Electricity Conservation Potential Review, 1988 – 2010:

Summary Report

Phase I: Unconstrained Potential

ELECTRICITY CONSERVATION POTENTIAL
IN BC HYDRO'S SERVICE AREA

COLLABORATIVE COMMITTEE FOR
THE 1991-1994 CONSERVATION POTENTIAL REVIEW

VANCOUVER, B.C. - FEBRUARY 1993

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Summary Report

Phase 1: Unconstrained Potential

SUMMARIES OF TECHNICAL REPORTS BY

M.K. JACCARD & ASSOCIATES

MARBEK RESOURCE CONSULTANTS

in association with

PACIFIC ENERGY ASSOCIATES, INC.

PRISM ENGINEERING LTD.

SHELTAIR SCIENTIFIC LTD.

PREPARED FOR THE COLLABORATIVE COMMITTEE

FOR THE 1991-94 CONSERVATION POTENTIAL REVIEW

SPONSORED BY B.C. HYDRO

VANCOUVER, B.C. – FEBRUARY, 1993

Preface from the Collaborative Committee

Introduction

The 1991-94 Conservation Potential Review has been a precedent-setting effort in cooperative decision-making. The Review is a collaborative effort involving B. C. Hydro, West Kootenay Power, Ltd. and representatives of their customers and organizations in the province interested in electricity planning. The Review's primary objective is to develop comprehensive estimates of electricity conservation potential (technological, social, economic, and achievable) for British Columbia to the year 2010 that all these parties can agree upon. It is the first such collaborative effort in the utility industry in Canada.

This document summarizes the results of Phase I of the Review: consultant studies of the residential, commercial and industrial sectors of B.C. Hydro's service area to estimate **unconstrained technological, social and economic potentials**. Phase II of the Review is being undertaken to estimate how much of this technically possible conservation may be realistically expected to be achievable. **Achievable potential estimates from Phase II are expected to be available in 1994.**

West Kootenay Power used the same consultants to obtain similar information for its service area. West Kootenay's study was conducted without a collaborative process and is published separately. Taken together, these estimates for B.C. Hydro's service area and West Kootenay Power's work, indicate the possible size of electricity conservation as a resource in the province.

Objectives

Electricity conservation is the key element in the Demand Side Management resource option in B.C. Hydro's Electricity Plan. For conservation to play its optimal role as a resource to help meet future electricity needs, estimates of its possible scope are required that have a high degree of reliability. This Review has been undertaken as part of B.C. Hydro's ongoing efforts to improve understanding of the possible size and scope of electricity conservation and the role it can play in the utility's resource mix to serve future demand for electricity.

This Review is undertaken as a collaborative exercise in order to arrive at estimates that all the major stakeholders in the province can agree upon and use as a common basis for decision making. It is undertaken with such broad representation in the decision making in order to draw on the knowledge, experience, insight, and creativity of the many individuals and organizations in the province who have promoted conservation and implemented energy efficiency measures.

The Collaborative Process

This Collaborative Committee was formed to oversee the conduct of the Review to bring into the decision-making representatives of organizations and interest areas which have a strong interest in electricity planning. The Committee has thirteen members directly representing two utilities and 34 organizations. Since many of these organizations are associations, there are several hundred organizations indirectly represented on the Committee. Each member of the Committee was selected by organizations collectively making up an area of interest and seeks to represent the perspective of all organizations in that interest area. Members represent residential, commercial and industrial utility customers; environmental organizations; First Nations' Peoples; local governments; B.C. Hydro; and West Kootenay Power, Ltd.

Staff from the Ministry of Energy, Mines, and Petroleum Resources joins the Committee's discussions but does not participate in its decision-making. Staff from the B.C Utilities Commission hold Standing Observer status at all Committee meetings. The Committee chose an independent party to chair its meetings and facilitate its decision-making.

The members of the Committee represent a wide spectrum of perspectives, backgrounds, areas of interest, and experience. They began meeting in February of 1991 and have guided the design and conduct of the Review ever since, including approving terms of reference, selecting consultants, determining all key assumptions and parameters to be used by the consultants, and reviewing and approving all documentation of the effort. Despite its diversity and sometimes dramatic differences of opinion, the Committee has successfully used a consensus-based decision process. Discussion continues until agreement is reached. The Chair is authorized to take steps to prevent deadlock, if consensus proves to be elusive. However, the Committee has yet to have to resort to any of these failsafe measures; to date, the Committee has been successful in reaching consensus.

It is the hope of the Committee that its successful experience with consensus decision-making among diverse, and sometimes adversarial, perspectives will encourage others to try more cooperative approaches to decision making.

Acknowledgements

In addition to the Committee members and their alternates, there are other volunteers involved in the Review. Many individuals have generously allowed the consultants to draw on their knowledge and experience. Others have served as members of working groups that have made recommendations as to how to deal with externalities and uncosted environmental and social impacts.

The total number of contributors to the Review's work to date, including volunteers and utility and consultant staff, exceeds 100. Thus, the Review results have been shaped by the collective expertise of a significant cross section of experience.

The Collaborative Committee wishes to acknowledge the contributions of these many individuals and to thank them for their efforts.

Significance of the Results -- It Can Be a Personal Matter

The consultants' work in Phase I of this Review indicates that electricity conservation can be a significant component in the resource mix to meet future electricity needs in the Province. The unconstrained technological and social potential in the year 2010 is estimated to be on the order of 27,000 to 33,000 GWh, depending upon economic and population growth rates. Of this potential 22,000 to 27,000 GWh is expected to be "economic", that is obtainable at a cost that is equal to or less than the cost of new electricity supply. By comparison, this economic potential is five to six times the electricity consumed in the City of Vancouver in 1992 by B.C.Hydro's residential and commercial customers.

The consultant's work in Phase I also clearly indicates that our individual and collective behavior can make a signicant difference. For example, if we, as consumers, operated and maintained our current refrigerators in the most electrically efficient manner we could reduce their electricity consumption on the order of 25%, clothes washers by 84%, or clothes dryers by 21%. This is an example of social potential, as defined by this study.

On any single electricity bill these savings may not seem to be very large in dollar terms. However, these same savings aggregated across all consumers can become very significant in energy terms, with no changes in equipment or technologices used, and no change in the level of service provided by the electricity. For example, the aggregate social potential in the residential sector is estimated to be 450 GWh to 530 GWh annually by the year 2010. This is roughly two and a half times the electricity consumed by residential and commercial customers in the City of Vernon in 1992.

If we were willing to buy the most electrically efficient models currently available when we replace our existing equipment, we could reduce the electricity consumption by 80% in refrigerators, 60-80% in clothes washers, and 68% in clothes dryers. This is an example of technological potential, as defined in this study. Further technological improvements in these appliances expected by 2010 will increase the possible savings even more. Clearly, our individual behavior and decisions can make a major difference in the amount of electricity that will be needed in the future.

An Invitation to the Reader

For this Review, the consultants used the best information available at the time. However, there are limitations and weaknesses in the information available, especially on existing installed equipment and current floor areas. There are also many areas where judgements have to be made, for example in forecasting developmental rates for technologies and their future costs.

The Committee invites the reader to contribute his or her knowledge to improving the base information used in the Review. The full consultants' technical reports on each sector, which are summarized in this document, are available from B. C. Hydro (see inside front cover for address). Interested readers are invited to check the data, assumptions, and judgments and comment on their accuracy in light of their own knowledge and experience.

Readers are also invited to assess the consultants' work on social potential. The research that has been possible in this effort is a useful start, but only a step toward understanding the potential impact of changes in electricity consumers' behavior and decision making. Your thoughts and suggestions on what the consultants' have done and on what should be done to improve our collective knowledge in this area would be appreciated.

Comments on assumptions and data used, on social potential, or on any other aspect of the Phase I work may be sent to the address on the inside front cover of this document.

The Collaborative Committee members look forward to hearing from you.

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Romeo de la Pena
Union of B.C. Indian Chiefs/Native Groups
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February, 1993

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Introduction

The 1991-94 Conservation Potential Review was undertaken to improve our understanding of the potential for electricity conservation in British Columbia.

Conservation is a key element in the Demand Side Management resource option in B.C. Hydro's electricity plan to meet future supply needs. The Review's objectives are:

- Phase one: to identify the likely outside limits of electricity conservation potential and
- Phase two: to explore the levels of electricity conservation that are most likely achievable under a variety of levels of investment, public and private commitment, public acceptance, pricing, regulation and legislation.

The Review estimates the potential impact of conservation as a resource to help meet future electricity needs.

The Review is overseen by a Collaborative Committee representing the major interest areas in the province concerned with electricity planning. One of the Collaborative Committee's objectives has been to produce estimates of electricity conservation potential that the interested parties in the province understand and accept as a sound basis for decision-making about the use of electrical energy conservation.

In order to assist B.C. Hydro in planning resources to meet future electricity needs, the Collaborative Committee is examining the potential for customers to use electricity more efficiently.

The Collaborative Committee directed the work of two groups of consultants in Phase I. M.K. Jaccard and Associates of Vancouver studied the industrial sector. Marbek Resource Consultants, in association with Pacific Energy Associates, Sheltair Scientific and Prism Engineering, studied the commercial and residential sectors. This report summarizes the consultant's work in Phase I of the Review.

The two consultants worked with terms of reference set by the Committee. They used very similar methods, although variations in the nature of each sector and in the information that was available required them to adjust the approach in some areas. The specific differences are discussed in the summary of the findings in each sector. However, because their assumptions and definitions were established by the Collaborative Committee, their observations and conclusions can be read together as a comprehensive report.

TERMS OF REFERENCE

The Collaborative Committee defined the key terms of reference as follows:

Time period

The studies use 1988 as a **base year** against which to compare changes in electricity use and efficiency. 1988 was the last year in which B.C. Hydro's customers and the market place were unaffected by the utility's conservation initiatives. Power Smart programs began in 1989, so subsequent years show energy consumption levels affected by conservation programs. The consultants were asked to estimate electricity conservation potential in a world without Power Smart, so they needed a base unaffected by that initiative. The consultants were asked to provide an estimate of electricity conservation potential in the **target years** 2000 and 2010.

Geographical area

The geographical area of the study is the B.C. Hydro service area, which includes most of the province of British Columbia. The main exceptions include parts of the Okanagan and the Kootenays, served by West Kootenay Power Ltd., and parts of the central West Coast served by Alcan Ltd. A similar study of the West Kootenay Power service area is underway and will be published separately.

Rates of growth

Based on rates of growth for B.C.'s population and its gross domestic product (GDP) accepted by the Committee, the researchers projected changes in the amount of electricity the residential, commercial and industrial sectors of the province would use. They applied these rates as described in the chapters below. Table 1 lists the rates used.

Table 1. Projected Annual Growth Rates in B.C. (per cent)

	1988-2000		2001-2010	
	Low	High	Low	High
Population	1.6	2.2	1.1	1.8
GDP	1.9	3.8	1.6	3.2

Fuel substitution

To focus the study on electrical efficiency alone, the study assumptions prevent the substitution of other forms of energy for electricity and do not include energy-producing technologies, such as cogeneration.

RESEARCH METHODS

The general approach used is to compare the electrical efficiency of the base year, 1988, with the possible electrical efficiency of the target year, 2010, and with the mid-point year, 2000.

- The consultants projected the growth in electricity consumption for the residential, commercial and industrial sectors, using the growth rates accepted by the Collaborative Committee.
- They then reviewed the technologies that are now on the market, or that could be market-ready by the year 2010.
- Finally, they estimated the impact on the projected growth rates of adopting the new electricity-conserving technologies.

These studies are **"unconstrained"**, that is, the consultants did not limit them to changes in electrical use that are most likely to take place. The consultants were instructed to assume 100% penetration of the most electrically efficient technologies that are expected to be market ready in the years 2000 and 2010. "Market ready" means that development of the technology has advanced enough that it could be on the market by the year 2010.

The researchers analyzed the effect of these assumptions as if the 100% assumption would not result in costs from retiring equipment earlier than normal or expected practice. However, the researchers did use the Total Resource Cost Test to compare the cost of saving electricity with the cost of generating new electricity. In addition, the researchers compared the cost of saving electricity using various levels of environmental credit and various discount rates to see how important specific prices are in judging the "economic" rating of each technology.

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To organize their research, the consultants used the basic technique of "disaggregation," that is, of breaking down a subject into smaller parts, and analysing the parts. They defined a variety of electricity "end uses," specific types of work that electricity users need to do, such as providing space heat in a single detached home. Many of the end uses were defined very precisely, down to the size of motor used to operate a particular industrial process.

This method is widely used in analysing energy conservation because the potential for conservation varies greatly from one end use to another. The researchers were able to draw conclusions with greater reliability and accuracy than would be possible if they had to rely on general statements about each industry or electricity use. For example, they were able to estimate that by the target year in the residential sector, energy efficient refrigerators could reduce electrical consumption from 1600 kilowatt-hours per year to an average of 250 kilowatt-hours per year for Vancouver Island single family households, potentially saving 85% of the electricity that would be used if electrical efficiency were the same as that in the base year. The potential savings are different for other appliances because of the different technologies each use; they are different in other types of households because people in townhouse or apartment households tend to use appliances differently; and they are different in other regions of British Columbia because people's use of their appliances can change with climate and geography. The disaggregation method gives relatively precise estimates for each use of electricity, which the researchers can then add together to create a total picture of the potential electrical savings for the entire province.

After analysing the present use of electricity, the researchers projected the amount of electricity that B.C. residents would use in the target years, assuming that population and economy grow at the projected rates, but *electrical efficiency* stays at the level of the base year. This projection is known as the **"frozen efficiency"** estimate.

To evaluate the potential for conservation, the consultants made additional projections with a series of other assumptions.

- They estimated future consumption of electricity if B.C. Hydro customers adopted all of the energy efficient technologies that could be on the market by the target years. This is known as the **"technological potential."**
- They estimated future consumption of electricity if B.C. Hydro's customers changed their behaviour to use electricity more efficiently. For example, more electrically efficient behaviour in the residential sector would include running a clothes dryer with only full loads. In the commercial sector, electrically efficient maintenance practices would include regular cleaning of light fixtures. This is known as the **"social potential."** In these studies, the researchers estimated "social potential" *after* estimating the "technological potential", calculating the impact of behavioural changes on already-efficient technology. The "social potential", calculated in this way, is smaller than it would be if it were calculated on the basis of present technology.
- The researchers estimated future consumption of electricity if B.C. Hydro customers adopted the electrically efficient technologies and activities whose expected costs are equal to or less than the cost of new electricity supply. This is known as the **"economic potential."**

These terms are technically defined based on the assumptions outlined, and may not accurately reflect the future. They appear in quotation marks to emphasize that they may not have their common meaning.

