THE ENDLESS ENERGY PROJECT

A BLUEPRINT FOR COMPLETE ENERGY SELF-SUFFICIENCY IN BRITISH COLUMBIA

GLOBE Foundation

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In partnership with BC Hydro, Day 4 Energy, the Power Technology Alliance, National Research Council of Canada and Western Economic Diversification

FOREWORD

The GLOBE Foundation is proud to lead the Endless Energy Project. With our partners – BC Hydro, Day 4 Energy, National Research Council, Power Technology Alliance and Western Economic Diversification – the Endless Energy Project has provided a practical guide to energy self sufficiency by the year 2025 - primarily from renewable energy resources such as biomass, hydro, solar, wind and waste to energy systems.

Energy prices, security of energy supply and global warming are driving the development of new energy sources and the adoption of measures to cut energy consumption in all segments of the economy. Few would argue that these driving forces are likely to abate. What the Endless Energy Model does is to clarify the uncertainties about the future of our energy economy and sets out a practical guide to achieving energy self sufficiency without any loss to our quality of life.

Indeed, British Columbia is one of the few areas of the world where energy self sufficiency without dependency upon fossil-based fuels is possible. The implications for our economy are significant to say the least, as are the contributions such a shift in our energy use will have in terms of reducing greenhouse gas emissions.

The report that follows details the assumptions and data that have gone into creating the Endless Energy Model. What is singular about this model is that it can be replicated in any other province, state or region to produce an equivalent roadmap to energy self-sufficiency.

The GLOBE Foundation will make this report available to many others far and wide who are in need of a guide to a sustainable future. By sharing what we have in British Columbia with the rest of the world, we can help to create a better future for our children and our children's children.

John D. Wiebe

President & CEO

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Measuring Energy
Units Used in this Report

In keeping with international practice, the Petajoule (PJ) is used in this report to allow direct comparisons among various types of energy supplied (electricity, fuel and heat for example) and energy uses. For comparative purposes, one PJ is sufficient energy to supply the gas and electricity needs of 9,000 B.C. households for one year or gasoline to drive 7,000 automobiles on B.C. roads for a year. In 2000 B.C. used 1,142 PJ.

TJ - Terajoule (1/1000th part of a PJ)
GJ - Gigajoule (1/1000th part of a TJ)
MJ - Megajoule (1/1000th part of a GJ)

Kilowatts and Megawatts
Megajoules and Gigajoules

Kilowatts and Megawatts measure the capacity to produce electrical energy which in turn is measured in Kilowatt hours, Megawatt hours or Gigawatt hours. For example, an ideal one Kilowatt generator operating for ten hours can produce 10 kWhrs of electricity.

1 kWhr = 3.6 MJ
1 MWhr = 3.6 GJ
1 GWhr = 3.6 TJ

Capacity Factors

All machines are less than 100% efficient. Some can operate less than 24 hours / day (for example, solar or wind generators). To take account of these real world facts, a capacity factor is used. Multiplying the capacity of a device to generate electricity (kW's, MW's ....) by its capacity factor and time in operation provides a good estimate of the energy it is likely to produce (kWhrs, MWhrs...).

ENDLESS ENERGY PROJECT

The Endless Energy project is an exploration of the implications of energy self-sufficiency for British Columbia by 2025, based on indigenous renewable and clean energy sources and conservation measures. It is a project of the GLOBE Foundation in partnership with BC Hydro, Day 4 Energy, the Power Technology Alliance, the National Research Council of Canada, and Western Economic Diversification.

For individuals, governments and companies faced with increasing energy prices and economic uncertainties associated with security of supply and climate change, longer term energy self-sufficiency is a reasonable strategic posture. The purpose of the Endless Energy Project is to provide a better understanding of the implications of such a strategy for B.C. from a practical engineering and economic viewpoint.

Assumptions

- Geophysical realities determine the upside potential of energy supply from natural resources, annual renewable supplies and non-renewable reserves.
- The competitiveness and reliability of technologies that convert natural resources into electricity, fuels or heat determines both the potential scale of energy supplies from various natural resources and the future mix of energy supplied to each consuming sector.
- Energy supply and conservation technologies may be grouped as; major capital infrastructure projects for utilities, industries and the built environment, or local or distributed energy systems, or products and approaches to reduce consumption and pollution.
- Market forces and economic facts and trends determine the practical potential for energy self sufficiency and the future portfolio of energy supply and conservation technologies by consuming sector.
- Industrial and financial capacity and innovation and entrepreneurship determine the degree to which local firms could develop, supply, install and operate the technologies, systems and components required for energy supply and conservation applications in the various energy consuming markets.

In combination, these factors determine the potential for British Columbia to capitalize on its natural resources and build a world scale energy technology industry.

ECO-AUDIT

Printed in Canada using recycled paper made from 100% post-consumer waste and bleached without the use of chlorine compounds. By doing so we achieved the following savings:

4	Trees
81	Pounds of solid waste
765	Gallons of water
157	Pounds of greenhouse gases
1,036	BTUs of energy

The Eco-Audit is an estimate based on research done by the Environmental Defense Fund.

EXECUTIVE SUMMARY

The Endless Energy project is a facts-based examination of British Columbia's potential to be energy self-sufficient from renewable sources by 2025. The report covers energy use in all sectors of the economy, and energy supply from all sources indigenous to the province. The main conclusion is that British Columbia could reasonably look forward to energy self-sufficiency in 2025 based on a combination of renewable energy supply, cleaner burning fuels, such as hydrogen and ethanol, and energy use reduction in homes, businesses, and public sector operations.

In nearly all sectors of the economy, major investments are being made to cut energy costs and to gain better control over future energy expenditures. Nowhere is this trend more evident than in B.C.'s forest industries (the province's largest energy consuming sector). In 2000, forest biomass waste supplied two-thirds of the industry's total energy demand. By 2025, if present trends continue, forest industries would derive 84% of their energy needs from biomass waste. Similar large-scale trends are occurring in building construction, where renewable sources like geo-exchange space heating and solar hot water heaters are replacing gas and electric heaters; and in the vehicle fleet, where hybrid technologies have the potential to cut gasoline consumption by up to 40%.

The Endless Energy project has quantified these and many other trends and combined them to show that moving from 40% renewable supply in year 2000 to 100% renewable supply in 2025 is not only possible, but also a reasonable strategy in light of increasing concerns about energy prices, security of supply and climate change.

Importantly, the scenario described implies little disruption in the way people live and how businesses operate. However, it does imply a major expansion in economic growth as a result of: increased energy and technology exports; major investments in energy use reduction and renewable energy supply in all sectors of the economy; and replacement of petroleum imports with indigenous biofuels and electricity.

The report concludes that achieving energy self-sufficiency from renewable energy sources (or renewables in combination with clean fossil fuel technologies), is both feasible and practical for British Columbia. Since 80% of greenhouse emissions result from fossil fuel consumption, the effect on greenhouse gas emissions would be dramatic. An Endless Energy economy in action in British Columbia would garner the world's attention.

The GLOBE Foundation recognizes the magnitude of the challenge such a course presents; but through dialogue and practical application of the capabilities of all Canadians, Endless Energy can become a reality in British Columbia.

INTRODUCTION

There is widespread concern about our global energy future. Rising energy prices, uncertainty about the security of energy supplies – particularly from politically unstable parts of the world – and the environmental impacts of continued dependency of fossil fuels are at the root of calls for energy self sufficiency.

Many see energy conservation as the key to self sufficiency; others look to technology and the switch to renewable energy sources as the answer. However, energy self sufficiency presents a far more complex set of challenges that must be dealt with - challenges that have enormous economic, social and environmental consequences.

What is needed is a tool that cuts through the many complex issues at stake to provide a rational basis for policy and program planning. This is precisely what the Endless Energy model does.

Three perspectives on the world's energy future are at the root of the Endless Energy model: a sustainable fossil fuels future; a renewable energy future; and a future that is predicated on the continuation of current trends. While these alternate futures scenarios have many overlapping features, there are distinct differences in emphasis.

The renewable energy future assumes widespread, low-cost energy conversion technologies will be in place and renewables will form the basis of our energy economy. The sustainable fossil fuel future proposes that 'clean' fossil fuels will dominate our energy future in combination with renewables. The current trends future assumes that fossil fuels will continue to supply two thirds of our energy needs, together with significant expansions of renewable energy sources and nuclear energy generation.

The Endless Energy model views all three of these 'futures scenarios' as plausible options that could come to pass in different regions. The model starts from the simple premise that climate change, coupled with energy price and supply, will force individual economies to make the best use of their indigenous energy resources, while striving to reduce their consumption of expensive fossil fuels. Inevitably this would result in a global patchwork of regional energy supply portfolios.

For example, oil rich states may well continue to do "business as usual" and power their entire economies from indigenous oil and gas supplies well into the foreseeable future. Jurisdictions like Alberta, with large-scale coal and non-conventional fossil fuel reserves, may well become "clean fossil fuel" economies based on new technologies for highly efficient combustion of non-conventional fossil fuels and carbon sequestration.

A region less well endowed with conventional fossil fuel reserves will be more inclined to exploit alternate or renewable energy sources.

To recap, the Endless Energy model presumes that local indigenous energy sources, whether renewable or not, will become increasingly attractive as the basis for the energy futures of most local economies, driven by price (in comparison with oil and gas) and increasing concerns about energy security and climate change. Consequently, the more supply options available to a region, the more robust its future energy economy is likely to be.

British Columbia has an almost unrivalled portfolio of energy supply options. It has world scale coal reserves, a huge standing timber base, an extensive network of hydroelectric facilities, untapped reserves of natural gas, coal bed methane and off-shore methane hydrates, and large-scale potential for geothermal, solar, wind, biomass and ocean wave and tidal developments.

As well, British Columbia's hydro-electric dam system is capable of providing a significant degree of energy storage capacity for large-scale intermittent renewable electrical generation. Also there is considerable potential in BC for 'run-of-river' and other small scale hydro projects.

BC also enjoys widespread public engagement in sustainability issues and a broad base of highly innovative, competitive technology firms, scientists and engineers focused on the development and implementation of energy and environmental technologies.

Consideration of these factors has led the Endless Energy model to conclude that an energy self-sufficient future based on indigenous renewables makes good long term economic sense for British Columbia.

However the Endless Energy model is not tied solely to the British Columbia energy economy. The model, and the analytical methodology it employs, can be applied in other regions and jurisdictions to generate energy futures scenarios that are more appropriate to the indigenous resources and economic priorities of the region in question.

The report that follows provides a brief but comprehensive overview of how the Endless Energy model deals with the complex and often confusing array of issues pertaining to clean technology development, regional economic growth patterns, changing energy prices and demand patterns, climate change issues, and consumer behavior in so far as they help shape energy futures options.

This report then applies that model to examine the potential for a renewable energy future in British Columbia and how that future could come about. As noted, the model confirms that based on current technology development trends, anticipated economic and social demand factors, and the availability of indigenous resources, the province could be energy self sufficient by 2025 based solely on renewables and energy conservation measures. Not all jurisdictions are so fortunate.

The Endless Energy model provides a clear, facts-based assessment tool that can be applied to any region or economy to assess the technological, economic and energy supply options available to that region or economy. This powerful and informative tool takes into account trends related to technology development and deployment, changing energy supply patterns, anticipated shifts in energy demand arising from changing consumer preferences, and broader economic and security parameters.

As such, the Endless Energy model provides a powerful tool that can be used to guide policy and program decision making today that will lead to a truly sustainable energy future for British Columbia.

GLOBAL DRIVERS AND SCENARIOS

Population growth will expand global energy demand. However, the global aggregate portfolio of technologies to supply that demand is subject to the relative importance attached to technology development, climate change and energy security. The scenarios discussed below explore the world's energy future from each of these perspectives.

Renewable Energy Future

A technology development focused scenario for an energy future based on modern renewables (e.g. solar, wind, geothermal and ocean energy) was published by the German Advisory Council on Global Change. It was predicated on the huge potential of solar energy world wide (c.f. Geophysical Information on B.C.'s renewable resource endowments) and the assumption that widespread, low cost conversion technologies would be in place.

Sustainable Fossil Fuels

This scenario considers that climate change will be addressed on a global basis through a combination of "clean" fossil fuels and renewables. Although conventional fossil fuels may become scarce over the coming decades, there is no shortage of non-conventional resources and there are abundant reserves of coal. Geologic storage of CO_2 and other forms of carbon sequestration would allow either conversion to "clean fuels" (such as hydrogen) or combustion to take place without adding significantly to global CO_2 levels.

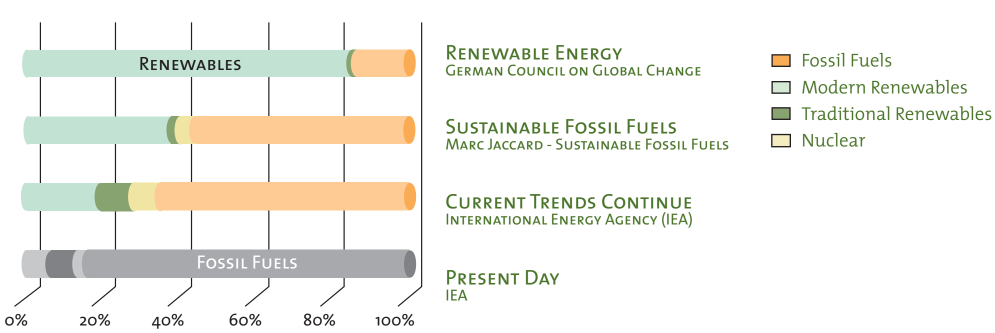
Current Trends Continue

Under these conditions, fossil fuels would supply ~2/3 rds. of global demand in 2100, and modern renewables and nuclear would expand significantly. This scenario implicitly assumes that climate change issues would be addressed on a case-by-case basis and that environmental issues will continue to be outweighed by energy security considerations.

Population Growth Forecasts

Population growth is seen by most forecasters as the primary driver for energy consumption. World population is projected to rise from
~6 billion in 2000 to ~10.5 billion in 2100. Current world energy consumption is ~420 Exajoules (1 EJ = 1,000 PJ). Estimates of consumption in the three scenarios for 2100 range from ~1,200 EJ to 1,600 EJ.

Global Energy Futures Three Scenarios for 2100



BRITISH COLUMBIA'S ENERGY ECONOMY

The B.C. energy economy consists of three main parts: energy supply, energy use and energy exports. It includes all the fuel (oil, natural gas, biomass and coal) and electricity produced and used, imported and exported, and all the ways energy is used in homes, businesses, institutions, industry and transportation.

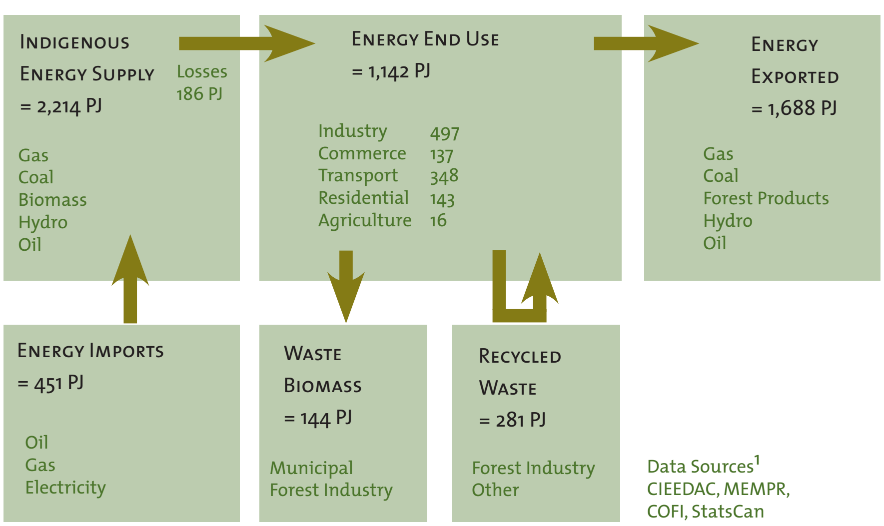
Petajoules

Each year, B.C. produces some 26 million tonnes of coal, 30 billion cubic metres of natural gas and 60,000 Gigawatt hours of electricity. In keeping with international practice, the Petajoule (PJ) is used in this report to allow direct comparisons among the various types of energy supplied and energy uses. For comparative purposes, one PJ is sufficient energy to supply the gas and electricity needs of 9,000 B.C. households for one year or gasoline to drive 7,000 automobiles on B.C. roads for a year. Looking back to the year 2000, B.C. used 1,142 PJ.

Energy Economy - Year 2000

The following chart is an overview of British Columbia's energy economy in 2000.
It shows total energy produced in the province was 2,214 PJ and total energy consumed was 1,142 PJ. Although B.C. produced far more energy than it used, it was a net importer of petroleum products (~340 PJ imported). Additionally, biomass harvested by the forestry and agriculture industries had greater value as wood and food products than as energy sources and therefore did not contribute significantly to energy use directly. However, the forest industries derived ~65% of their energy requirements in 2000 from wood waste and recycling spent pulping liquor. Approximately 40% of B.C.'s entire energy use in 2000 came from renewable energy sources - hydroelectricity and biomass.

British Columbia's Energy Economy in the year 2000



Data Sources[1]
CIEEDAC, MEMPR, COFI, StatsCan

40% of British Columbia's energy needs are supplied from renewable sources; forest biomass and hydroelectricity.

