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The economics of residual fuel and fibre production on the B.C. coast

G.S. Nagle, M.R.C. Massie, G. Robinson
P. Oakley and G.H. Manning

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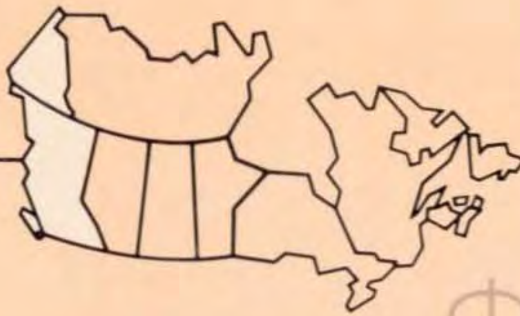

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The economics of residual fuel and fibre production on the B.C. coast

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Foreword

ENFOR is the acronym for the Canadian Government's ENergy from the FORest (ENergie de la FORêt) program of research and development aimed at securing the knowledge and technical competence to facilitate in the medium to long term a greatly increased contribution from forest biomass to our nation's primary energy production. This program is part of a much larger federal government initiative to promote the development and use of renewable energy as a means of reducing dependence on petroleum and other non-renewable energy sources.

The Canadian Forestry Service (CFS) administers the ENFOR Biomass Production program component which deals with such forest-oriented subjects as inventory, harvesting technology, silviculture and environmental impacts. (The other component, Biomass Conversion, deals with the technology of converting biomass to energy or fuels, and is administered by the Renewable Energy Branch of the Department of Energy, Mines and Resources). Most Biomass Production projects, although developed by CFS scientists in the light of ENFOR program objectives, are carried out under contract by forestry consultants and research specialists. Contractors are selected in accordance with science procurement tendering procedures of the Department of Supply and Services. For further information on the ENFOR Biomass Production program, contact...

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Abstract

The potential for a residual wood fibre industry on the B.C. coast was investigated using a simple model. The model includes the amount of residual fibre available, the cost of extracting and processing the fibre using ten different systems, the expected demand for that fibre in light of several oil price scenarios up to the year 2000, transportation costs, and other economic factors.

Under the conditions assumed in this study, there is a potential for a residual wood fibre industry on the B.C. coast. Such an industry could employ 300 to 570 people and could provide between $9 and $17 million in wages. The economic impact of such a new industry on the region is discussed.

Résumé

La possibilité d'implanter une industrie de fibres résiduelles de bois sur la côte de la Colombie-Britannique a été étudiée à l'aide d'un modèle simple, dont les variables comprennent les fibres résiduelles disponibles, le coût d'extraction et de traitement des fibres par 10 procédés différents, la demande prévue de fibres compte tenu de plusieurs scénarios pour le prix du pétrole jusqu'à l'an 2000, les coûts de transport et d'autres facteurs économiques.

Si les hypothèses avancées sont valables, il est possible d'implanter sur la côte de la Colombie-Britannique une industrie de fibres résiduelles de bois qui emploierait de 300 à 570 personnes dont l'enveloppe de paye totale pourrait varier entre 9 et 17 millions de dollars. L'impact économique d'une industrie de ce genre dans la région est discuté.

Preface

The analysis on which this report is based was initiated in 1983 and the consultants' report completed in March, 1985. A number of the assumptions used in the analysis are probably no longer valid, the most conspicuous of which is the range of oil prices specified in the various scenarios. The recent (1986) dramatic decline in the price of oil has made many price and economic forecasts obsolete overnight.

Whether these low oil prices continue for any significant amount of time, or whether they are a momentary anomaly on the upward spiral remains to be seen. The report should be read in light of these uncertainties.

Contents

Page

FOREWORD 3
ABSTRACT/RÉSUMÉ 4
PREFACE 4
INTRODUCTION 9
Background 9
Objectives 10
ADDITIONAL SOURCES OF FUEL AND FIBRE 10
Logging Residues 10
Ministry of Forests Waste Survey System 10
Additional Material from Current Log Flows 11
Residual Resource Summary 12
RECOVERY SYSTEMS AND COSTS 13
Systems Selected for Analysis 13
Costs of Operation of B.C. Coast Logging 16
Costs of Operation of Selected Systems 17
Yarding to Roadside 18
Processing Costs 18
Transport of Incremental Residual Materials 19
Summary Cost Analysis — System Base Cases 20
FUEL AND FIBRE DEMAND 20
Current (1985) Fuel and Fibre Balances and Prices 23
Fibre 23
Hog Fuel 24
Forecast Fuel and Fibre Balances and Prices 24
Energy Consumption in the Forest Industry 24
Energy Equivalent Value of Hog Fuel - A Forecast 24
Pulp and Raw Material Balances and Prices 26
FINANCIAL VIABILITY OF RESIDUE OPERATIONS 26
Operator Revenues versus Costs 26
Potential for a Residue Industry on the B.C. Coast 27
REGIONAL SUPPLY ESTIMATES 29
Regional Harvest and Transportation Patterns 29
Defining Regional Residual Fuel and Fibre Supply Industries 30
Supply Estimates for Three Major Zones of the B.C. Coast 32
REGIONAL ECONOMIC CONSIDERATIONS 35
Efficient Use of Forest Resources 35
Economic Prices and Costs 36
Potential Impact in the Economy of the Coast Region 37
REFERENCES 39
APPENDICES 40