Cost comparisons

To estimate whether a new electricity-conserving technology is economic, the consultants compared its cost to the cost of generating the electricity that would otherwise be used. The cost of generating new electricity rises from 2.3 cents per kilowatt-hour in 1992 to 6.3 cents per kilowatt-hour in the years 2000 and beyond.* These are the costs that B.C. Hydro estimates it will have to pay to acquire additional electricity supply to meet increasing demand for electricity (excluding the cost of any utility-based conservation programs and unpriced environmental and social impacts). When the cost of the technology is expected to be equal to or less than the cost of the new electricity supplies, the consultants listed the technology as "economic."

The **cost** of a new technology is defined as the cost of acquiring and operating it, averaged over its life, divided by the expected saving in kilowatt-hours, and discounted at 8% (real) per year. The consultants also used real discount rates of 4% and 12% to see if the technology would be economic under different economic conditions. They also applied a range of **environmental credits** to try to reflect the possible uncosted environmental impacts of providing new electricity supply. Applying the environmental credits indicates whether or not accounting for the unpriced cost of environmental impacts will affect the "economic" status of an electricity-conserving technology.

The different levels of environmental credit are listed in Table 2.

Table 2. Cost of new electricity supply with environmental credits

	1990 cents per kilowatt-hour 2000	2010
0% Environmental credit	6.3	6.3
15% Environmental credit	7.2	7.2
30% Environmental credit	8.2	8.2
60% Environmental credit	10.1	10.1
100% Environmental credit	12.6	12.6

*The cost of new supply used in this Review will not correspond to cost of new supply numbers contained in other B.C. Hydro publications. The cost of generating new electricity used here is a special cost series generated from B.C. Hydro's 1991 cost of new supply estimates. This special cost series was run without the cost of B.C. Hydro's Power Smart programs to ensure that conservation was not being compared to itself in the Total Resource Cost Test, which is used to determine economic potential.

RESULTS

The studies showed a significant unconstrained potential for electricity conservation under the assumptions the researchers used.

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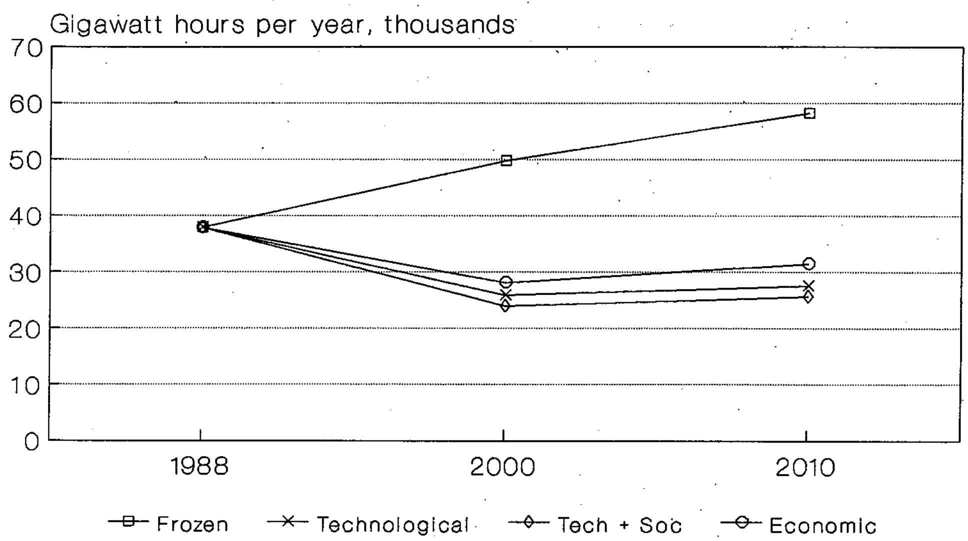
- With no changes in efficiency, by the year 2010 increases in the use of electricity could be as high as
  - 51% in the residential sector if growth is high, or 30% if growth is low;
  - 74% in the commercial sector if growth is high, or 42% if growth is low; and
  - 46% in the industrial sector if growth is high, or 10% if growth is low.
- Adopting the most electrically efficient technologies ready to be marketed by the year 2010, and changing their behaviours to use electricity as efficiently as possible, B.C. Hydro's customers could save:
  - from 75% to 76% of the electricity that would be consumed in the residential sector in the year 2010 if efficiency levels were to remain at 1988 levels;
  - from 68% to 69% of the electricity that would be consumed in the commercial sector in the year 2010 if efficiency levels had remained at 1988 levels; and
  - from 39% to 42% of the electricity that would be consumed in the industrial sector in the year 2010 if efficiency levels had remained at 1988 levels.
- Adopting only those conservation measures that are "economic" compared to the cost of generating new electricity, with no environmental credit and an 8% real discount rate, B.C. Hydro customers could save:
  - 57% of the electricity that would be consumed in the residential sector in the year 2010 if efficiency levels had remained at base year levels;
  - from 57% to 58% of the electricity that would be consumed in the commercial sector in the year 2010 if efficiency levels had remained at base year levels; and
  - from 34% to 37% of the electricity that would be consumed in the industrial sector in the year 2010 if efficiency levels had remained at base year levels.
- Environmental credits increase the "economic" potential.
  - In the residential sector, an environmental credit of 15% to 30% makes most technologies "economic", and a 100% credit makes the "economic" potential virtually the same as "technological" plus "social".
  - In the commercial sector, an environmental credit of 30% makes virtually all technologies "economic", and the "economic" potential is the same as "technological" plus "social".
  - In the industrial sector, virtually all technologies are "economic" with no environmental credit, and the "economic" potential is very similar to the "technological", though 2% to 3% below "technological" plus "social" even with a 100% credit..

Figure 1 illustrates the overall electricity conservation potential under high and low growth conditions.

Comparison of Electricity Consumption
High Economic and Population Growth
All sectors



Comparison of Electricity Consumption
Low Economic and Population Growth
All sectors

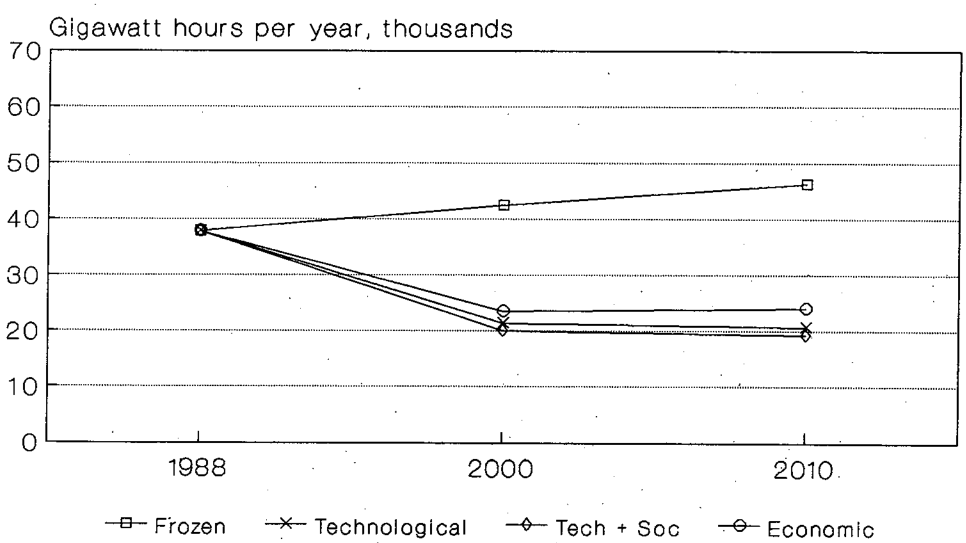


Figure 1. Electricity consumption, high and low economic growth.

RELATION TO POWER SMART

The Collaborative Committee instructed the consultants to assume a world without Power Smart or other utility conservation programs. Power Smart is B.C. Hydro's conservation initiative that began in 1989 to offer B.C. Hydro customers financial incentives to acquire more electrically efficient equipment, as well as information and advice on using electricity in the most efficient manner. Consequently, to estimate the remaining conservation potential, readers must subtract the electrical savings already achieved, and the savings expected to be achieved, by the Power Smart programs from the consultant's estimates.

For example, in the industrial sector, M.K. Jaccard and Associates estimate an "economic potential" from 7900 to 9700 gigawatt hours (GWh) annually by the year 2010. The existing industrial Power Smart programs, as of fall 1992, are expected to result in a saving of 1240 GWh by 2010. The difference is from 6660 to 8460 GWh that can still be targeted. In the commercial sector, Marbek Resource Consultants estimates an "economic potential" of up to 8770 GWh annually by the year 2010; current Power Smart programs are expected to capture 1380 GWh. In the residential sector, Marbek's estimate of "economic potential" is up to 9080 GWh annually by 2010; existing Power Smart programs are expected to capture 1540 GWh by 2010.

CAUTIONS

These conservation potential studies are based on very specific assumptions and definitions. They do not describe achievable levels of electrical efficiency. Instead, they provide an estimation of the efficiency that might be possible if practical constraints on changing technology are ignored and the most electrically efficient technologies and practices were adopted. These estimates represent an outside limit on the size of electricity conservation as a "resource" that can be used to meet future electricity needs. However, forecasting the pace and direction of technological change over a 20-year period is fraught with uncertainties. The estimates in this Review may be proven over time to be conservative. The predictions of other similar studies in the last 30 years have often demonstrated the hazards inherent in predicting the pace of technological change. Even estimates that their authors considered to be on the fringe have substantially underestimated the scope of change in energy efficiency world wide. The estimates in this study may also turn out to be understatements.

A second phase of this Review is underway to estimate how much of the unconstrained potential electricity users might realistically be able to achieve. The results of Phase II are expected in 1994.

This summary report simplifies many of the observations and conclusions of the consultants' full reports. To examine the detailed data and the precise methods and assumptions used, readers should review the reports prepared by Marbek and Jaccard. Copies of the full technical reports are available from B.C. Hydro.

The residential sector

INTRODUCTION

The residential sector study examined the potential for electricity savings among B.C. Hydro's residential customers if they were to adopt new electrically efficient technologies and maintain their homes for maximum electrical efficiency over the period from 1988 to 2010. This phase of the study assumes that people's behaviours and institutions do not restrict the use of new technology, and estimates how much of the savings would be cost effective.

Key findings

B.C. Hydro's residential customers used 10,547 gigawatt-hours (GWh) of electricity in 1988. If the level of electrical efficiency remained the same, the amount would rise to 15,967 GWh in 2010 if population growth were high, and 13,694 if population growth were low. The largest electrical end use in the base year was for appliances, accounting for 5773 GWh, followed by space heating with 3091 GWh, and water heating with 2334 GWh.

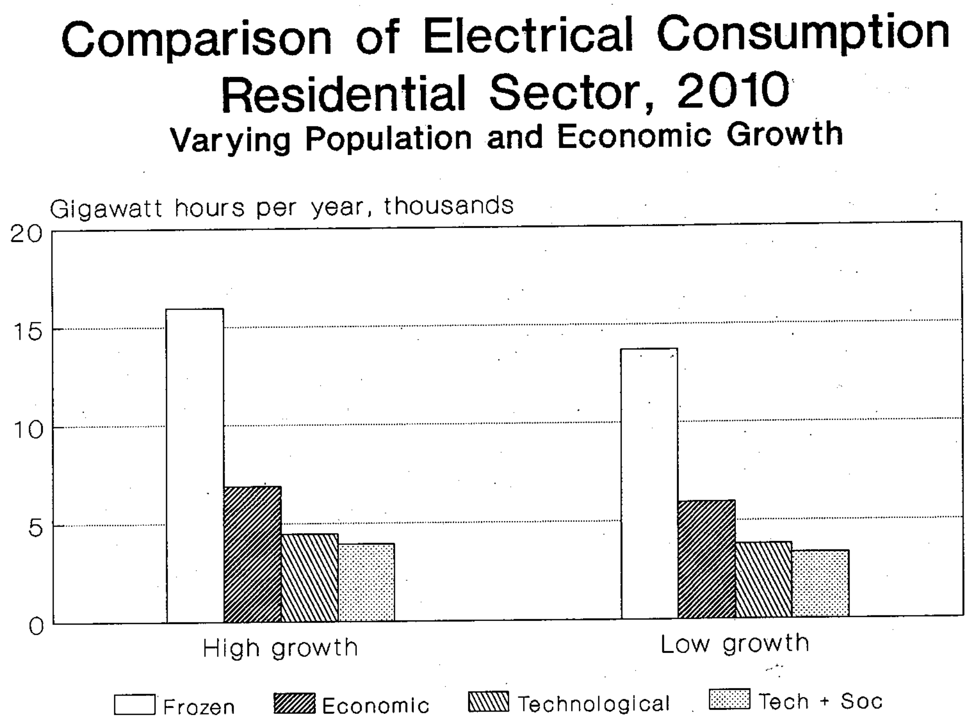
Terms are technically defined, and may not have their common meaning.

If homeowners adopted all the electricity saving technologies possible, the total residential electricity use in 2010 would be 72% lower than it would be if electrical efficiency were unchanged from the base year.

The assumptions may not accurately reflect the future.

- If, in addition to adopting electricity-efficient technologies, homeowners also adopted the most efficient ways to use and maintain their homes, total residential electricity use in 2010 would fall an additional 4%. It would then be 76% lower than it would be if electrical efficiency were unchanged.
- If homeowners adopted the technological changes that were "economic," compared to the cost of new electricity, total residential electricity use in 2010 would be 57% lower than it would be if electrical efficiency were unchanged.
- With an environmental credit of 30%, virtually all the technological efficiency improvements are also "economic," and the potential savings in 2010 would be 77%.

Figure 2 summarizes these projections.



Source: Table 15.1

Figure 2. Comparison of residential electricity consumption

Definitions

This study uses certain terms to describe the assumptions of the various model projections. These terms are technically defined and may not bear their common meaning, so they appear in quotes in this report.

- **"Frozen efficiency"** means that the *marginal* electrical efficiency a product or technology had in 1988 is maintained throughout the period from 1988 to 2010; that is, the efficiency of new equipment that customers were purchasing in 1988 would apply until 2010. A "frozen efficiency" forecast of electricity consumption levels is one that would result if no improvements in energy efficiency occurred except for those that households are already adopting.
- **"Technological potential"** means the savings that would occur if households did the following:
  - replaced all appliances, water heating equipment and space heating systems with the most electrically efficient equipment available on the market;
  - retrofitted existing electrically heated homes and built new electrically heated homes to the highest possible standard, and
  - retrofitted non-electrically heated homes so that no supplemental electric heat was needed.
- The "technological potential" estimate assumes that households make no energy-saving changes in their behaviour.
- **"Social potential"** means the savings that would occur if households changed their behaviour to use electricity more efficiently. Because the impact of behavioural changes in the target years is calculated only on already-efficient technology, the impact is lower than it would be in the base year or if current day technology was used for the comparison.
- **"Economic potential"** means the savings that would occur if households adopted the "technological potential" changes that were "economic" and changed their behaviour to use electricity efficiently. **Economic** here means that the cost of saving a kilowatt-hour, minus any environmental credits, is less than or equal to the long run cost of new electricity supply after the year 2000, 6.3 cents/kWh.
- **"Environmental credit"** means an extra charge added to the cost of new electricity to reflect the possible uncosted environmental impacts of providing new electricity. Applying the environmental credits indicates whether or not accounting for the cost of environmental impacts will affect the "economic" status of an electricity-saving technology.