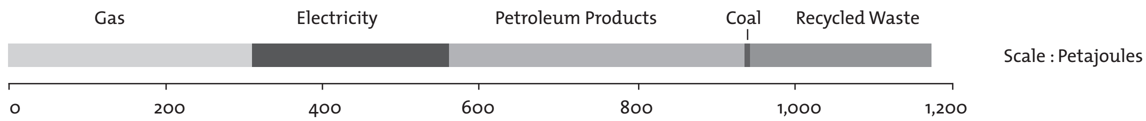
1 - Canadian Industrial Energy End-use Data and Analysis Centre (CIEEDAC). British Columbia Ministry of Energy, Mines and Petroleum Resources (MEMPR). Council of Forest Industries (COFI)

ENERGY USE IN BRITISH COLUMBIA

In 2000, B.C. used some 380 PJ of petroleum products (gasoline ~50%, diesel fuel ~24%, aviation fuels ~20% and heavy oil ~6%), 343 PJ of which were imported. Automobiles and other light vehicles accounted for 45% of all petroleum products used in B.C.

Natural gas supplied 300 PJ of B.C.'s energy needs in 2000, waste biomass supplied 225 PJ, and electricity supplied 220 PJ. Coal and coke was used in some industrial operations such as cement plants. The vast majority of B.C.'s coal production was exported.

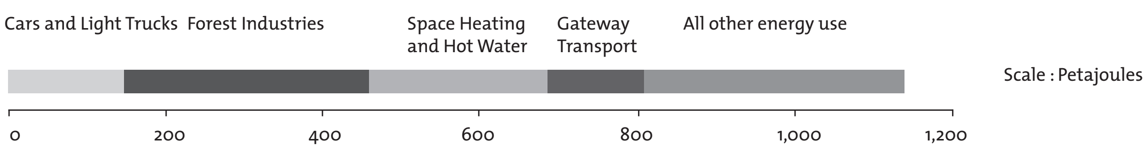
Energy Supply in B.C. - year 2000



87% of natural gas use was for space heating (homes, businesses, industry, institutions) and industrial processes in equal proportions. 50% of B.C.'s electricity use was for industrial plants and 50% for heating, lighting and appliances in homes, businesses and institutions. B.C.'s forest industries accounted for nearly all waste biomass energy used and transportation for 80% of petroleum products used.

Looked at as a whole, private automobiles and light trucks, forest industries, space and water heating in homes and businesses, and international gateway transportation accounted for some two-thirds of B.C.'s total energy requirements in 2000:

Energy Use in B.C. - year 2000



Energy Produced in British Columbia

The following chart summarizes B.C.'s energy production* (PJ) for year 2000 and fossil fuel reserve estimates:

Energy Source	Produced	Losses	Exports	Ultimate Reserves
Gas	994	167[1]	546	97,000
Coal	475[2]		464	31,500,000
Biomass	401		562[3]	
Hydro Electricity	222	18[4]	36	
Oil	123		80	3,600
Coal Bed Methane[5]	0		0	95,000
Methane Hydrates[5]	0		0	370,000
	2,214	**186**	**1,688**	

Scale : Petajoules

* Excluding secondary generation and waste to energy systems

1 - Losses due to gas flaring, use as fuel for pipeline pumping, processing shrinkage and plant waste
2 - Metallurgical coal production ~25 million tonnes; calorific value ~17,500 MJ / tonne
Thermal coal production ~1.4 million tonnes; calorific value ~30,000 MJ / tonne
3 - Calorific value green wood at energy source ~10,900 MJ/tonne. Exported dried lumber ~21,000 MJ/tonne
4 - Transmission losses
5 - Estimates: Coal bed methane - Ministry of Energy, Mines and Petroleum Resources, Methane Hydrates - NRCan

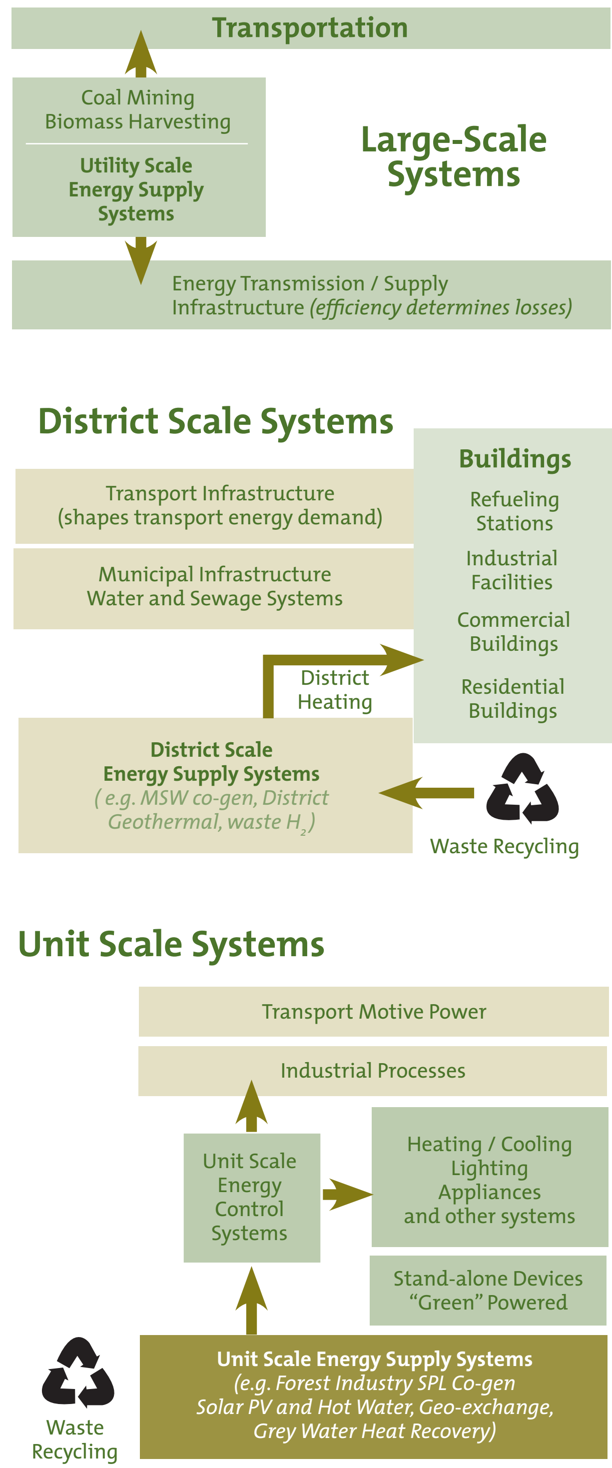
B.C.'S ENERGY SYSTEM

The collection of province-wide (large-scale), municipal or multi-unit (district), and unit scale energy supply and useage systems make up B.C.'s overall energy system.

Large-scale systems, primarily in rural B.C., comprise energy production facilities (dams, oil and gas wells, coal mines, electrical generation) transmission infrastructure (electrical grid, pipelines and transportation infrastructure) and biomass harvesting. Large-scale renewables include; hydro, wind, geothermal and biomass conversion facilities (fuel, electricity and heat).

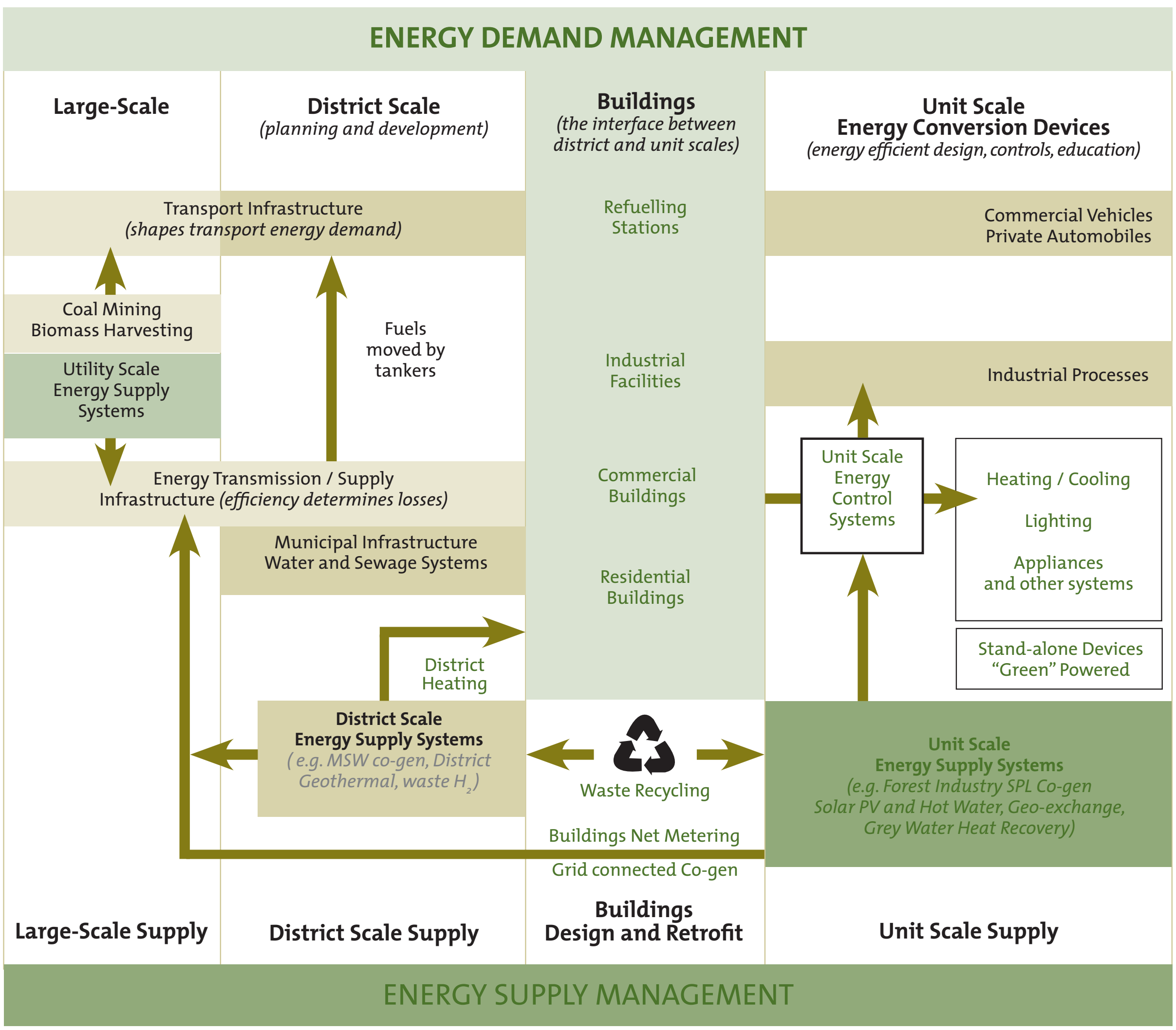
District scale systems are by definition urban systems. They include municipal road, water, and sewage infrastructure and district scale waste recycling. District scale renewables include municipal and industrial waste to energy systems, and district scale geothermal heating. Energy demand reduction at the district scale is accomplished through sustainable community planning and projects together with a range of building codes and standards for energy use.

Unit scale systems include individual vehicles, homes, commercial buildings and industrial facilities and attendant heating, cooling and lighting devices, together with the entire range of appliances and equipment used in residential, commercial and industrial operations. Unit scale renewables include solar and geothermal systems, and waste to energy systems for residential, commercial and industrial facilities (e.g. forest industry waste already supplies a major part of B.C.'s energy requirements). Demand reduction measures include: energy control devices, codes and standards for ICE's and heating devices, energy efficiency retrofits across-the-board to buildings, plants and energy conversion devices, and stand-alone renewable powered devices.



The Role of the Built Environment

B.C.'s energy system as a whole (see chart below) is both a demand management and an energy supply system. The built environment (buildings and municipal infrastructure) is the primary interface between supply and demand, and between large and district scale systems on the one hand and unit scale systems on the other. Key energy demand management roles of the built environment include: planning and design of transportation infrastructure, development planning to shape transport energy demand, building design to reduce space heating requirements, and the development and installation of waste collection systems for potential energy supply. Unit and district scale energy supply in the built environment completes the picture.



The built environment is both a demand regulator (through planning and design) and energy supplier from waste to energy, solar and geothermal energy systems for districts and individual buildings.

ENERGY USE TRENDS IN B.C.

Four main energy consuming sectors are considered in this section: residential, commercial, transportation and industrial. The focus for each section is on the dominant activity or consuming group responsible for the majority of energy use. For example, space heating is the dominant energy using activity in both residential and commercial sectors.

Energy Intensity

Energy intensity is a primary measure used in this report energy to forecast energy consumption. It is the energy used (Gigajoules) per head of population or the energy used to produce one dollar of Gross Domestic Product (GDP). The choice of GJ / capita or GJ / $ GDP is determined by economic considerations. For example, residential energy use is largely determined by population, whereas industrial energy use is largely determined by economic output.

Population Growth

B.C., as a whole population, is projected to increase by ~30% to 2025. The number of persons in private households was ~3.86 million in 2001 (Census). Total population was ~4.1 million. GVRD projects an increase from ~2 million in 2000 to ~2.7 million in 2021. Greater Vancouver would account for ~75% of the province's population growth to 2025 based on linear projections. Consequently, the following assessments of energy trends in B.C. consider Greater Vancouver separately from all other regions.

> Energy use is determined by population and economic output, shifting to a service economy affects the parametres used to measure it.

Gross Domestic Product

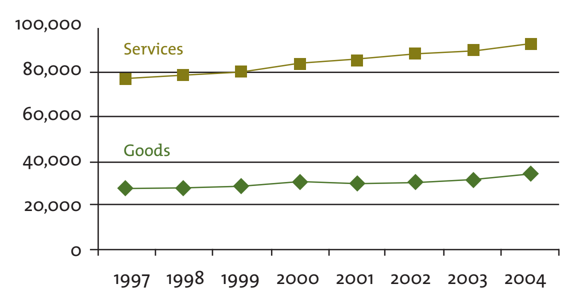
Total market value of the goods and services produced by the British Columbia economy as reported by BC Stats from 1997 to 2004 (millions of Canadian dollars):

1997	1998	1999	2000	2001	2002	2003	2004
104,554	105,827	109,008	113,919	115,139	118,847	121,817	126,857

Should GDP continue to grow at the same rate, the province's GDP would reach ~$190 billion by 2025.

If present trends continue, services GDP would increase by ~$58 billion to 2025 and goods GDP by ~$19 billion, causing a shift in overall energy demand to the service sector.

GDP from Goods and Services - British Columbia (millions $Cdn)



Residential Buildings Energy Use

Energy intensity for residential buildings was essentially unchanged at ~35 GJ per person per year from 1996 to 2002. Energy consumption per household in 2000 is estimated in the diagram below:

Energy Consumption per Household - Year 2000

	GJ/Household	# Households[2]	Energy Consumed (TJ)
Single Detached	120[1]	841,540	100,901
Single Attached and Low-Rise Apartments	72	547,310	39,406
High-Rise Apartments (>5 stories)	35	101,570	3,555
		1,490,420	143,862[3]

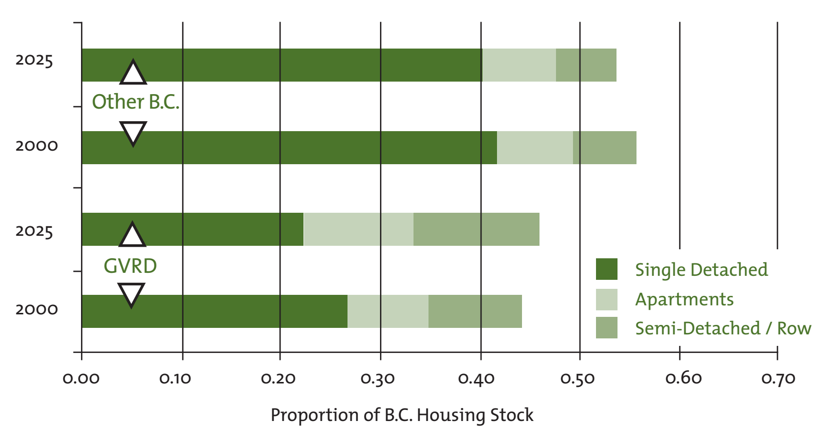
1 - CREEDAC
2 - Canada Census 2001 (3,858,730 people in private dwellings)
3 - CIEEDAC

Projected Demand

The province's residential energy demand is projected to increase by ~27% by 2025 to 180 PJ (180,000 TJ) based on energy intensity and housing trends. Estimates of the province's residential building stock were derived from a detailed analysis of household census data and GVRD Land Use data 2001. Increases in single and multi-family buildings construction required to meet population growth and urban densification targets indicates a significant increase in apartments, semi-detached and row houses in Greater Vancouver. Construction increases in other regions of B.C. were estimated on the basis of numbers of occupants per building type and projected population increase.

Some 185,000 new residential buildings would house a 30% increase in B.C.'s population by 2025. Residential energy consumption would rise by 27% to 180,000 TJ.

Changes in Housing Stock - Years 2000 to 2025



Energy Use by Activity

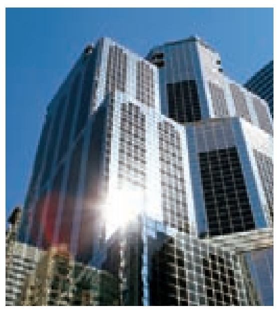
Household energy consumption for three main categories[1] of dwellings is shown below. Space and water heating accounted for ~80% of total residential household energy use (gas and electricity) in 2000. However, building energy efficiency is increasing; space heating (GJ / M^2) declined from 0.45 in 1990 to 0.33 in 2003 (NRCan).

