SIZE 6 (HP)
TOTAL INSTALLED HP:	1	87	235						600				32	70					5	45	915	1000			164	668	2373	1120		
# OF MOTORS	4	4	4						12				15	4					1	4	16	5			74	50	40	7		
ENERGY kWh/TONNE	0.1	5.7	15.3						39.2				2.1	4.6					0.3	2.9	59.8	61.0			10.7	44.9	155.2	68.3		

470 kWh/T TOTAL ENERGY CONSUMED BY MOTORS IN THE PROCESS

5000 kWh/T ADD TYPICAL ELECTROLYTIC POWER CONSUMPTION

5470 kWh/T ELECTRICITY CONSUMPTION PER TONNE OF THE FINISHED PRODUCT

673938 MWH/YR TOTAL ANNUAL ELECTRICITY CONSUMPTION BY SODIUM CHLORATE INDUSTRY IN B.C.

(ENERGY CONSUMED BY MOTORS COMPUTED AS:
INSTALLED kW*LOAD FACTOR/TONNES OF FINAL PRODUCT*MOTOR POWER FACTOR)

TEMANEX CONSULTING INC.

Appendix C

Chemical Products Process Technologies

ISTUM-I Code	Technology Description
Chlor-alkali Technologies	
EL CCL HG	Caustic/chlorine electrolysis - mercury cell
EL CCL DIA	Caustic/chlorine electrolysis - diaphragm
EL CCL MB	Caustic/chlorine electrolysis - membrane cell
EL CAUSTIC	Caustic electrodialysis - new electric alternatives, including bipolar membrane and sodium sulfate electrolysis
NONEL CAU	Caustic/chlorine electrolysis - non-electrolytic alternatives, including improved recycling (demand reduction)
Sodium Chlorate Technologies	
EL S-C G	Sodium chlorate electrolysis - graphite cell
EL S-C M	Sodium chlorate electrolysis - metal cell
EL S-C BM	Sodium chlorate production with bipolar membrane, caustic byproduct
Hydrogen Peroxide Technologies	
EL HP BM	Hydrogen peroxide production with bipolar membrane, caustic byproduct
OR HP AN	Hydrogen peroxide process - anthraquinone
OR HP ALC	Hydrogen peroxide process using methyl-benzyl-alcohol
Sodium Chlorate Technologies	
REFORMER	Process to convert air and natural gas to methane and ammonia
Sodium Chlorate Technologies	
PHENOL	Phenol and by-products production, Chatterton
Sodium Chlorate Technologies	
CRYO AIR	Air compression and distillation, cryogenics

CHAPTER 8

PETROLEUM REFINING

8.1 Description of the Production Process

The refining of crude oil is a complex, energy-intensive process. The degree of complexity is, to some extent, determined by the type of crude to be refined and the end products. There are, however, typical procedures used in all refineries. For example, all refineries physically separate the various components of crude oil by a distillation process and then chemically alter certain of these compounds to increase the output of more desired products. Usually over 40% of the process energy is provided by refinery gases and waste liquid fuels. Electricity accounts for approximately 8-10% of the energy required (EPRI, 1986).

Because of their complexity, petroleum refineries present a considerable challenge to process modelling. A refinery process model for ISTUM-I was recently completed as part of a research project on greenhouse gas emissions for the Canadian World Energy Conference and the Canadian Department of Energy, Mines and Resources (Margolick et al., 1992). However, the petroleum industry is only responsible for about two percent of industrial electricity demand in B.C. This demand is primarily for the pumping and compression machine drive end-uses. Moreover, the refineries in B.C. are not expected to see dramatic renovation over the forecast period.

As a consequence, it was decided that petroleum refining would be treated in the same way as other non-electricity-intensive industries. This means that a process flow model was not simulated. Instead, end-use services, especially pumping and compression, were linked directly to the output forecasts. This information produced the driving variables for simulating the evolution of equipment stocks for each scenario and run. The results should be very close to the full simulation with the process flow model, and for such an inconsequential branch (in terms of electricity) small differences due to the simpler method would be undetectable.

8.2 Modelling the Petroleum Refining Industry

Output Forecasts

Table 8.2.1 presents the high and low forecasts for the petroleum refining industry.

Table 8.2.1 Petroleum Refining Output Forecast
(thousands of cubic metres)

	1988	2000	2010	
Refined product	9668	10000	10000	High
		8000	8000	Low

(Source: B.C. Hydro Load Forecasting Department, 1991)

In both the high and low growth scenarios the B.C. petroleum refining industry is not expected to see significant growth in output. This is due to (1) less than vigorous growth in B.C. demand for petroleum products, and (2) increasing import of refined petroleum products via pipeline from more modern refineries in Alberta.

Process Flow Model

The process flow model aggregates the entire production process into one process node. This is represented in node 5 of the other manufacturing flow model. The electricity conservation potential analysis is then concentrated in the auxiliary systems.

Together, pumping and compression account for over 90% of electricity demand. This ratio is assumed to be constant into the future, as there is little variation in electricity demand by production process. Thus, the output forecasts are used to drive the auxiliary systems flow model, with the demand for pumping and compression growing in step with output.

8.3 Results

Table 8.3.1 and Table 8.3.2 present the aggregate results for electricity demand over the 22 year forecast period.

Table 8.3.1 Petroleum Refining End-use electricity Demand:
Low
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	380	313	313	
Natural		282	268	14.3%
Econ 1		129	124	60.3%
Econ 3		126	121	61.3%
Econ 5		120	115	63.2%
Tech		129	123	60.4%
Tech Soc		115	111	64.6%