Methodology

The consultants, Marbek Resources Consultants Ltd., in association with Sheltair Scientific Ltd., and Pacific Energy Associates, Inc., used current research and computer analysis to analyze how residential customers use electricity in B.C. Hydro's service area.

- The consultants examined current research on patterns of electricity use in B.C. homes as well as in homes in other North American regions.

The researchers estimated the amount of electricity used for various purposes in homes and compared the amount to the level that would be possible using energy-efficient technologies and practices.

- From this data, they established a 1988 baseline of residential electricity use for B.C. Hydro's service area, divided into three regions — Vancouver Island, the Lower Mainland and a region consisting of the North and the Southern Interior. (This summary report uses totals for all three regions, unless a regional variation is particularly significant.)
- The researchers analyzed the electricity used in a variety of different housing types, such as standard electrically heated new single-family homes, energy-efficient single-family homes, apartments and townhomes.
- They estimated the amount of electricity used for each of the common residential end uses, such as space heating, water heating, laundry, cooking and so forth.
- They estimated the changes in housing stock and household equipment that will take place over the 1988 to 2010 study period as households renovate old buildings and equipment.
- They estimated the possible reduction in electricity use if residents adopted more efficient ways to operate their homes and appliances.

Using published information about the potential for efficiency improvements in housing and household equipment, the researchers used two computer modelling programs, HOT2000 and HEET, to calculate the electricity demand under the "frozen" efficiency conditions, and the "technological," "social" and "economic" potential as defined above.

The study analyzes only residential customers in B.C. Hydro's service area. Apartment buildings with five floors or more were analyzed in the commercial sector study because their energy characteristics are similar to those of high rise commercial buildings, but the results of the analysis are included here.

The rate of projected increases in the number of dwellings is based on rates of population growth, assuming that population grows at the following rates:

Projected Annual Population Growth Rates in B.C. (per cent)

1988-2000		2001-2010	
Low	High	Low	High
1.6	2.2	1.1	1.8

HOUSING CONSTRUCTION

The HOT2000 computer modelling program analyzed electricity consumption for five types of existing homes:

- **detached single family homes with basements**, including homes with a partial crawlspace or slab-on-grade foundation;
- **detached single family homes with crawlspaces**, including mobile homes and homes with a partial slab-on-grade foundation;
- **detached single family homes with slab-on-grade**;
- **multiple dwellings**, such as duplexes, rowhouses, and townhouses;

- **apartments,** including condominiums, under five stories and with separate electric metering for each unit.

Almost 700,000 single detached homes existed in B.C. Hydro's service area in 1988, along with 249,000 apartment suites (including those over five floors), 55,000 mobile homes, 50,000 row houses and 40,000 miscellaneous types of homes. By the year 2010, the total increases from 1.1 million homes to 1.7 million if growth is high and 1.4 million if growth is low. The proportion held by each type remains almost the same, except that detached homes fall from 64% to 62%, with row homes accounting for most of the shift.

Figure 3 shows the number of each type of home in the study area, and the growth in each type to the year 2010.

Various programs in British Columbia have in the past encouraged households to choose electricity as their main heat source, while more recent programs, especially since the 1970s, have encouraged electricity conservation. In addition to homes using electricity as the primary heat source, 30% to 60% — depending on location — of non-electrically heated homes use electricity as a supplemental source of heat.

Existing housing

To estimate the potential electricity savings that could result from upgrading existing buildings and building electrically efficient new homes, Marbek and their associates used a computer model, HOT2000, to estimate the heat lost by typical buildings. They used this model to calculate the amount of energy lost through the various parts of the building envelope, and then to estimate the effect of **"retrofitting,"** or upgrading, the building. The typical buildings used are as follows:

The consultants used representations of typical buildings, based on averages of wall and floor areas, insulation levels and air leakage rates, to calculate the electrical energy needed to heat each type of home.

Buildings existing in 1988

- Non-electrically heated, all ages
- Electrically heated, built pre-1976
- Electrically heated, built post-1976
- Electrically heated, super energy-efficient pre-1976 home or retrofit
- Electrically heated, super energy-efficient post-1976 home or retrofit

Buildings built after 1988

- Standard electrically or gas or oil heated home, post-1988
- R2000 or Quality Plus electrically heated home
- Advanced home with high insulation and integrated mechanical systems

These typical buildings are composites based on the actual housing that previous surveys have found throughout British Columbia. They use averages of wall and floor areas, insulation levels and air leakage rates to calculate the electrical energy needed to heat each type of home. In B.C. Hydro's service area, approximately 749,000 homes are non-electrically heated, 246,000 are standard electrically heated homes and 6000 are super-efficient electrically heated homes.

Assumptions and cautions. The computer modelling program used to calculate building heat loss, HOT2000, is not designed for use with apartments or drafty older buildings. It likely underestimates heat losses from air leakage. The researchers therefore adjusted the model to allow it to account for heat losses from common areas of apartment buildings and through party walls. The researchers assumed that retrofitting does not change the temperature in the house, although in some cases, that assumption may not be accurate. For example, when a formerly cold, unused basement is retrofitted, residents may choose to heat and use it.

Building upgrade potential

Up to 20,000 kWh of heating electricity per home per year could be saved if all existing homes used all the energy saving technology available, and up to 15,000 kWh per home per year if all new homes were built to high efficiency standards.

The researchers looked at two forms of building upgrade over the study period: retrofitting existing homes to high technological standards, and building new homes to high standards. They considered the effect of the following:

- **reducing air leakage** by 75% or more, to 1.5 air changes per hour in retrofit homes, and less in new construction;
- **upgrading ceiling and wall insulation** to the maximum levels, with high density insulation and rigid insulation sheathing or an equivalent;
- **replacing standard windows and window frames** with casement style windows using low emission panes in frames that are thermally broken;
- **replacing doors and frames** with metal-clad insulated doors;
- **insulating basements and slabs,** except for existing basement floors; and
- **installing mechanical ventilation systems** with built-in heat recovery.

Analysis of the upgrading showed that, if B.C. householders adopted all the technological changes available, up to 75,000 MJ per year (20,000 kWh/yr) per house could be saved through B.C. Hydro's service area in existing single family homes, and up to 50,000 MJ per year (15,000 kWh/yr) in new homes. Figure 4 summarizes the electricity savings potential.

Social practice

As well as changes in the physical structure of houses, the Marbek study looks at the potential savings from changes in people's activities in relation to electricity use. Social practices that relate to the building structure include:

Householders could save about 6% of the heating electricity lost through their home's structure if they changed practices such as window cleaning, use of drapes, upkeep of weatherstripping and closing of fireplace dampers.

- **window cleaning and use of drapes** — Dirty windows and closed drapes reduce the solar heat that enters a building. Keeping windows clean and opening drapes during the day to improve solar heating can reduce the electricity needed for heat by about 2%.
- **upkeep of weatherstripping** — Poor upkeep of weatherstripping allows heated air to leak out of the house. Proper upkeep can reduce heating needs by about 3%.
- **closing fireplace dampers** — Open fireplace dampers can account for up to 25% of the air leakage from a house. Closing them when they are not in use can save approximately 2% of the overall heat used.

The researchers estimate that about 6% of the total energy lost through a single detached or row home's structure, and 5% of the energy lost through an apartment's structure, can be saved by modifying these social practices.

SPACE HEATING AND COOLING

Households use electricity both as a primary heat source and for supplemental heat when another fuel provides the main source of heat. Three types of electrical equipment provide heat:

- **electric resistance baseboard or radiant ceiling and floor coils**;
- **electric forced air furnaces**; and
- **heat pumps.**

All forced-air heating systems also use electricity to run blower motors, and many non-electrically heated homes use electric heaters as a supplemental heat source.

Electric resistance heaters

Electric resistance heating is already almost 100% efficient. However, social and technological changes such as the use of temperature setbacks and more accurate thermostats could save about 17% of electric heating energy.

Electric resistance baseboard heaters, which range from 70% to 100% of the electric heating systems used, are 100% efficient. The only technological improvements that are likely are in the controlling thermostat. Current thermostats are not very accurate, and people tend to set them high to maintain their comfort when the thermostat allows room temperature to drop. More sensitive thermostats would allow people to set the thermostat accurately. Accurate thermostats, used properly, could produce overall savings of 10% compared with standard bi-metallic thermostats. Improved heat reflectors and fans and other improvements might produce additional savings, but no studies have measured this potential.

Some changes in behaviour can reduce the amount of electric resistance heating households use. Approximately 43% of the respondents in one survey lower the temperature setting at night and for at least part of the day, reducing electric heating demand in the home by about 10%. If every household able to set back the temperature for at least part of the day without sacrificing comfort did set it back consistently, they could reduce heating electricity by an additional 10%. Overall, the researchers estimate that this measure and improved thermostats could save 17% of the electric resistance heating energy currently used.

Forced air furnace fans

Electric forced air furnaces use electric resistance heaters to heat air and blow it through vents, much like furnaces that use other energy sources. Typically, furnace fans run for 1850 hours per year in the Lower Mainland and Vancouver Island, and for 2350 hours per year in colder areas. For a single detached house, this usage adds up to 700 and 900 kWh per year, respectively. Fans running continuously on a two-speed basis will run for approximately 4000 hours per year. More efficient blower motors and fans could reduce the blower energy by 59%.

Temperature setbacks, filter cleaning and maintenance could save 3% of the electricity used on furnace blowers.

Temperature setbacks can also save on blower energy, since the blowers run less frequently during the setback time. In addition, if the 30% of households that do not regularly clean furnace filters and maintain their furnace blower systems were to do so, they could save an additional 3% of their home heating electricity.

Overall, these changes in social practices could reduce furnace fan electricity by about 4%.

Air source heat pumps

Heat pumps use motors and fluids to extract heat from low grade sources, such as atmospheric air. They concentrate the heat and move it to where it is needed. They also work in reverse to remove heat and disperse it into the atmosphere. Households in the North and the Interior rarely use heat pumps. In the Lower Mainland and on Vancouver Island, however, about 7% of electrically heated single detached homes use them. Several new generations of heat pump are available, which are up to 40% more efficient than standard heat pumps. One high-efficiency model also heats domestic hot water, and reduces hot water electricity demand by up to 50%. Although these units are not likely to be cost-effective for the low heating and cooling demands of energy-efficient new houses, room-sized heat pumps are in use in Japan, and should be commercially available within the study period. Thermostat setbacks and good maintenance can also save about 5% of overall heat pump electricity.

Supplemental heat

5% to 10% of heat in non-electrically heated homes comes from supplemental electric heaters.

Households use electricity extensively for supplemental heat because it is easy to use. They can move an inexpensive electric space heater into cool rooms, or wire electric baseboard heaters cheaply into additions and crawlspaces. The researchers estimate that on average 5% to 10% of the heat in non-electrically heated homes actually comes from supplemental electric heaters. They also estimate that in electrically heated homes, from 15% to 35% of the heat comes from wood and other sources. They estimate that homes and retrofits that meet the "technological potential" standards will need no supplemental heating.

More than half of the electrically heated single detached homes in the Lower Mainland use wood stoves or fireplaces as a significant source of supplemental heat. This figure rises to 70% in other regions of B.C.

Space cooling

About 2% of houses in B.C. Hydro's service area use central air conditioning, and about 4% use room air conditioners. More efficient compressors, fans and heat transfer coils can reduce the electricity used by air conditioners to approximately 50% of that of a standard air conditioner. One solar powered air conditioner on the market in Japan can save up to 90% of the electricity used by standard air conditioners.

Social practices can save air conditioning electricity. If households use awnings, curtains, shutters, trees and other means to reduce solar heating, and install improved insulation and venting, they can reduce the cooling load by 25% or more. Households can save an additional 5% by locating the air conditioner out of direct sunlight or by installing a reflective cover over it.

Ventilation

Existing homes use kitchen and bathroom fans to provide ventilation, while energy-efficient new homes and retrofits often use central ventilators that salvage heat before venting stale air. Householders can improve ventilation efficiency by a factor of ten if they replace fans with high efficiency ones and use heat recovery equipment to reclaim heat lost in outgoing ventilation air.

DOMESTIC HOT WATER

Domestic hot water heaters account for 20% or more of household electricity, the second largest single use. The number of people in the household and the way they use hot water determines the actual energy consumption. In general, households use an average of 78 litres per day per person. Single and multiple unit homes draw about 5800 kWh per year for water heating, while apartments draw about 3600 kWh per year.

Over 90% of Vancouver Island houses use electric water heaters, compared to 29% of Lower Mainland single family homes. A conventional water tank losses heat at a rate of 130 W, approximately equivalent to losing two litres of heated water per hour, so wasteful use of hot water can wipe out any savings through tank improvements within seconds.

Improved tank insulation and tank wraps can reduce heat losses from the standard 130 W to 65 W, a 50% reduction. If homes suitably located for solar water heating were to install solar collectors, they could save 40% to 45% of their electric water heating energy. Heat pump systems, using waste heat from exhaust air or from the pump's chilling cycle, can reduce water heating electricity by 40% to 50%. Recovering waste heat from appliances such as showers, clothes washers and dishwashers can save up to 55% of the energy used by an electric resistance hot water heater.

Social savings from storage tank water heaters include maintenance and upkeep measures. Low-flow taps and showerheads can reduce flows by 50% without affecting the way people use hot water, and approximately 15% of water used for handwashing could be saved by turning taps off as soon as people finish washing. In all, the researchers estimate that 30% of the water heating load could be saved by changing taps and showerheads and handwashing practices. Combined with 50% more efficient hot water heaters, householders could save 70% of the electricity used for heating water. Households can make most effective use of solar hot water by scheduling hot water use for times when the solar collector is working.

Improved insulation can reduce hot water tank heat losses by 50%. But wasting hot water can wipe out within seconds any savings made through tank improvements.

Assumptions and cautions. The researchers assumed that only 10% of all water heaters are fitted with thermal traps, thermal wraps or pipe insulation over the first three feet of hot pipe. Approximately 88% of water heaters have 40 gallon tanks, and 10% have 60 gallon tanks.

INTEGRATED MECHANICAL SYSTEMS

Integrated mechanical systems combine space and water heating, ventilation and air conditioning to reclaim heat that would otherwise be lost. They use heat from outside sources, such as solar heat, and store extra heat collected at one time to meet heat loads at another.