HOUSEHOLD ENERGY CONSUMPTION - YEAR 2000

ENERGY USE / HOUSEHOLD	Space heat	Hot water	Lighting	Appliances
Single Detached	70	26	6	17
Single Attached and Low-Rise	42	16	4	10
High-Rise Apartments	20	8	2	5
EST. **TOTAL B.C.** (TJ)	**83,000**	**32,000**	**7,000**	**20,000**

Scale: Terajoules

Sources: NRCan, Canada Infrastructure Energy Report 2004, BC Hydro, Smart Growth
1 - Household size varies from ~3 persons / detached home to ~1 person / high-rise apartment



Commercial Sector Energy Use

Commercial energy consumption is defined by energy use in commercial, institutional, office and government buildings. It is determined primarily by floor space and service sector employment. Total commercial energy use in 2000 (CIEEDAC) was ~137 PJ (gas ~58 PJ, electricity ~50 PJ, petroleum products ~28 PJ). ~120 PJ of this use can be attributed to commercial buildings (NRCan). Petroleum products used in commercial operations for retail and wholesale deliveries and trades services such as building, office and travelling services have been allocated to local transportation (see next section). Four main commercial energy using groups were identified on the basis of employment and building energy use:

COMMERCIAL BUILDINGS ENERGY USE BASED ON EMPLOYMENT AND BUILDING ENERGY USE - YEAR 2000

	Employment[1] (,000's)	Building[2] Energy Use (TJ)	TJ / 1,000 employees
Wholesale and Retail	304	37,500	123
Office-Based Services	347	36,700	106
Healthcare and Education	338	26,500	78
	1143	**108,700**	

1 - BC Stats 2 - NRCan

These four groups represent ~80% of all service employment in B.C. (excluding transportation) and ~91% of energy use in commercial buildings. The following table and pie chart summarize energy use by activity for year 2000:

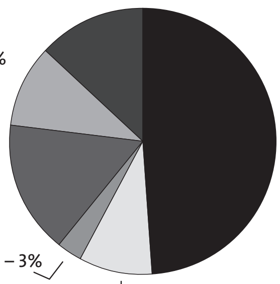
Commercial Buildings Energy Use - Year 2000

Activity	Space Heating	Water Heating	Space Cooling	Lighting[3]	Equipment
Energy (TJ)	58,500	10,500	3,500	19,600	23,800

Scale: Terajoules

3 - Not including ~900TJ used for street lighting

Energy Use per Building



Growth in office and distribution facilities is increasing the sector's energy consumption faster than population growth. A 43% increase in commercial energy use to 2025 is projected if current trends continue.

Projected Demand for Commercial Sector Energy Use

Based on linear projections of data from 1990 to 2003, commercial buildings energy use in 2025 would rise to ~172 PJ, a 43% increase over year 2000. Service sector expansion in the economy as a whole is driving new retail, wholesale and office building construction (e.g. GVRD office space[4] is projected to increase by ~60% from 2000 to 2025, and retail by ~30%). New floor space added in these sectors generally consumes more energy per M^2 than does new institutional floor space for health care and education (see chart):

1999 - 2003	Employment Change	Energy Use Change (TJ)	Floor Area Million Sq. Metres
Wholesale and Retail Distribution	-0.8%	3,700	1.2
Office-Based Services	3.7%	4,300	3.45
Healthcare and Education	12.3%	200	2.27

4 - GVRD Forecast of Industrial and Commercial Development Trends 1991 to 2021 - Published 2003

Commercial energy users are primarily domestic services, with B.C.'s population as their main client base; therefore, energy intensity was assessed on a per capita basis. Average energy intensity from 1999 to 2003 was ~30 GJ / capita and is on an upward trend.

Domestic Transportation Energy Use

Domestic transportation for the movement of goods, services and people within British Columbia comprises; local commercial transportation services, household vehicles and bus, ferry and train services including light rapid transit. In total, domestic transportation used ~217 PJ in year 2000, accounting for 87% of motor gasoline and diesel fuel sales in B.C. household vehicles accounted for the largest share; see table. Energy intensity for transportation as a whole remained steady at ~81.5 GJ / capita from 1993 to 2003.

Licensed Passenger Vehicles

Est. Year 2000[A]	Numbers	Fuel Used[B] Litres 10^6
Cars and SUV's	1,370,000	2,523
Pick-ups, Vans	310,000	1,205
Other Household Vehicles		66
Buses	8,000	50
Transient Vehicles[C]		910

Licensed Commercial Vehicles

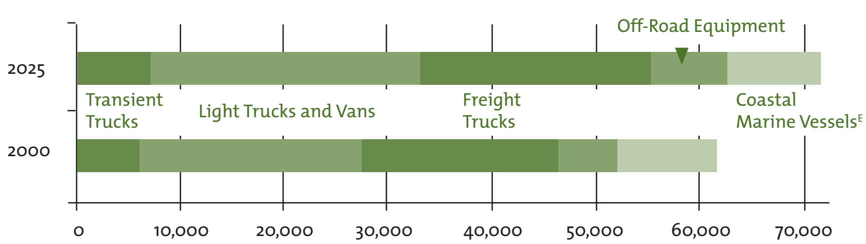
Est. Year 2000[A]	Numbers	Fuel Used[B] Litres 10^6
Light commercial	210,000	571
Medium Heavy Trucks	75,000	227
Heavy Trucks	10,000	258
Ferries and Coastal Vessels	800	387
Light Aircraft		4[D]

A - Numbers of vehicles based on ICBC, Stats Can, NRCan, Transport Canada data
B - Fuel consumption data from NRCan, StatsCan and Transport Canada adjusted to match actual fuel sales
C - Includes interprovincial and BC / Wa. State travel (e.g. 11.5 million vehicles Can / US border crossings in 2000)
D - 5,600 light aircraft: aviation gasoline used ~4 million litres - all jet fuel assigned to Gateway Transport next section.

Projected Demand for Domestic Transportation Energy Use in B.C.

If current trends continue, domestic transportation energy use is projected to reach 257PJ in 2025. This is based on linear projections of data from 1993 to 2005 for numbers of registered B.C. vehicles, and fuel efficiency data from US DoT (25% improvement by 2025 over year 2000). The two charts show projected changes in energy consumption for goods and passenger vehicles year 2000 to 2025. Total goods vehicle energy use is projected to increase from ~61 PJ to ~72 PJ. Most of this increase is due to more light delivery trucks. Total passenger vehicle energy use is projected to increase from ~156 PJ in 2000 to ~186 PJ in 2025. More cars and other light passenger vehicles accounts for ~80% of this increase.

Goods Vehicles - Energy Use (TJ)



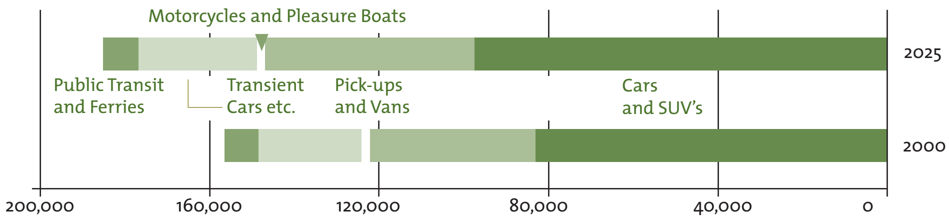
E - Tugs, barges, and larger working boats

Scale: Terajoules

Domestic transportation energy use would increase to ~257 PJ in 2025 if current trends continue (year 2000 ~217PJ). But hybrid, fuel cell and electric vehicles and other factors may actually reduce 2025 use to 30% below year 2000.

However, hybrid vehicles and potential for fuel cell and electric vehicles, could reduce average fuel consumption* for the B.C. light vehicle fleet to between 4 and 7 L /100 Kms; a 30% overall drop in domestic transport energy use over 2000.

Passenger Vehicles - Energy Use (TJ)



Scale: Terajoules

* Estimated av, B.C. light vehicle fuel consumption in 2000: ~11.8 cars and SUV's to 14.9 L /100 Kms light trucks and vans
Efficient infrastructure and judicious urban transport planning improves fuel consumption by reducing vehicle trip times

Gateway Transportation Energy Use

Gateway transportation moves international cargo and passengers. It comprises international airports and seaports and their serving airlines, road carriers, transit, shipping lines, railways, and coastal marine carriers. International transportation includes long haul continental transportation but excludes transportation to and from contiguous US states. In total, gateway transportation used ~102 PJ in year 2000. In general terms, international trade is becoming more energy efficient. Energy intensity per dollar of GDP is declining, from ~3.2 GJ / $GDP in 1997 to ~2.8 GJ / $ in 2003.

Estimated Year 2000	Moves	Fuel[A] Litres 10^6	Volumes Carried
Gateway Truck Movements	600,000	90	420,000 containers - TEU's[B]
Aircraft Takeoffs and Landings	338,000	1,600	16,000,000 passengers
Train Moves[C]	20,000	290	77,800,000 tonnes
Ship Arrivals[D]	3,800	600	80,100,000 tonnes

A - Fuel provided in B.C. For aircraft and ships fuel used in B.C. does not equate to fuel provided
B - Approximately 35% of container movements are bound for local destinations; these are handled by truck
TEU = Twenty Foot Equivalent Unit. Most containers are about two TEU's.
C - Trains typically comprise ~100 rail cars. Tonnage figure includes ~790,000 long haul containers
D - Ship arrivals includes 336 cruise ships carrying ~1.05 million passengers

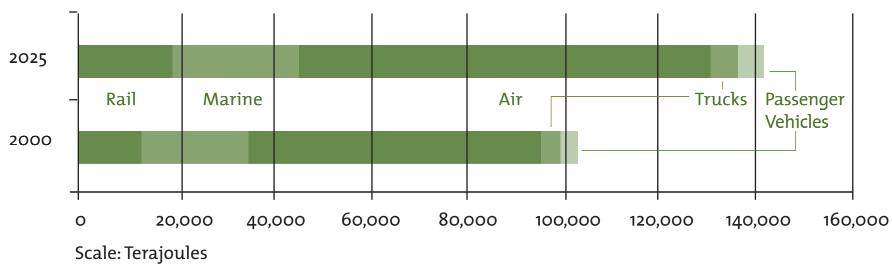
Although gateway transportation demand is projected to increase dramatically by 2025 (air passengers double and cargo volumes up 50%), logistics, infrastructure and technology investments could limit growth in energy use to 18% up ~18 PJ on year 2000 energy use of ~102 PJ.

Projected Demand for Gateway Transportation Energy Use in B.C.

If current trends continue, gateway transportation energy use is projected to reach between 141 and 150 PJ in 2025 (39 - 48% increase over 2000). This is due largely to rapid expansion in Asia Pacific trade and travel, led by container and air passenger volume increases. Air passengers through Vancouver International Airport are forecasted to grow to 33 million in 2027, and container volumes through the Port of Vancouver to 5.5 million in 2020. Bulk commodity volumes are also expected to increase; total international marine cargo through B.C. ports in 2000 was ~80 million tonnes, by 2025 volumes may exceed 120 million tonnes (including containerized cargo). These increases will create demands on rail, truck and domestic transport services (passenger carriers and local commercial goods carriers). Additionally, Greater Vancouver accounts for >90% of B.C.'s gateway transportation, consequently urban transportation infrastructure efficiency has a significant impact on energy use.

The chart below shows projected increase in energy demand assuming that a majority of container expansion to 2025 is handled by rail. It includes energy use for moving cargo and passengers directly to and from ports and airports and cruiseship terminals. Improvements in rail and air motive power efficiency, increased use of water borne transport in the gateway logistics chain and improvements on key urban thoroughfares could limit increases in energy use to ~120 PJ in 2025 (18% increase over 2000).

Gateway Transportation Energy Use by Mode



> Industry energy use in 2000 accounted for ~557 PJ (49% of total B.C. use). However, energy intensity is declining and by 2025 industry energy use would be ~620 PJ if present trends continue.

Industry Energy Use

The term "industry" in the Endless Energy model includes: all primary, secondary and tertiary manufacturing, agriculture, utilities and pipelines, and construction. Industry energy use in B.C. in 2000 was ~557 PJ[1] from: gas ~170 PJ, electricity ~109 PJ, petroleum ~40 PJ and waste to energy ~226 PJ. Energy intensity from 1997 to 2003 was on a downward trend (~13.1 to 12.6 GJ/$ GDP goods produced). If current trends continue industry would use ~620 PJ in 2025.

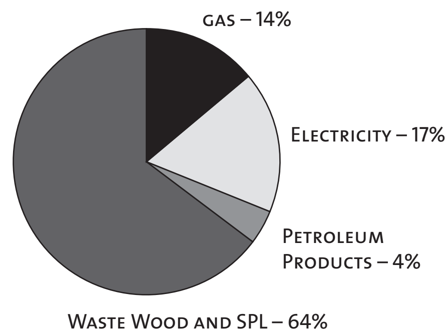
Industry Energy use in B.C. (TJ)

1 - Space heating included - estimated at ~12 PJ on the basis of 28.8 GJ / employee

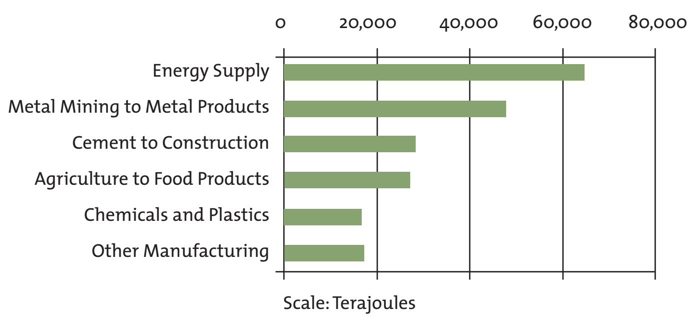
Forest Industries

Forest industries (pulp and paper, forestry and wood products manufacturing) used ~351 PJ, ~64% of which (225 PJ) came from wood waste and spent pulping liquor (SPL). Co-generation accounted for ~86% of this waste energy supply. Co-gen electrical capacity using woodwaste was ~648 MW in 2000, SPL capacity was ~490 MW and thermal capacity of wood waste co-generation was ~3,100 MW. In the pulp and paper sector, waste to energy supplied 61% of total use in 1990 rising to 70% in 2002. Should current trends continue, B.C.'s forest industries would derive ~84% of total energy use from waste in 2025.

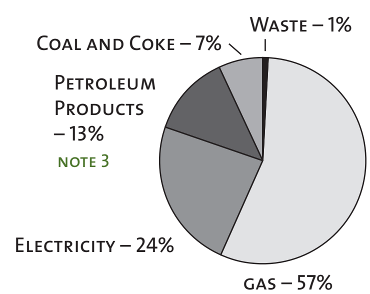
B.C Forest Industry Energy Supply - Year 2000



Other B.C. Industries Energy Use by commodity value chain (TJ)



Other B.C. Industries Energy Supply - Year 2000



Other Industries Energy Use

Other industries were analysed on the basis of commodity value chains, including primary[2], secondary[3] and tertiary[3] industries (see chart).

- Energy supply industries (oil and gas, coal mining, and gas and electrical utilities) ~65 PJ
- Metal mining to metal products (ore mining, smelting refining, metal fabrication, machinery and transport equipment manufacture) ~48 PJ
- Cement manufacture and construction industries ~28 PJ. Cement manufacture accounted for nearly all coal and coke use by industry.
- Agriculture and food and beverage products ~27 PJ
- Chemical and plastics (materials and products manufacturing) ~16 PJ.
- Other manufacturing includes textiles, furniture, electronics ~16 PJ.

1 - Primary industries energy use data from CIEEDAC
2 - Industries identified as other manufacturing in CIEEDAC reports were disaggregated on the basis of GDP
3 - Off-road vehicles (forestry, construction, mining etc.) energy use also included in domestic transportation

B.C. IN 2005 – CURRENT TRENDS CONTINUE

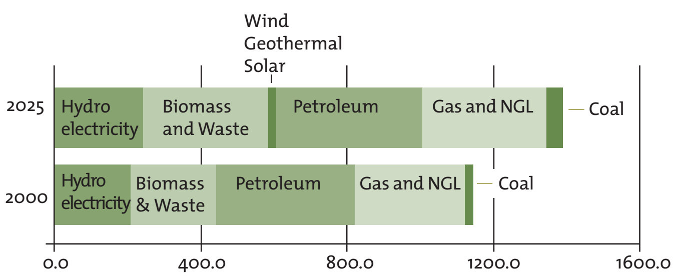
Energy Supply

Four major developments are shaping B.C.'s energy economy: recent moves by BC Hydro to expand electricity supply from renewables and clean coal, a trend to energy self sufficiency in the forest industries, more efficient vehicles, and a growing volume of beetle killed timber (>500 million m^3 or ~2,500 PJ). The chart summarizes the implications of these developments. Key points include increasing reliance on biomass, hydro and other renewables (43% in 2025 up from 39% in 2000), slow growth in petroleum use, and greater use of domestic coal production.

Energy End Use

Total energy end use is projected to increase by 21% to 2025 over year 2000 (based on data and analyses presented on previous pages). Among sectors whose energy use is driven primarily by population, only commercial buildings are projected to exceed population growth. More capital intensive sectors, whose energy use is driven primarily by output, are projected to increase use at well below projected GDP increase (see chart).

CHANGES IN B.C. ENERGY SUPPLY - YEARS 2000 TO 2025



Scale: Petajoules

Biomass and coal supply in 2025 exceed end use due to conversion factors for new capacity

Increased use of waste, biomass and renewables coupled with increasingly efficient end use in nearly all sectors of the economy, add up to a greener, more self sufficient future for B.C. However, imported petroleum would still account for 30% of energy use in 2025.

Changes in Types of Energy Used

Increasing energy self-sufficiency in the forest industries and the introduction of ethanol blended gasoline are projected to expand the use of biomass as an energy source by 46% to 2025 over year 2000. Forest industry energy use from biomass would increase from 225 PJ in 2000 to ~300 PJ in 2025. Moves to ethanol blended fuels by domestic transport would translate into ~22 PJ from ethanol, assuming a 10% blend by 2025. Coupled with projected improvements in vehicle efficiency of ~25% by 2025 total petroleum products demand would increase by ~7%. Natural gas and gas liquids (NGL) and electricity use are projected to increase by ~40% in total.