Figure 8.2.1 Flow Model: Other Manufacturing

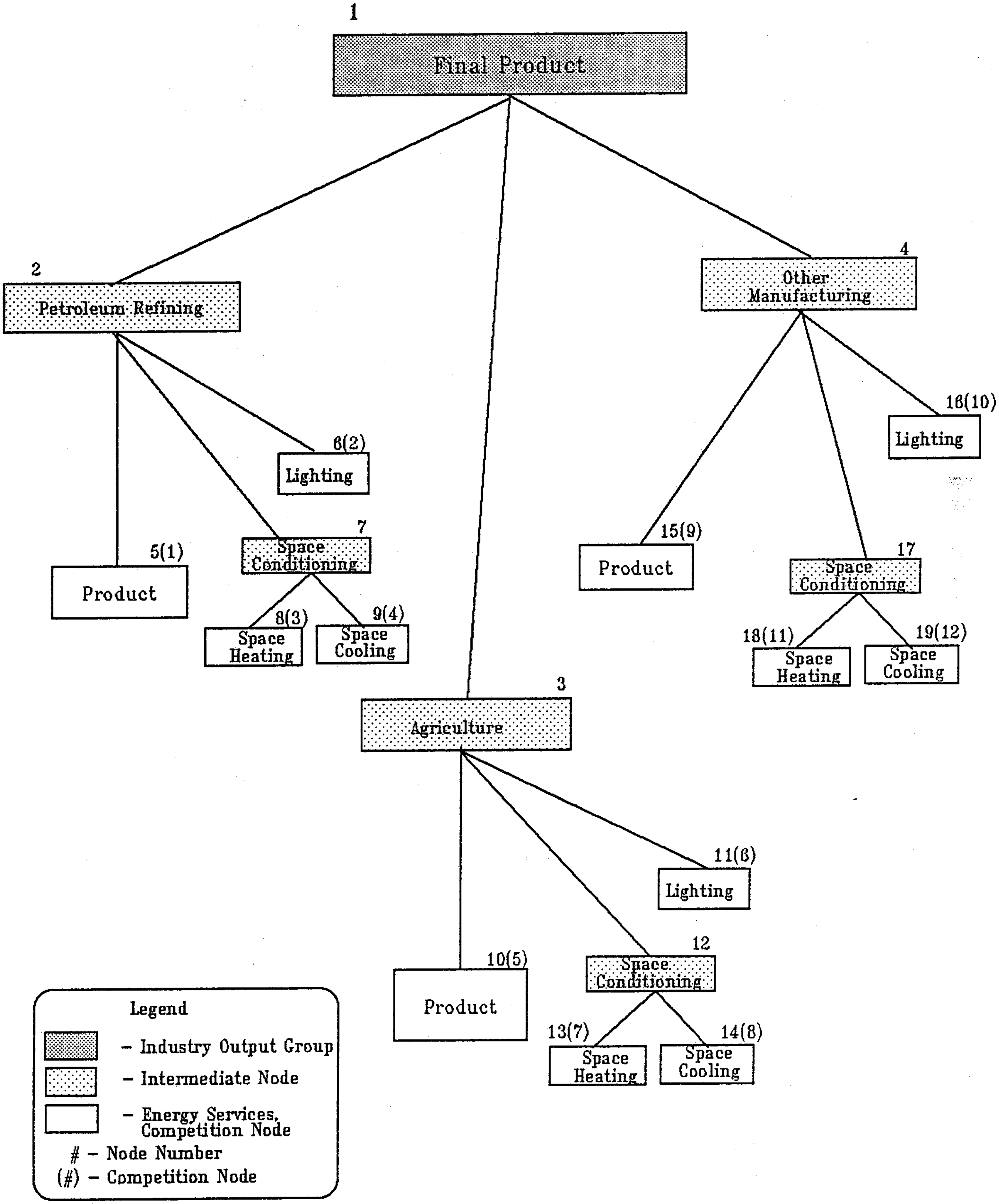


Figure 8.2.1 cont'd

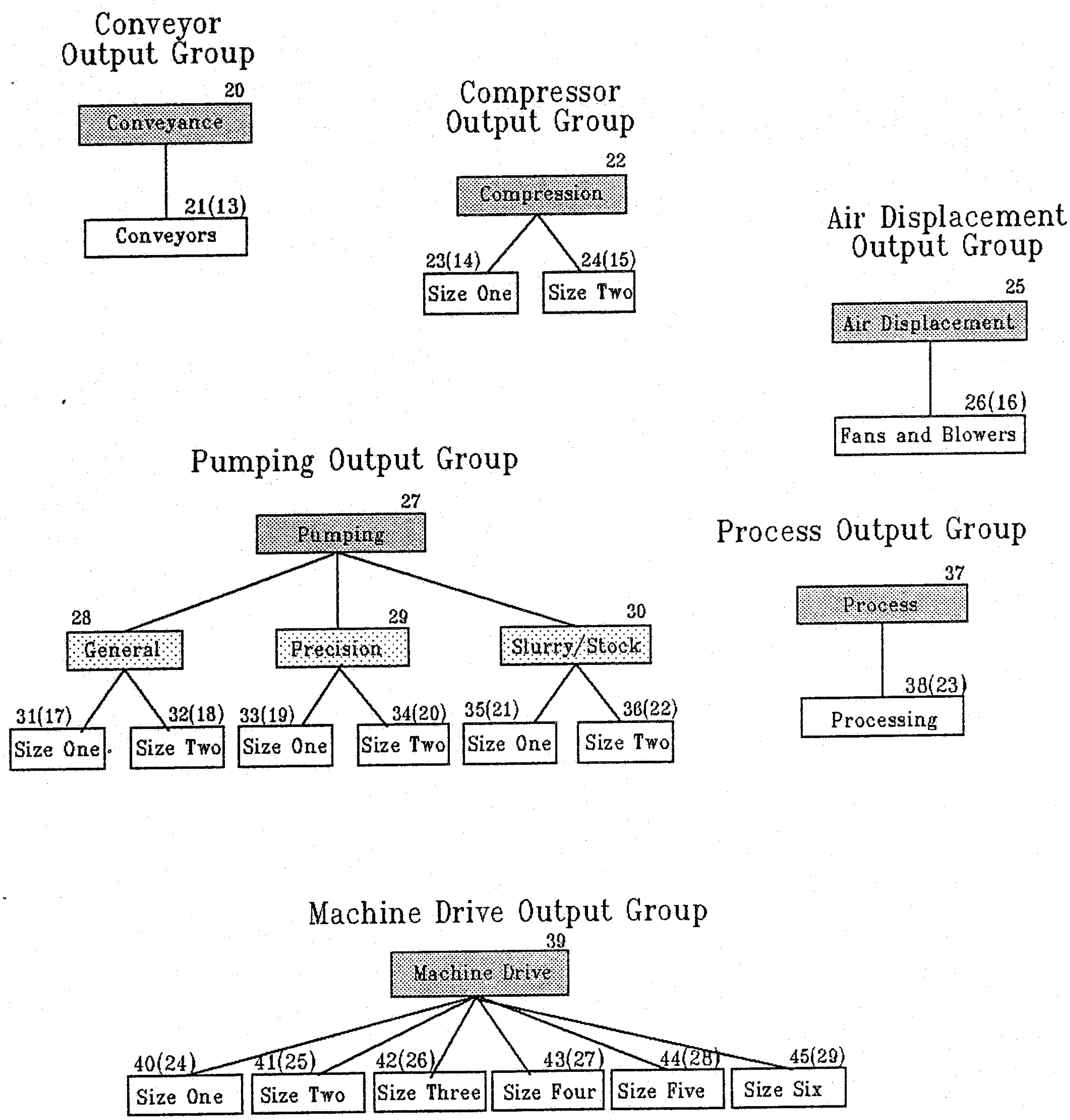


Figure 8.3.1 Petroleum Refining End-use Electricity Demand

High Growth

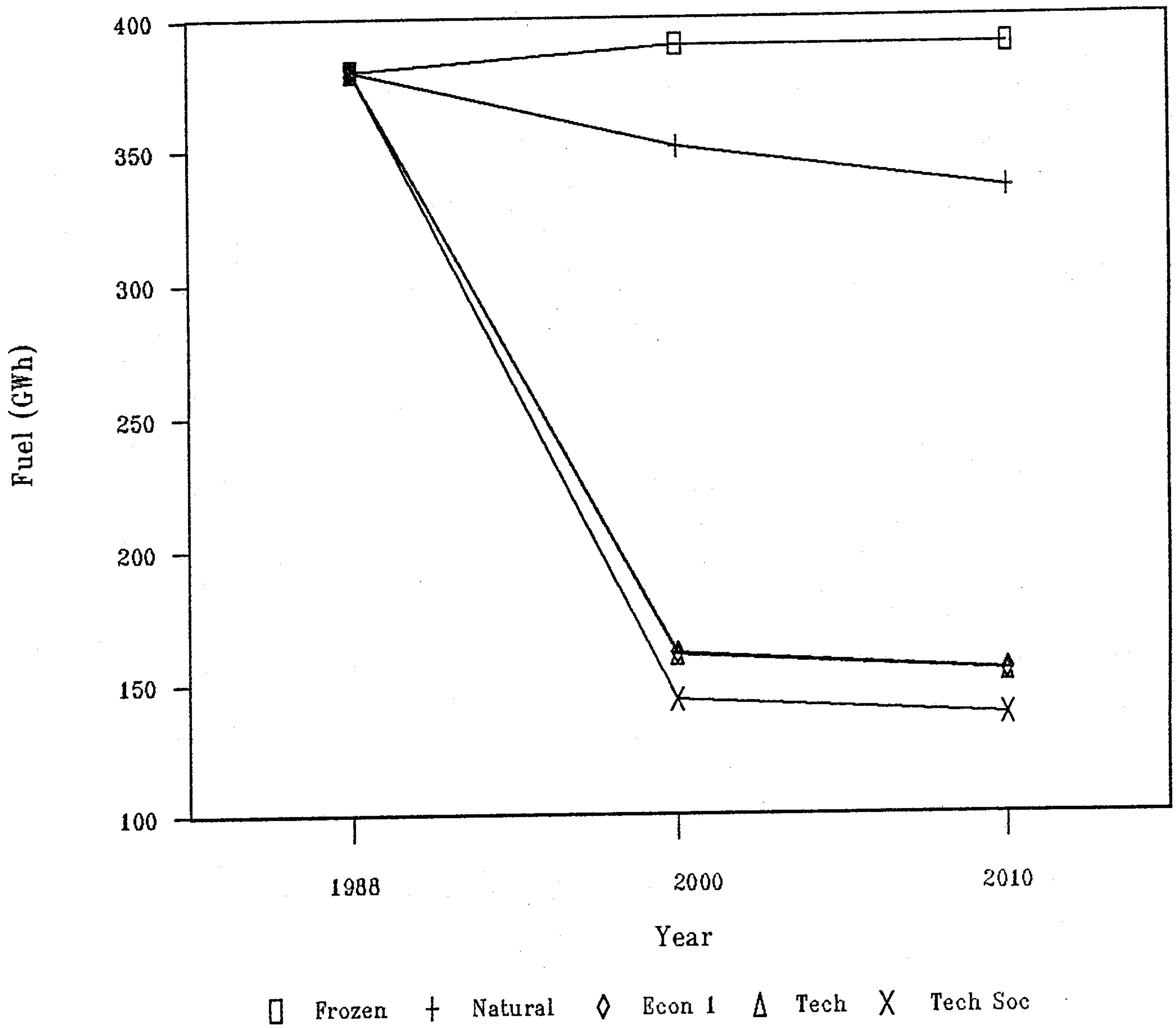


Table 8.3.2 Petroleum Refining End-use electricity Demand:
High
(GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	380	389	389	
Natural		351	335	13.9%
Econ 1		160	154	60.4%
Econ 3		156	150	61.4%
Econ 5		149	143	63.3%
Tech		160	153	60.5%
Tech Soc		143	137	64.6%