Integration can work at various levels:

- **Space heating and air conditioning using a heat pump** can reduce heating and cooling electricity by about 60%, due to the greater heating efficiency of heat pumps compared to electric resistance heating.
- **A heat pump with a desuperheater** takes excess heat from the heat pump to pre-heat the domestic hot water system, reducing electricity consumption by 45% compared to a conventional heat pump and hot water heater, or by 75% compared to electric resistance space and water heating.
- **Ventilation heat recovery** uses heat from ventilation air to pre-heat the hot water system. It can recover heat from sources such as solar gain, lighting and appliances, further reducing the demand for conventional heat.
- **Greywater heat recovery** reclaims heat from waste water, such as laundry and bath water, reducing hot water electricity needs by 55%.
- **A fully integrated system** combines the above systems with hot and cold storage units to provide space and water heating or cooling as needed. A heat pump transfers excess heat into the storage system, and delivers it to reduce heating, cooling and hot water electricity consumption by almost 40%.

Assumptions and cautions. Gas-powered cogeneration-heat pump systems, which could supply heat for room heating and appliances and supply electricity for lights and appliances, were not considered although they might greatly reduce the need for residential electricity supply.

MAJOR APPLIANCES

Marbek and their associates studied the following major appliances:

- Refrigerators
- Freezers
- Clothes washers
- Clothes dryers
- Dishwashers
- Range/microwaves

Refrigerators

Over 85% of single family detached homes have auto-defrost refrigerators. The percentage is much lower in apartments. Electricity consumption in 1988 averaged 1692 kWh per year for a standard refrigerator in a Lower Mainland house. Manual defrost refrigerators, which are being replaced and will likely disappear before 2010, consume an average of 745 kWh per year.

Households can save electricity by cleaning coils, defrosting regularly, selecting a size no larger than needed, choosing a model without a freezer compartment if one is not needed, and not locating the refrigerator in a warm area. Although the changes do not apply in all cases, overall they could save 26% of the electricity households use to run a typical auto-defrost refrigerator.

Changing social practices could save 26% of the electricity households use for auto-defrost refrigerators. Technological improvements could reduce electricity use by up to 85%.

Technological improvements, such as improved insulation and high efficiency compressors, can reduce the electricity demand of a standard refrigerator by 82%, and by 85% if evacuated panels are used in place of standard insulation, a potential saving of up to 1438 kWh per year for a single family detached home in the Lower Mainland.

Freezers

Over half of all single detached homes have free standing freezers. A standard 13 cubic foot freezer in a Lower Mainland house used an average of 1465 kWh per year in 1988, although consumption was considerably lower for new machines.

Social practices that could change the electricity consumption of freezers include the following:

- Locating freezers away from heat sources and defrosting annually could save about 4% of the electricity a freezer uses in typical operation.
- Adjusting the temperature setting to the optimum level and cleaning condenser coils could save about 2%.
- Choosing the right size instead of one that is larger than needed could reduce electricity demand by 20%.

Technological improvements could reduce electricity used for freezers by up to 77%. An additional 12% of that electricity could be saved by changing social practices.

Together, these changes amount to an average saving of 12% compared to standard patterns of use.

Improved insulation and compressor operation could reduce the electricity demand by 73%, while evacuated panels in place of standard insulation could reduce electricity demand by 77%, a potential saving of 1128 kWh per year in a Lower Mainland single detached home.

Clothes washers

Approximately 95% of single family houses have clothes washers. Washing 24 loads per month with an average washer used 980 kWh per house in the Lower Mainland in 1988. Around 88% of the electricity goes to heat water, while the remaining 12% powers pumps and motors.

The following social practices could reduce the electricity used by clothes washers:

- Using only cold water washes would save the 88% of clothes washing electricity that is used to heat water (although this would only affect electricity consumption where water is heated electrically).
- Using full loads instead of partial loads could reduce typical electricity use by 10%.

These changes amount to an 84% potential saving overall.

Changing social practices could save 84% of the electricity households currently use for clothes washers. Technological improvements could reduce future electricity use by up to 82%.

Various technological improvements could save electricity used for both water heating and motor drives. More temperature and water level controls could reduce electricity demand to 62% of the standard consumption. Horizontal axis machines with a high speed spin cycle use considerably less water, and also expel more water, saving clothes drying electricity. They use about 82% less electricity than standard machines, for a potential saving of up to 804 kWh per year in a single family detached house in the Lower Mainland. Combination washer-dryers and advanced machines, such as spray washers, now under development will further reduce hot water use.

Clothes dryers

From 86% to 92% of single family homes have electric clothes dryers. Electricity use for 24 loads per month in a Lower Mainland house averaged 803 kWh in 1988. Most of the energy heats air, while the remainder operates the drum motor and fans. Approximately 90% of the heated air is vented to the outside.

Social practices that could reduce clothes drying electricity include the following:

Technological improvements could reduce electricity use for clothes dryers by up to 76%. Changing social practices could save an additional 21% of that electricity.

- Using clothes lines when feasible could save up to 25% of the electricity used by dryers.
- Drying only full loads instead of partial ones could save up to 40% of the electricity a dryer uses.

Averaged over the population, these changes create a potential saving of 21%.

Moisture sensors and exhaust air heat recovery can reduce the electricity a dryer uses to 74% of the standard consumption. More advanced equipment such as a heat pump dryer and a microwave dryer, which may become commercial during the study period, could reduce electricity demand to 24% of the electricity a standard dryer used in 1988, a potential saving of up to 610 kWh per year in a Lower Mainland single detached home.

Dishwashers

From 53% to 69% of houses have dishwashers. Using an average of 24 wash cycles per month, a standard dishwasher in a Lower Mainland house consumed approximately 975 kWh per year of electricity in 1988, 88% for water heating and the remainder for pumps and motors.

Technological improvements could reduce the electricity households use for dishwashers by up to 51%. Changing social practices could save an additional 5% of that electricity.

The most significant social practice that could affect electricity use is turning off the electric dish dryer, saving about 9% of the electricity dishwashers use.

Overall, these changes could result in an average saving of 5% of the total electricity B.C. households use for dishwashers.

Technological savings can be achieved with models that reduce water use and boost water temperature internally (allowing the hot water tank to be set to a lower temperature). These changes can lower the standard consumption rating by 51%, a reduction of 497 kWh per year in a Lower Mainland single detached dwelling.

Electric ranges/microwaves

From 83% to 87% of single family houses have electric ranges and from 78% to 82% have a microwave oven. Microwave ovens can save from 25% to 75% of the electricity used by standard ranges, although they now perform tasks that were uncommon in the past, such as re-heating sandwiches. Together, standard range/microwave use in single family homes totals up to 769 kWh per year.

The following social practices can affect electricity used in cooking:

- Greater use of microwaves instead of oven cooking can reduce electricity consumption by about 15%.
- Greater use of pressure cookers and internal heat cookery, such as crockpots, could save up to 30% of electricity consumption.

Averaged over the population, these changes could reduce cooking electricity by about 41%.

Technological improvements could reduce electricity used for ovens and stoves by up to 64%. Changing social practices could save an additional 41% of that electricity.

Technological savings for electric ovens include improved insulation and air seals, and radiant walls to reflect heat from the oven walls. Pressure cookers and internal heat cookware reduce the need for electric stovetops, while magnetic induction stovetops could reduce stove top electricity use by 50%. Together, these factors would reduce electricity demand by 64%, up to 491 kWh per year in the Lower Mainland for a single family detached home.

Assumptions and cautions. The saturation level of appliances will not increase significantly over the study period, except for dishwashers, which will have a low overall impact, since 87% of dishwasher electricity is already used for washing by hand. Manual defrost refrigerators will be replaced with auto-defrost models in all new construction and will be phased out of existing households. Microwave ovens will rise to 95% saturation.

LIGHTING

The electricity consumed for lighting depends in part on the size of a residence and number of occupants. In addition, weather is a factor, with the 80% of households in coastal regions using their electric lights more than homes in dryer areas do. While single family homes use from 770 to 840 kWh per year, apartments use from 343 to 412 kWh per year. Approximately 60% of homes do not switch off unnecessary lights, which researchers estimate total five 60-watt lights per household, or 18% of the lighting electricity used. This percentage represents potential savings from changes in social practice.

Technological improvements could reduce electricity used for lighting by up to 75%. Changing social practices could save an additional 18% of that electricity.

Incandescent lamps account for almost 100% of residential lighting, using a total of 840 kWh per year in a Lower Mainland single family household and 412 kWh per year in a Lower Mainland apartment. Krypton-filled incandescents use 15% less power for the same light intensity. Compact fluorescent lamps can reduce yearly consumption to 14 kWh, 25% of the electricity used by incandescents. Low voltage halogen lamps offer a similar level of efficiency.

MINOR APPLIANCES

A typical single family household uses between 704 and 842 kWh per year on a variety of household appliances, including:

- small cooking appliances, such as toasters and frying pans
- televisions and video recorders
- music systems
- waterbed heaters
- car block heaters
- computers
- electric lawnmowers
- hot tubs and jacuzzis

Technological improvements could reduce electricity used for minor appliances by up to 30%. Changing social practices could save up to 19% of that electricity in addition.

Householders can significantly reduce the electricity they use on many appliances, especially by turning them off when they are not in use. Some possible savings through changes in social practice are:

- Turning off televisions when they are not in use, saving about 15% of the electricity the television uses.
- Turning car block heaters on an hour before use instead of leaving them on all night, reducing their electricity use by 90%.
- Insulating and covering waterbeds, reducing the electricity used to heat the water they contain by 30%.

The overall impact of these improvements would be to reduce electricity used for minor appliances by 19%, about 155 kWh per year in a single family detached home in the Lower Mainland.

Some technological changes, particularly the use of timers and sensors, can reduce the electricity used by appliances, although savings will be reduced by an increase in the number of appliances per household. The researchers estimate that the overall potential for savings through technological changes is 30%.

CONSERVATION POTENTIAL PROJECTIONS

If efficiency of electricity use remained unchanged from 1988 levels, residential electricity use would increase 51% between 1988 and 2010 if population growth is high, and 29% if population growth is low.

"Frozen efficiency"

Using the data about the existing patterns of electricity consumption in homes, Marbek and their associates projected the demand for electricity from B.C. Hydro's residential customers in the years 2000 and 2010 using a variety of assumptions. The "frozen efficiency" projection estimates the consumption if the population continues to grow, but energy efficiency stays at the level of new 1988 technology and the way people use electricity in their homes does not change.

For B.C. Hydro's market area as a whole, residential electricity use would increase 51% between 1988 and 2010 if population growth is high, and 29% if population growth is low. In each case, space heating makes up about 27% of the total, water heating makes up about 22%, and appliances make up 51%.

Assumptions and cautions. Market saturation of appliances remains constant, except that manual defrost refrigerators are phased out. Market shares for fuel, housing type, and type of electric heating equipment are constant, except that gas heating in new homes on Vancouver Island increases as natural gas becomes available. Electricity use reflects both technological and social practices of 1988.

"Technological potential"

The "technological potential" projection estimates the savings that could be gained over "frozen efficiency" if all appliances, water-using and water-heating equipment, building practices and heating systems are replaced with the most efficient technology possible. Social practices, that is, the way people use electricity in their homes, do not change from 1988 practices.

If all residential technological improvements were in place by the year 2010, residential customers could save up to 72% of the electricity that would have been used in 2010 at baseline levels of efficiency.

The HEET model indicates a large potential for residential electricity conservation. Total residential electricity use could fall by 64% in the year 2000 and by 72% in the year 2010, compared to what it would be if electricity efficiency remained frozen at 1988 levels. The potential is slightly higher on Vancouver Island because residents there use more electricity for heating, and slightly lower in the Interior because residents there use less electricity for heating.

The greatest reduction in electricity use comes from reduced space heating, as the model assumes houses meet super energy-efficient standards, use high efficiency heat pumps for electric heat, and use no supplemental electric heat. These changes would reduce space heating electricity by over 90% compared to what it would be in 2010 at "frozen" 1988 levels of efficiency.

The model projects that homeowners could reduce the use of electricity for appliances by over 60%, and electricity for water heating by about 75%, compared to what they would be in 2010 at 1988 efficiency levels.

Assumptions and cautions. It is assumed that existing equipment is replaced at the end of its useful life, and existing homes are retrofitted to the most efficient technological standards by 2000.

"Social potential"

If, in addition to adopting all technological improvements, householders adopted all electricity-saving social practices by the year 2010, they could save an aggregate of an additional 4% of the electricity that would have been used in 2010 at 1988 levels of efficiency.

When the model compares the effect of using the most efficient operating and maintenance practices in the home, in addition to the "technological potential," it projects further potential savings of 4% compared to what electricity use would be in 2010 using 1988 practices. Efficient practices include activities such as proper use of electric thermostats, proper maintenance of heat pumps and the use of cold water for clothes washing. The "social potential" savings would be much higher for homes at a 1988 level of efficiency, but the projection is based on efficient practices in homes that already meet the most efficient "technological" standards.

"Economic potential"

Savings of up to 57% of the electricity that would be needed in 2010 at baseline efficiency levels are "economic," compared to the cost of generating new electricity. With a 60% environmental credit, virtually all the technologies studied would be "economic."

The researchers calculated the potential savings that would occur if households upgraded their homes and appliances to the level that would be cost-effective compared to the long run marginal cost of generating new electricity. The results show that a large proportion of the savings the researchers identified as "technological" and "social" are also "economic." Super energy-efficient house construction and renovations, as well as most energy-efficient appliances, lighting and heating equipment, are "economic" compared to the cost of new electricity. Table 4 lists technologies that meet the "economic" test.

Overall, the researchers found an "economic" potential for residential electricity savings of 57% from the level consumption would be at in 2010 if efficiency were "frozen" at 1988 levels, even with no environmental credit. The savings come from a 71% to 73% reduction in space heating electricity, a 49% reduction in appliance electricity use and a 56% reduction in water heating electricity use.

The researchers calculate that with 15% and 30% environmental credits, most of the potential "technological" plus "social" savings are "economic," and with a 100% credit, all technologies are "economic."

Assumptions and cautions. To be considered "economic," new technologies must meet the Total Resource Cost Test, which compares the annualized cost of a technology with new electricity priced at 6.3 c/kWh saved in the year 2000 and a discount rate of 8%. Environmental credits of 15%, 30%, 60% and 100% were also considered to compare the impact of including an allowance for unpriced external costs. To test sensitivity to the discount rate, rates of 4% and 12% were also used. Technologies under development, for which no reasonable cost estimate was available, were not tested.