Figures

Page

1. Primary extraction systems in use on the B.C. coast 11

2. Supply regions of the B.C. coast 14

3. Type and location of processors used to extract fibre from logging operations 16

4. Relationship of yarding cost to piece size in the Queen Charlotte Islands (high-cost region) and the South Coast Mainland (low-cost region) 19

5. Relationship of chipping cost to machine utilization 19

6. Total owning and operating costs of land transportation systems for residual materials 20

7. Total owning and operating costs of marine transportation systems for residual materials 20

8. Average and marginal Costs of system 1 (hog chipper in landing) 22

9. Average and marginal costs of system 2 (hog chipper in sortyard) 22

10. Average and marginal costs of system 3 (barker and chipper in sortyard) 22

11. Average and marginal costs of system 4 (landing shear for millyard chipper) 22

12. Average and marginal costs of system 5 (landing shear for millyard barker and chipper) 22

13. Average and marginal costs of System 6 (sortyard shear for millyard hog chipper) 22

14. Average and marginal costs of system 7 (sortyard shear for millyard barker and chipper) 23

15. Average and marginal costs of system 8 (marine barker and chipper) inaccessible regions 23

16. Average and marginal costs of system 9 (marine barker and chipper) accessible regions 23

17. Average and marginal costs of system 10 (barker and chipper in sortyard) inaccessible regions 23

18. Marginal and average costs and maximum and base average revenues of system 1 (hog chipper in landing) 27

19. Marginal and average costs and maximum and base revenues of system 2 (hog chipper in sortyard) 27

20. Marginal and average costs and base average revenues of system 3 (barker and chipper in sortyard) 27

21. Marginal and average costs and base average revenues of system 8 (marine barker and chipper) 27

22. Process flow for development of regional fibre supply curves 30

23. Location and relative wood requirements of pulp and paper mills on the B.C. coast 32

24 Location of weighted regional import centres for residual fibre on the B.C. coast 34

25. Development of a residual fuel and fibre industry on the south coast over time 35

26. Estimated supply of fuel and fibre from a residuals industry in the South Coast zone of B.C. 35

27. Estimated supply of fuel and fibre from a residuals industry in the West Coast Vancouver Island zone of B.C. 35

28. Estimated supply of fuel and fibre from a residuals industry on the North Coast zone of B.C. 35

29. Economic viability of a residue-based fuel and fibre industry on the South Coast zone of B.C. 37

Tables

Page

1. Summary by management unit of waste surveys, in the Vancouver Forest Region 12
2. B.C. Coast logging wastes, estimated volume by piece size, TSA's and TFL's 13
3. Estimates of extractable residual volume by region of the B.C. Coast 14
4. Estimated species distribution of residuals from old-growth logging by regions of the B.C. coast during the next decade 15
5. Estimated total extraction costs ($/m^3) of material delivered to the Fraser River or Howe Sound from each of the supply regions of the B.C. coast in 1983 17
6. Estimated base residual yarding costs by region 18
7. Break-even cost of whole-tree chipping at different levels of machine utilization 21
8. Disposition of the total roundwood harvest, on the B.C. coast during 1978/79 21
9. Heavy fuel oil price forecasts 25
10. Energy equivalent value of hog fuel 25
11. Energy equivalent value of hog fuel at various discount rates 26
12. Estimated marginal and average revenues for each system at different levels of utilization 28-29
13. Annual allowable cut in each region of the B.C. coast 31
14. Location, capacity, products and roundwood requirements of pulp and paper mills on the B.C. coast 31
15. Destination of pulpwood on the B.C. coast, by region of origin, volume, and distance travelled by mode of transportation 33
16. Allocation of salvage area by system and region on the B.C. coast 34
17. Expected operating levels of a residual fuel and fibre industry on the B.C. coast, 1986-2000 37
18. Annual economic impact of a residual fuel and fibre industry on the B.C. coast, 1986-2000 38

Introduction

Background

The Pacific forests of British Columbia (B.C.) yield a wide range of wood-based products which the coast forest industry ships as raw materials, semi-processed goods and final products for long distances over protected inland waterways. Because of this resource diversity, and low-cost transportation systems, the industry is highly integrated and many different products are derived from each hectare logged.

These product flows have included by-products and wastes from each stage of processing such as slabs, edgings, sawdust, and shavings from sawmills, clippings and sander dust from plymills, dissolved lignin from chemical pulp mills, and so on. Over time, wood "wastes" from various operations have gradually become resources within those operations or for other mills or industries.