Table 8.3.3 Petroleum Refining End-use electricity Demand:
High Frozen Efficiency Run
(GWh)

Service	1988	2000	2010
Machine Drive	365	373	373
Pump	300	307	307
Air Displacement	17	17	17
Compression	48	49	49
Conveyance	0	0	0
Other	0	0	0
Electrolysis	0	0	0
Process Heat	0	0	0
Light	13	15	15
Other	2	2	2
Total	380	389	389

Table 8.3.4 Petroleum Refining End-use electricity Demand:
High Technological Efficiency Run
(GWh)

Service	1988	2000	2010	% Reduction from Frozen in 2010
Machine Drive	365	150	144	61.4%
Pump	300	116	110	64.2%
Air Displacement	17	10	9	47.1%
Compression	48	25	24	51.0%
Conveyance	0	0	0	0.0%
Other	0	0	0	0.0%
Electrolysis	0	0	0	0.0%
Process Heat	0	0	0	0.0%
Light	13	8	8	46.7%
Other	2	2	2	0.0%
Total	380	160	153	60.7%

In both the high and low growth scenarios, there is significant opportunity for conservation potential, higher than those of pulp and paper. Social potential conservation is greater than in pulp and paper, as well.

Tables 8.3.3. and 8.3.4 provide an end-use service listing for petroleum refining. Pumping dominates the end-use requirement, accounting for more than 75% of total electricity demand.

8.4 Analysis and Caveats

Petroleum refining has a high degree of conservation potential, greater than the pulp and paper industry, because of the relative importance of pumping and compression. Conservation potential for both the low and high growth scenarios is therefore based on a shift towards the more efficient pump and compressor systems.

The petroleum refining industry is in decline in British Columbia. Major investment in newer more efficient technologies to reduce electricity demand is not likely. Although there is some potential for electricity conservation in this industry, particularly in the auxiliary systems, little investment will be forthcoming. Thus, the natural estimate may be high, since it estimates the same penetration of efficient motors as is expected to occur in other sectors.

Appendices

to

Chapter 8

Petroleum Refining Industry

Appendix A

Petroleum Refining Industry Assumptions

Auxiliary Systems:

(1) No conveyor systems are used in petroleum refining.

(2) Load factor for petroleum refining auxiliary systems:

Process drive	.80 at .9 utilization
Pumping	.65 at .9 utilization
Fans and Blowers	.65 at .9 utilization
Compressors	1.0 at .7 utilization

(Willis, 1991)

(3) Social Potential parameters:

a. Motor Systems

System	Potential
Pump	10%
Air Displacement	5%
Compression	15%
Process Drive	2%
Process Heat	10%
Lighting	10%
HVAC	5%

b. Economic Runs

Run	Percentage of Potential (from above Table)
Frozen	0%
Natural	0%
Economic 1	0%
Economic 2	15%
Economic 3	25%
Economic 4	45%
Economic 5	70%
Technological	0%
Technological/ Social	100%

(Welchman, 1992; Willis, 1992; Scott, 1992; Evans, 1991; Temanex, 1992; Merrill, 1991; Mellis, 1991)

The motor system end-use breakdown for other manufacturing activities, excluding agriculture, was:

a. Pumping	37%
b. Conveyance	43%
c. Compression	11%
d. Air Displacement	6%
e. Other	3%

(Marbek, 1991)

For the agriculture branch the motor system end-use requirements were estimated at:

a.	Pumping	90%
b.	Conveyance	10%

This analysis differs from that used for the rest of B.C. industry because B.C. Hydro electricity sales data and 1988 information on GDP output is used to determine auxiliary system end-use electricity demand and base stocks. No additional primary or secondary data was used to develop the other manufacturing branch analysis.

9.2 Modelling Other Industries

Output Forecasts

Unlike the electricity-intensive industries, the output of the rest of the industrial sector is not based on physical output but rather GDP. This creates additional uncertainty into the forecasts due to the inclusion of more parameters which could effect the output indicators.

Table 9.2.1 presents the high and low forecasts for the other manufacturing industry.

Table 9.2.1 Other Manufacturing GDP Forecast
($1990 - millions)

	1988	2000	2010	
Other Manufacturing	8 653	10 974	13 377	High
		9 750	10 770	Low

(Source: B.C. Hydro Load Forecasting Department, 1991)

In both the high and low growth scenarios the B.C. other manufacturing branch is expected to grow significantly to the year 2010. In the high growth scenario output should increase by 55% while in the low scenario this growth reaches only approximately 25%.

Process Flow Model

Again, as in the case of petroleum refining, the production process is represented by one node which allocates the entire allotment of auxiliary service end-use demand to one step (see Figure 9.2.1). Therefore, the energy demand representation of the other branch is composed of the auxiliary systems flow model

9.3 Results

Table 9.3.1 to 9.3.4 and Figure 9.3.1 present the aggregate results for end-use electricity demand over the 22 year forecast period.

Table 9.3.1 Other Manufacturing End-use electricity Demand: Low (GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	1 729	1 954	2 160	
Natural		1 825	1 956	9.4%
Econ 1		1 230	1 340	38.0%
Econ 3		1 205	1 313	39.2%
Econ 5		1 162	1 266	41.4%
Tech		1 221	1 330	38.4%
Tech Soc		1 126	1 227	43.2%

Table 9.3.2 Other Manufacturing End-use electricity Demand: High (GWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	1 729	2 200	2 678	
Natural		2 051	2 425	9.5%
Econ 1		1 384	1 659	38.0%
Econ 3		1 357	1 627	39.3%
Econ 5		1 308	1 568	41.4%
Tech		1 375	1 647	38.5%
Tech Soc		1 267	1 520	43.3%