	2000	2025	Increase	
Residential Buildings	144	183	27%	
Commercial Buildings	120	172	43%	Population increase ~30%
Domestic Transport	217	257	18%	
Gateway Transport	102	141	39%	
Forest Industries	347	358	3%	GDP increase ~67%
Other Industries	210	262	25%	
Totals (PJ's)	**1,140**	**1,374**	**21%**	

B.C. IN 2025 – ENDLESS ENERGY SCENARIO

Based on current trends and indigenous renewable energy resource potential (see page 35), it is proposed that a self-sufficient and sustainable British Columbia energy economy would be powered primarily by electricity and biomass: a bio-electric economy. How this could come about and what that would entail from a practical engineering and economic viewpoint is the subject of the remainder of this report.

Approach - Net Aggregate Demand

Total energy used in B.C. ($\mathbf{E_T}$) equals the total demand from all unit and district scale energy consuming systems and devices like buildings, industrial processes, cars and appliances. A certain amount of energy is produced from unit scale supply systems ($\mathbf{E_{US}}$):

e.g. residential solar hot water heating, and from district scale supply systems ($\mathbf{E_{DS}}$)

e.g. district heating and municipal waste to energy systems

The aggregate energy demand net of all unit and district scale systems $\mathbf{E_{Net}} = \mathbf{E_T} - \mathbf{E_{US}} - \mathbf{E_{DS}}$ must be supplied by large-scale systems. The approach used to develop an Endless Energy scenario is therefore to assess potential for demand reduction to reduce $\mathbf{E_T}$ and for expanding $\mathbf{E_{US}}$ and $\mathbf{E_{DS}}$ and hence determine $\mathbf{E_{Net}}$. Then to examine the potential of large-scale renewable and clean energy sources and technologies to meet net aggregate demand. Key to these considerations are projected cost competitiveness of supply and conservation technologies (e.g. cost per kilowatt of installed capacity and return on investment), the difficulties posed for the adoption of new technologies by installed infrastructure and systems (e.g. hydrogen fuelled vehicles), energy security (e.g. price volatility and supply disruption impacts) and extreme event risks (e.g. tsunamis and ocean energy systems).

Cars, Demographics and Fuel Supply

B.C.'s potential for a self-sufficient energy future is influenced by two overarching factors: consumption of petroleum products and demographics. Cars and light vehicles are the main consumers of imported petroleum products, and population growth (and hence expansion in B.C.'s vehicle fleet) is increasingly concentrated in the densely populated South West. Yet the vast majority of the province's biomass (from which renewable fuels could be produced) is in rural B.C. and increasingly energy self-sufficient forest industries are likely to account for bulk of available waste forest biomass (see chart below). Vehicle fuels from indigenous sources required by the Endless Energy scenario must therefore come from sources other than forest industry production waste[1].

	PJ / Year
Available waste forest biomass (Year 2000)	**95**
Forest industries use of waste forest biomass (Year 2000)	226
Projected use 2025 (current trends continue)	301
Increase in forest industries biomass use - Years 2000 to 2025	**75**

1 - However, beetle killed timber and harvesting residues could change this situation in the medium term.

A self-sufficient bio-electric energy economy for B.C. in 2025 is the basis of the Endless Energy scenario. However, energy for transportation must come from indigenous sources other than forest industry waste.

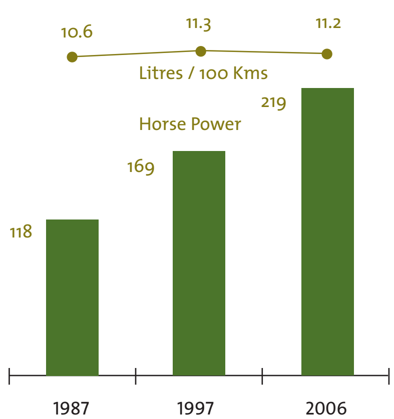
TRANSPORTATION ENERGY OUTLOOK

Automakers have made major gains in engine performance. Internal combustion engines (ICE's) in new model cars introduced into the US market (see chart) develop almost twice the horsepower per volume of fuel in 2006 than in 1987. However, as the chart indicates, new models have also increased in power output by 85%. A review of the response by the automobile industry to the oil price shocks of the 1970s and 1980s is instructive; improved fuel economy was achieved largely through smaller engines.

US Automobile Trends (EPA)

	1975	1980
Adjusted Fuel Economy (Litres/100 Kms)	18.0	10.6
Horsepower	137	118

Performance by Automobile Model Year (US)

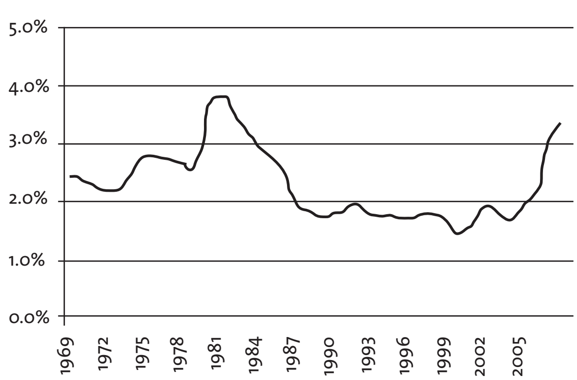


EPA - Light Duty Automotive Technology and Fuel Economy Trends 1975 - 2006

Interestingly, the response of the US automobile market to improved fuel consumption was to commence purchasing larger vehicles as gasoline prices declined. Truck sales increased from 19 to 28% of auto vehicles sold in the US from 1975 to 1987. This trend has persisted, most probably because the price of gasoline compared to household income dropped until 2002.

Comparison of fuel costs to income and changes in new model fuel consumption indicates that when the price of 1000 gallons of gasoline remained above ~2.5% of household income for a sustained period that new model fuel consumption declined significantly. Gasoline prices have only recently (2005) reached this point; nevertheless, new hybrid vehicles are now entering the market in increasing numbers with gasoline consumption of 40-45% lower than existing models.

Percentage of Average Household Income[1] required to purchase 1000 US gallons of gasoline in the US dropped continually until 2002



The real price of motor gasoline has risen to levels not seen since the early 1980's. This may push consumers to hybrids in larger numbers.

1 - Median household income estimates. Montgomery, Maryland US

However, even before the introduction of the hybrid, actual fuel use per automobile in the US fleet was declining:

US automobile use (US DoT)	1980	1990	2000
Fuel Use / Vehicle: Litres / 100 Kms	14.8	11.6	10.7

Steadily declining motor gasoline sales per capita in B.C. mirror this trend:

BC Motor Gasoline Sales (BC Stats)	2000	2001	2002	2003	2004	2005
Litres / Capita	1,306	1,322	1,307	1,265	1,236	1,193

Hybrids and Electric Vehicles

Hybrid vehicles use a combination of electric motor and internal combustion engine (ICE) to provide higher torque and better acceleration than is available in comparable conventional vehicles of equal horsepower, even though the hybrids usually weigh more and have smaller gasoline engines. Improved fuel consumption is achieved by running a smaller ICE closer to its full power which is more efficient for a given load than larger, heavier ICE's operating at a lower percentage of maximum power. Additionally, regenerative braking is used to capture energy that would be lost to heat through braking and employ it to recharge the battery component. As well, ICE's are shut down when the vehicle comes to a full stop to save fuel loss to idling in traffic. This combination of technologies allows leading hybrid designs to achieve a 45% and higher reduction in fuel consumption over traditional ICE powered vehicles. Current design trends are towards larger batteries and smaller ICE's, leading to the so-called "plug-in" concept which would use battery power for the majority of operation and require recharging from buildings' electrical supplies after each day's use. The plug-in hybrid is practically an electric vehicle (EV).

Hybrids: Scenario 2025

2005 US studies[I] of hybrid plug-in technology fuel savings to the US economy and average actual full hybrid fuel use efficiency improvements for 45% were used in the following estimates. Should plug-in hybrids achieve 10% market share of all B.C. light vehicles and the balance of the B.C. fleet achieved a 45% improvement in gasoline consumption over the average B.C. light vehicles in 2000, fuel use would drop by ~89PJ and electricity use would increase by ~6.7 PJ, primarily in residential buildings.

Number light vehicles 2025 (current trends continue)	**2.8 million**
Projected fuel use (PJ) (current trends continue)	**172**
Fuel use reduction (PJ):	
Plug-in hybrids comprise 10% of fleet	20
Balance of fleet 45% efficiency improvement	69
Scenario 2025 (PJ):	
Fuel use	84
Electricity use	7

Hybrid technology is shifting to larger batteries and smaller gasoline engines, leading eventually to the plug-in hybrid. Widespread adoption of plug-in hybrids would cut gasoline use but put new demand onto the electricity grid.

Technological Challenges: Plug-in Hybrids and EV's

It is generally considered that the following challenges will be overcome as battery and electric motor technologies advance. Technology developments are focused on:

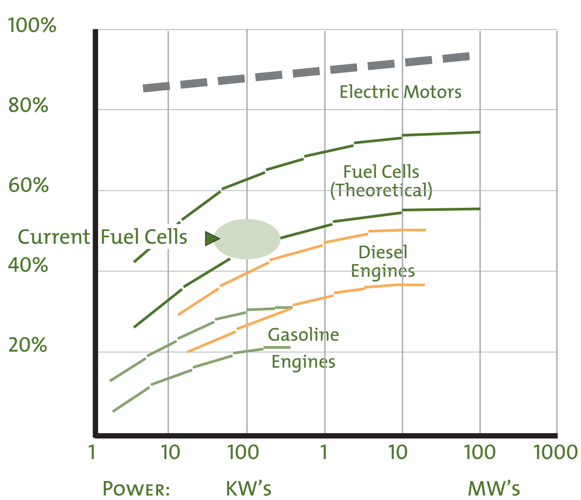
- Increased battery power and life improvements in battery technology
- Approaches to cost and weight reductions for hybrid vehicles
- Deeper discharge capability necessary for longer (battery only) trips

1 - Uhrich "Using Hybrid Vehicles" 2005 article in U. of Iowa Tau Beta Pi publication

Fuel Cell Light Vehicles

A fuel cell operates much like a battery but does not require electrical recharging. It can generate power almost indefinitely, as long as fuel is supplied. It has two main advantages over ICE's; considerably higher efficiency and very low or zero emissions. There are several types of fuel cell (FC), however the **Proton Exchange Membrane FC** (PEMFC) is the leading candidate for FC light vehicles. PEMFC's work by establishing a continuous electro-chemical reaction at about 80°C using very pure hydrogen and oxygen to produce electricity and steam. Canada, Japan, the US and Europe have invested heavily in PEMFC technology for light vehicles. DOE targets for FC's in light vehicle applications are $30 / kW by 2015 and 5,000 hrs. by 2010 respectively. Current PEMFC costs estimated at ~$110 / kW; durability ~2,000 hours.

Relative Efficiency Power Plant Only



Hybrids a New Pathway for Fuel Cells

Replacing smaller ICE's in hybrids is conceptually easier than developing FCV's. As the chart below indicates, to achieve an overall efficiency of 80% in an ICE hybrid requires the electric motor to run 81% of the time. In a FC hybrid, 80% overall efficiency can be obtained by running the electric motor only 50% of the time. Both battery and FC developers benefit from reduced performance demands. And hybrids, unlike FC vehicles, are compatible with installed gasoline distribution infrastructure and existing ICE maintenance facilities. As hybrids gain ground in the market, they can be expected to cause evolutionary changes in energy supply systems and vehicle maintenance capabilities which, over time, would facilitate the transition to FC / battery hybrids. However, hydrogen supply issues remain for PEMFC's. The use of hydrogen rich distillates (e.g. methanol or even gasoline) using existing distribution systems coupled with reforming technologies to convert distillates to hydrogen and carbon dioxide at refueling stations offers a likely pathway to overcome difficulties associated with transportation of hydrogen. Other, less developed FC types such as Solid Oxide and Direct Methanol PEM FC's able to operate directly from a range of hydro-carbon fuels could obviate the need for hydrogen storage and distribution.

Hybrid Power Plant Efficiency and Electric Motor useage for ICE and FC Hybrids

	ICE	Fuel Cell
Overall Hybrid Efficiency	**80%**	**80%**
Electricity motor run time (% duty cycle)	**81%**	**50%**
Efficiency gain over current ICE cars	128%	128%

A fuel cell vehicle fleet running on hydrogen would require a revolutionary change in fuel supply infrastructure and vehicle maintenance facilities. Hybrid fuel cell vehicles and liquid hydrogen rich fuels may offer an evolutionary pathway to market success.

Fuel Cell Light Vehicles: Scenario 2025

For scenario purposes, it is proposed that FC hybrids will enter service in competition with plug-in battery / ICE units and by 2025 would power 10% of the B.C. light vehicle fleet. FC / Battery hybrids may use 75% less fuel than conventional ICE's, leading to a further 13 PJ drop in overall fuel consumption in the B.C. fleet by 2025.

RESIDENTIAL BUILDINGS ENERGY OUTLOOK

In order to assess potential energy use in residential buildings, analyses were carried out for energy use reduction and energy supply both for retrofits in the existing building stock and for new construction.

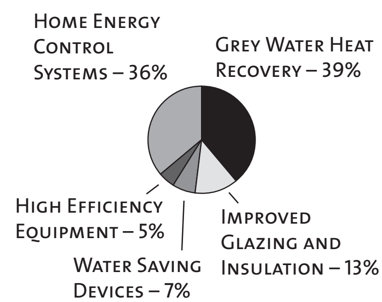
Energy Use Reduction

An increasing proportion of household budgets spent on energy is expected to drive investment by homeowners and landlords in energy saving retrofits. Based on conservative estimates of retrofit potential for home energy saving, residential energy use in B.C. is likely to be ~20 PJ less in 2025 than the current trends continue scenario would suggest. Home energy control systems and grey water heat recovery systems accounted for 75% of projected energy savings. 100% adoption of all technologies identified in all B.C. homes would yield a drop of 56 PJ (12% below year 2000 energy use). Retrofit estimates were based on the following: percentage of retrofits in the housing stock by 2025, and estimated percentage energy savings by technology.

Home Energy Saving Assumptions[1]	Retrofit % age	Per Unit Saving %
Grey Water Heat Recovery	10 - 17%[2]	7.1
Insulation and Glazing	10%	6.5
Water Saving Devices	50%	4.1
Energy Saving Equipment	100%	8.1
Energy Monitoring and Control Systems	50%	5.0

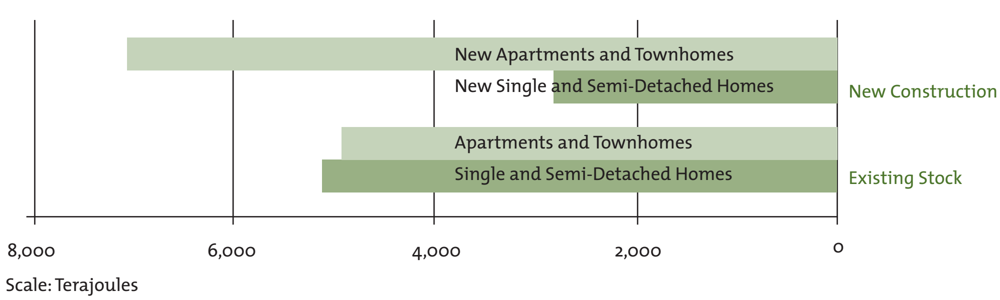
1 - Based on CREEDAC studies and other sources
2 - 17% single family / semi-detached units fitted with shower drain system. 10% of apartment buildings fitted with total grey water recovery

Contributions to Residential Energy Savings by Technology
Total Savings ~20PJ to 2025



New construction energy savings were based on 100% utilization of all technologies listed in 183,000 new buildings (~76,000 single family and 107,000 apartment buildings), and the anticipated energy use reductions for the residential occupants only - noting that apartment buildings may be mixed use (residential and commercial). Total energy savings to 2025 mirrored existing and anticipated numbers of buildings by type. New apartment buildings and townhomes contributed the largest savings:

New Construction Energy Savings (TJ)



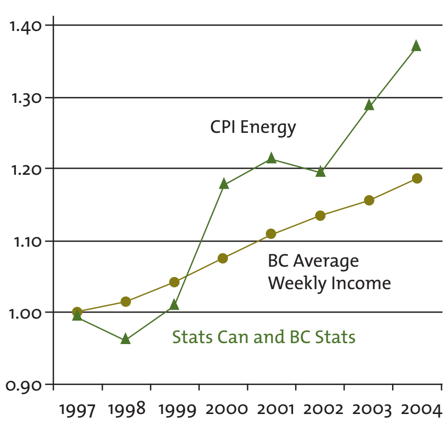
Energy Supply Potential in Residential Buildings

Energy supply from on-site renewables is becoming increasingly attractive as the price of energy continues to rise faster than incomes. However, the main deterrent for most renewable energy installations are the capital costs; the exception being solar hot water. The table below shows typical year 2000 installation costs.

Comparison of Installation Costs - Year 2000

	GJ	$ / installed system
Solar Hot Water	10	4,000
Solar PV	10	30,000
Geoexchange	100	20,000
Geothermal	100	30,000 + deep well drilling

Energy Consumer Price Index Canada and Average Weekly Incomes B.C.