Table 4. "Economic" residential technologies

	Environmental credit at which technology becomes "economic"
Appliances	
Refrigerators	
Improved compressor + insulation	0%
High efficiency	0%
High efficiency + evacuated panels	30%
Freezers	
Improved compressor + insulation	0%
High efficiency + evacuated panels	0%
Clothes washers	
Reduced water	0%
Horizontal axis	0%
Clothes dryers	
Moisture sensor	0%
Heat pump	60%
Dishwashers	
Moisture sensor	0%
Booster heater	0%
Ranges	
Convection oven	60%
Bi-radiant oven + improved cookware	30%
Lighting	
Compact fluorescent (1 hr/day)	60%
Compact fluorescent (2 hr/day)	0%
Compact fluorescent (3 hr/day)	0%
Furnace blowers	
Efficient unit, 1850 hr/year	0%
Water heating	
Water restrictors	
Low flow showerhead	0%
Tap aerator	0%
Electric water heaters	
CSA standard	0%
High efficient	0%
Solar water heater	15%
Desuperheater	0%
Space heating	
Air source heat pumps	
Improved compressor	0%
Scroll compressor/variable speed	0%
Super energy-efficient retrofit	
Single w/ basement/crawlspace	0%
Single w/ slab on grade	15%
Multiple unit	0%
Apartment	100%
New energy-efficient housing	
Super energy-efficient	0%
Advanced house (Vancouver Island)	15%
Advanced house (LM/Interior)	0%

Source: Marbek, Summary, Table 5

The commercial sector

INTRODUCTION

The study of the commercial sector estimated the electricity savings that could be achieved by commercial and institutional electricity users in B.C. Hydro's service area if they adopted new electrically-efficient technologies, and operated and maintained their electrical equipment for maximum efficiency over the period from 1988 to 2010. This phase of the study assumes that human behaviours and institutions do not restrict the use of new technology, and estimates what portion of the savings identified would be cost effective.

Key findings

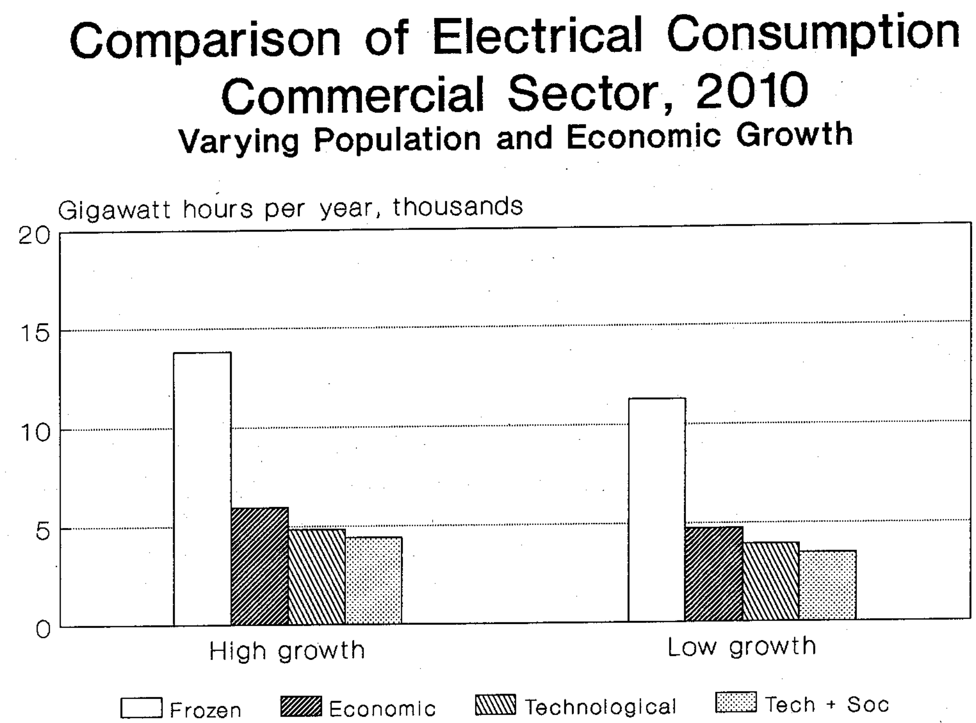
B.C. Hydro's commercial customers used 7935 gigawatt-hours (GWh) of electricity in 1988. Lighting accounts for 47% of the electricity used in the commercial sector, or 3729 GWh. Space heating and cooling account for 22%, or 1736 GWh, and all other uses make up the remaining third of the electricity used. If the level of electrical efficiency remained the same, the amount would rise to 13,807 GWh in 2010 if commercial growth were high, and 11,268 if commercial growth were low. These high and low projections form the baseline electrical consumption for the commercial sector.

B.C. Hydro's commercial customers used 7735 GWh of electricity in 1988, a consumption rate that could rise to 13,807 by 2010.

- If commercial customers adopted all the electricity-saving technologies possible, total commercial electricity use in 2010 would be 65% lower than it would be if electrical efficiency were unchanged.
- If, in addition to adopting the most efficient technologies, commercial customers also adopted the most efficient ways to use and maintain their equipment, total commercial electricity use in 2010 would be about 68% lower than it would be if electrical efficiency were unchanged.
- If commercial customers adopted the technological changes that were "economic," compared to the cost of new electricity, total commercial electricity use in 2010 would be as much as 58% lower than it would be if electrical efficiency were unchanged.
- Many electricity-saving technologies are "economic" with no environmental credits and virtually all are "economic" with a 30% environmental credit.

Figure 3 summarizes these projections.

If all commercial customers adopted all the electricity saving technologies possible, commercial electricity use in 2010 would be 65% lower than it would be if electrical efficiency remained at 1988 levels.



Source: Table 12.1

Figure 3. Comparison of Commercial Electricity Consumption

Definitions

This study uses certain labels to describe the assumptions of the various model projections. These labels are technically defined and may not bear their common meaning, so they appear in quotes in this report.

- The **commercial sector** is a complex one, made up of commercial and institutional electricity users in very diverse sub-sectors — roughly, those B.C. Hydro customers who are neither residential nor industrial. The sub-sectors included are the following:
  - large offices (over 3700 m^2)
  - small offices (less than 3700 m^2)
  - non-food retailers
  - food retailers
  - restaurants
  - wholesalers and warehouses
  - hotels and motels
  - hospitals
  - nursing homes
  - schools
  - universities and colleges
  - high rise apartments (five floors or more, suites and common areas)
  - other buildings
  - other non-building electricity uses

Non-building electricity uses, which make up 1.4 GWh of sales per year, or 16% of sales in the commercial sector, were not included in the analysis. They include uses such as power for electric bus systems and municipal water pumping systems. High rise apartments were analyzed in the commercial sector, but the conservation potential it identified was transferred to the residential sector and reported there.

- **"Frozen efficiency"** means that the *marginal* electrical efficiency a product or technology had in 1988 is maintained throughout the period from 1988 to 2010; that is, the efficiency of new equipment that customers were purchasing in 1988 would apply until 2010. A "frozen efficiency" forecast of electricity consumption levels is one that would result if no improvements in energy efficiency occurred except for those that commercial customers are already adopting.
- **"Technological potential"** means the savings that would occur if commercial customers did the following:
  - replaced all plug-in equipment, water heating equipment and space heating and cooling systems with the most electrically efficient equipment available on the market;
  - retrofitted existing electrically heated buildings and built new electrically heated buildings to the highest possible standard.
- The "technological potential" estimate assumes that commercial customers make no electricity-saving changes in their operating and maintenance practices.

- **"Social potential"** means the savings that would occur if commercial customers changed their operating and maintenance practices to reduce their electricity consumption as much as possible. Social potential ranges from 2% to 15%, because it is estimated after calculating the potential savings from technological changes. It would be significantly higher if calculated in relation to existing technology.
- **"Economic potential"** means the savings that would occur if households adopted the "technological potential" and "social potential" changes that were "economic." **Economic** here means that the annual cost of saving a kilowatt-hour, minus any environmental credits, is less than or equal to the long run cost of electricity, 6.3 cents/kWh. In estimating "economic potential," **environmental credits** of 15%, 30%, 60% and 100% were considered to study the impact of including an allowance for unpriced external costs.
- **"Environmental credit"** means an extra charge added to the cost of new electricity to reflect the possible uncosted environmental impacts of providing new electricity. Applying the environmental credits indicates whether or not accounting for the cost of environmental impacts will affect the "economic" status of an electricity-saving technology.

Methodology

The consultants studied electricity use for each sub-sector, and projected the growth of each electricity use in each sub-sector.

The consultants, Marbek Resources Consultants Ltd., in association with Prism Engineering Ltd. and Pacific Energy Associates, Inc., analyzed how commercial customers use electricity in B.C. Hydro's service area.

- The consultants researched the way electricity is used by various sub-sectors of the commercial and institutional market, making use of existing reports on electricity use in British Columbia and North America, interviews with experts familiar with the patterns of B.C.'s commercial and institutional electricity use, and audits of actual electricity use in specific cases.
- They estimated the amount of electricity used in each sub-sector for each of the common commercial end uses, such as lighting, space heating and cooling, water heating, refrigeration, cooking and so forth.
- From this data, they established a 1988 baseline of commercial electricity use in each sub-sector for B.C. Hydro's service area.
- They estimated the growth in the commercial and institutional electricity consumption that will take place in each sub-sector over the 1988 to 2010 study period as commercial customers replace old buildings and equipment.
- They estimated the possible reduction in electricity use if commercial customers adopted more efficient ways to use electricity, and they calculated the electricity demand under "frozen efficiency" conditions, and the "technological," "social" and "economic" potential as defined above.

The study analyzes only commercial customers in B.C. Hydro's service area. Electricity use for apartment buildings with fewer than five floors are analyzed in this sector, but the results are included in the residential sector study.

The researchers projected increases in the amount of commercial and institutional space based on rates of growth for B.C.'s population and its gross domestic product (GDP). They assumed that growth in commercial sub-sectors would depend mostly on increases in the GDP, while growth rates in institutional sub-sectors would depend on increases in population. Table 5 lists the rates used.

Table 5. Projected Annual Growth Rates in B.C. (per cent)

	1988-2000		2001-2010	
	Low	High	Low	High
Population	1.6	2.2	1.1	1.8
GDP	1.9	3.8	1.6	3.2

COMMERCIAL AND INSTITUTIONAL FLOOR SPACE

The amount of electricity that commercial customers use depends mainly on the floor space they occupy and the type of work they do. To project the electricity consumption for each sub-sector, therefore, Marbek and their associates reviewed the growth in floor space that other studies project for each sub-sector by the years 2000 and 2010. They estimate that overall commercial floor space will grow from 44.1 million square metres in 1988 to 73.7 million square metres in 2010 if growth is high, or to 59.6 million square metres if growth is low. Table 3 shows projected growth by sub-sector.

Commercial floor space will grow from 44.1 million square metres to 73.7 million square metres if growth is high, and to 59.6 million square metres if growth is low.

Table 3. Projected Commercial Sector Growth, 1988 to 2010 by sub-sector (million square metres)

		High Growth		Low Growth	
Sub-sector	1988	2000	2010	2000	2010
Large office	1.0	1.4	1.7	1.3	1.5
Small office	7.3	10.1	12.4	9.7	11.4
Non-food retail	6.8	9.4	11.4	7.6	8.1
Food retail	1.0	1.4	1.7	1.1	1.2
Restaurant	0.9	1.2	1.5	1.1	1.3
Wholesale/Warehouse	6.6	10.4	13.0	7.6	8.4
Hotels/motels	2.5	3.4	4.0	3.0	3.4
Hospitals	1.3	1.6	1.9	1.5	1.7
Nursing homes	1.0	1.3	1.5	1.2	1.3
Schools	5.8	7.6	9.1	7.1	7.9
University/College	1.9	2.4	2.9	2.3	2.5
High rise apt.	4.6	6.0	7.2	5.6	6.3
Other Buildings	3.5	4.5	5.4	4.2	4.7
Total	44.1	60.8	73.7	53.3	59.6

Source: Marbek, Table 3.8

Assumptions and cautions. Although occupancy rates fluctuate in commercial buildings, the 1988 rate of 85% to 90% was considered to be normal. The researchers assumed that cyclical variations in occupancy would not affect the rate of growth when averaged over the study period.

COMMERCIAL SECTOR ELECTRICITY USES

Commercial and institutional electricity users need electricity to power several major building systems, or end uses. The consultants divided the electrical end uses into the following categories:

- general lighting
- service area lighting
- other (high bay) lighting
- space heating
- space cooling
- heating, ventilating and air conditioning motors
- plug-in equipment
- refrigeration equipment
- cooking equipment
- water heating (other than space heating)
- miscellaneous equipment

Lighting

Commercial customers used approximately 3730 GWh of electricity for all types of lighting in 1988, or 47% of total electricity in the commercial sector. General lighting in commercial buildings is usually four-foot fluorescent tube lighting with 40-watt lamps, conventional ballasts, and on/off switching at the circuit breaker. Warehouses, retailers, universities and schools use a significant number of eight-foot fluorescents and high intensity lights, while restaurants, nursing homes and apartments use large amounts of incandescent lighting. New buildings tend to use lower levels of lighting, as well as more efficient fluorescents and high intensity lamps.

- **High efficiency fluorescents** can replace standard fluorescents, and **compact fluorescents** can replace incandescent lamps in many applications.
- Commercial customers can select from a variety of **energy-efficient high intensity lamps**, including metal halide, high pressure sodium and low pressure sodium. High frequency induction lamps are expected to be available by the year 2000.
- For fluorescent lights, manufacturers have produced **high efficiency ballasts** for many years, and they are beginning to produce **electronic ballasts** that can save 65% of the electricity used by standard fluorescent light ballasts.
- Highly polished **optical reflectors** can reduce electricity consumption by up to 33% while reducing light output by 10 to 25%.

- **Automatic controls** such as timers and occupancy sensors can reduce lighting consumption by up to 50% in areas that are not used all the time. **Dimming systems** controlled by photocells reduce electricity consumption by 30% to 50% in perimeter areas where daylighting can be used.
- **New designs** to take advantage of existing daylight and reduce light levels to the optimum level could reduce consumption by as much as 50% to 75%, when used with new efficient lighting technologies.

Together, these unconstrained options could save 89% of the electricity that would be used for lighting in 2010 if electrical efficiency were to remain "frozen" at 1988 levels. Changes in operating and maintenance practices can also save significant lighting electricity. Operating measures include reducing the hours of lighting, turning lights off when no-one is in the room, and reducing light levels where bright lights are not needed. Maintenance changes include cleaning reflectors and lenses regularly, and setting timers and controls for specific needs. Taken together, these practices could save an additional 2%.

Lighting accounts for 47% of electricity in the commercial sector. If all commercial customers changed to the most efficient lighting options, they would save 89% of the lighting electricity that would be used in 2010 at 1988 efficiency levels.

Space heating

Space heating accounts for 12% of electricity in the commercial sector, approximately 950 GWh in 1988. The electricity used depends primarily on a building's construction and its ventilation system. Building construction varies greatly; some buildings are concrete and glass towers with little or no insulation and windows on up to 35% of the wall area; others are wood or masonry buildings with minimal insulation and 25% window area; warehouses tend to have about 5% window area. Roofing is usually wood planking or steel deck. New buildings tend to have higher insulation levels, less air leakage and double glazing.