Figure 9.2.1 Flow Model: Other Manufacturing

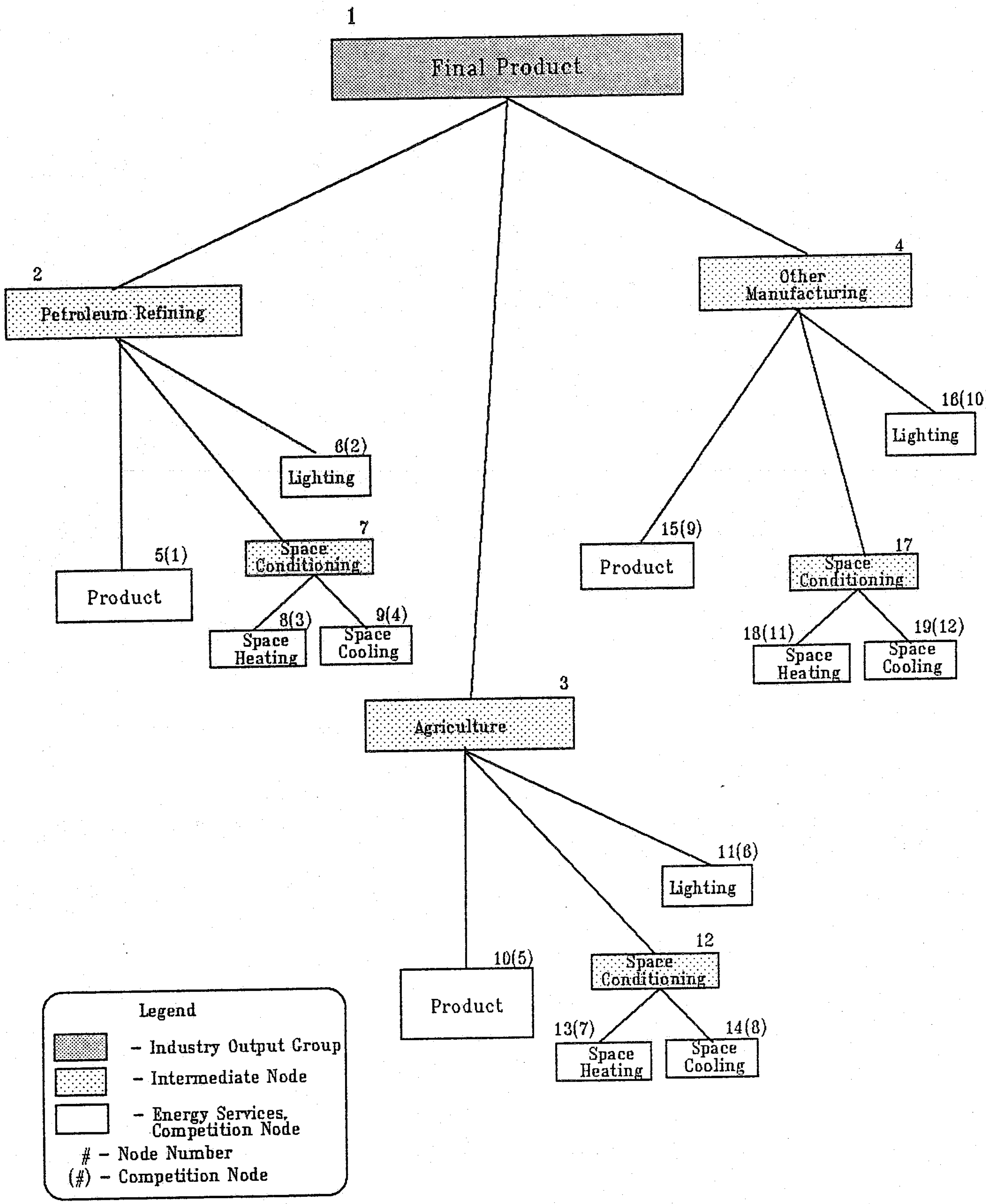


Figure 9.2.1 cont'd

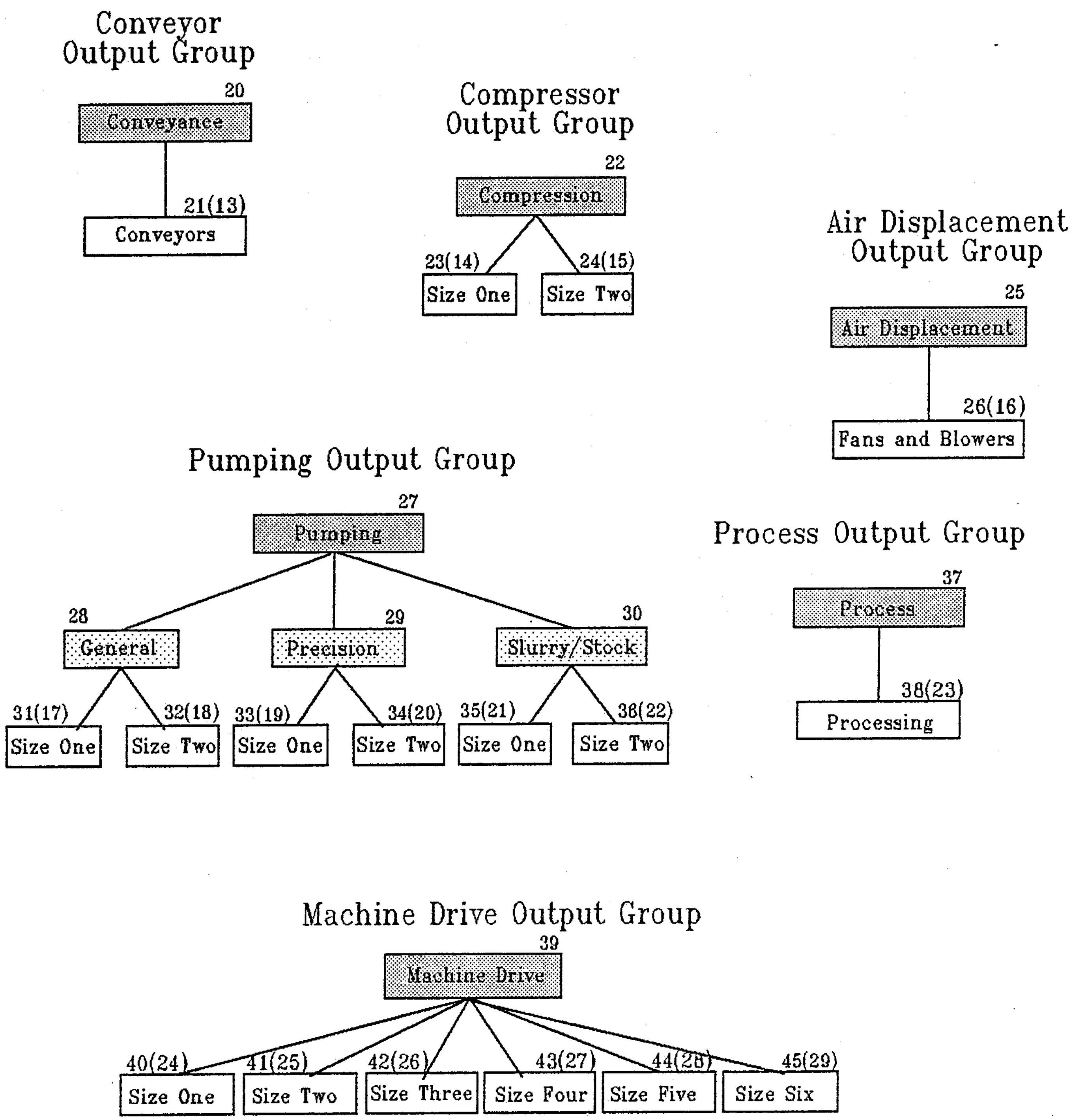


Figure 9.3.1 Other Manufacturing End-use Electricity Demand

High Growth

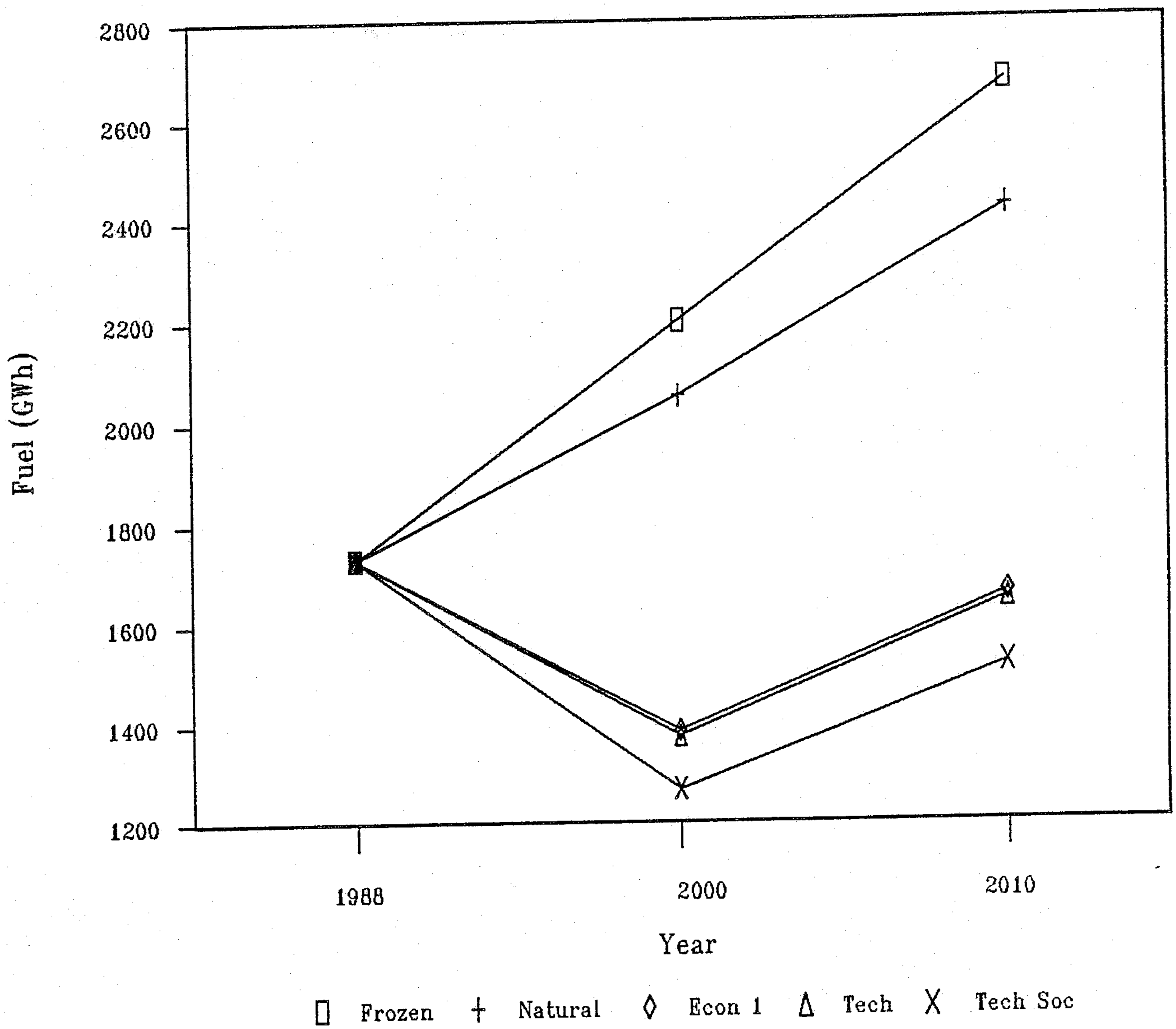


Table 9.3.3 Other Manufacturing End-use electricity Demand:
High Frozen Efficiency Run
(GWh)

Service	1988	2000	2010
Machine Drive	1 351	1 713	2 088
Pump	602	764	931
Air Displacement	76	96	117
Compression	131	167	203
Conveyance	507	640	781
Other	36	45	55
Electrolysis	0	0	0
Process Heat	184	233	273
Light	143	187	234
Other	51	67	83
Total	1 729	2 200	2 678

Table 9.3.4 Other Manufacturing End-use electricity Demand:
High Technological Efficiency Run
(GWh)

Service	1988	2000	2010	% Reduction from Frozen in 2010
Machine Drive	1 351	977	1 170	43.9%
Pump	602	288	335	64.0%
Air Displacement	76	54	63	46.2%
Compression	131	86	102	49.8%
Conveyance	507	509	621	20.5%
Other	36	39	48	12.7%
Electrolysis	0	0	0	0.0%
Process Heat	184	233	273	0.0%
Light	143	97	121	48.3%
Other	51	66	83	0.0%
Total	1 729	1 375	1 648	38.5%

The conservation potential for this branch is high, comparable to the pulp and paper industry. The social potential is also high, approximately 5% relative to the technological run.

Tables 9.3.3 and 9.3.4 list the end-use service breakdown for other manufacturing. Pumping and conveyance dominate energy service demands in this branch.

9.4 Analysis and Caveats

The electricity conservation potential is due to the predominance of pumping and conveyance. Moreover, the installed capacity of small motors in the total motor stock is greater for this branch than others. Smaller motors have a greater potential for efficiency improvements than do larger horsepower motors.

This branch consumes less than 10% of total industrial end-use electricity demand and although electricity conservation potential exists it is localized in the pumping system since the potential for conveyance is smaller. Total technological electricity conservation potential is therefore, approximately 39%.

Appendices

to

Chapter 9

Other Manufacturing Industry

Appendix A

Other manufacturing Industry Assumptions

Auxiliary Systems:

(1) Conveyor are inclined at 7.5 degrees in other manufacturing.

(2) Load factor for other manufacturing auxiliary systems:

Process drive	.80 at .9 utilization
Pumping	.65 at .9 utilization
Fans and Blowers	.65 at .9 utilization
Conveyance	.65 at .9 utilization
Compressors	1.0 at .7 utilization

(Willis, 1991)

(3) Social Potential parameters:

a. Motor Systems

System	Potential
Pump	10%
Air Displacement	5%
Conveyance	5%
Compression	15%
Process Drive	2%
Process Heat	10%
Lighting	10%
HVAC	5%

b. Economic Runs

Run	Percentage of Potential (from above Table)
Frozen	0%
Natural	0%
Economic 1	0%
Economic 2	15%
Economic 3	25%
Economic 4	45%
Economic 5	70%
Technological	0%
Technological/ Social	100%

(Welchman, 1992; Willis, 1992; Scott, 1992; Evans, 1991; Temanex, 1992; Merrill, 1991; Mellis, 1991)

Appendix B

Other Manufacturing Industry Motor Systems Base Stocks

Motor system base stocks were not developed for other manufacturing because of the disaggregate nature of the production processes involved. The effort required to collect motor system base stock data outweighs the benefits of improved accuracy in electricity conservation potential estimates for other manufacturing.

Appendix C

Other manufacturing Industry Process Technologies

A production process model was not simulated in ISTUM-I because of the diverse nature of the production processes involved. As a result, electricity end-use demand was simulated using only auxiliary systems.