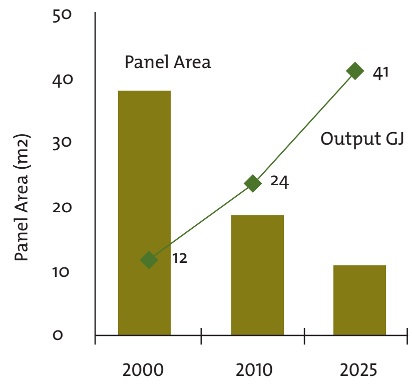


Relatively low cost technologies such as home energy monitoring and control and grey water heat recovery are projected to make significant reductions in home energy use. Coupled with improved building designs and efficient equipment, 2025 energy use could be 12% below year 2000.

Outlook for Cost Reduction

Solar water heating, geoexchange and geothermal systems involve a degree of customized design and comprise heat exchangers, pumps, piping and specialized installation services (e.g. deep well boring for geothermal installations). Cost reductions may be expected through system standardization, modularization and some economies of scale in sub-system and component manufacture.
A likely scenario is that system costs will remain at year 2000 prices, although installation costs will rise somewhat with labour rates.
The outlook for solar photovoltaics (PV) is for significant gains in efficiency from improved materials, improved architecture of solar panels, and improved solar collection and concentration. In 2000, ~38 m^2 of solar panels were required for a 5 kWpeak capacity system generating ~12 GJ. Based on an analysis of various technology cost projections, by 2025 ~11 m^2 of panels would be needed for 5 kWpeak capacity generating 41 GJ. Grid tied systems that allow power generated to be averaged over the year are the predominant configuration.

Panel Area and Power Output
5 Kilowatt Peak Solar PV System
Years 2000 - 2025



Estimates of capital costs and payback periods for 2025:

	GJ	Capital Cost[2]	2025[1] Energy Cost	Comparable Furnace Cost	Payback Period[3]
Solar Hot Water	10	$4,500	$440.00		10
Geoexchange	100	$24,000	$4,400.00	$4,500.00	5
Geothermal	100	$45,000	$4,400.00	$4,500.00	9
Solar PV	100	$25,500[4]	$4,400.00		6

Assumptions:
1 - CPI energy increases 1.87 over year 2000 - Energy cost: basic charges + useage
2 - Labour costs increase by 75%
3 - Simple payback calculation
4 - No allowance for building materials cost savings in new construction for example: Building Integrated Solar PV roofing incorporates solar cells into conventional roofing products such as tiles or metal roofing

Capital costs are a significant barrier to on-site renewables in residential buildings. However, increasing energy prices and improvements in technologies are expected to improve competitiveness of renewables considerably.

Based on the outlook for unit scale energy, capital costs in residential buildings (previous page), significant market penetration by 2025 may be expected for:

- Solar water heating in single and semi-detached retrofits and new construction
- Geoexchange systems in new construction and retrofits in some multi-unit buildings
- Geothermal systems in larger multi-unit buildings and new developments
- Solar PV (buildings integrated, grid-tied) in single family and detached buildings (new and retrofit), competing with geoexchange systems in new townhouse and low-rise construction.

For 2025 scenario purposes, the estimated percentages of technology adoption by building type for both existing stock (retrofits) and new construction to 2025 were:

Projected Technology Adoption by Building Type - Year 2025 (%)

Retrofits	Solar Hot Water	Geoexchange	Geothermal	Solar PV
Single Family and Semi-Detached	10	5	0.1	20
Townhouses and Low-Rise	10	10	5	10
High-Rise Apartment Buildings	1	0.1	5	1

New Construction	Solar Hot Water	Geoexchange	Geothermal	Solar PV
Single Family and Semi-Detached	20	5	1	20
Townhouses and Low-Rise	20	20	10	20
High-Rise Apartment Buildings	5	0.1	5	1

Projected energy supply in retro-fit and new construction for each technology and building type is shown below. Total energy generated in 2025 is projected to be ~36 PJ.

Projected Energy Supply 2025 (TJ)	Detached and Semi-Detached		Townhouses and Apartments	
	Retrofit	New Construction	Retrofit	New Construction
Solar Hot Water	1,200	400	700	700
Geoexchange (space and water heating)	2,900	500	2,300	2,500
Geothermal (space and water heating)	100	100	3,800	1,800
Solar PV (appliances and lighting)	11,600	1,900	2,800	2,600
Totals	**15,800**	**2,900**	**9,600**	**7,600**

Small Wind and Micro-hydro

Small wind and micro-hydro offer excellent potential at a limited number of sites. Based on BC Hydro Green Energy studies, total energy supply from these technologies is unlikely to exceed 1 PJ in total. Consequently, they were not included in the scenario.

COMMERCIAL BUILDINGS ENERGY OUTLOOK

Differences in operating cost structures and price elasticity for delivered goods or services affects potential investment levels in energy technologies for commercial and institutional buildings (see table below). Public sector services (health care, education and public administration) have limited flexibility in annual operating budgets to accommodate rising energy costs which fosters capital investments in energy saving. For amenities (e.g. sports arenas, airports, theatres, and hotels), increases in energy costs are ultimately reflected in ticket prices and room rates which have limited price elasticity; this also encourages energy saving investments. However, for retail operations, energy costs have little impact on price competitiveness, which allows energy cost increases to be passed on to consumers. A degree of price flexibility also exists in commercial office space leases. CIBEUS 2000[A] noted energy saving retrofits in 12% of office buildings, however retail was not among the main sectors undertaking energy saving retrofits.

Commercial Buildings British Columbia 2000	Floor Area[A] M^2 (,000's)	Energy[A] Used (TJ)	GJ/M^2	Retrofit[A] Percentage
Public Sector	27,800	41,300	1.49	15
Amenities (Public and Private)[B]	6,600	11,900	1.80	18
Private Sector	33,400	64,800	1.94	8

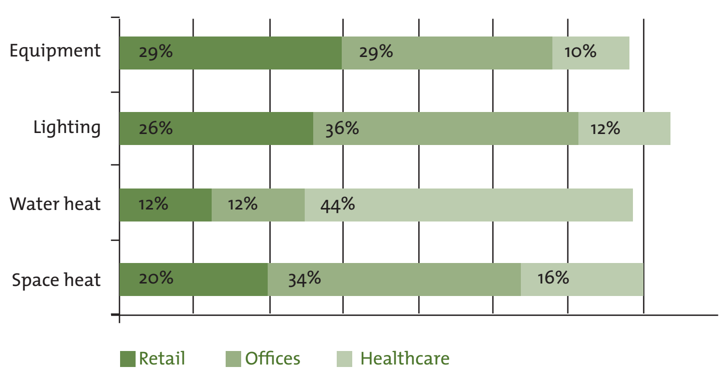
A - Based on The Commercial and Institutional Building Energy Use Survey (CIBEUS 2000)
B - Public assembly, entertainment and recreational facilities, accommodation

High Energy Use Activities: Specific Sectors

Retail business, offices and health care account for ~71% of energy use in commercial buildings in British Columbia. More specifically, offices account for ~1/3rd of all space heating, lighting and equipment energy use. Retail operations are also heavy users of energy for equipment (29% of total use) and lighting (26%).

Installation of modern lighting equipment and systems (e.g. light pipes to replace electricity use with "piped" daylight) and high efficiency office equipment in 50% of office and retail establishments could reduce electricity use by ~7,000 TJ. Lastly, it was noted that healthcare operations consume ~44% of energy used for hot water by commercial buildings in B.C. Grey water heat recovery systems in healthcare facilities could reduce energy consumption by up to ~2,700 TJ.

High Energy Use Areas in B.C. Commercial Buildings
Percentage of Total Energy Use



Energy saving retrofit investments are concentrated in the public sector and in public amenities. Offices, retail and healthcare offer large potential for further savings.

Energy Use Reduction in Commercial Buildings

Retrofit Potential

If all commercial buildings were retrofitted[C], electricity use could be reduced by ~23% and gas use by ~11% for a total energy use reduction of 17% (~20.4 PJ). However, newer buildings have a much higher rate of retrofit activity (~62%) than older buildings (~37%)[A] . Taking this observation into account, there is a practical potential for a 10% overall drop in energy use (~11.8 PJ) in the existing (year 2000) building stock tabulated in the age-based scenario below.

	Year 2000	Energy Use	Scenarios for Energy Savings (TJ)			
	Area[A] M^2 (,000's)	Energy Used Year 2000 TJ[A]	**Age Based Scenario[A,C]** electricity	gas	**All Retrofitted Scenario[C]** electricity	gas
Public Administration	12,000	15,000	1,100	500	1,800	800
Healthcare	6,500	20,000	900	900	1,500	1,500
Education	9,300	6,000	200	300	400	500
Accomodation	3,400	6,000	400	200	700	400
Business Offices	14,000	22,000	1,400	800	2,300	1,400
Retail and Food Services	11,800	29,000	2,200	900	3,600	1,500
Commercial and Wholesale	7,500	13,000	1,000	400	1,700	700
Other	4,800	9,000	400	200	600	400
Totals	69,300	120,000	7,600	4,200	12,600	7,200

A - Based on The Commercial and Institutional Building Energy Use Survey (CIBEUS 2000)
C - Demand Side Management Potential in Canada Energy Efficiency Study - 2006 Report to Canadian Gas Assn.

New Construction Outlook

The table below shows projected energy consumption in new construction year 2025, based on two studies; Regional Floor Space Forecast for the GVRD[D] and Potential for Energy Efficiency[C]. This assumes utilization of measures to reduce energy consumption through energy management control, low energy lighting, efficient equipment and auxiliary motors, grey water heat recovery and improved thermal envelopes as defined by Demand Side Energy Management Potential study[C].

Projected Energy Consumption in New Construction - Year 2025

Energy Use (TJ)	New Area M^2 (,000's)	Construction % Inc. 2025[D]	Energy Use 2025 electricity	gas
Retail and Food Services	3,600	30	3,300	3,700
Business Offices	8,300	59	3,700	5,900
Public Administration	1,200	10	500	900
Wholesale and Warehousing	5,100	69	2,700	3,000
Healthcare	2,000	30	1,200	3,700
Accomodation	1,000	30	900	700
Other	3,700	30	2,500	3,700
Totals	**24,900**		**14,800**	**21,600**

D - Commercial and Industrial Real Estate Development Trends and Forecast GVRD

Retrofits could cut energy use in the existing stock of commercial buildings in B.C. by ~12 PJ. New construction to 2025, even with a range of energy saving measures, may still increase energy use by ~37 PJ.

Energy Supply Potential in Commercial Buildings

Unit scale energy supply technologies applicable to commercial buildings include: geoexchange, geothermal, solar air heating, solar hot water heating, and solar PV. Four factors limit potential unit scale energy supply in commercial and institutional buildings: limited impact of energy costs on operating budgets noted previously, payback periods, the requirement for firm (uninterrupted) energy supply, and operational disruptions caused by major retrofits. Taking these factors into account, potential energy supply from retrofits is ~2.6 PJ and ~4.0 PJ from new construction.

Scenario 2025

Payback periods required for energy saving investments in commercial buildings averaged ~4.8 years in 2000 (CIBEUS 2000). Retrofits of unit scale energy supply technologies may currently yield paybacks of 10 - 20 years. As costs reduce and energy prices rise (see Residential Buildings), payback periods are projected to improve. Highest retrofit potentials exist in larger public sector buildings, amenities and leased office space:

Energy Supply Retrofits (TJ's) - Year 2025

	Geoexchange	Solar Air	Solar Water	Solar PV
Public Administration	490	60	60	10
Healthcare	700	70	920	10
Amenities		20	110	
Business Offices		80	70	10
Totals	**1,190**	**230**	**1,160**	**30**

Geoexchange retrofits in 5% of buildings. Solar wall retrofits in 10% of buildings. Solar hot water retrofits in 10% of offices and amenities and in 20% of healthcare facilities. Solar PV in 1% of buildings
No allowances included for : Geothermal retrofits or Retail or wholesale sector retrofits.

For new construction, the outlook for unit scale energy supply is improved by shorter payback periods. Additionally, a trend towards larger buildings and business park locations allows potential for district scale energy supply from geothermal or other technologies for all business park tenants. With creative designs, larger high-rise buildings also offer good potential for energy supply technologies, particularly geothermal and solar technologies. The following table describes a 2025 energy supply scenario for new construction:

Payback Periods

Retrofit payback period

= Total cost divided by annual cost of displaced purchased energy. Total cost ~ capital and installation cost of energy supply technology + cost of removal of incumbent energy using technology + costs impacts of disruptions

New construction payback period

= Marginal cost divided by annual cost of displaced purchased energy. Marginal cost ~ capital and installation cost of energy supply technology. minus the costs of displaced energy using system and its installation

Solar and earth energy technologies may generate ~6.6 PJ of energy in commercial buildings by 2025. New high-rise construction and expanding business parks are high potential sites for new technologies.

Energy Supply New Construction (TJ's) - Year 2025

	Geothermal	Geoexchange	Solar Air	Solar Water	Solar PV
Business Parks	280	570	150	120	90
1 to 9 Storey Buildings	90	1,210	30	900	170
High-Rise Construction	190	20	100	70	30
	560	**1,800**	**280**	**1,090**	**290**

Scale: Terajoules

Estimated Percentage Technology Adoption

	Geothermal	Geoexchange	Solar Air	Solar Water	Solar PV
Business Parks	10%	20%	80%	50%	10%
1 to 9 Storey Buildings	1%	13% av.	17% av.	30% av.	5%
High-Rise Construction	10%	1%	80%	50%	5%

DISTRICT SCALE ENERGY OUTLOOK

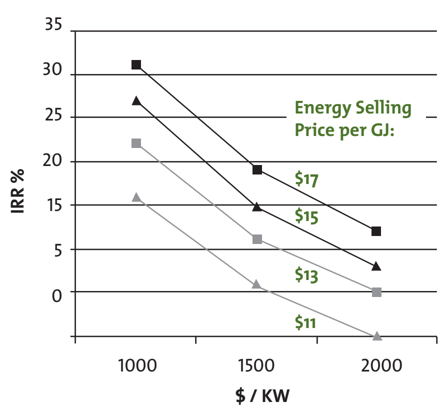
District scale energy systems include energy supply and energy conservation measures in specific localities involving collections of buildings (residential, commercial or industrial) or vehicles. The significance of district scale energy systems to this report is their potential to alleviate demand for large-scale energy supply through expanded use of local renewable energy resources at scales beyond the capacity of most individual households and businesses.

Types of District Scale Supply for Buildings

For the purposes of this report, two basic types of supply are considered; district scale heating systems for collections of buildings, and local electricity generation from renewables - either grid tied or operating as a "micro-utility" for local electricity supply.

District heating systems could include: geothermal, geoexchange, and biomass. Local electricity generation systems could include: forest biomass co-generation, MSW or land-fill gas co-generation, geothermal, solar, wind, small hydro and possibly ocean tidal or wave in certain coastal communities.

Internal Rate of Return 20 TJ Plant Example



Economic Considerations

In order to establish a district scale energy supply system, a reasonable Internal Rate of Return (IRR) is required on capital investment. For illustrative purposes, the chart shows IRR for a 20 TJ plant selling energy at between $11 / GJ (gas price to residential consumers) and $17 / GJ (~6 cents per kWhr) assuming; a capacity factor of 90%, interest on borrowed capital over 20 years at 5%, with operating costs of $40,000 per year. 20 TJ energy supply would serve the space and water heating requirements of ~350 current low-rise residential units or ~25,000 M^2 of office space.

High Capacity Factor Technologies

Current capital costs ($ / kW) for a number of technologies with capacity factors in the range of 80 - 95% are generally sufficiently competitive to encourage investments in district scale energy supply systems:

$ / kW CAPEX[1]	Electricity	Thermal Estimates[2]
Biomass Co-gen	2000	500 - 1000
Municipal Solid Waste	3000	1000 - 1500
Landfill Gas	1500	500
Geothermal	3000	1000 - 1500

Capacity Factors

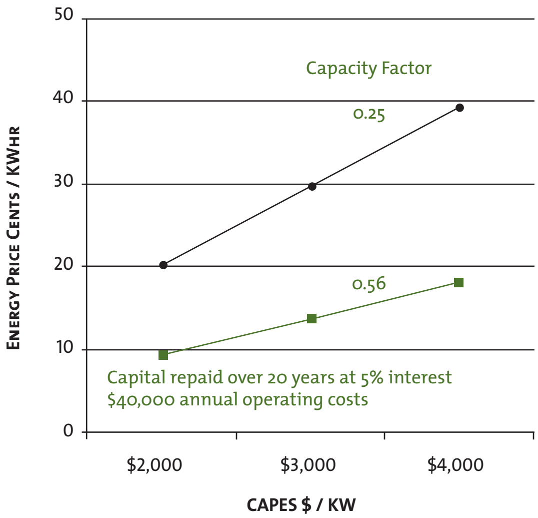
Capacity factors are measures of the efficiency and continuity of energy supply. Electricity generation from forest waste is a highly efficient and reliable technology (CF ~0.85). e.g. a 10MW capacity plant operating for 8,760 hours would generate 10*8760*0.85 = 74,460 MWhrs of energy.

1 - CAPEX = Capital Expenditures
2 - A majority of capital cost studies address electricity generation. Thermal capacities are generally much higher for a given investment, however this is offset to some extent by CAPEX for steam distribution.

Lower Capacity Factor Technologies

Solar, wind, ocean tidal and wave electricity generating installations typically have capacity factors in the range of 0.15 - 0.35. This means that larger capacity plants (measured in kW's) are necessary to generate the same energy output (measured in kWhrs or GJ's) as higher capacity factor technologies like small hydro (capacity factor ~0.56). Consequently, the price of energy to repay the initial capital investment in district scale supply systems increases for lower capacity factor technologies. The following graph illustrates the impact on energy price of capital investment and capacity factor for a 20 TJ system that would generate an IRR of 10%.