Building owners can make their buildings more efficient by adding roof and wall insulation, either on the inside or outside, to about R16. Additional insulation reduces heat loss, thermal bridging and air leakage. In new buildings, insulation to about R30 is usually practical. Various window treatments can reduce heat loss from windows, from add-on films to new multiple-layered, thermally broken "super" windows. Building designs and landscaping of new buildings can make maximum use of solar gain and reduce heat loss due to winds.

Space heating accounts for 12% of electricity in the commercial sector. If all commercial customers changed to the most efficient heating options, they would save 87% of the heating electricity that would be used in 2010 at 1988 efficiency levels.

In most large commercial buildings, a central air system provides heated ventilation air by drawing in outside air, heating it in steam or hot water coils, mixing it with interior air and pumping it to occupied areas. In smaller buildings, rooftop units with gas heaters commonly provide warm air. Hot water or electric radiators provide extra heat in cool areas. About 10% to 20% of offices and a smaller percentage of other buildings use heat pumps. New buildings often use more electric resistance heating, especially in apartments and leased space. New buildings now use more zone controls and variable volume air pumps to reduce heating electricity consumption.

High-efficiency heat pumps can reduce electricity consumption by as much as 50% when compared with electric resistance heating. Building managers can also install heat exchangers in new and existing buildings to recover heat from stale ventilation air before it leaves the building.

Taken together, these unconstrained options could save 87% of the electricity that would be used for space heating in 2010 if electrical efficiency were to remain "frozen" at 1988 levels.

Space cooling

Space cooling accounts for 8% of electricity in the commercial sector. If all commercial customers changed to the most efficient heating options, they would save 50% of the cooling electricity that would be used in 2010 at 1988 efficiency levels. Changing to the most efficient operating and maintenance practices for heating would save an additional 6%.

About 8% of commercial building sector electricity, about 630 GWh in 1988, powers space cooling systems. Excess heat in buildings usually comes from solar gain and from internal heat sources such as lighting, equipment and people.

In large offices and institutional buildings, a central plant uses chillers to cool water, and draws ventilation air through chilled coils. Smaller buildings use a refrigerant in roof-top units to cool air directly, often with a separate unit for each individual commercial space. Many apartments, hotels and motels use room air conditioners. New office buildings began using tinted windows to reduce solar gain, and improved lighting technology to reduce cooling loads. Most roof-top cooling equipment on new buildings uses an economizer to improve efficiency.

New technology that can improve air cooling efficiency includes:

- **high efficiency chillers and air conditioners**, which can save 22% to 26% of the electricity a standard chiller uses;
- **economizers and evaporators** to take advantage of cool outdoor air and humidity levels, for electricity savings of 12% to 30%;
- **desiccant cooling** to remove moisture and the latent heat it contains from the air, for an electricity saving of 13%;
- **solar driven absorption systems**, using solar collectors to power a refrigerant system, with savings depending on the sunlight available.

Taken together, these unconstrained options could save 50% of the electricity that would be used in 2010 if electrical efficiency were to remain "frozen" at 1988 levels. Adopting the most efficient maintenance practices, closing drapes to prevent overheating from the sun, and similar measures could save an additional 6%.

HVAC electricity loads

Heating, ventilating and air conditioning (HVAC) systems use electricity to drive the fans and pumps that circulate air, chilled water and so forth. In 1988, HVAC electricity totalled about 870 GWh, 11% of commercial building electricity sales. Older large office and institutional buildings tend to use constant volume systems, delivering a set volume of air at a constant speed, with some room controls. Smaller units often have a single fan, with no need for pumps unless they use hot water heating. New buildings use compartmentalized systems with variable volume so that they power fans and pumps only when and where fresh air is needed.

Building owners can save HVAC electricity by using energy-efficient new technology.

- **Compartmentalized and variable volume air handling systems** in new and existing buildings can save 20% to 40% of the electricity used to drive ventilating fans, and 10% to 20% of the heating and cooling electricity as well.
- **Low temperature distribution** requires the pumping of smaller amounts of air, but at cooler temperatures, for a 25% saving of both fan electricity and cooling electricity.
- **Displacement ventilation** uses 100% outside air and requires far less fresh air than conventional systems, for a saving of up to 85% of the fan electricity.
- **Air and water balancing** involves careful calculation of the minimum air and water flows needed, rather than adopting "off-the-shelf" system designs, for possible savings of 27% of the fan electricity and 10% of cooling electricity.
- **Automated systems and digital controls** use computerized controls to schedule and operate fans, pumps and dampers at optimum energy-saving levels in large buildings. They can save 20% of fan electricity and 5% of heating and cooling electricity.
- **Energy efficient motors** can save 3% to 6% of the electricity standard motors use to drive ventilation systems.
- **Variable speed pumping** varies motor power with the demand of the system, allowing fan and pump motors to use up to 30% less power.

All together, these unconstrained options could save 42% of the electricity that would be used for heating, ventilating and air conditioning in 2010 if electrical efficiency were to remain "frozen" at 1988 levels. Better servicing and maintenance of HVAC systems also provides some potential for savings.

Heating, ventilating and air conditioning motors account for 11% of electricity in the commercial sector. If all commercial customers changed to the most efficient HVAC options, they would save 42% of the HVAC electricity that would be used in 2010 at 1988 efficiency levels.

Plug-in equipment

Office equipment such as computers and copiers, electric appliances and lab equipment are present in most sub-sectors, though in differing amounts and concentrations. They totalled 630 GWh of electricity in 1988, 8% of the total.

More efficient office equipment is available:

- **Desktop computers with power management software, laptop computers** and **LCD screens** can reduce computer electricity use by 50%, and overall office equipment electricity by 15%.
- **Ion deposition photocopiers** avoid the need for heated fusing rollers, saving about 50% of the electricity a photocopier uses. **Power management software** can also ensure copiers use electrical energy efficiently.
- **Ink jet printers** can replace many low volume laser printers and avoid the need for heated fusing rollers, to save about 3% of overall office equipment electricity.

Taken together, these unconstrained options could save approximately 34% of the electricity that would be used for plug-in equipment in 2010 if electrical efficiency were to remain "frozen" at 1988 levels. Changes in operating practices, mainly turning off unused equipment, could save an additional 15%.

Plug-in office equipment accounts for 8% of electricity in the commercial sector. If all commercial customers changed to the most efficient equipment options, they would save 34% of the equipment electricity that would be used in 2010 at 1988 efficiency levels. Changing to the most efficient operating and maintenance practices for office equipment would save an additional 15%.

Refrigeration accounts for 7% of electricity in the commercial sector. If all commercial customers changed to the most efficient refrigerating options, they would save 24% of the refrigeration electricity that would be used in 2010 at 1988 efficiency levels.

Refrigeration

Refrigeration is used mainly for food storage by the food retail and warehousing sub-sectors, or for ice production. Refrigeration equipment takes about 550 GWh of electricity, 7% of total commercial sales.

Two electricity conserving technologies are coming into use:

- **Multiplexed compressors**, with advanced controllers and defrosters, can serve individual refrigerators and coolers instead of operating at one level for the whole refrigeration system, saving up to 20% of the refrigeration electricity of a standard system.
- **Glass doors and covers** on refrigeration cases can save 10% to 15% of refrigeration electricity.

Taken together, these unconstrained options could save approximately 24% of the electricity that would be used for refrigeration in 2010 if electrical efficiency were to remain "frozen" at 1988 levels.

Cooking

Cooking, hot water and miscellaneous equipment account for about 5% of electricity in the commercial sector. If all commercial customers changed to the most efficient options, they would save 17% of the electricity from these categories that would be used in 2010 at 1988 efficiency levels.

Cooking is a minor electricity use in many buildings, but uses significant amounts of electricity in institutional cafeterias and restaurants. Cooking equipment uses 130 GWh of electricity, almost 2% of total electricity in the commercial sector. Changing to the most efficient cooking equipment could save 25% of the electricity that would be used in 2010 at 1988 efficiency levels.

Hot water

Separate from hot water used for building heating systems, commercial and institutional electricity consumers use hot water for washing, cleaning and food preparation. Users with high water demands, such as schools, hospitals and hotels, often have a central hot water plant, but smaller users such as offices and warehouses usually use a domestic-type hot water tank. New buildings tend to have hot water boilers separate from the main heating boiler. Commercial hot water demands total 120 GWh, 1% of total commercial sales.

- **Low flow showerheads and aerators** can reduce the volume of hot water needed for wetting and showering by 50%, but cleaning and food preparation require full water flows.
- **Refrigerant heat recovery,** where customers use large refrigerators, uses waste heat to reduce boiler power consumption.
- **Automatic tap shutoffs** and **reductions in water temperature** also provide some savings.

Changing to the most efficient water heating equipment could save 38% of the electricity that would be used in 2010 at 1988 efficiency levels.

Miscellaneous equipment

Miscellaneous equipment includes uses such as elevators, exterior lighting, pipe tracing and slab heating. At 170 GWh in 1988, it represented 2% of electricity in the commercial sector. The consultants identified no potential for conservation in this category.

CONSERVATION POTENTIAL PROJECTIONS

"Frozen efficiency"

The "frozen efficiency" projection estimates the electricity consumption in the commercial sector if population and gross domestic product grow at their projected rates, but efficiency of electricity use stays at the level of new 1988 technology and commercial customers do not change their electricity consuming practices.

If efficiency of electricity use remained unchanged from 1988 levels, commercial electricity use would increase 74% between 1988 and 2010 if growth were high, and 42% if growth were low.

B.C. Hydro's commercial electricity sales would increase 74% between 1988 and 2010 if population and GDP growth were high, from 7935 GWh to 13,807 GWh. If growth were low, electricity sales would increase 42%, to 11,268 GWh. The small office and non-food retail sub-sectors dominate, with 42% of total consumption between them. General and service area lighting are the largest end uses, together accounting for 46% of all electrical uses.

Assumptions and cautions. Growth rates for each sub-sector are calculated individually, but the amount of electricity used per square foot of space is held to 1988 levels. Electricity use reflects both technological and social practices of 1988. Lighting levels, ventilation levels, equipment, insulation and so forth are held to their 1988 levels, while levels for buildings built between 1988 and 2010 are held to the level of new 1988 buildings.

"Technological potential"

Marbek and their associates calculated the electricity savings that would occur if all electricity-using equipment were replaced with the most efficient options possible. They developed "packages" of electrically efficient equipment for each electricity use and calculated the savings possible from each package. They assumed that lighting, ventilation and other electricity uses would be reduced to their optimum levels, existing buildings would be upgraded to the highest practical levels, and new buildings would be designed and built for the maximum electricity efficiency practical. Operating and maintenance practices remain as they were in 1988.

If all technological improvements were in place in the commercial sector by the year 2010, B.C. Hydro's commercial customers could save up to 65% of the electricity that would have been used in 2010 at 1988 levels of efficiency.

The consultants calculate that commercial customers could reduce their electricity consumption by 55% overall in the year 2000 and by 65% in the year 2010, compared to what the levels would be if electrical efficiency were "frozen" at 1988 levels. The greatest potential is in electricity used for general and service area lighting and space heating, where the conservation potential is over 87%. A 50% conservation potential was identified for space cooling, 42% for HVAC electricity and savings of 24% or more were identified in most other sectors. By sub-sector, unconstrained potential ranges from 37% among food retailers to 77% in schools.

Assumptions and cautions. Interactions such as the effect of waste heat from lights and other equipment were taken into account where they were significant. The researchers assumed that currently available technology would be in use by the year 2000, and technologies under development would be in use before 2010.

If, in addition to the technological improvements, commercial users adopted all electricity-saving social practices by the year 2010, they could save an additional 3% of the electricity that would have been used in 2010 at 1988 levels of efficiency.

"Social potential"

When the researchers compared the effect of using the most efficient operating and maintenance practices, including the maximum correct use of control systems, in addition to changing all equipment to the most efficient available, they projected further potential savings of 3% compared to what electricity use would be in 2010 using 1988 practices. The researchers found that operating practices that can affect commercial electricity use concerned the scheduling of lighting and the scheduling and maintenance of HVAC equipment. Other behavioural changes the commercial electricity users could adopt to conserve electricity were switching lights off in individual offices; closing blinds to reduce solar gain; and turning off equipment that is not in use. The effect of these changes varies in each sub-sector, but they have the greatest effect in schools (80%) and small offices (79%).

"Economic potential"

The researchers calculated the potential savings that would occur if commercial electricity users adopted the most efficient operating and maintenance practices, and upgraded all buildings and equipment to the level that would be cost-effective compared to the long run marginal cost of generating new electricity. The results show that most of the savings that electricity users could achieve by adopting the most efficient equipment available are also "economic." The greatest potential is in space heating, where more effective insulation and building practices could save 70% of the electricity that would otherwise be used in 2010. Electricity users could achieve similar savings in general and service area lighting.

Savings of up to 57% of the electricity that would be needed in 2010 at "frozen" 1988 efficiency levels are "economic," compared to the cost of generating new electricity. With a 60% to 100% environmental credit, all the technologies studied would be "economic."

With no environmental credits, the researchers found an "economic" potential for commercial electricity conservation equal to 57% of the electricity that would be used in 2010 if efficiency were "frozen" at 1988 levels. With a 60% environmental credit, virtually all of the potential "technological" plus "social" savings are "economic," and with a 100% credit, all are.

Assumptions and cautions. To be considered "economic," new technologies must meet the Total Resource Cost Test, which compares the annualized cost of a technology with new electricity priced at 6.3 c/kWh saved in the year 2000 and a real discount rate of 8%. Environmental credits of 15%, 30%, 60% and 100% were also considered when a technology could not meet the simple test. To test sensitivity to the discount rate, rates of 4% and 12% were also used. Only technologies expected to be market ready by 2010 were considered. Technologies under development, for which no reasonable cost estimate was available, could not be evaluated. Operational and behavioural changes were assumed to be cost effective.

The industrial sector

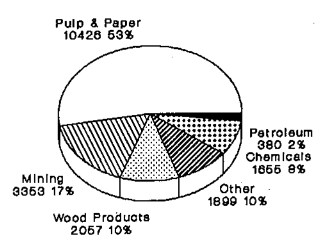
INTRODUCTION

The study of the industrial sector estimated the electricity savings that could be achieved by industrial users of electricity in B.C. Hydro's service area if they adopted new electricity-efficient technologies, and operated and maintained their electrical equipment for maximum efficiency over the period from 1988 to 2010. This phase of the study assumes that people's behaviours and institutions do not restrict the use of new technology, and estimates what portion of the savings identified would be cost effective.