CHAPTER 10

SUMMARY, DISCUSSION AND RECOMMENDATIONS

10.1 Summary

Objective and Method

The objective of this study was to estimate the Technological, Economic and Social potential for improved electricity efficiency in B.C. industry over a 22 year forecast period under alternative scenarios of industrial output and various runs involving alternative prices and decision making behaviour.

The method involved:
(1) construction of detailed process models of electricity-intensive industries,
(2) disaggregation of electricity demand by end-use,
(3) collection and estimation of base stock, efficiency and cost data on key electricity end-use technologies in each industry,
(4) technology data input and calibration of the process models,
(5) estimation of behavioural parameters for the process models,
(6) model simulations for all scenarios and runs,
(7) adjustment of model results to account for aspects of research and analysis conducted externally to the modelling process, notably the estimation of social potential.

Methodological Innovations

The estimation of electricity conservation potential is a field in which methodology is rapidly developing. This study seeks to make an innovative methodological contribution in two aspects.

1. This is the first study, to our knowledge, to estimate the base stocks and efficiency potential of all components of industrial motor systems. While some case study research has noted the importance of including all components of a motor system, previous industry-specific research into simulating aggregate electricity conservation potential has examined only the potential from two devices: high efficiency motors and electronic variable speed drives. The case study research shows that other components of the system can also make important contributions to efficiency improvements. In this study, not only are all components of motor systems incorporated, but they are linked to the specific production processes in each industry. Thus, changes in industrial structure and in major production processes will be reflected in the demands for different types of motor systems and in the consequent estimates of efficiency improvement potential.

2. Almost all of the simulation and analysis of this study has been achieved with the use of a second generation end-use energy demand model, ISTUM-I. This is B.C. Hydro's model for long run electricity demand forecasting. Use of this model as the key analytical tool has several advantages for some of the broader goals of electricity efficiency research. First, equipment base stock, efficiency and cost estimates are immediately available to B.C. Hydro. Second, a second generation model easily allows for follow up investigations: one can quickly rerun the model for alternative scenarios and prices. Third, a second generation end-use model can serve as a tool for integrating demand-side management and forecasting. Behavioural parameters can be adjusted in the model to match B.C. Hydro's data on consumer behaviour, and then various demand-side management initiatives (grants, rate structure) can be modelled, using ISTUM-I, to test for their impacts. This latter dimension closely matches the objectives of the second phase of the efficiency potential review being undertaken by B.C. Hydro and the Collaborative Committee.

Aggregate Results

Table 10.1.1, Table 10.1.2 and Figure 10.1.1 summarize the study aggregate results for the B.C. industrial sector.