Historically, wood-based fuels have played an important role within the forestry sector and in the economy of B.C. Fuelwood fired all initial mechanization of the logging industry from the turn of the century through to the end of railroad logging in the 1940s. Bark and other mill wastes generated steam for most of the mill power in the industry, long before power grids and gas lines were in place. In the cities, slabs, edgings and sawdust were important home fuels until the early 1950s.

All of these energy by-products were delivered and produced at practically no extra cost in the line of normal forest industry extraction and milling operations. Between 1930 and 1950, mill operators realized that clean, solid wood wastes were suitable for chipping to make raw material for chemical pulps. This led to the introduction of barkers at sawmills and the gradual withdrawal of nearly all clean solid wood from the "waste" or fuel stream into pulp production.

This development coincided with the widespread introduction of industrial petro-fuels and the expansion of hydroelectric generation and transmission in B.C. Steam power was gradually replaced with electrical or diesel power in the forest industry. Sawdust was similarly displaced in the household market by petroleum products and electricity. The large accumulations of nonmarketable woody by-products (sawdust, planer shavings, unsound and other miscellaneous wood and bark) were traded or disposed of within the industry as "hog fuel" to be burned for process heat, or often burned simply as the cheapest method of disposal.

In the 1960s and 1970s concern over air pollution caught up with disposal burners and they were phased out of important forest industry centers. Increasing quantities of hog fuel were consumed in boilers in the pulp and paper industry for process heat. A price gradually developed for this material, although it is still very low in relation to its full extraction cost.

As world market demand for forest products increased, the coast forest industry expanded its capacity. Logging costs began to climb rapidly. The value of pulpwood, including chips, increased. This generated a new interest in some kinds of sawdust as a pulp input in the coast industry.

As the fully integrated use of all woody materials (except possibly bark) appeared to be on the horizon in the mid 1970s, the petroleum crisis struck. Escalating petroleum energy costs injected an entirely new element into the wood/fibre utilization patterns on the B.C. coast. Forecasts of continually expanded demands for forest products, together with forecasts for continually rising prices for petroleum products, led to forecasts of serious near-term fuel/fibre scarcity on the B.C. coast. This increased interest in new sources of raw materials from the forest base. Since there were few unallocated forest areas or "greenfield" harvest rights, new material would have to come from more intense utilization of each hectare logged.

Over the past five years, governments and the forest industry have conducted extraction and processing trials aimed at deriving fuel and fibre from forest residuals. Their objective was to develop new, cost-effective systems to extract material from the forest floor which, under previous logging operations, had been left in place.

Most of this "new" material contained both solid wood suitable for pulp fibre and various other woody materials (such as bark) suitable for hog fuel. The type of material posed several technological challenges for extraction, processing and separation of the two basic product streams. Not surprisingly, these trials did not discover a lode of cheap raw materials for either energy or pulp fibre. However they did clarify the new margins and the new product mixes which might be expected in future.

The completion of a broad range of trials, together with the easing of the rises in petroleum prices, provided an opportunity for an economic study of the likely futures of residue-based fuel and fibre production on the B.C. coast. This report presents the results of that review and analysis.

This analysis is from a social perspective. Subsidies, taxes, and the tax status of the particular company are important considerations from the private perspective in determining financial feasibility, but because these are transfers rather than a real claim on economic resources, they are excluded from this analysis. From the public policy perspective this approach is justified because it is the investment's impact on the economy as a whole that is important, rather than the financial effects on a particular entity.

Objectives

The major objectives of the study were:

1. To describe the current wood-based fuel utilization patterns of the B.C. coast forest industries.

2. To describe the current pulp fibre utilization patterns of the coast forest industry including exports of raw fibre or chips.

3. To identify the forest biomass available for extraction.

4. To identify the marginal and average costs of extraction and processing associated with several systems of biomass extraction (systems for fuel only and fuel/fibre extraction).

5. To analyze the microeconomics of each defined extraction system.

6. To evaluate several regional supply/demand scenarios and assess the regional economic impact of various levels of incremental fuel/-fibre production on the B.C. coast.

Additional sources of fuel and fibre

Logging residues

The portion of the stand left behind after normal coast logging varies with a wide range of natural factors such as species, age of the stand, terrain and stand density. Engineering design and equipment factors, while also governed by the natural characteristics of the forest, also affect the portions of the stand remaining after logging. Figure 1 outlines the major primary extraction systems used on the B.C. Coast. The logging systems used have an impact on the proportion of the stand left behind and where the residuals are located.

Engineering design elements which affect forest residuals include the spacing of roads (which primarily affects the average yarding distance), the size and location of landings, the shape of settings (a higher proportion of residuals is left in long yarding corners), and so on.

The B.C. Forest Service has developed regulations governing the allowable residuals after logging on public lands. Logging residuals are measured on each major logged area and penalties may be assessed if these limits are exceeded. This regulatory effort provides the best available data source on logging residuals on the coast of B.C.