Key findings

Industrial customers used a total of 19,770 GWh of electricity in 1988. Pulp and paper accounts for over half of the industrial electricity demand, and the largest four sectors — pulp and paper, mining, wood products and chemical products — account for 88%. Figure 4 shows the portion of industrial electrical consumption used by each of the major sectors in B.C.

Industrial Electricity Consumption
By sector, 1988 (GWh)



Source: Table 1.5.3

Figure 4. Electrical consumption of industrial sub-sectors

Motor systems consume more electricity than any other end use, perhaps 90% of all the energy used in industry.

Motor systems, that is, motors and the linked equipment they drive, consume more electricity than any other end use, perhaps 90% of all the electricity used in industry. Chemical producers also use electric power for electrolysis, and some customers use minor amounts of electricity for process heating. All industries use electricity for lighting and cooling.

Industries may be able to increase efficiency 19% to 60%, compared to their 1988 levels of efficiency, under some of the assumptions used.

- If energy efficiency were to remain unchanged from the average level of 1988, overall electricity consumption by industry would increase between 10% and 46% by the year 2010, depending on the rate of economic growth.
- When the study considered "natural" change, including both decreases from more efficient electricity use and increases from new electrical uses, but not including changes resulting from utility-sponsored conservation programs, the demand for electricity falls approximately 8% from the level it would be with no improvements in electrical efficiency.
- The potential for savings would be higher — 36% to 39% — if all industrial equipment were replaced by the year 2010 with the most efficient market-ready technology.
- The conservation potential would be almost as high — 34% to 37% — if industry replaced its equipment only with technologies that will be cost effective by the year 2010, compared to the cost of generating new electricity. In other words, most efficient new technologies are also "economic", compared to the cost of new electricity supplies.
- The greatest savings would result from replacing equipment with the most efficient market-ready technology and, in addition, changing from standard operating practices to the most energy-efficient operating practices. Changing operating and maintenance practices could increase the savings by an additional 3%.

Figures 5 summarizes these projections.

These results for industry as a whole mask significant differences among end uses, particularly in electricity used to power various motor-driven systems. If industry replaced its equipment with the most efficient market-ready technology, for example, it could improve its efficiency as shown in Table 6.

Table 6. "Technological" efficiency improvement, by end use

Type of equipment	Per cent of electricity saved by most efficient technology, compared to equipment at 1988 level of efficiency
Pumping	60%
Compressors	50%
Air displacement (fans and blowers)	48%
Conveyors	20%
Direct drive motors for industrial processes	13%

(Source: Jaccard, Executive Summary, Table 3)

Since different industries use different mixes of pumps, compressors and other equipment, they rank differently when study results are compared. Table 7 shows the electricity saving each of the main industrial sectors could achieve if they replaced their equipment with the most efficient market-ready technology.

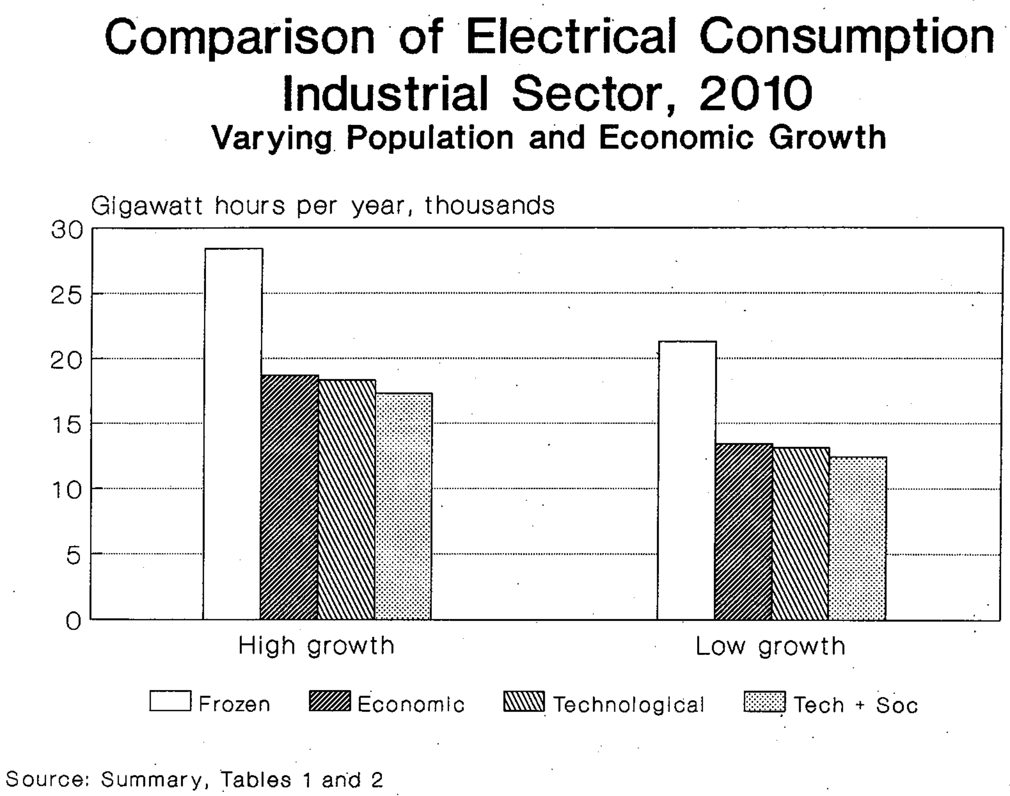


Figure 5. Comparison of industrial electricity consumption.

Table 7. Projected efficiency improvement, by industry (High growth, 2010)

Type of industry	Per cent of electricity saved by most efficient technology, compared to equipment at 1988 level of efficiency
Pulp and paper	42%
Mining	25%
Chemicals	23%
Wood products	19%
Other Manufacturing	38%

(Source: Jaccard, Executive Summary, Table 4)

Pumping systems show the highest potential savings and the pulp and paper industry uses a large number of pumps, so the pulp and paper sector shows the greatest conservation potential.

Although the mining industry uses large conveyors, with significant potential for increased efficiency, much of its electricity drives crushing and grinding machines which are already relatively efficient. Similarly, the wood products industry is already relatively efficient since much of its electricity consumption powers machine processes that have low energy losses. The chemicals industry uses most of its electricity for electrolysis, which does not have a high potential for improvement.

Electricity savings result from greater efficiency in two ways:

- **Higher efficiency equipment** requires less electricity to do the same job. For example, high efficiency motors can deliver the same horsepower for less electricity.
- **Higher efficiency industrial processes** require less work to produce the same output. For example, pulping processes that use medium consistency pulp in place of low consistency pulp, for example, pump less water and reduce the electricity needed for pumping.

Methodology

Computer analysis simulates various changes over the study period, based on recorded data and estimates made by experts.

The consultants, M.K. Jaccard and Associates, used a computer model of economic behaviour to simulate technological evolution over the 22-year study period. The model, known as ISTUM-I (Intra-Sectoral Technology Use Model — Industry), is used for research and analysis by several Canadian and U.S. agencies. It not only calculates the energy demand for any given level of input, but it also calculates the effect over time of retiring old technologies and introducing new ones.

As with any economic model, ISTUM-I requires information about existing conditions, factors affecting change and projected rates of change. To gather this information, the researchers combined existing data on electricity use with information they compiled from a wide array of sources. This information was critically evaluated with the help of extensive interviews with industry experts.

On the basis of the interviews, the consultants compiled flow models for each industry. A flow model simulates the major steps in the production of industrial commodities. The consultants analyzed each step to determine how much of each end use is required. They analyzed the end uses within each step by size and by efficiency level. For example, they divided motor systems into five main categories, depending on the type of equipment the motor would drive — their end uses — and sub-divided each category into subcategories based on the horsepower rating of the motor and its efficiency level.

In consultation with the industry experts, the consultants projected the energy-efficient technologies that would be market-ready by the year 2010, and estimated the savings that the new technologies would produce, compared to the baseline 1988 efficiency level.

To estimate the "natural" change in electricity use, the researchers discussed investment decision-making with industry and marketing representatives, and compared that information with data about actual investment patterns. They estimated "social potential" in a similar way, taking into account the different conditions of each industry.

The study area includes only B.C. Hydro's service area and areas likely to be added to the B.C. Hydro grid by 2010. Therefore, some major industrial electricity users, such as Alcan and Cominco, are not included as they fall into the service areas of other electricity suppliers.

To focus the study on electrical efficiency alone, the study assumptions prevent the substitution of other forms of energy for electricity and do not include energy-producing technologies, such as cogeneration. This is sometimes an important factor in the industrial sector.

Definitions

This study uses certain labels to describe the assumptions of the various model projections. These labels are technically defined and may not bear their common meaning, so they appear in quotes when they are used in this report.

Terms are technically defined, and may not have their common meaning.

The assumptions may not accurately reflect the future.

- **"Frozen efficiency"** means the average electrical efficiency a product or technology had in 1988. (The studies of the residential and commercial sector used a *marginal* definition of "frozen" efficiency; that is, they are based on the efficiency of technologies newly installed in 1988. The industrial sector report uses an *average* "frozen" efficiency, based on the average efficiency of a particular technology throughout the industry, because available data were not detailed enough to determine marginal efficiency.)
- **"Natural change"** in efficiency means the changes that would occur if industry followed its normal investment behaviour, with normal economic growth and energy prices, but without any conservation incentive programs (such as Power Smart).
- **"Technological potential"** means the change that would occur if industry retired all its equipment by the year 2010 to install the most electrically efficient equipment then on the market or ready for commercialization.

- **"Economic potential"** means the change that would occur if industry switched its equipment and its operating practices by the year 2010 to adopt any equipment and practices 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. The model calculated five different "economic potentials," called Econ 1 through Econ 5, adding in environmental costs varying from 0% to 100% of the electricity cost.
- **"Social potential"** means the changes that would occur if industry switched its operating and maintenance practices to use those that would provide the most electrically efficient operation, instead of standard current practices.

MOTOR SYSTEMS

A motor system is a linked system of equipment which converts the power of a motor shaft into useful work in an industrial process, such as pumping, conveyance or air compression. While previous studies concentrated mostly on motors and variable speed drives only, this study examines all motor system components.

Motor systems are the largest end use of electricity among B.C. Hydro's industrial customers. They account for approximately 90% of industrial end uses, except in the chemical industry, where motor systems account for about 16%.

Motors

Motors are a mature technology, but high efficiency motors are available that can reduce electrical consumption significantly.

In general, motor technology is mature; that is, there have been no major technological advances for the past 20 years, and only small additional improvements in motor efficiency are expected. Many energy-saving improvements have already been adopted by industry. In spite of the efficiencies industry has already achieved, the study found that greater use of high efficiency motor technology can reduce electricity use further.

High efficiency motors can improve electrical efficiency by 1% to 5%. However, the greatest conservation potential comes from reducing losses caused by auxiliary equipment. Parts of the motor system such as the controller, driving mechanism, pumps, fans or other equipment, piping, etc. often reduce overall system efficiency.

Industry primarily uses alternating current polyphase motors and alternating current synchronous motors operating at approximately 85% to 95% efficiency. DC motor systems, consisting of the motor and its attached equipment, controllers and rectifiers, can be as low as 65% efficient, but must still be used in specialized applications. New DC motor systems using solid state rectification have an efficiency of about 95%.

Due to the cost of replacement, most existing motors will likely remain in use until parts are no longer available. However, since high quality AC motors can now be controlled using variable speed drives, they can offer the controlled speed and torque that could only be provided by DC motors in the past. Consequently, many DC motors will likely be replaced over the study period with AC motors.

Electronic variable speed drives (VSDs) match the motor speed to the load requirements, reducing the demand for electricity when less power is needed. Older mechanical speed controllers work by throttling back the equipment driven by the motor without reducing the speed of the motor itself. Variable speed drives can increase efficiency by 10% at the control device itself and by up to 20% where the equipment is throttled.

Auxiliary systems

The industrial sector's greatest efficiency improvements come from reducing efficiency losses caused by auxiliary equipment driven by motors.

The potential for each particular motor system varies, so this study analyzed representative systems in five categories: pumping, air displacement, compressor, conveyance and process. (The process category includes uses specific to production processes, such as ore grinders, pulpers, etc. These are discussed in later sections.)

- **Pump systems** use approximately 30% of total industrial electricity. By 2010, their efficiency could improve by approximately 10% compared to 1988, mainly from better designs to reduce friction and losses, and from increased use of variable speed drives.
- **Fans and blowers** (air displacement systems) make up about 20% of the electricity consumed by industrial motor systems. Improvements in design and materials could increase blower system efficiency by about 10% by 2010. In addition, variable speed controls offer a potential saving of about 15% to 20% compared to 1988 levels.
- **Compressor systems** average 15% to 20% efficiency, because gases absorb energy when compressed and because of pressure losses from air leakage. Improved maintenance to reduce leakage could improve efficiency by 10%, relative to 1988 levels, and a further 5% improvement could come from improved design of the compressor itself. Improvements in variable speed control offer an additional improvement of 10%.
- **Bulk conveyor systems** operate with an efficiency of 89% to 98%. Little potential for improved efficiency is seen except in replacing mechanical speed controls with variable electronic controls, where applicable.

Investment and operations issues and practices

Electricity cost and rate of use are typically not the key factors in motor purchase decisions.

- Many applications require very specific types of motors to be used.
- Capital costs for higher efficiency motor systems can be greater than those for standard efficiency motor systems.
- Technical limitations may restrict the use of advanced controllers such as variable speed drives.

Over-sizing and periods of inactivity reduce the overall work actually done to about 60% to 90% of the motor's potential. Closer matching of size and workload could reduce electricity consumed by motor systems by an estimated 3%.

Four factors contribute to the significant stock of inefficient industrial motor systems.

- Electric motors have a long life, over 40 years in some cases, and they are not normally replaced unless they burn out.
- Motors over 20 HP are normally re-wound up to four times. This lengthens their service life, but reduces efficiency by about 1% to 2% over the life of the motor.
- Motor selection requires 10% to 40% greater capacity than is needed for steady usage. This provides for demand peaks on startup and during short-term transients as well as capacity for future needs.
- Equipment usage is often seasonal, leaving some of a motor's capacity unused for parts of the year.

Future developments may provide some additional potential for electricity savings. Gravity-driven pumping systems, guided automatic vehicles and computerized compressor controls are being considered in various operations.

Assumptions and cautions. For the purposes of this analysis, many assumptions have been made. Key assumptions include the following. 50% of motors over 25 HP have been rewound, up to four times. DC motors will be replaced with AC motors, except in special cases. Variable speed drives are 95% efficient, regardless of the system they drive. The efficiency of the components of a motor system are not affected by the addition of a VSD. Direct drive motor systems may be more highly used than the model assumes, especially in the case of pumps, possibly overstating the pump system potential for conservation in industry by up to 10%, and by 1% to 2% of overall conservation potential in the industrial sector.