Table 10.1.1 B.C. Industry Electricity Consumption: Low (TWh)

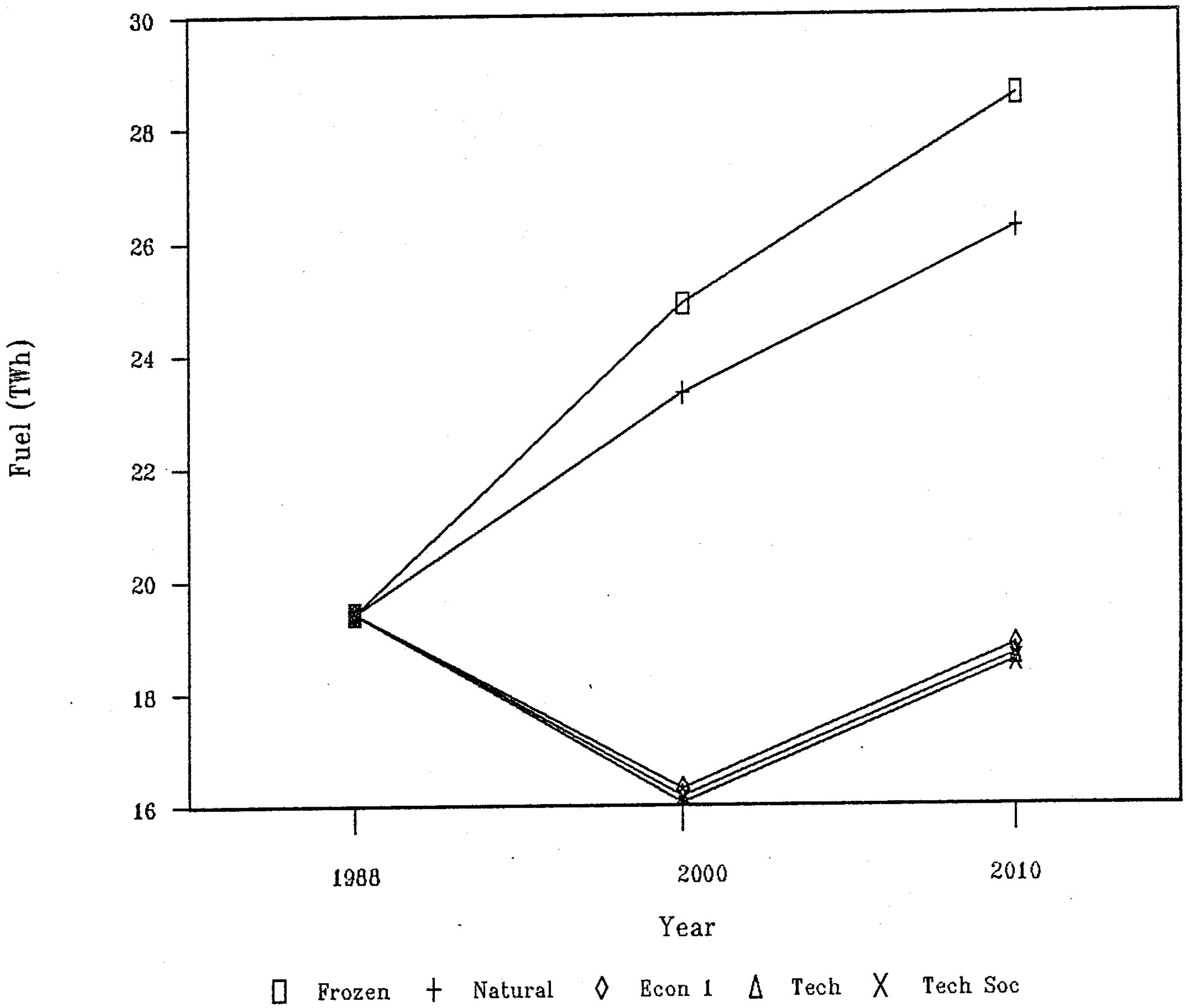
	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	19.4	20.0	21.3	
Natural		18.7	19.3	9.3
Econ 1		12.7	13.4	37.1
Econ 3		12.5	13.2	38.0
Econ 5		12.2	12.9	39.5
Tech		12.4	13.1	38.6
Tech/Social		11.8	12.4	41.6

Table 10.1.2 B.C. Industry Electricity Consumption: High (TWh)

	1988	2000	2010	% Reduction from Frozen in 2010
Frozen	19.4	24.8	28.4	
Natural		23.2	26.1	8.3
Econ 1		16.2	18.7	34.2
Econ 3		15.9	18.4	35.3
Econ 5		15.5	17.9	37.0
Tech		15.8	18.3	35.8
Tech/Social		14.9	17.3	39.3

Figure 10.1.1 B.C. Industry End-use Electricity Demand

High Growth



10.2 Discussion

Analysis of Results

While the end-use electricity consumption differs from the high to low output forecasts, the percentage efficiency improvement potential is similar for both scenarios; the comments that follow therefore apply to both output scenarios.[1] Also, the percentage efficiency improvement is almost the same in the years 2000 and 2010; therefore, while the comments that follow refer only to the latter time period, they are applicable to both.

The Natural Change in Electricity Intensity results in about a 9% decrease in end-use electricity consumption relative to that of the Frozen Intensity. This is because (1) standard efficiency technologies experience a gradual efficiency improvement as old equipment is retired and replaced by new, and (2) some high efficiency technologies are allowed to slowly increase their share of the total stock. However, as noted in the methodology section, we found no evidence from other studies to suggest that in a world without Power Smart there would be a significant increase in the market share of high efficiency motor system technologies. Therefore, even in cases where the economics of high efficiency technologies were extremely favourable (as they have been historically), we assumed that penetration rates would only slightly surpass historic levels. This assumption is the key causal factor in explaining why our Natural Change in Electricity Intensity forecast shows only a 9% reduction from the Frozen Intensity forecast.

Tables 10.1.1 and 10.1.2 show only three of the five Economic runs. This is because the gradient is rather small from Economic 1 to Economic 5. The aggregate results range from 34% to 42% electricity reduction relative to the Frozen Intensity forecast. As well as some technology shifts, the higher numbered Economic runs include cost-effective changes in operation and maintenance.

All Economic runs are very close to the results of the Technological run. This is because the most electricity efficient market-ready technologies were almost all found to be economically attractive under the initial Economic run, that with no environmental credit. Increasing the environmental credit therefore had no effect on the technology choices.

In both the high and low output scenarios, the Economic 5 and Economic 4 runs surpass the Technological run in their reduction in electricity consumption relative-to-Frozen. This is because the Technological run assumes standard equipment operating and maintenance practices, whereas estimates of cost-effective changes in these practices are allowed in the Economic runs.

The Technological / Social run shows the greatest electricity saving potential; this is because it includes the least-electricity technologies and the best practices in operation and maintenance. The Technological / Social run decreases electricity consumption by

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1. Differences in the high and low output results are solely attributable to exogenous changes in relative product composition within and between industries; these industry structure changes were in the terms of reference provided for the study.

about 3% more than the Technological run. This means that the aggregate Social potential (as defined in the terms of reference) is about 3%.

The aggregate results mask significant differences between sectors. A good example is to look at Technological Potential (relative-to-Frozen), which has an aggregate value of 36% to 39%. The greatest potential for improved efficiency was found among pumping and compression motor systems. Therefore, the pulp and paper industry, with considerable pumping, showed the greatest Technological Potential (relative-to-Frozen) for improved efficiency, achieving a level closer to 44%. The pulp and paper results are also caused by the shift to more electricity-efficient mechanical pulping systems, and a reduction in pumping demand as batch processes are replaced with continuous processes in chemical pulping. In contrast, the Technological and Economic efficiency improvements in other key branches were in the 20% to 25% range (relative-to-Frozen), although the reasons vary from industry to industry. Electricity consumption in the chemical industry is dominated by mature electrolysis processes, which do not have high potential for efficiency improvement. This is why the Technological potential in this industry is in the range of 24%. In mining, electricity is primarily consumed by large grinding motors. Because they use so much electricity, these motors have already been designed and installed with a concern for electricity efficiency. The Technological potential is estimated at 25%. The wood products industry is dominated by process-specific machine drive equipment, such as saws, debarkers, lathes, edgers and planners. Again, this equipment does not offer the same potential for efficiency improvement as can be found with end-uses such as pumping, which is why the wood products industry only shows a Technological potential of about 20%.