Ministry of forests waste survey system

In order to estimate fibre residues that could be used for hog fuel and/or pulp chips on coastal B.C., the computerized waste survey data base of the B.C. Forest Service, Vancouver Forest Region, was sampled and the data were analyzed.

The waste survey data are based on sample plots taken in logged settings in the Timber Supply Areas (TSA's) and Tree Farm Licenses (TFL's) in the region. These plots are taken in the "slash" and at the landings (grapple and high lead). In essence, the information shows the number of pieces and volume left after logging by species, piece size, type of material (log, slab, top, etc.), and other characteristics. The B.C. Forest Service uses the information to establish

TERRAIN	YARDING SYSTEM	TYPES	DESCRIPTION
STEEP & BROKEN	CABLE	Steel Spar	Steel mast to 120 ft tall; running cables reach 500-750 ft. in near circle around central spar (in landing at roadside); logs grasped by chokers set by chokermen in woods, cable lifted/dragged to landing
		Grapple Yarder	Track mounted short tower which walks along road; running cables can reach 300-500 ft depending on terrain and use of backhoe for tail-spar; logs grasped by large grapple controlled by machine operator, cable lifted/dragged to roadside
		Variants of above	Various skylines, towers using chokers or grapples; usually for long reaches, deep gullies
FLAT & ROLLING	SKIDDER	Track or Wheel Skidders	Machine drives close to logs; short cable reach, with or without very short tower; chokers or grapple used to grasp logs; machine drags to roadside landings

Figure 1. Primary extraction systems in use on the B.C. coast.

unrecovered wood volumes for adjusting stumpage charges related to utilization and for cut control purposes.

Additional material from current log flows

Traditionally the bulk of logs harvested from coastal forests in B.C. have been sorted and stored in water at some stage en route to mills. Rising logging costs and log values, together with a higher proportion of "risk" logs (small logs and sinkers), led to rising concern with water losses of logs. Increased concern regarding the environmental impact of log storage and handling in marine environments, including the costs and risks of water-borne debris, have also contributed to a gradual reduction in the total sorting and bundling operations executed in booming grounds, particularly in the south coast. Many sorting and bundling operations have shifted to "dryland-sort" yards.

The wood and bark waste problem did not disappear with this change, but merely shifted to a new location. In the typical sort yard, bark, branches, and broken pieces of wood mix with the dirt and gravel on the yard during mechanical handling of the logs. This debris steadily accumulates in the yard, creating a serious disposal problem.

A review of the problem (Smith 1977) indicated that the rough equivalent of 5 m^3 of debris is generated for each 100 m^3 of solid wood log volume handled in such yards. Assuming a normal 50% solid content for such material, perhaps 2.5 m^3 of wood, bark and dirt is thus accumulated. The breakdown of piece sizes in the study indicates that about 30% of the total debris (not including dirt) is in pieces 15 cm and larger. Assuming this material to be 60% recoverable wood and 40% unrecoverable wood and bark, there is 1.5 m^3 of recoverable fibre and 1 m^3 of hog fuel for each 100 m^3 passed through such a yard. Although this volume might not justify a processing facility, additional fuel and fibre from incremental woods operations could make the yard operation economic and enable the recovery of this material. A similar situation exists in all current marine operations. Losses to the marine environment continue, and a significant fraction could be recovered if barge-borne incremental recovery operations were in place.

Residual resource summary

The waste survey data obtained from the B.C. Forest Service was used to estimate residual volumes that had potential for use for either hog fuel or pulp chips under specified conditions. Detailed results are reported separately (Nawitka Renewable Resource Consultants 1984). All the TSA's and more than half of the TFL's in the region were sampled for the years 1981 and 1982. Sample size based on the number of plots taken in any one year for the five TSA's and the regional TFL's varied between 25 and 50%. In total the data analyzed reflected 636 plots (113 landing plots and 523 slash plots) on 97 settings or openings representing 2815 ha of logged area. (For total Forest Service waste survey statistics, see Table 1.)

In analyzing the data, particular attention was directed at the number of pieces and piece size, where they were located, the type of material (particularly "logs"), and species (i.e., "whitewood" indicating a potential for pulp). Potential volumes of residual fibre available by both size and type for all TSA's and TFL's are given in Table 2. This study concentrates on the large pieces which would have the lowest extraction costs.