Energy Prices
Capital Costs and Capacity Factors
20 TJ Plant Example



Outlook to 2025

Technological advances are projected to improve both capital cost / kW and capacity factors for solar, ocean energy and wind power. Energy generation costs for the 20TJ example plant could drop from 13 - 26 cents / kWhr to 7 - 12 cents / kWhr. However, to allow for a reasonable return on investment energy prices to local consumers would have to be considerably greater. For example, a plant providing 20 TJ to 350 residential consumers in 2025 at a base energy price of $23 / GJ (~8 cents / kWhr) would require subsidies of between $70[1] and $150[2] per residential unit to generate an IRR of 10% on a capital expenditure of $3,000 / kW. Rising energy prices to 2025 would improve the situation.

Role of Smaller Communities

Although these factors may make retrofitting of district scale solar, wind, ocean energy systems uneconomic in urban, grid connected areas, smaller communities offer good potential for such systems. There were some 82 B.C. municipalities with populations of less than 5,000 in 2004 (BC Stats). Since the costs of grid connection may greatly exceed the premiums required to install and operate them profitably, remote (not grid connected) communities are particularly attractive sites for district scale renewables. Furthermore, in order to develop renewable technologies (and thereby improve capacity factors, capital and operating costs) demonstration sites are essential; therefore remote communities offer attractive niche markets for new district energy supply technologies. Installing district scale renewable energy supply systems in 20 smaller municipalities could provide ~400 TJ of new capacity.

1 - Capacity Factor = 0.56   2 - Capacity Factor = .25

Regional Supply and Demand Considerations

Renewable Supply Portfolios by Region

The following chart outlines likely portfolios of technologies for the various regions of B.C. based on availability and accessibility of renewable energy supply:

Region (see map)	1	2	3	4	5	6	7	8
Geothermal	Medium to high grade resource potentials in significant areas of all regions							
Solar	Available in all regions averaging ~1,350 kW / m2 / year							
Geoexchange	Available in all regions							
Municipal Waste	Highest Concentrations							
Forest Industry Biomass	High		Highest Concentrations			High	High	High
Agri-Biomass								High
Wind	High			High	High	High	High	
Ocean Energy	High					High		

Note: All types of energy except ocean energy are available in all regions to some degree.

Demand from New Residential and Commercial Construction

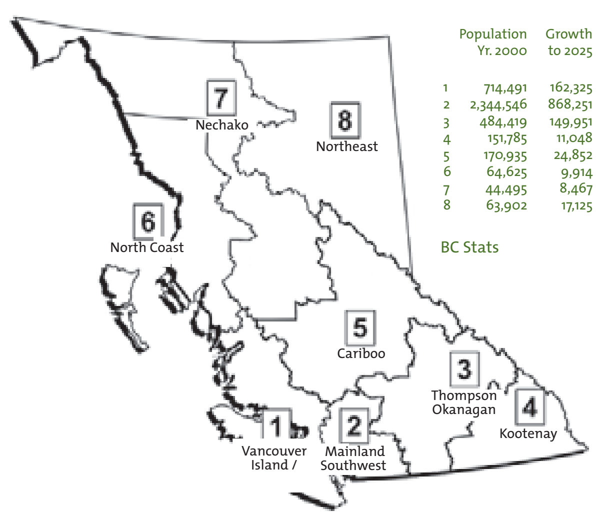
The advantage of long-term fixed energy costs and environmental considerations can make renewable technologies attractive alternatives for new developments. Additionally, costs of installing and operating district scale energy supply systems can be levied on a per square metre basis as a on-going part of monthly maintenance costs (e.g. geoexchange space and water heating are ~\$2.50 / m^2 / month in some new GVRD condominiums).

Regions 1, 2 and 3 (see map) are expected to see the greatest increases in new construction to 2025. The following chart outlines estimated energy demand by region to 2025:

Energy Use New Construction - Years 2000 to 2025

Units: TJ's

	Residential	Commercial
1. Vancouver Island/Coast	8,000	5,000
2. Mainland/Southwest	21,000	25,000
3. Thompson-Okanagan	7,000	4,000
4. Kootenay	500	500
5. Cariboo	1,200	1,000
6. North Coast	500	500
7. Nechako	500	500
8. Northeast	1,000	500



Energy demand from new construction offers high potential for district scale renewables. Each region of the province has a portfolio of renewable energy endowments that could help meet growing local energy demands.

Business Parks Potential

As noted previously, a trend towards larger commercial buildings and business park locations creates potential for district scale energy supply from renewables in high growth business and industrial parks:

- Costs for renewable energy supply systems can be offset by the capital costs of displaced energy using systems which may provide acceptable payback periods.
- District scale renewable energy supply in business and industrial parks allow capital costs to be shared among leaseholders engaged in new construction.

Analyses of NRCan and GVRD published studies indicates that ~6.7 million square metres of new office and commercial space could be located in business parks in B.C. between year 2000 and 2025. Approximately 6.1 million m^2 of this development is projected to occur in regions 1, 2 and 3 (based on population growth estimates) and would consume ~7,800 TJ of energy. For scenario purposes, it is proposed that a significant proportion of this new demand could be met through the establishment of renewable energy powered business and industrial parks.

Scenario: "Micro-Utility" Business Model

In this scenario, business parks could become attractive locations for the establishment of profitable "micro-utilities" provided the capital costs of renewable energy supply could be paid for from the construction budgets of the leaseholders. Capital costs offsets and fixed longer term energy rates could make such an approach economically attractive for leaseholders. For example, a "micro-utility" operator investing a nominal $400,000 in a 20 TJ plant could repay interest charges at 5% over 20 years on the full capital investment of leaseholders in a $3,000 / kW capacity renewable energy plant; and generate a 12% IRR by providing base load energy at a 20 year retail price of ~5 cents / kWhr to leaseholders who put up the bulk of the capital costs. Expansion to established businesses in the park could be accomplished through an appropriate rate structure. Such a model would rely on net metering, so that "micro-utility" plants could be scaled to match base load requirements of the parks concerned and provide round the clock demand for energy supplied.

Renewable Energy Business Parks: Scenario 2025

Assuming that a profitable business model could be developed along the lines suggested, it is entirely possible that municipalities concerned about environmental issues could designate high growth parks as "solar," "geothermal," or "waste to energy" parks. In this scenario, a significant proportion of business and industrial park locations could be powered primarily from renewables by 2025; total energy supply from renewables could approach 20 PJ.

> Creative business models and municipal leadership could turn business and industrial parks into renewable energy showcases. Analyses suggest that profitable "micro-utilities" could power solar, geothermal or waste-to-energy designated parks.

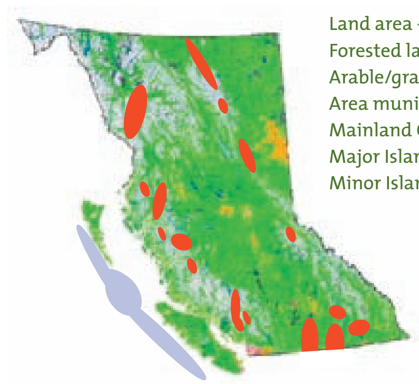
LARGE-SCALE SUPPLY OUTLOOK

The inset map provides an outline of B.C.'s forested and agricultural areas, high potential geothermal and wave resources, and locations of mountainous and urban regions. The chart below provides order of magnitude estimates of renewable energy sources.

These estimates serve a similar purpose to those of ultimate reserves for non-renewables. Two examples illustrate this point:

Example 1:
Ultimate reserves of natural gas in B.C. are estimated at some 97,000 PJ; however, proven reserves in 2004 were estimated at ~11,000 PJ.

Example 2:
The ultimate energy potential of hydroelectric sites in B.C. is estimated at ~700 PJ/Yr. Current facilities are tapping ~400 PJ / year of this potential to produce ~220 PJ / year of electricity.



Land area ~95 million hectares
Forested land base ~60 million hectares
Arable/grazing land ~4 million hectares
Area municipal lands ~1.4% of land area
Mainland Coastline ~7,022 Kms
Major Islands perimetres ~10,835 Kms
Minor Islands perimetres ~7,868 Kms

Mining activity
Mountainous regions
High potential geothermal areas
High potential inshore wave areas

Order of Magnitude Estimates
B.C.'s Renewable Resource Endowments

Energy Source	Natural Endowment Estimates 100% efficient energy conversion	PJ / Year
Solar	Insolation 1,350 KWhrs/m²/year on urban lands within municipal boundaries	20,000
Geothermal	High potential land area ~43,000 Km² 1,700 high grade deposits to 3 Km depth based on comparable US data	13,500
Wind	Energy of air mass flow at mapped 7 m/s wind sites to 50m height over 3,000 Kms (mostly mountainous or coastal regions)	1,000
Ocean Wave	Ocean Wave energy nearshore mapped at 30 - 48 KW/m²	900
Hydro	Energy potential at existing and potential large and small hydro sites	700
Forest Biomass	Annual allowable cut ~70 million m³, density 455 Kg/m³, calorific value 10,900 MJ/m³	350
Ocean Tidal	Tidal energy at 89 measured sites: Mainland and Vancouver Island coasts	100
Agri-Biomass	Energy value of total annual tame hay harvest ~1.4 million tonnes 18.1 MJ/Kg	25

Large-Scale Solar Potential

Solar Technologies

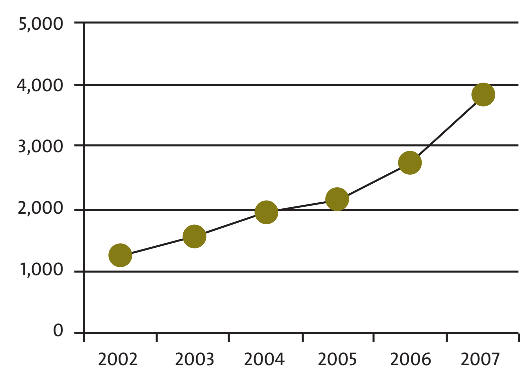
There are two basic technological approaches to solar energy: solar photovoltaics (direct conversion of sunlight to electricity) and solar concentrators (use of focused sunlight for heat to power a turbine / generator with steam or hot air). These technologies are exemplified by projects from Germany and Australia: the Bavaria Solar Park (in operation with a capacity of 10 MW from 57,600 solar panels covering 62 acres) and the Solar Mission project in New South Wales based on a novel solar tower concentrator technology (planned capacity of 200 MW capable of supplying the electricity requirements of 200,000 households). Solar power is intermittent and diffuse, consequently energy storage technologies are an essential component of solar energy systems of either type.

Note: Solar insolation in Bavaria is similar to that in British Columbia whereas the Solar Mission project enjoys higher insolation.

Global Outlook

Global capital investment in solar energy generation was estimated at ~$1.2 billion in 2002, doubling by 2006[1]. The US Department of Energy forecasts continual cost and efficiency improvements for large-scale solar focused on solar concentrator technologies (c.f. Australia's Solar Mission project): "Concentrating solar power technologies currently offer the lowest-cost solar electricity for large-scale power generation (10 megawatt-electric and above). Current technologies cost US $2 - $3 per watt… Advancements in the technology and the use of low-cost thermal storage will allow future concentrating solar power plants to operate for more hours during the day and shift solar power generation to evening hours. Future advances are expected to allow solar power to be generated for US 4¢ - 5¢ per kilowatt-hour in the next few decades…"

Global Capital Investment[1] (Cdn. $ millions)
Solar Energy Generation



The British Columbia Situation

The Thompson / Okanagan and Northern regions of the province offer higher potential (> 1,460 kWhrs / m2 / year) locations for large-scale solar installations. Five large-scale solar installations of a similar magnitude to the Solar Mission project could produce 8 - 20 PJ in British Columbia by 2025, allowing for improvements in technology (as suggested by the US DOE and other estimates).

1 - Scottish Enterprise Report on Alternate Energy 2004

Large-Scale Geothermal Potential

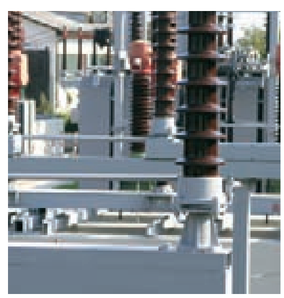
Geothermal Energy Systems

At depths of 1 - 4 kilometres below the surface, highly pressurized water is heated to 100°C to 300°C. To generate electricity, hot, high pressure geothermal water is piped to power plants on the surface where 30% to 40% of it 'flashes' (explosively boils) to steam. The steam is then separated from the remaining hot water and fed to a turbine/generator unit to produce electricity. The residual water is returned to the reservoir through injection wells to help maintain pressure and prolong productivity. For lower temperature geothermal reservoirs (100°C and 150°C), binary-cycle power plants are used. In a binary plant, geothermal waters are passed through a heat exchanger to heat a secondary working fluid (for example, isopentane) that vaporizes at a lower temperature than water. In unit or district scale systems (discussed previously), geothermal hot water is used for space heating rather than to generate electricity.

Magma from the earth's interior rises close to the surface in some locations where its heat can be harnessed to generate electricity. There are extensive high grade geothermal deposits in most regions of British Columbia that could be developed to supply a large part of the province's energy needs. Scenario: 32 PJ by 2025.

Geoexchange is Different from Geothermal

Geoexchange systems (ground source heat pumps) rely on a constant ground temperature to depths of ~200 metres. In these systems heat is "pumped" from the ground during cold weather and "pumped" from the air to the ground during hot weather for cooling.



Global Outlook

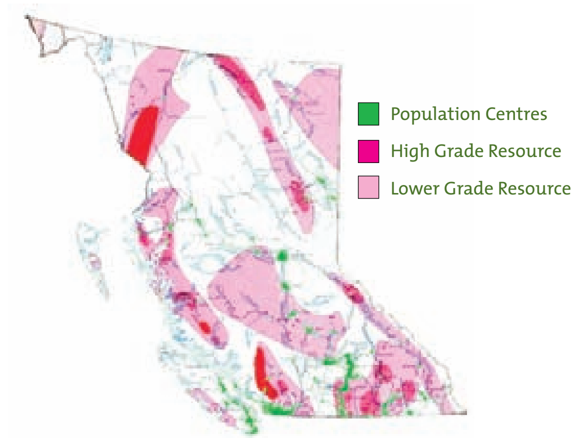
Geothermal technologies are mature and competitive. Temperature, drilling depth and site accessibility are the main factors affecting economic development of geothermal deposits. Annual global capital investment in geothermal energy is estimated[1] at ~$ 2 billion / year.

British Columbia Situation

British Columbia has extensive high and mid grade geothermal deposits in most regions. A review of population centres and geothermal deposit locations (see inset map) shows high potential for geothermal energy supply in the densely populated Southwest (Regions 1 and 2) and in Region 3 (Thompson / Okangan), 4 (Kootenay) and 5 (Cariboo). The Meager Creek geothermal project near Pemberton, B.C. would access a geothermal resource with an average temperature of 220°C to 240°C and estimated development potential of 100 MW to 250 MW of electricity generating capacity. Although geothermal energy has not garnered the same level of public attention as other renewables world-wide, in British Columbia the potential exists to generate a significant proportion of the province's energy needs from geothermal resources. For scenario purposes, 32 PJ by 2025 is proposed from large-scale geothermal.

1 - Scottish Enterprise Report on Alternate Energy 2004

Geothermal Deposits in British Columbia



Sources:
BC Hydro / Canadian Cartographics
BC Stats

British Columbia's coastal and mountainous areas offer enormous potential for wind energy generation. 114 PJ of wind energy by 2025 is a possible scenario.

Large-Scale Wind Potential

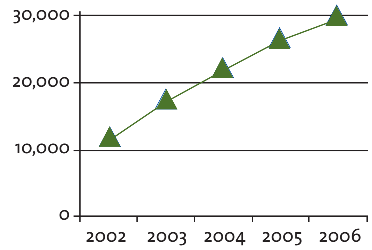
Wind Energy Systems

There are two main types of wind turbine power generators: vertical axis ("egg beaters") and horizontal axis ("windmills") machines using either lift or drag forces to harness the wind. Other than some experimental machines, most current installations are horizontal axis lift devices with rotor diametres of 50 - 100 metres. Large-scale wind farms (~100 MW) may comprise 50 to 100 or more wind turbines. Sophisticated systems to manage power output from many turbines with varying wind speeds are necessary to provide continuous smooth power to the electricity grid. Since power output is determined by the swept area of the wind turbine rotor multiplied by the wind speed cubed, the trend is towards larger diametre machines. Sites with wind speeds of 6 - 8 m/s are considered to have good economic potential. Sites with wind speeds less than 4 m/s are considered poor candidates. Sites where wind speeds are higher and less variable are therefore prime candidates for wind energy development; mountainous or coastal areas fit these criteria.

Global Outlook

At the end of 2001, the cumulative installed global wind energy capacity was estimated[1] at ~25 GW (55,960 turbines), of which ~7 GW were installed in 2001, representing a compound rate of wind energy development of 40% in terms of capacity installed annually over a five year period. In 2002, global capital investment in wind energy systems was estimated at $11.6 billion[2] and was projected to reach ~$30 billion in 2006. The majority of wind energy investments were at on-shore locations (~95%), although the proportion of off-shore wind to total wind energy investment is increasing.