Comparison with Other Studies

The roughly "37% relative-to-Frozen" result for Technological and Economic Potential is the critical finding of this study. It is interesting to compare this with other research, even though methodologies will differ to some extent. We have done this as a final step in our study.

1. One of the most well-publicized estimates of electricity efficiency potential was that of Amory Lovins of the Rocky Mountain Institute (Gellings et al, 1990). Lovins estimated that the U.S. could reduce its total 1990 electricity consumption by 75% with complete penetration of currently market-ready technologies. This 75% technological potential was also claimed to be an economic potential, since the life cycle cost of all incremental improvements in efficiency were less than or equal to 4 cents (U.S.)/kwh saved at a discount rate of 4% real.

The Rocky Mountain Institute estimate for the industrial sector was based on a major study of motor systems (Lovins et al., 1989). This study suggested that efficiency improvements of 28 to 60% (relative to today - i.e. relative to Frozen) could be achieved just by switching to high efficiency motors and electronic variable speed drives, and by better system design. Thus, the study argues that significantly higher savings would be attained if all components of the system (e.g. pumps and fans) were also optimized. The researchers maintain that the entire 28 to 60% efficiency gain is achievable at a cost of less than .5 cents/KWh. This cost is significantly lower than the estimate of most other studies, including this one.

The upper estimate of 60% is dramatically higher than the 37% aggregate estimate in this study. However, while in our study, efficient motor / pumping systems are, on average, close to 60% more efficient than existing systems, efficiency improvements in other uses of electricity do not show as much potential. According to our aggregate results, the average Technological potential relative-to-Frozen, by end-use category, is the following: air displacement - 48%, compression - 50%, conveyance, 20%, and direct process machine drive - 13%. Direct process machine drive represents a significant share of total industrial electricity use. This explains why our estimate is significantly lower than that of the Rocky Mountain Institute.

2. Another study (Barakat and Chamberlin, Inc., 1990) also focused only on high efficiency motors and variable speed drives. It estimated efficiency gains (relative to Frozen) of 29% to 45% for industrial applications. Again, the estimates would have undoubtedly been higher if all components of motor systems had been included.

3. MARBEK (1991) made an estimate of drivepower efficiency savings potential for three branches of Canadian industry: pulp and paper, iron and steel, and chemical. The estimate of Technological and Economic aggregate efficiency potential was lower than the other studies cited here, in the 15% to 20% range. MARBEK listed three factors that explain why this estimate is lower: only electronic variable speed drives and efficient electric motors are included, as opposed to total motor systems; efficiency improvements from process change were excluded; chemicals and iron and steel are two sectors in which much of the electricity consumption is direct process (electrolysis and electric arc reduction), with less potential for efficiency gains than mechanical systems. In contrast, a greater share of total B.C. industry electricity consumption is by mechanical systems.

4. A recent Electric Power Research Institute study of the entire U.S. economy to the year 2000 attained results similar to this study of British Columbia (Gellings et al., 1991), although it did not estimate economic potential. Table 10.2.1 summarizes the study's results for the industrial sector.

Table 10.2.1 Electricity Conservation Potential in U.S. Industry (MWh)

	1987	2000	% Reduction from Frozen Forecast
Frozen	845	1 290	
Natural		1 166	10%
Technological		720	44%

The 44% aggregate Technological potential conceals important differences by end-use category. The Gellings study estimates a total motor drive Technological efficiency improvement of 50%. However, the study does not disaggregate by type of motor system end-use (pumping, conveyance, etc.), nor does it estimate the potential efficiency improvements for all auxiliary components of a motor system. On that basis, one would expect the efficiency potential estimate, at least for a motor system end-use such as pumping, to be lower than ours,[2] which it is. Another factor is that motor systems represent only 70% of total U.S. industrial electricity consumption, whereas they count for 90% in B.C.

As noted above, our methodology is unique in its effort to estimate the stocks and efficiencies of all components of motor systems. This requires some heroic assumptions about the average base stock efficiencies of existing pumps, fans, compressors, etc. However, there are many industrial case studies which helped to guide our estimates, along with the advice of industry experts. Two of these are discussed below.

5. Norgaard et al. (1983) used case studies to estimate total system efficiencies in pumping for Denmark. Their estimate of Technological Potential was 70% relative-to-Frozen.

6. Larson and Nilsson (1990) also examined case studies and then extrapolated these to make end-use estimates for all sectors of the Swedish economy. They estimated a total Technological potential (relative-to-Frozen) of 50 to 65% for pumping systems, and 50 to 60% for air displacement systems.[3] All of these gains were economic at 5 cents/KWh and a real discount rate of 4%. Some of these case studies focused specifically on large pumping systems in Swedish pulp and paper mills. These estimated aggregate Technological efficiency improvement potential of about 50% relative-to-Frozen.

Issues and Caveats

At various stages, this research project presented imposing challenges. Some of these are reviewed here in order to better qualify and explain the results.

1. As the previous section showed, the decision to extend the estimate of efficiency potential beyond motors and drives to include all auxiliary components of motor systems was unavoidable to fully meet the terms of reference - i.e. a complete estimation of the technological, economic and social potential for increased efficiency. However, such an effort involves a trade-off between comprehensiveness and accuracy. While there have been several broad surveys estimating motor efficiencies and the efficiency effects of adding electronic adjustable speed drives, there is little comprehensive knowledge about the current efficiencies of base stock (1988) auxiliary equipment. This was estimated as best as possible from survey results, expert opinion and model calibration. But there remains a chance that significant error in this estimation has occurred.

Using subjective probability analysis[4], we estimate, with about 90% confidence (i.e., 9 times out of 10), that the Technological efficiency (relative-to-Frozen) may have over

2. The numbers in this table are taken from the first dimension of the analysis, and therefore exclude the effect of new penetrating electro-technologies. Thus, the study is within the same parameters as ours.
3. Note that Swedish industry is generally found to be at least as electricity-efficient as B.C. industry.
4. This involves using experiential knowledge to subjectively estimate a probability distribution.

or underestimated the efficiency potential by as much as 15%. This implies an aggregate Technological efficiency improvement potential ranging from about 31% to 43% relative-to-Frozen, when both the high and low output scenarios are included.

2. The terms of reference requires two types of estimates about industry behaviour: investment behaviour and operation and maintenance behaviour.

Investment behaviour information is especially required for the Natural Change in Intensity run. While it is generally found that industry requires very short paybacks for discretionary incremental investments to improve energy efficiency, even this assumption was insufficient to explain behaviour with respect to the selection of auxiliary equipment. Even though efficiency differences can be significant, industry experts and equipment marketers generally argue that the issue of efficiency is rarely considered when auxiliary equipment is purchased.

To quote Philip Hummel, Manager of Demand Forecasting at EPRI (February 12, 1992):

> "I am not surprised that ISTUM is finding many of the investments in premium efficiency motors and adjustable speed drive economically attractive. It is generally the case that a large industrial motor will annually consume electricity costing 10 to 20 times more than its capital cost. First cost, therefore, accounts for typically only 1-3 percent of life-cycle cost.
>
> Ironically, though, industrial motor purchases are still first cost driven because end-users are often not the purchaser. Equipment manufacturers who specify motors as part of an equipment 'package' are not as concerned with first cost vs operating cost trade-offs."

This would explain why more efficient equipment, with extremely short paybacks (about one year), has not historically penetrated the market. This historically derived estimate of behaviour required that we override the cost-based technology selection algorithm in the model, constraining the market penetration of efficient motor systems (all components) to less than 20%.

Industry operation and maintenance assumptions were also required, because the terms of reference call for estimates of the difference between best practice and standard practice, as well as changes in practice that may be cost- justified under the different Economic runs. It was difficult to find industry experts willing to estimate the change in efficiency attributable to changes in operation and maintenance practice, disaggregated by industry branch and end-use. However, we did arrive at estimates of best practice potential that we feel confident to be as accurate as possible without the benefit of a major behavioural study. We also asked our industry experts to estimate the changes in maintenance practice that would be cost-effective under the various Economic runs. These were used to provide "rough" estimates specific to each Economic run.