In Table 3 the material which has the potential for the lowest extraction costs has been identified

Table 1. Summary by management unit of waste surveys in the Vancouver Forest Region[a/]

Regional management unit	Net area logged (ha)	Plots measured[b/]	Landings measured	Slash waste	Landing waste	Total waste
				------(m^3 per ha logged) ------		
1981						
Nootka	722.9	99	16	43.7	2.2	45.9
Kingcome	679.3	127	18	41.4	6.6	48.0
Soo	377.1	93	11	26.9	3.0	29.9
Quadra	1113.3	251	32	53.5	4.9	58.4
Fraser	1107.7	219	51	39.4	3.4	42.8
Regional TSA's	4000.3	789	128	43.3	4.1	47.4
Regional TFL's	3641.7	643	50	54.3	6.2	60.5
1982						
Nootka	454.5	73	14	34.5	1.8	36.3
Kingcome	893.4	151	24	40.4	3.2	43.6
Soo	262.9	44	7	33.4	2.5	35.9
Quadra	954.5	223	40	58.2	3.0	61.2
Fraser	863.3	172	36	25.5	3.0	28.5
Regional TSA's	3428.6	663	121	40.3	2.9	43.2
Regional TFL's	3249.6	649	97	62.1	7.9	70.0

a/ Unavoidable plus avoidable waste; for trees having a minimum 13 cm butt radius i.b. at 0.3 metre stump, to a top radius i.b. of 8 cm.

b/ Slash and grapple landing plots equal 0.04 ha, high lead landing plots average approx. 0.1 ha.

Source: Ministry of Forests, Vancouver Forest Region, Forest Waste Survey records, 1981 and 1982.

by supply regions (Figure 2). This "net" volume omits badly broken or deformed wood, some small pieces and some unavoidable waste (i.e., material in a physical situation dangerous or very difficult to remove). This table indicates the base estimates of raw material available for extraction and processing in each region.

Appendix 1 was used to derive area/volume relationships. These are summarized for both 1981 and 1982 in Appendix 2, which also reports a "general" waste figure (cut control) for the volume shown and an estimated species composition. Table 4 shows the estimated species composition of residuals from each supply region from old-growth logging in the next decade.

Recovery systems and costs

Systems selected for analysis

Systems included in this study were used in recent pilot trials under actual coast conditions. Such trials yielded usable productivity and cost estimates for extension to regional supply estimates. Two basic product streams were considered. The first is hog fuel only, where residual woody materials and bark are chipped or shredded without separation to form a fibrous fuel mass which can be fed into existing hog fuel boilers. The second major product stream involves removing the bark from the chipable wood frac-

Table 2. British Columbia coast logging waste[a/], estimated volume by piece size, TSA's and TFL's

	In logging slash							
	TFL's				TSA's			
Piece Length m	Total volume m^3/ha	Pieces	Piece size m^3		Total volume m^3/ha	Pieces	Piece size m^3	
1.0-2.9	6.12	22.56	0.27	0.32	5.13	16.61	0.31	0.34
3.0-4.9	17.25	51.02	0.34		10.94	31.32	0.35	
5.0-6.9	9.79	21.95	0.45	0.59	6.02	14.89	0.40	0.54
7.0+	11.17	13.62	0.82		6.38	7.94	0.80	
TOTAL VOLUME	44.33				28.47			

	In landings							
	TFL's				TSA's			
Piece Length m	Total volume m^3/ha	Pieces	Piece size m^3		Total volume m^3/ha	Pieces	Piece size m^3	
1.0-2.9	11.42	46.89	0.24	0.29	13.71	51.31	0.27	0.30
3.0-4.9	38.76	127.68	0.30		40.75	129.72	0.31	
5.0-6.9	29.94	62.71	0.48	0.56	32.97	66.59	0.50	0.68
7.0+	27.97	40.11	0.70		50.30	56.21	0.89	
TOTAL VOLUME	108.09				137.73			

[a/] Volume of logs and slabs, downed trees and treetops; B.C. Forest Service data, Vancouver Region

Source: Nawitka Renewable Resource Consultants.

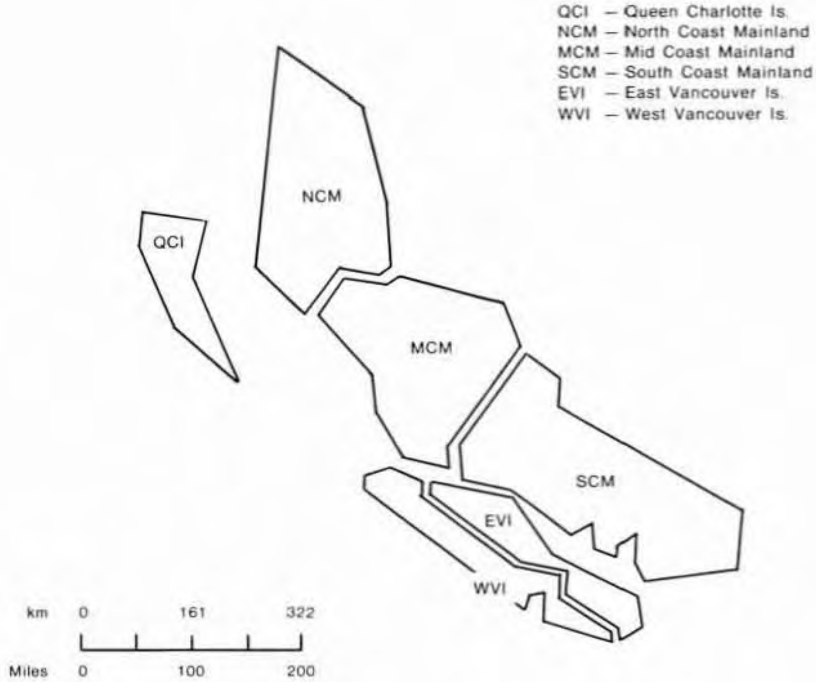


Figure 2. Supply regions of the B.C. coast.