Global Capital Investment (Cdn. $ millions) Wind Energy Generation[2]

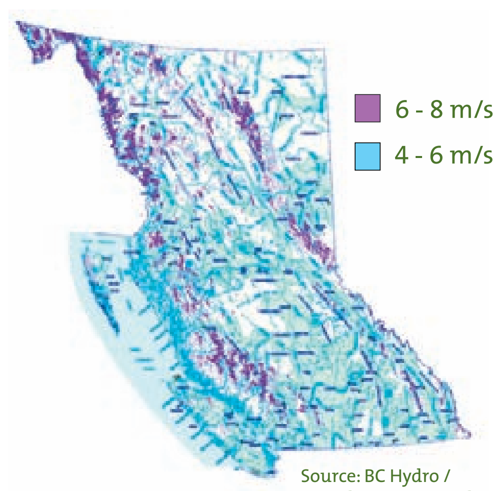


The British Columbia Situation

British Columbia's on and off shore wind resources are extensive (see map). Wind energy potential[1] in British Columbia from a number of high potential sites, where wind energy installations were technically feasible, was estimated at 4,800 MW. Total energy potential from those installations is estimated at ~57PJ. Development of number of major wind projects is ready to proceed. For scenario purposes, it is proposed that wind energy could reasonably be expected to provide up to ~114 PJ by 2025 in light of technological advances (larger rotors and improved output of wind farms / acre) and rising energy prices.

1 - Wind Energy Study in BC - Helimax 2002
2 - Scottish Enterprise Report on Alternate Energy 2004

Wind Speeds in British Columbia



Source: BC Hydro / Canadian Cartographics

Hydro Power Potential

Hydroelectric Systems

Water turbines used in hydroelectric plants are mature, reliable technologies. Depending on the circumstances, a watercourse is either dammed up to use the potential energy contained in the water at that location, or large quantities of water are fed directly through turbines on a shallow gradient. This latter type is known as a "run-of-river" plant.

Global Outlook

In 2002, there were some 45,000 large hydroelectric dams in operation worldwide[1], of which approximately 300 were 'mega dams'; 97 per cent of world hydropower is supplied by large hydroelectric plants with more than 10MW capacity. Annual global investments in hydro-electric facilities fluctuates significantly as a result of the scale of individual investments (e.g. the Three Gorges Dam in China). In 2002, global investment was estimated[2] at ~$7.8 billion, in 2004 at ~$2.0 billion.

The British Columbia Situation

Approximately 90 per cent of electricity on the power grid in British Columbia is generated by large hydroelectric plants. This provides a reliable, low-cost and flexible electrical system and some of the lowest electricity rates in North America, which is clearly an important advantage for British Columbia consumers. However, it can also represent a competitive challenge for alterative energy sources seeking to supply the British Columbia market.

- Total energy supply from hydroelectric facilities (both public and private sector, large and small) is ~220 PJ.
- Detailed studies by BC Hydro have assessed potential of small hydro in B.C. from over 750 possible sites.
- A growing number of independent power producers is expanding energy supply from small hydro projects.
- Estimated potential for small hydro is ~39 PJ.
- Additional capacity from development of the Site "C" dam and a significant number of smaller projects could increase British Columbia's hydroelectric energy supply by ~60 PJ for a total of ~280 PJ by 2025.

1 - German Advisory Council on Global Change
2 - Scottish Enterprise Report on Alternate Energy 2004

Major Hydroelectric Dams in British Columbia

	(MW)
Gordon M. Shrum	2,730
Revelstoke	1,980
Mica	1,805
Kemano	900
Peace Canyon	694
Kootenay Canal	580
Seven Mile	594
Bridge River	466
Waneta	450

Some 750 sites have been assessed for small hydro potential. Total capacity from those sites ~2.4 GW with an energy supply potential of 39 PJ

Hydroelectric facilities in B.C. supply ~220 PJ of energy each year. The potential exists to increase hydroelectric generation to ~280 PJ, approximately 39 PJ of which could come from small hydro projects.

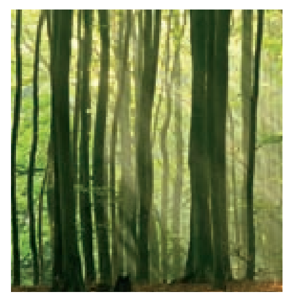
Large-Scale Biomass Potential

Biomass to Energy Technologies

Biomass for energy includes harvesting residues from trees and crops and plants grown entirely for energy; for example, corn for ethanol. It also includes animal waste and fats. Because no net CO_2 emissions are released to the air (other than emissions due to production and transport of the biomass and biofuels), energy from biomass is considered to be 'climate-neutral'. For biomass to be a 'sustainable' energy source, the stock of biomass must not be depleted. The global sustainable bioenergy potential is estimated at ~100EJ per year[1], of which 40% is from forestry residues and by-products, 17 % from agricultural waste and 36% from energy crops.

1 - German Advisory Council on Global Change

Biomass is generally a low density energy source with two main advantages; low cost and potentially carbon neutral. A variety of technologies have been developed to utilize energy crops and waste biomass (in all its forms), as easily transportable, higher energy fuels.



Biomass Fuels

- **Liquid fuels** to replace or supplement gasoline / diesel fuel
- **Gaseous fuel** for use in power or heating plants
- **Solid fuels** for use in power or heating plants

Liquid Fuel Production Technologies

There are a variety of well understood technologies for the production of liquid fuels that use a wide variety of biomass feedstocks. All require energy inputs and a degree of pre-processing for the feedstock. Many have associated saleable byproducts that improve the economics of production. The chart below is a simplified overview of the situation:

Feedstock	Base Technology	Output
Cellulosic: wood or hay	Pyrolysis	Bio-oil (16 -19 MJ / Kg)
Sugar rich, starchy crops: corn or wheat	Fermentation	Ethanol (30 MJ / Kg)
Municipal Waste	Hydro Thermal Upgrading (HTU)	Bio-crude (30 - 36 KJ / Kg)
Vegetable Oils and Animal Fats	Transesterification	Bio-diesel (45 MJ / Kg)

Bio-oil or bio-crude can be used directly in stationary power plants or in co-fired generation plants in combination with other fuels like coal. They may also be further processed to produce higher energy fuels like methanol or bio-diesel, however this requires additional energy inputs. Nevertheless, lower energy bio-oil can be produced on-site in smaller scale portable facilities which improves the economics of transportation for feedstocks like forest slash or tame hay.


Bio-oil

Bio-diesel[1] or ethanol can be used directly in internal combustion engines. Ethanol is less combustible than gasoline (it has a lower cetane number) and so is unsuitable for compression ignition engines (diesel engines). Without modifications, spark ignition engines (as in most automobiles), require ethanol to be blended with gasoline.


Small Scale Bio-diesel Plant

Gaseous Fuel Production Technologies

Gasification technologies are thermo-chemical processes that use heat to convert any carbon-containing fuel (such as wood waste) into a clean burning gas commonly referred to as syngas (calorific values are typically 4 - 6 MJ / m^3). After cleaning, syngas may be used directly to fuel gas turbine or other internal combustion engines.

1 - Promoted as “Sun Diesel” by Volkswagen and Daimler Chrysler

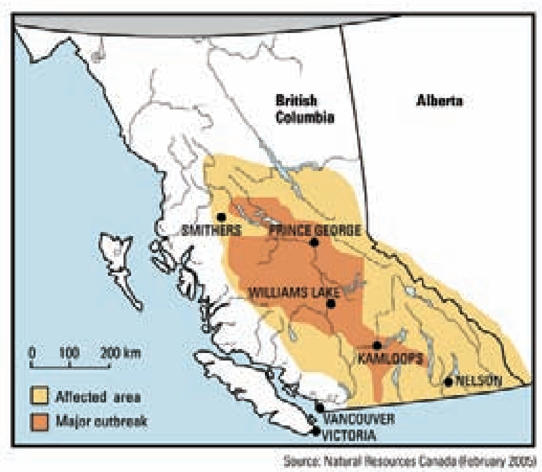

Modern Syngas Plant Nexterra / Tolko - B.C.

Forest Waste to Energy Potential

Forest Waste

In 2005, an estimated 1.2 million bone dry tonnes (BDt) / year (energy value ~24 PJ) of mill hog fuel and pulp chips were generated in excess of forest industry requirements, together with an estimated 2 million BDt (energy value ~40 PJ) of harvesting residues left at roadside. As noted earlier, a trend towards energy self- sufficiency in the forest industries is projected to expand total energy supply from waste by ~25 PJ by 2025, replacing both natural gas and electricity in plant operations. This trend is supported by growing volumes of road side waste from beetle killed timber harvesting estimated (2006) at 7 - 9 million bone dry tonnes (~140 to 190 PJ).

Total Area Affected by Mountain Pine Beetle in Western Canada



Energy demands from new construction in forest industry intensive regions could be met by profitable new partnerships among industry, municipalities, utilities and developers.

Scenario 2025

For forest industry intensive regions of the province, the potential therefore exists for new partnerships to supply new residential or commercial developments with space and water heating fuelled by forest waste, augmented by beetle killed timber and associated harvesting residues. For example, building larger capacity co-gen systems where industry facilities are sufficiently close to expanding urban developments could supply steam, or possibly syngas, to both industry and municipal consumers. The increased costs of building such co-gen plants and installing energy supply infrastructure for residential and commercial consumers would be offset by displaced gas systems (for steam this would include cost offsets from both supply lines and furnaces). Based on analyses shown earlier in this report, Internal Rates of Return would likely exceed 10% at $11 / GJ.

Growth in energy demand for buildings in Regions 1, 3 and 5 (high concentrations of forest industries and larger population increases) is projected to be ~25,000 TJ by 2025 (coincidentally, projected forest industry waste to energy system expansion by 2025 is also projected to be ~25,000 TJ). New construction in these regions is projected to comprise ~72,000 new residential buildings and ~6.7 million M^2 of new commercial space. For scenario purposes, it is proposed that 10% of that increased energy demand (2,500 TJ) could be met by a 10% capacity expansion in projected forest industry co-gen and thermal energy supply growth. Potential also exists for local electricity supply from forest industry co-gen facilities. New grid connected generation capacity using forest biomass is covered in the section on large-scale energy supply.

Gas to Liquids (GTL) Technologies

Syngas may also be further processed to produce methanol or other higher energy liquid fuels using well understood Fischer-Tropsch processes. Conventional FT plants however are uneconomic at scales appropriate to biomass supply (~1,000 tonnes / day). New catalytic technologies (now operating at pilot plant scales) promise to overcome this challenge. Microbial conversion technologies, which require lower energy input, have been demonstrated at small scales.

Solid Fuel Production Technologies

Pelletization compresses low density biomass (60 - 150 Kg /m3) by mechanical means to ~650 Kg / m3 with an energy density of ~18.5 MJ / Kg for easy storage, handling and distribution.

Wood Pellet Mill
Premium Pellet BC

There are a number of permutations of technology and feedstocks to produce higher energy density liquid, gaseous and solid fuels from biomass. Research is concentrated on reducing energy inputs for fuel production and modifications to engines, furnaces and power plants to use bio-fuels efficiently.

Bio-Fuels: Stage of Development and Production Costs

The development situation for liquid biofuels is characterized by various permutations of feedstock type and technologies. Ethanol from field crops (like corn or wheat) and bio-diesel from vegetable oils and animal fats account for most current biomass liquid fuel production. World ethanol production in 2005[1] was ~45 billion litres (~1,000 PJ) and bio-diesel ~4 billion litres (~138 PJ). Major production cost elements include; delivered feedstock cost (including transport), energy inputs, and the amortized plant capital costs.

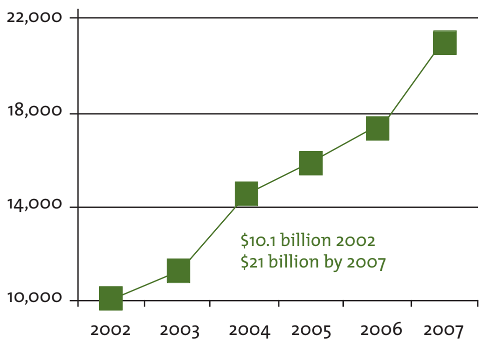
Large Scale Ethanol Plant
Husky Oil - Saskatchewan - 2004
130 million litres / year

Corn ethanol production costs in 2004 were ~45 cents per litre (c / L) compared to gasoline at ~30 c / L. On an energy basis (ethanol has a lower energy density than gasoline), ethanol costs were ~65 c / L. Rising crude oil prices and the potential to use lower cost cellulosic feedstocks promise to reverse the differential between ethanol and gasoline over the longer term. Production processes for bio-oil and bio-crude are well established at lower volumes to supply fuel for heating and power plants. The situation for gas to liquids (syngas to methanol or bio-diesel) using Fischer-Tropsch processes is less favourable, primarily due volumes of feedstock needed to achieve the economies of scale necessary for a conventional GTL production facility[2]. Use of wood (see inset) as feedstock, new catalyst technologies or microbial conversion approaches promise to overcome this challenge.

An experimental industrial scale bio-diesel plant in Germany will use a version of the Fischer-Tropsch process to convert wood and other biomass to synthetic diesel fuel. Capacity: 13,000 tonnes / year increasing to 200,000 tonnes in 2008

Ethanol and bio-diesel production world-wide was ~49 billion litres in 2005. Capital investments in electrical generation alone from biomass are projected to reach ~$21 billion in 2007.

Global Capital Investment (Cdn. $ millions) Biomass Electricity Generation[3]



1 - Saskatchewan Potash Corp. 2006
2 - Batelle Pacific Northwest Labs - 2003 Presentation Micro-channel Catalytic Process....
3 - Scottish Enterprise Report on Alternate Energy 2004

Biomass Energy Use Technologies

Generally the use of liquid and gaseous biomass fuels to generate energy is achieved through existing internal combustion engine technologies with varying degrees of modification to fuel control and ignition systems. Markets for solid biomass fuels to provide high efficiency, low emissions space heating has led to major improvements in stoves and furnaces that today provide similar emissions to natural gas burning equipment.

Electricity and co-generation facilities using bio-mass (solid, liquid and gaseous) fuels are well established and provide electricity at competitive rates. There are many examples of municipal and industrial co-generation using waste biomass across the province, including forest waste, municipal solid waste, and landfill gas.

Liquid Fuels

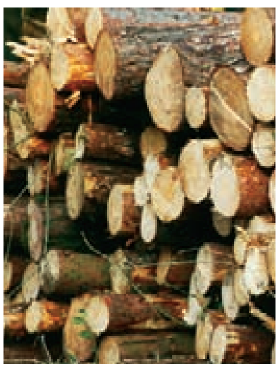
Nevertheless, the potential for ~100 PJ of feedstock per year exists for liquid fuel production. Over the longer term, energy crops could play an important role. Fast growing trees could provide an on-going biomass harvest to ensure supply to co-fired generation capacity in addition to fuels production. A total sustainable yield of 150 PJ / year or more may be reasonable. Other crops such as switchgrass and mustard seed could also provide significant volumes of biomass. Noting that 10% of the current tame hay, wheat and fodder corn harvest represents ~3.6 PJ of feedstock, 10 PJ / year may be practical should the economics of energy crop production continue to improve as a result of higher fuel prices. ~4 million litres of liquid fuels (~90 PJ) could be produced from 160 PJ of feedstock requiring an energy input of ~50 PJ[2].

1 - Total beetle killed timber is estimated to be ~500 million m^3 or 2,480 PJ
2 - Energy inputs and feedstock supply volumes per 1,000 L of liquid biofuel were derived from a review of studies from Natural Resources Research, Oregon and Hawaii.

The British Columbia Situation

Based on data from a variety of sources the chart below summarizes the potential availability of biomass feedstock for energy purposes in British Columbia:

Increasing energy self-sufficiency in the forest industries (primarily by replacing some 30 PJ of natural gas consumption with biomass), plans to expand electrical energy generation through co-firing and co-generation of forest waste, an expanding B.C. Pellet industry (~12 PJ of pellet production in 2006) and increased use of MSW and landfill gas could increase overall utilization of B.C.'s biomass to ~300 PJ over the next decade. Growth of bio-fuels production in British Columbia is dominated by gasification technologies feeding large-scale industry and power plants and wood pellet export.



	(PJ)
Forest Industries	
Spent Pulping Liquor (SPL)	150.0
Wood Waste	128.0
Slash from Operations (not incl. Beetle-Killed timber)	40.0
Est. Beetle Killed Timber as Road-Side Slash[1]	40.0
Forest Industry Total	**358.0**
Agricultural Industries	
Tame Hay Crop	25.8
Wheat and Fodder Corn Crops	10.6
Est. 10% Agri-biomass could be available for Energy	**3.6**
Municipalities	
Municipal Solid Waste est. Available	21.5
Sewage Total est. Methane Generation Potential	4.1
Yellow Grease	0.8
Demolition Landfill est. Available	0.6
Landfill Gas	0.3
Municipal Total	**27.2**
GRAND TOTAL POTENTIAL BIO-ENERGY FEEDSTOCK	**390 PJ**
Of which ~225 PJ is presently used in the Forest Industries.	

Note - 1: SPL estimate based on actual energy use
Note - 2: Forest biomass energy density varies with moisture content

Sustainable biomass supply in British Columbia is approximately 400 PJ, assuming that a proportion of beetle killed timber could be replanted with fast growing trees for energy supply. Wood gasification and wood pellet production are major growth industries.

Ocean Energy Potential

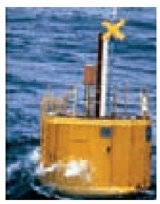
Wave Systems

Wave energy devices fall into two main categories: "over-topping" devices and "displacer / reactor" systems. In an "overtopping" device, waves pass "over the top" of a weir into a reservoir. As the wave recedes, the head of water in the reservoir pushes the water through a turbine in the bottom of the weir and back out to sea. Displacer reactor systems, as the name suggests, consist of two main components: a "displacer" that moves with the waves, and a "reactor" that resists movement of the displacer. The resistance forces are converted into energy through a "power take off" system. There are a number of displacer / reactor system configurations in various stages of development.