3. The results of the five Economic runs and the Technological run are all very close. This may seem counterintuitive to some, but it is consistent with other research. In the research cited above, those studies that included an economic analysis generally found that most technological efficiency improvements were economic relative to avoided supply-side investments.

In spite of our results, and those of others, there are undoubtedly technologies, which will be market ready in 2000 or 2010, whose cost would make them only economic under one of the economic runs with an environmental credit. As a precaution, we made a second search (with experts and our sub-contractors) at the end of the study for such technologies. A few more "exotic technologies" were added to the model database. However, the general result was still the same. Almost all efficient technologies were still economic under the Economic 1 run. A few efficient technologies only penetrated with the addition of an environmental credit. And a few efficient technologies still did not become economic, even in the Economic 5 run - i.e. the 100% environmental credit. The Economic and Technological results remained very close.

4. Although the terms of reference did not permit interenergy substitution among end-use technologies, we were asked to examine the possible effects of emerging electro-technologies on our results. Specific cases are noted in the various industrial sectors. In some limited cases, the effects may be significant. For example, it is conceivable that there could be a significant penetration of electric dryers for various paper and wood products. However, in most cases the potential effects of emerging electro-technologies were not found to be significant. One reason is that the major penetration of an electro-technology in B.C. (mechanical pulping) is determined exogenously, set to occur in all runs, including the Frozen efficiency run. A second reason is that B.C.'s other electricity-intensive industries do not have great electro-technology potential. A recent analysis of the U.S. (Gellings et al., 1991) found most of electro-technology potential in the steel industry, where electric arc furnaces are projected to continue their dramatic penetration.

5. The methodological decision to focus on all components of motor systems involved some trade-offs. First, individual process technologies were identified as having a fixed demand for various motor system services: so much air displacement, so much conveyance, etc. However, in some cases it may be possible to substitute one generic motor system for another (air displacement for conveyance), while achieving the same process service (transporting wood chips) with less electricity. For example, wood chips could be transported by blowers instead of conveyors for the same sawmill process. Substitution of this nature is not possible with the methodology that was chosen. However, we did assess the areas in which this limitation may affect the results and found few cases. Moreover, many types of substitution of this nature are either (1) disallowed by the terms of reference (no interenergy substitution) or (2) included as a possibility by the model because they represent substitutions between processes rather than between types of motor systems (chemical debarking is allowed to compete with mechanical debarking).

Second, the electricity efficiency objective may be best estimated by focusing on total optimization at the level of the plant rather than at the level of the motor system. In some cases, this would result in lower efficiency improvements than estimated in this study. For example, selection of the most electricity efficient motor system may negatively affect operating conditions and efficiencies elsewhere in the plant (transformation losses, etc.) (D. Scott, pers com., 1992). In other cases, this would result in higher efficiency improvements than estimated in this study. For example, total plant optimization would undoubtedly change the way in which many existing plants are designed, with some benefits for reducing electricity consumption. The net effect of these countervailing tendencies is difficult to predict. We were unable to find experts willing to guess what this net effect might be. We have therefore not tried to estimate the effect of total plant optimization.

10.3 Recommendations

Reducing Technological Data Uncertainty

There is now considerable information being gathered internationally and locally on the efficiencies and costs of new complete motor systems (including all auxiliary equipment). This information is a key driver in the Technological and Economic Potential estimates of this study. In contrast, the area of greatest technological data uncertainty is the efficiencies of the motor system base stocks currently operating in industry. Case study measurements in Swedish pulp and paper mills showed that these efficiencies can vary significantly. In this study, we estimated these efficiencies from expert opinion and from some case studies of industry in other regions.

We feel that uncertainty in the base stock efficiencies, and in equipment configurations, account for the greatest share of the uncertainty in our estimates of efficiency improvement potential. For example, estimates of base stock efficiency depend on the extent to which auxiliary mechanical equipment (pumps, fans, etc.) is connected either directly to electric motors or via mechanical speed control devices, and on the efficiencies of those devices and drives. <u>Therefore, we recommend that future industrial demand-side research focus on case study analysis of mechanical efficiencies and configurations of all components of the motor systems in industrial plants, especially in B.C.'s pulp and paper industry.</u> This information should be gathered in a systematic way that allows extrapolation of results, from representative samples, to the estimation of entire industrial branches.

Variable speed drives present the greatest opportunities for improving the mechanical efficiency of motor systems; the degree of load variability determines the potential for efficiency gains by adding an electronic variable speed drive. Yet, there are no detailed assessments of the variability of the load for various types of motor system end-uses in each of B.C.'s key industries. <u>Therefore, we recommend that future industrial demand-side research focus on case study analysis of load variability for various types of motor system end-uses.</u> This information should be gathered in a way that allows for extrapolation, from representative samples, to estimates for individual industries.

Behavioural Parameter Uncertainty

The ISTUM model selects technologies as a function of life cycle cost. Research on industry behaviour shows that life cycle cost (with an appropriate discount rate) can provide an adequate means of simulating a large set of investment decisions, as long as there are no crucial non-cost factors affecting the decision. However, research shows that life cycle cost is not always a good tool for estimating the penetration rate of the more efficient auxiliary equipment components of motor systems. Even an assumption of very high discount rates does not allow the model to accurately simulate investment decision making with respect to motor systems. Because of this, research by electric utilities throughout the U.S. has begun to focus on industry decision making with respect to more efficient motor systems. Some of this is summarized in the above quote from Phillip Hummel of EPRI. The objective is to identify and estimate the key factors affecting new technology decision making. These would include estimates of, for example, (1) the perceived risks of new technologies, (2) the importance of reliability as a decision factor, and (3) the relative trade-off between capital cost and life cycle cost in the technology selection decision.

Therefore, we recommend that research be undertaken that identifies the most effective means of convincing industry decision makers of the benefits of more efficient motor systems. This may involve research of decision making behaviour and of product marketing techniques. This information can be incorporated in a tool, such as the ISTUM-I model (for planning and forecasting), via non-cost technology parameters indicating market acceptability. It would also allow for use of the model to estimate long run price elasticities; with these behavioural parameters set, the model could be simulated under different electricity prices with the results used to calculate own and cross-price elasticities.[5]

5. Own-price elasticity refers to how the demand for a product changes in response to a change in its own price, everything else held constant. Cross-price elasticity refers to how the demand for a product changes in response to changes in other products, be they substitutes or complements.

Appendix A

to

1991-1994 Electricity Conservation Potential Review: The British Columbia Industrial Sector

Report Structure of Volume II: Technical Report

Volume II to this report contains the results for all high and low growth model simulations by industry and sub-product. For example, in the pulp and paper industry there are report tables of the industry total as well as for chemical pulp, mechanical pulp and paper products. A maximum of three sub-products are reported per industry, however, in some cases there are only one or two sub-products.

1. Product Categories

a.	Pulp and Paper	- Industry Total - Chemical Pulp - Mechanical Pulp - Paper Products
b.	Mining	- Industry Total - Coal Mining - Metal Mining
c.	Wood Products	- Industry Total - Saw Mills - Structural/Veneer - Remanufacturing
d.	Chemicals	- Industry Total - Electrolysis - Hydrogen Peroxide - Ammonia/Oxygen
e.	Petroleum Refining	- Industry Total
f.	Other Manufacturing	- Industry Total - Agriculture - Other Manufacturing

2. List of Tables

1) Aggregate Total Electricity Demand
2) Electricity Demand in Auxiliary Units
3) Electricity Demand by Auxiliary Unit and Technology Type in Each Run
4) Aggregate Total Electricity Demand in Sub-Process 1
5) Electricity Demand in Auxiliary Units in Sub-Process 1
6) Electricity Demand by Auxiliary Unit and Technology Type in Each Run in Sub-Process 1
7) Aggregate Total Electricity Demand in Sub-Process 2
8) Electricity Demand in Auxiliary Units in Sub-Process 2
9) Electricity Demand by Auxiliary Unit and Technology Type in Each Run in Sub-Process 2
10) Aggregate Total Electricity Demand in Sub-Process 3
11) Electricity Demand in Auxiliary Units in Sub-Process 3
12) Electricity Demand by Auxiliary Unit and Technology Type in Each Run in Sub-Process 3

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