Table 3. Estimates of extractable residual volume in regions of the B.C. Coast[a/]

Region	TFL's[b/] %	TSA's %	Slash volume Landings (m^3/ha)	Slash volume setting (m^3/ha)
Queen Charlotte Islands	80	20	114	42
North Coast Mainland	75	25	116	43
Mid-Coast Mainland	10	90	135	36
South Coast Mainland	20	80	132	33
East Vancouver Island	80	20	114	43
West Vancouver Island	85	15	113	43

a/ Estimated extractable wastes only. Vancouver Region Plots QCI, NCM, MCM estimated using like regions from Table 1.

b/ Derived from B.C. Forest Service statistics on productive forest land in TSA's and TFL's

Table 4. Estimated species distribution of residuals from old-growth logging by regions of the B.C. coast during the next decade

	REGION											
	QCI		NCM		MCM		SCM		EVI		WVI	
SPECIES	m^3/ha	%	m^3/ha	%	m^3/ha	%	m^3/ha	%	m^3/ha	%	m^3/ha	%
Fir	0	0	0	0	16	3	78	11	318	49	29	3
Cedar	185	34	148	27	210	33	164	23	60	9	266	31
Hemlock	210	39	243	45	227	36	252	35	216	33	388	45
Balsam	0	0	65	12	98	15	162	22	31	5	133	15
Spruce	110	20	44	8	32	5	8	1	2	0	13	2
Cypress	32	6	40	7	50	8	57	8	5	1	32	4
Lodgepole Pine	8	1	3	1	5	1	5	1	15	2	4	0
Total	545	100	543	100	638	100	725	100	647	100	865	100

Source: Nawitka estimates from B.C. Forest Service Inventory and 1981/82 residuals data.

tion of the residuals in order to generate clean, bark-free chips for pulp production, as well as a hog fuel fraction made up of bark and unsuitable or inseparable woody materials.

Technological progress in the utilization of barky chips in pulp production, or in the separation of bark from chips after primary processing, has not been adequate to change the conclusion that a product stream of mixed bark and chips was not feasible for pulp purposes (Economics Unit, PFRC 1977).

Forest residual processing equipment recently tested on the B.C. coast includes mobile chipping units which can process a wide range of material sizes in woods-landings or log-yards and blow hog fuel directly into trucks or other transporters. Without the ability to remove bark, all such units are classified as hog chippers in this study. Hog chippers may also be fixed to foundations in sort yards or mill yards enabling less costly operation and larger capacities.

Problems with handling, feeding and transporting woods-run forest residues led to efforts to develop mobile and fixed shearing equipment which would produce uniform piece sizes from the jumble of forest residues for easier loading, transportation and processing. Such shears can also be located in the landing or in various yards. When combined with a barker system (usually a drum type to handle this type of material), shears can be used in the production of the fibre and fuel product stream.

Various barkers have been used in forest residual trials on the coast of B.C. Ring and screw barkers may remove bark from uniform pieces by an action not unlike that of a pencil sharpener. Drum barkers gradually beat bark off small pieces tumbling inside the rotating drum. A wide range of processes and equipment is used for this purpose and each is described in the referenced trials.

A wide range of chippers is used to make uniform sized pulp chips from clean wood of various sizes. Mobile units can now handle whole logs up to medium size, while fixed units in yards can chip large pieces. The costs of various chipping operations on the B.C. coast are well established.

One new type of processor is included in the analysis. This is a "barge-mounted marine processor." It was designed and built by Crown Forest Industries Limited to generate chips and hog fuel from forest residuals in remote coastal locations.

The processor offers many of the advantages of a fixed yard system, while also offering mobility to a large number of coast locations where processors would likely be uneconomic as permanent fixtures.

The ten systems (Figure 3) selected for inclusion in this study were chosen on the basis of the product stream and on the location of the various combinations of the above types of processing equipment. This array of systems covers the most significant possibilities for the near-term future.

Costs of operation of B.C. coast logging

The history of B.C. coast logging shows increasing mechanization to handle large logs in steep terrain. Road construction costs are high, due to terrain, the high proportion of rock, and heavy rains. The cost of heavy equipment increased sharply in recent years. Crew accommodation and transport in remote locations is extremely expensive. Traditionally the high volumes and values per hectare have justified the economic reach farther and farther back into rugged coastal terrain. However, coast logging costs are currently assessed to be among the highest of any major forest region in the world (e.g., Jaako Poyry 1983; Woodbridge Reed 1984).