PULP AND PAPER

Changing by the year 2010 to the most efficient market ready equipment could reduce pulp and paper electricity use by 42% of the electricity that would be used at 1988 levels of efficiency.

The pulp and paper industry accounts for 53% of the end-use electricity consumption of B.C. Hydro's industrial customers, a total of 10,426 GWh in 1988. Although parts of the industry are shifting to more electricity-intensive processes, changing to the most efficient equipment available by the year 2010 could save 42% of the 15,882 GWh of electricity that would be needed in 2010 at "frozen" 1988 levels of efficiency.

Three main products of industry use most of the electricity, while three other products consume only a small amount.

- **Chemical pulping**, currently almost half the present production, uses solvents to dissolve wood into loose fibre mats, largely for export sales. Because of changes to new pulping methods, production of chemical pulp is likely to decline by 5% to 10% by 2010.

- **Mechanical pulping** and **thermo-mechanical pulping** use grinders to break wood into fibre, both for export and for local newsprint production. Newer processes, using heat to soften the wood and produce higher quality fibre, are rapidly increasing their share of production, although they use more electricity.
- **Newsprint and paper production** form a large part of the pulp and paper sector, and are likely to continue to grow, possibly almost doubling production by 2010, if economic growth is high. Newsprint is primarily produced from mechanical pulps.
- **Recycled pulp** is a small segment of the industry, and, although likely to grow, will remain minor relative to first-generation pulps.
- **Tissue paper** is also a small segment of the industry, but is likely to grow to some extent.
- **Coated paper production** is the smallest segment of B.C. production. Its growth potential is currently unclear.

The increasing importance of thermo-mechanical pulping will increase electricity demand, since it relies on electrical power to drive pulping grinders and chippers. Thermo-mechanical pulping may also use electric power to preheat wood chips, although most of this heat will come from burning wood waste and black liquor.

Process changes to recover more fibre from raw wood will demand more electricity as the pulp and paper industry develops.

In all pulping processes, pumps and fans consume a very large portion of the power used, together totalling 48% of all electrical power uses. Power consumed by pumps and fans would be reduced by 70% compared to the 1988 efficiency if all equipment were changed to the most efficient market-ready technology by the year 2010. This sharp decrease results from increases in efficiency (improvements in design and the introduction of electronic variable speed drives) and from shifts to new processes that require less pumping. Switching from standard to most efficient practices in the operation of compressors and pumps may save an additional 3% of electricity demand.

Improvements in the production of paper are also significant. If paper mills changed by the year 2010 to the most efficient equipment available, their efficiency would improve about 42% relative to 1988 levels. Overall papermaking improvements are more limited than improvements in pulping, because in paper production electricity is used for heat as well as for driving motors, and less improvement in heating efficiency is possible.

Producing recycled paper requires less electricity than producing first-generation paper, but because production of recycled paper is likely to be small, its impact on overall electricity use is limited. New paper drying technologies are likely to be more electricity intensive. Explosion pulping, a hardwood pulping technology, could reduce electricity demand significantly if it could be applied to softwoods; however, it was not included in the analysis as experts are not sure that it can be applied to softwoods successfully.

Assumptions and limitations. Paper production includes newsprint, linerboard and wood-free writing paper. Substitution of electricity for steam or gas-fired driers is not included, although some substitution may occur. The potential for conservation in pumping may be overstated if the assumptions about the relative numbers of direct drive pumps and v-belt pumps are not accurate.

MINING

Mines in B.C. Hydro's service area account for 17% of the end-use electricity consumption in the industrial sector. Almost 70% of that is used to power high-horsepower motors in crushing and grinding operations.

Primary metals (including gold, silver, copper, lead, and so forth) and coal use 99% of the electricity, with industrial minerals such as limestone, gravel and gypsum accounting for the remainder. Metal production in 1988 totalled 619,000 tonnes, while coal production totalled 25,000,000 tonnes.

About 3% of metal mining takes place underground, while the vast majority of metal and coal is mined in open pits. Although the two forms of operation make similar energy demands overall, underground mines need electric power to pump water and maintain a well ventilated and safe atmosphere in mine shafts.

Electricity demand in mining consists of two broad uses, extraction and preparation:

- **Extraction and transportation of raw material** from the mine to the mill or processor usually requires diesel-powered trucks and loaders or electric-powered conveyors. Conveyors tend to be more economic, and many mines are switching to electric-powered conveyor systems.
- **Preparation of raw material for shipment** to refiners or other customers consumes almost three-quarters of the electricity used in the mining sector. Motor-driven crushing and grinding machines reduce mineral ore to small particles, and concentrators separate the ore from waste rock. At coal mines, crushers break down the coal to wash out waste. On average, coal mining consumes 17.5 kWh of electricity per tonne of raw ore, while metal mining consumes 23.2 kWh/tonne.

If mining sector equipment were converted to the most technologically efficient by the year 2010, electrical efficiency would increase by more than 24% compared to 1988 levels of efficiency. The savings result primarily from changes in auxiliary motor systems.

In a high-growth economic scenario, coal and metal mine outputs both increase by about 37%. In a low-growth scenario, coal output would increase 20%, while metal mine output would decrease 47%.

If the mining sector converted its equipment to the most technologically efficient by the year 2010 and growth is low, electrical consumption would be 1650 GWh, 28% lower than it would be if equipment remained at 1988 levels of efficiency. If growth is high, electricity consumption would be 3289 GWh, 25% lower. Metal mines have a lower potential for conservation than coal mines, so in the high growth scenario the potential for savings is lower than in the low growth scenario.

If, in addition to adopting the most efficient technology, the mining industry used the most efficient operating practices instead of standard practices, electricity consumption in 2010 would decrease by 33% in the low growth scenario, or 30% in the high growth scenario, from consumption at 1988 efficiency levels.

The potential increase in efficiency results mainly from improvements in auxiliary motor systems, such as pumps, fans and compressors. However, mines use almost 70% of their electricity consumption to drive crushing and grinding machines. These machines are designed for maximum efficiency when they are built, so more efficient motors would only save 1% to 2% more electricity.

Some current trends could increase electrical demand. Mine operators are making more use of electric ore conveyors and on-site smelters. Rock sorters also would use electricity, but by reducing the amount of waste material to be conveyed, overall electricity consumption might be reduced.

Assumptions and cautions. This analysis restricted switching between diesel and electricity, although switching normally occurs at higher electricity prices. It also assumes that the percentage of underground mining will remain constant; that the average hardness of ore-bearing rock will not change; and that the average ore concentration will not change. Changes in any of these assumptions could effect the consumption of electricity.

The mining industry uses almost 70% of its electricity consumption to power large grinding motors, which are already designed for high efficiency.

WOOD PRODUCTS

Manufacturers of wood products account for about 10% of industrial sector electricity end use. Most of the electricity used powers motors that drive conveyors, lathes, saws and other mill equipment. Special drying processes use small amounts of electricity, and about 14% goes to lighting, space heating and so forth.

If wood products manufacturers changed to the most efficient market-ready equipment by the year 2010, electrical efficiency improvements of 15% to 19% may be possible compared to using equipment with 1988 efficiency levels.

B.C. mills primarily produce timbers and structural products such as plywood and re-constituted boards. Large mills tend to use computer controls and modern technologies that make them more energy-efficient than smaller mills.

B.C.'s lumber industry faces an unclear future, with economic and technological issues that could severely affect the output of the industry.

- The high growth projection shows an increase in lumber products of 22%, but less than 6% in panel products.
- The low growth scenario projects declines of 9% and 23% respectively.
- The wood products industry is in the course of a long-term shift in its product line toward more value-added products, that is, products that involve more manufacturing. This change will make wood products more energy-intensive.

With energy efficiency "frozen" at its 1988 level, electrical consumption would rise by 8% by 2010, to 2222 GWh if growth is low and 2958 GWh if growth is high. But if equipment were replaced with the most efficient technology market-ready in the year 2010, consumption could be 15% to 19% lower than it would be at a 1988 level of efficiency. Most of the improvement would result from more efficient motor systems, as well as from more efficient lighting. If, in addition, the most efficient operating practices were used instead of standard practices, consumption would be 25% lower than the "frozen" 2010 level.

As the wood products industry shifts to more value-added products, it becomes more electricity-intensive.

Compared to other industrial sectors, this degree of improvement is low. This is because motor systems, which account for 63% of total electricity used, are unusually simple in this sector, and therefore relatively efficient. Much of the motor force drives process equipment, such as saws, lathes, chippers and so forth, that is directly coupled to the motor. These systems do not have speed controllers and indirect drive connectors, which reduce efficiency.

Because motor systems such as debarkers, saws and lathes are direct-coupled, the systems are relatively efficient. But in the dusty mill environment, cleaner operating practices could improve efficiency significantly.

However, improved operating practices could produce a higher degree of improvement than in other industrial sectors. The dust-laden environment of most wood products plants reduces the operating efficiency of many motor systems, and upgrading maintenance to the highest "Economic" level could reduce electricity consumption 5% more than changes in technology alone.

The forest industry also shows a larger gap than other industries between the energy savings that are economic using no environmental credit and the electricity savings when the most efficient technology is used (the difference between "Economic" and "Technological" potential). This gap results from the high capital cost of the new equipment.

Assumptions and cautions. Technology used for in-plant materials transport and the proportion of steam drive to mechanical drive were assumed to remain constant. Re-constituted panels were assumed to replace plywood over the modelling period, and certain other re-manufactured wood products were assumed to replace a portion of regular dimension lumber. Computer-controlled systems were assumed to make up 90% of mill systems, saving 5% of total electricity.

CHEMICAL PRODUCTS

Chemical producers account for 8% of the end-use electricity consumption of B.C. Hydro's industrial customers. Inorganic chemicals such as sodium hydroxide (or caustic) and chlorine, mainly produced to supply the pulp and paper industry, account for 96% of the total electricity consumed.

Methanol and its by-product ammonia, generated from natural gas, are the only significant organic chemicals. Because production of these chemicals is a small part of the industry and operates independently from the pulp and paper industry, their output is constant in the ISTUM-I model for the purposes of this review.

84% of electricity in the chemicals sector is used for electrolysis, a relatively mature technology in which experts project no major efficiency improvements.

- Chemical producers use two **electrolytic processes**, the chlor-alkali and sodium chlorate processes, to produce chemicals for wood digesting and pulp bleaching in pulp and paper mills. Electrolytic technology, which accounts for 84% of the electricity used in the chemicals sector, is relatively mature, and experts predict few gains in its efficiency.
- **Motor-driven processes**, such as pumps, compressors and chillers, account for a relatively small percentage of electricity demand, approximately 12%, and improvements in their efficiency would have only a minor impact overall.

The main factor affecting electricity demand in the chemicals industry is product demand by pulp and paper producers. Since the pulp industry is moving to bleaching processes that do not involve chlorine bleaching, the production of chlorine and sodium hydroxide, co-produced along with chlorine, will decline. Production of sodium chlorate, part of the alternative chlorine dioxide bleaching process, will increase, as will other alternatives such as hydrogen peroxide, oxygen and ozone. Although sodium chlorate uses an electrolytic process, none of the other processes do, so their electricity demand will be significantly less than the processes they displace.

By shifting all its equipment to the most efficient equipment that is market-ready by the year 2010, the chemicals industry could reduce its electricity consumption by 23% from what it would be if efficiency were "frozen" at 1988 levels. This would amount to a year 2010 consumption of 1536 GWh if growth is low, and 1773 GWh if growth is high. The chemicals industry already maintains a high operating standard and uses relatively efficient technology. Most of the efficiency gains result from improved compression and pumping systems. More efficient operating practices would increase savings only marginally.

Some new technologies offer small efficiency improvements for electrolytic processes. However, industry analysts expect them to have little impact due to the shift away from chlorine-based processes in B.C.

Assumptions and cautions. Demand for electrolytically produced chlorine compounds is assumed to decline, but it remains substantial. In part, this results from the fact that caustic, produced as a by-product of chlorine, remains in demand.

Demand from pulp and paper producers drives the chemical industry. As the pulp industry moves away from chlorine-based processes, the chemical industry will shift from electrolytic processes to non-electrolytic ones, reducing its electricity use.

OTHER MANUFACTURING

Other manufacturing includes the industrial activities that do not fall into the industrial sectors previously covered, such as agriculture, fishing, construction, petroleum refining and general manufacturing. These activities are extremely diverse, and account for less than 12% of B.C. Hydro's electricity demand.

Lighting, heating, ventilation and air conditioning account for about 10% of this demand, while motors and auxiliary systems account for the remaining 90%. In **agriculture** and **petroleum refining**, 90% of motor systems are used for pumping. Agriculture uses most of the remaining 10% for conveyors. In the **other industry category**, however, pumping accounts for about 37% of motor demand, conveyors for about 43%, and compressors, fans and other motors account for about 20% in total.

Analysts expect this manufacturing segment of B.C.'s industrial sector to grow by 17% overall in a low forecast to 2473 GWh, or 45% in a high forecast to 3067 GWh. These rates of growth would be approximately 10% higher except for the fact that the petroleum refining industry is expected to decline in size.

If these industrial electricity users were to change their equipment for the most efficient technology available by the year 2010, they would use 41% less electricity than they would if their energy efficiency were "frozen" at 1988 levels. If they also used the best operating practices, they would save another 5% of the electricity. Most of this electricity saving could come from using more efficient pumps and conveyors. Also, since these customers primarily use small horsepower motors, they can achieve greater improvements in efficiency than can users of large, more efficient motors.

Assumptions and limitations. For the analysis of this sector, the ISTUM-I model uses overall growth rates and average machine efficiencies instead of specific detailed analysis.

If equipment used for "other" industrial purposes were to change to the most efficient technology market-ready by the year 2010, 38% less electricity may be used than if energy efficiency were "frozen" at 1988 levels.

ECONOMIC POTENTIAL PROJECTIONS

If energy efficiency were to remain unchanged from the average level of 1988, overall electricity consumption by industry would increase between 10% and 46% by the year 2010, depending on the rate of economic growth.

- When the study considered "natural" change, including both decreases from more efficient electricity use and increases from new electrical uses, but not including changes resulting from utility-sponsored conservation programs, the demand for electricity falls approximately 8% from the level it would be with no improvements in electrical efficiency.
- The potential for savings would be higher — 36% to 39% — if all industrial equipment were replaced by the year 2010 with the most efficient market-ready technology.
- The conservation potential would be almost the same — 34% to 37% — if industry replaced its equipment only with technologies that will be cost effective by the year 2010, compared to the cost of generating new electricity. In other words, most efficient new technologies are also "economic", compared to the cost of new electricity supplies. As a result, calculating the impact of environmental credits made no sigificant difference to the "economic" potential.
- The greatest savings would result from replacing equipment with the most efficient market-ready technology and, in addition, changing from standard operating practices to the most energy-efficient operating practices. Changing operating and maintenance practices could increase the savings by an additional 3%.

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