Over Topping Device

Over-Topping Devices
Waves fill a reservoir, and, when they recede water in the reservoir flows through a turbine out to sea.

Displacer / Reactor Systems



Point Absorbers
Buoy like devices tethered to the sea bed. Motion of the device is transformed into energy.

Attenuators
Ride the waves like a ship. Movements of the device at its bow and along its length are restrained to generate energy.

Oscillating Water Columns
As waves enter and exit the partly submerged structure they act as a piston to compress and decompress air in a column.

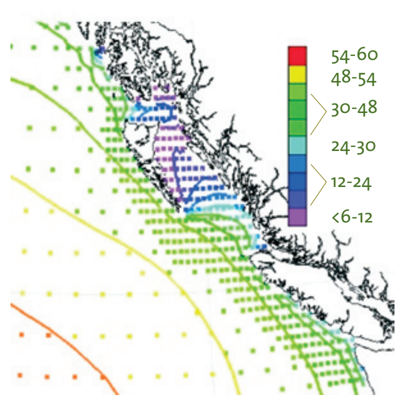
Global Outlook

A number of countries are presently active in R&D and demonstration of wave energy systems, the majority of which are oscillating wave column devices. The UK is generally considered to be in forefront of ocean energy developments. In 2005, there were some 38 companies developing wave energy devices world-wide[1]. Global capital investments[3] in wave power were estimated at $1.2 billion 2002. The outlook is for continual efficiency improvements and large-scale "wave farm" developments.

The British Columbia Situation

The mean annual wave power off Canada's Pacific coast is estimated[2] at ~37 GW over 915 kilometres. Based on current and projected device capacity factors and in comparison with UK studies carried out by the Carbon Trust, the potential energy generation from wave power in British Columbia is estimated at ~28 PJ. Planning for wave energy generation in British Columbia is at an early stage.

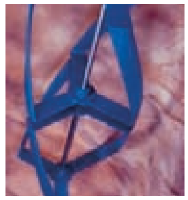
Wave Energy B.C. Coast (kW / m)



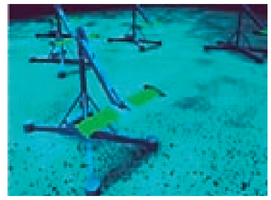
1 - Industry Canada Report prepared by NRC and Acton White Associates
2 - National Research Council of Canada presentation "Inventory of Canadian Marine Renewable Resources" - 2006
3 - Scottish Enterprise Report on Alternate Energy 2004

Tidal Current Systems

There are four main types of in-stream tidal flow systems: horizontal and vertical axis turbines, oscillating hydroplanes and venturi devices. All use tidal current to power a turbine / generator directly or, in a venturi device, indirectly.



Horizontal and Vertical Axis Turbines
Work on the same principle as windmills driving electrical generators.



Oscillating Hydroplanes
Oscillating hydroplanes, driven by tidal current, power a hydraulic motor / generator system

Venturi Devices
As water flows through a venturi a pressure drop is generated that drives a secondary turbine / generator

Global Outlook

The situation for tidal energy systems world-wide is much the same as for wave energy devices. There were some 17 companies in 2005[1] engaged in tidal energy development and demonstration projects. Global investments in tidal energy systems[2] were estimated at $1.4 billion. As the technologies become more competitive, large-scale tidal power farms are expected to be developed along the same lines as wind farms currently in operation.

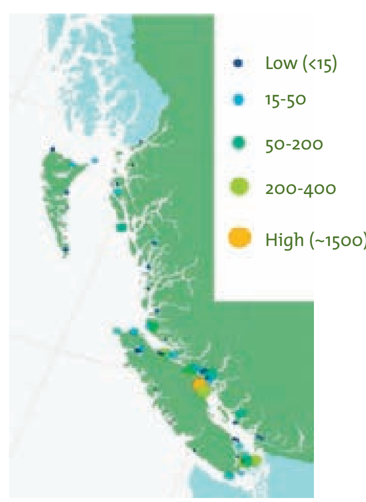
Tidal power potential along the British Columbia coast line has been estimated at ~4 GW from 89 sites. Small scale demonstration projects may spur development of this resource. By 2025, up to 9 PJ of tidal energy may be attainable for B.C.

The British Columbia Situation

The annual tidal power potential at 89 identified sites was estimated at ~4 GW[2]. Detailed assessments of tidal energy potential have been carried by BC Hydro and demonstration projects in B.C. have commenced with a horizontal axis generator located at Race Rocks. Based on assessments of current and projected device capacity factors, energy from tidal steams in British Columbia could reach ~9 PJ by 2025.

1 - Industry Canada Report prepared by NRC and Acton White Associates
2 - National Research Council of Canada presentation "Inventory of Canadian Marine Renewable Resources" - 2006

Tidal Power Potential Sites[2] B.C. Coast (MW)



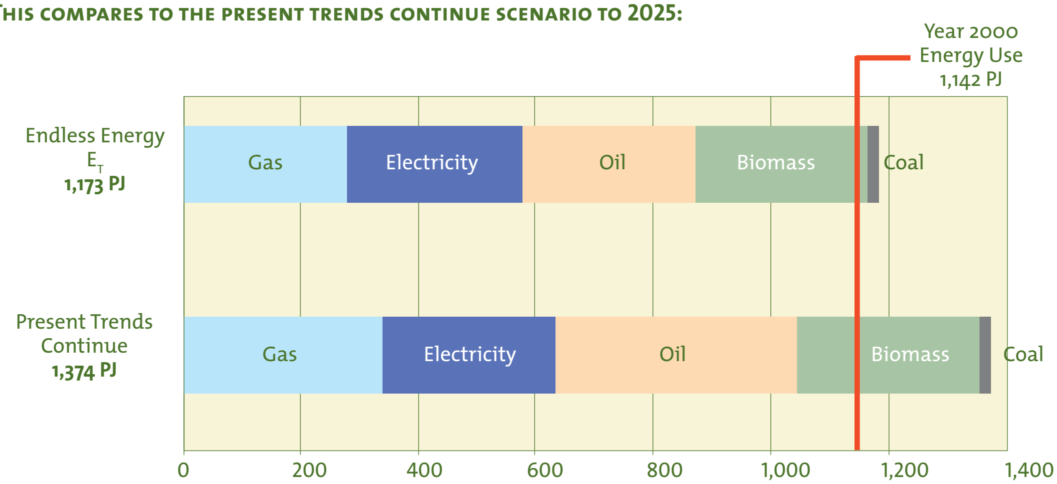
MATCHING RENEWABLE SUPPLY TO DEMAND

Total Energy Required in 2025 (E_T)

Under the Current Trends Continue scenario (page 16), 1,374 PJ would be required in British Columbia by 2025. Taking account of practical potential for energy use reduction as projected under the Endless Energy scenario (pages 17 to 29), total energy used (**E_T**) would drop to ~1,173 PJ (see chart below) by 2025.

	Totals (PJ's)	Gas	Electricity	Oil	Biomass	Coal
Forest Industries	**340**		60	14	266	
Other Industries	**236**	123	64	33	1	14
Residential	**163**	78	84			
Commercial	**159**	75	84			
Domestic Transport	**154**		8	128	25	
Gateway Transport	**120**			118	2	
Totals	1,173	276	301	293	295	14

THIS COMPARES TO THE PRESENT TRENDS CONTINUE SCENARIO TO 2025:



In summary, the main changes envisioned by the Endless Energy scenario are a drop in space heating energy use (which would curb natural gas consumption significantly), and a large drop in petroleum consumption as a result of improved fuel efficiency in transportation overall and a mainly hybrid vehicle fleet of automobiles and light vehicles. Electricity use would rise as a result of a plug-in hybrids and other electric vehicles.

Energy use reductions in British Columbia envisioned by the Endless Energy project would hold total energy consumption in 2025 to year 2000 levels even with a 30% increase in population and projected growth in GDP.

Energy supply from unit and district scale systems for homes, businesses and industry could reach 232 PJ - as much as the entire electrical grid in year 2000 - by 2025

Energy Supply from Unit Scale Devices (E_{US})

Taking account of the various technologies for unit scale energy supply (pages 17 to 29), total unit scale supply (**E_{US}**) could be ~89 PJ:

	Totals (PJ's)	Heat	Electricity	Biomass (heat and electricity)
Industry	41	25	13	4
Residential	39	20	17	2
Commercial	9	7		2
Totals	89	52	30	8

In summary, a combination of solar, geoexchange and geothermal heating technologies would provide ~52 PJ for space and water heating solar PV would provide ~30 PJ of electrical energy in homes and businesses and smaller scale biomass co-generation and increased use of clean wood pellet burning stoves would provide ~8 PJ of space heating in homes and businesses (largely in rural British Columbia).

District Scale Energy Supply (E_{DS})

Energy supply potential from district systems (**E_{DS}**) as assessed on pages 33 to 38 is summarized below:

Totals (PJ's)	Heat	Electricity	Biomass (heat and electricity)
142.9	70	30.4	42.5

A significant expansion of district scale heating and electricity supply is envisioned in business and industrial parks based on micro-utility business models outlined on page 34 using a range of geothermal, biomass, geoexhange, and solar technologies. Increased use of the municipal waste stream and new partnerships between forest industries and local communities would expand district scale biomass energy generation to ~42.5 PJ.

Additionally, a number of smaller communities may be powered entirely from local renewable sources e.g. wave or tidal energy in some coastal communities.

Net Aggregate Demand (E_{Net}) = 948 PJ

Referring to page 17, the net aggregate energy demand of all unit and district scale systems is calculated to be ~948 PJ:

$$\mathbf{E}_{Net} = \mathbf{E}_T\ (1{,}173) - \mathbf{E}_{US}\ (89) - \mathbf{E}_{DS}(142.9)$$

This must be met through large-scale energy systems. Traditional energy supply technologies would meet this large-scale demand:

E_{Net}	Gas	Electricity	Oil and Coal	Biomass
948	155	240	309	244

Large-Scale Supply

$\mathbf{E}_{Net}$ can be met from indigenous renewables and fossil fuels. It is also theoretically possible to meet demand entirely from renewables (see inset chart – total renewable potential is ~918 PJ). A massive shift to electricity and biofuels with attendant investments in plant and equipment would be necessary to realize this scenario. However, such investments would be offset to a significant degree by expanded natural gas exports (reduced domestic demand), and by large reductions in refined petroleum products imports. As well, the environmental and energy security benefits would be profound for all British Columbians. Even so, for some segments of the economy such shifts may be impractical (e.g. air transport would use ~90 PJ in 2025 for jet engines; changing to biofuels would require a global change in aircraft engine designs and fuelling infrastructure).

Renewable Energy Supply Potential

Solar	20
Geothermal	32
Wind	114
Hydro	280
Biomass Fuels	90
Biomass Heat & Electricity	345
Ocean	37
Total Potential	**918**

Units: PJ's

Two Major Challenges for a 100% Renewable System

Although sufficient energy could be produced, 35% of large-scale grid distributed electricity generation would come from intermittent sources (solar, wind and ocean). Ensuring grid stability and the availability of dispatchable power would then become a major challenge. The second challenge would be shortfall in fuels supply, particularly for transportation. As shown on page 48, some 274 PJ of petroleum products would be required in 2025 for B.C.'s transportation system. Biomass fuels potential is ~90PJ.

Natural energy sources are intermittent or location dependant. New approaches are needed to construct an energy supply system to harness renewables for electricity or fuel.

Intermittent Renewable Power Grid

Three key technologies are identified for a future British Columbia energy economy powered in large part by intermittent renewables like solar, wind and ocean energy: blended generation, large-scale energy storage and a "smart grid".

Blended Generation

Blended generation is based on the complementary nature of some renewables. For example, solar insolation is higher in the summer months, while wind energy tends to be higher in the winter season. A blend of the two sources can therefore deliver a more constant supply of energy year round than would be possible from either source alone.

Large-Scale Energy Storage Solutions

While blended generation would improve the performance of a renewable-energy dominated grid structure, intermittent energy sources require suitable energy storage facilities and/or non-intermittent energy sources to supply power when it is not available from intermittent sources. For British Columbia, the role of the existing dam system could be changed from base power supply to storage and power-shaping in order to allow the potential of intermittent renewables to be realized. In addition, there are a variety of other energy storage technologies[1] that could be used in district or large-scale systems:

ENERGY STORAGE TECHNOLOGIES	Cost / kW of Capacity Low	High	Discharge Period	Energy Storage Current[2]	(MW) Potential
Pumped Hydro	600	1,400	> 12 hrs	2,100	2,100
Compressed Air (in geologic formations)	425 - 500	1,000	Days	50 - 300	2,700
Superconducting Magnetic	300		5 hours	30	100 - 1000
Hydrogen Fuel Cell	500		As needed	0.2	100
Hydrogen	1,700		As needed	0.2	350
Flow Batteries	650	2,500	> 10 hrs	12	20 -100
NaS Batteries	259	2,500	~1 hour	0.3 - 6	20 -100

"Smart Grid"

A "smart grid" would be managed by computer-based, automated control systems to deliver quality power on demand. A smart grid would support the widespread integrated use of distributed generation from unit, district and large-scale renewables required by the Endless Energy scenario. It could also improve load control through "smart" appliances in homes and businesses. Standardized power and communications interfaces would allow interconnection of components, including energy supply sources, on a "plug and play" basis necessary for widespread adoption of plug-in hybrid vehicles (page 19).

1 - Data from various sources including; US DOE, Sandia National Labs, Electricity Storage Association
2 - Examples of some system types are in operation in at these scales

Fuels for Transportation

B.C.'s future transportation system would require ~274 PJ of fuel under the scenario described on page 48. A self-sufficient, sustainable energy economy would require this fuel to be produced either from renewable sources or clean non-renewables. Noting that at least ~90PJ of aviation fuel would continue to be supplied by petroleum based fuels.

Biofuels could potentially supply ~90 PJ of fuel on a sustainable basis (page 47). Other renewables in B.C. (page 48) are heavily weighted towards electricity generation, 274 PJ of which could be used to produce hydrogen for transportation. However, the energy inputs to produce hydrogen from electricity are presently 40 - 50% of the energy output (depending on the technology). This places an upper limit on hydrogen production from renewable electricity of ~164 PJ. This would be sufficient with biofuels production to meet nearly all of British Columbia's future transport fuel demand under an Endless Energy scenario. It would also be possible to meet demand from clean fuels such as gas or methanol using coal as the feedstock.

In either case, the Endless Energy 2025 self-sufficiency scenarios require that the vehicle fleet of the future would be very different from today, with a much larger role for public transit in major urban centres:

- Cars and light vehicles would be hybrids (burning hydrogen or methanol in ICE's or Fuel Cells), fully electric vehicles or Fuel Cell Vehicles running on hydrogen or methanol.
- Trucks and trains would be hybrids running on hydrogen or methanol, and public transit would be largely electric powered.

Endless Energy is achievable for British Columbia by 2025; either 100% renewable or in combination with clean fossil fuels.

CONCLUSION

The report seeks to provide a comprehensive, factual description of what it would mean to become a truly sustainable energy economy, achieving significant cuts to emissions estimated to be as much as 60% by 2025 over year 2000 levels.

Using British Columbia as a test case, it provides a comprehensive overview of how the Endless Energy model can translate the complex and often confusing array of issues pertaining to clean and renewable technology developments, energy conservation, regional economic growth patterns, changing energy prices/demand patterns, climate change issues, and consumer behavior into a clear set of energy futures options.

The report shows that an energy future for British Columbia based on renewable energy sources and conservation alone is achievable by 2025, and that a sustainable, self-sufficient energy economy can also be achieved in combination with clean fossil fuel technologies.

Moreover, the report shows that energy self sufficiency in British Columbia can be achieved without diminishing the quality of life our citizens have come to enjoy. Although there will be future changes in patterns of energy use and the technologies available to consumers, British Columbia could be self sufficient and to some extent insulated from potential shocks in the global energy economy.

Naturally, achieving a self sustaining energy future for British Columbia will hinge on policy and program decisions that will unfold over the coming years. Policy change was not within the ambit of the Endless Energy report and there are no policy recommendations in this report.

Nonetheless, the Endless Energy model provides a powerful, facts-based assessment tool that can be applied to any region or economy to assess the technological, economic and energy supply options available to that region or economy.

The report highlights the importance of decision making by municipalities – who to a large extent are the shapers of the built environment, building infrastructure, district-scale energy supply systems, and local transportation infrastructure.

The Endless Energy model also shows the importance of a systems approach to planning for a region's energy future, an approach that allows citizens, business and governments to work towards a common and clear end – energy self sufficiency for individual, businesses, municipalities, first nations and the Province as a whole.

The concept of energy self sufficiency for individual homes and businesses offers a pragmatic approach to energy preparedness against power outages caused by severe winter storms and other natural disasters.

For corporations and businesses, this report provides a clear and concise review of energy use and supply trends that will assist business planning and help maximize economic returns to shareholders. In particular, the Endless Energy model provides the insights needed to develop strategies for a more robust economy. By removing much of the uncertainties surrounding future energy supply and prices, the Endless Energy model provides a solid basis for developing public policies targeted towards sustainability.

Indeed, in applying the Endless Energy model to British Columbia, we gained a much better appreciation of technology development trends, anticipated economic and social demand factors, and the indigenous energy resources available to achieve self sufficiency.

This report has demonstrated that energy self sufficiency is possible in British Columbia, and likely could be possible in other jurisdictions. Getting to that stage will require significant regulatory and policy decisions, and the concerted efforts of both private and public sectors and of individual consumers.

To this end, the GLOBE Foundation presently will launch the next phase of the Endless Energy Project – namely a series of dialogues that will address the economic development and environmental implications of the Endless Energy model for people and industries, as well as provincial, state, municipal and national governments.

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