Most coastal logging equipment must be designed for the largest logs in the forest (a large Douglas-fir or spruce log may contain 10-15 m^3 of solid wood and weigh 8-12 tonnes). Equipment which will handle such logs is very badly suited to handle logs with less than 0.5 m^3.

Nonetheless average coast log size has been declining gradually for two decades and the number of very large pieces has been declining exponentially to where average piece size handled is about 1.1 m^3 in 1985. Many new machines are being designed to handle this new generation of log size. Grapple yarders, for example, are much better adapted to small piece size than are steel tower, high lead systems.

Also on the positive side, the protected inland waterways of the B.C. coast permit movement of logs and other forest products over long distances. A truck haul of 400 km (at say $0.12/$m^3$/km) would be impossible. But by log boom or barge at $0.011-$0.018/m^3/km on the coast waterway, such movements are eminently feasible. This enables greater regional integration of the forest industry on the B.C. coast than in most other regions of the world of comparable breadth.

Generalization is obviously risky when dealing with such a diverse resource in such variable terrain over such great distances. However in order to estimate the costs of extracting incremental fuel and fibre materials from the Pacific forest, some baselines must be estimated for current operations. Table 5 shows estimates of total extraction costs (for material delivered to the South Coast) for each of the supply regions. The vari-

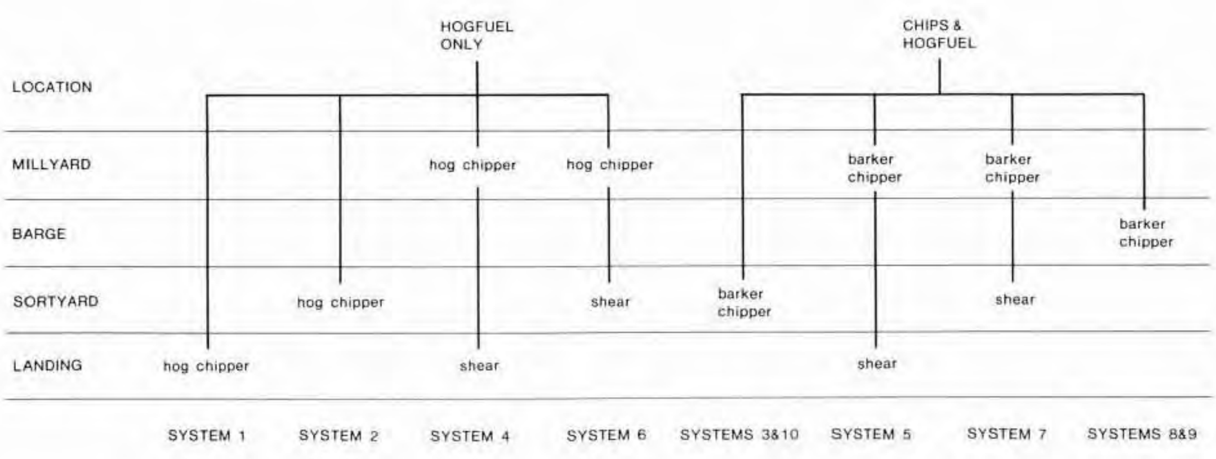


Figure 3. Type and location of processors used to extract fibre from logging operations.

Table 5. Estimated total extraction costs ($/m³) of material delivered to the Fraser River or Howe Sound from each of the supply regions of the B.C. coast in 1983[a/], by Region ($/m³)

ACTIVITY	REGION						Weighted average
	QCI	NCM	MCM	SCM	EVI	WVI	
Felling/Bucking	4.15	4.15	4.15	4.15	4.15	4.15	4.15
Yarding	7.50	7.50	7.50	7.10	7.40	7.50	7.37
Loading	3.55	3.55	3.55	3.45	3.45	3.50	3.49
Truck Haul	3.70	5.05	4.20	5.25	4.95	4.00	4.62
Road Maintenance	2.15	2.00	2.00	0.75	1.30	1.50	1.38
Sort & Boom	5.20	5.20	5.20	5.20	5.20	5.20	5.20
Marine Trans & Mkt	5.50	5.00	4.00	2.50	2.50	2.50	3.07
Roads & Engineering	6.00	5.00	5.00	2.00	4.00	4.00	3.79
Camp & Crew Transport	17.80	12.50	12.50	3.15	5.55	5.55	7.00
Stumpage, Profit & Risk	11.60	10.90	10.90	8.90	10.30	10.30	10.13
TOTAL DEL. COST/m³	67.15	60.85	59.00	42.45	48.80	48.20	50.20

[a/] Overheads included on all activities except stumpage, royalty, profit and risk.

Source: Derived from B.C. Forest Service, FERIC, and Nawitka studies.

ance shown, from $42/m³ in the South Coast Mainland region to $67/m³ in the Queen Charlotte Islands region, reflect higher costs of maintaining crews and equipment in increasingly remote locations. Obviously these estimated averages do not define the full range of logging costs which is probably more like $25-$75/m³. However, the table shows that the cost of extracting residuals will depend on their location as well as on the extraction and processing technology used.

Since the prospective fuel and fibre operations will be incremental in nature, not all of the costs shown in Table 5 need apply to this extra volume. Specifically, the cost of stumpage, roads and engineering, road maintenance and felling and bucking are largely inapplicable to the incremental supply of forest residual materials. Camp and crew transport costs have been apportioned to defined residual operations in relation to their proportion of the total field operations. Specific operating costs have been estimated for yarding, loading, hauling, marine transport and processing as outlined in the following section for each of the ten residual supply systems.

Costs of operation of selected systems

Three principal types of activity are involved in each system: movement of the residual pieces to roadside, processing the pieces into usable form (one or more processes at various locations), and transportation activities from the landing in the woods to a final utilization center. The cost of each activity is governed by variables which can be quantified for various conditions.

For example, in yarding to roadside one of the prime variables is piece size, given the normal equipment mix for the regular logging operation. The unit costs of processing depend on the degree of utilization of the processing machinery (the proportion of its time that is spent in actual processing work as opposed to waiting for raw material or moving from location to location). Handling costs with different processors and the type of power available at each site can also effect these costs. Unit transport costs depend most heavily on whether the material is transported by land or by water and the distance the material is moved. Each of these costs will vary with the region of source of the residuals and the region of destination or use.

Yarding to roadside

Regional variation—Table 6 shows the estimated base yarding cost (roughly 1.1 m^3 piece-size) for each supply region. The normal yarding cost for each region has had a camp cost factor added to it to cover the extra costs of supporting the manpower involved in these incremental operations. These costs add only 10-15% to the production yarding costs in the more accessible southern regions, but add 25-33% to costs in the upper coast regions.

These yarding cost estimates provide a base from which to estimate the impact of piece size on yarding cost for actual residual materials in each region.

Variation with piece size—Using normal coast cable logging equipment, the unit cost of yarding rises very steeply as piece size declines. Since the average costs per "turn" (return trip to the roadside of the butt rigging or grapple) are relatively fixed, the cost per unit of yarding is dependent mainly on the volume of logs brought in with each turn. The relationship has been studied in many cable logging operations, and is typified by that shown in Withycombe (1979). The relationship established in that study has been updated and translated to B.C. coast conditions.

The average size of the largest residual pieces under 1981/82 coast conditions as derived in Table 2 is also shown in the table, together with the estimated cost of yarding such a piece to roadside in each region. These estimates form the basis for the yarding costs as appropriate in each simulated operation of systems 1 to 10.

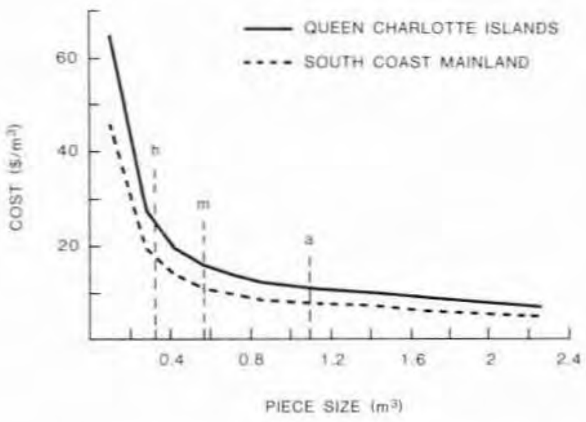
Figure 4 shows the relationship of yarding cost to piece size and the spread between the highest-cost region and the lowest-cost region.

Processing costs

The costs of processing in each relevant operation — shearing residual pieces, barking and chipping (fibre or hog) — were estimated for each system. Each unit processing cost estimate assumes an efficient level of utilization of the particular machine. The importance of this factor can be seen in Figure 5 and Table 7. These particular figures

Table 6. Estimated base residual yarding cost by region ($/$m^3$)

	Region					
	QCI	NCM	MCM	SCM	EVI	WVI
Logging activity costs only	$37.75	$37.45	$35.60	$30.40	$32.95	$32.35
Yarding cost share (%)	019.9	020.0	021.1	023.4	022.5	023.2
Yarding share camp cost	$3.54	$2.50	$2.63	$0.74	$1.25	$1.29
Residual base yarding cost	$11.04	$10.00	$10.13	$7.84	$8.65	$8.79



h – AVERAGE SIZE OF INCREMENTAL PIECES TO GET FROM MEDIUM TO HIGH RESIDUE UTILIZATION

m – AVERAGE PIECE SIZE TO MEDIUM RESIDUE UTILIZATION

a – AVERAGE PIECE SIZE NORMAL LOGGING, B.C. COAST

Figure 4. Relationship of yarding cost to piece size in the Queen Charlotte Islands (high-cost region) and the South Coast Mainland (low-cost region).

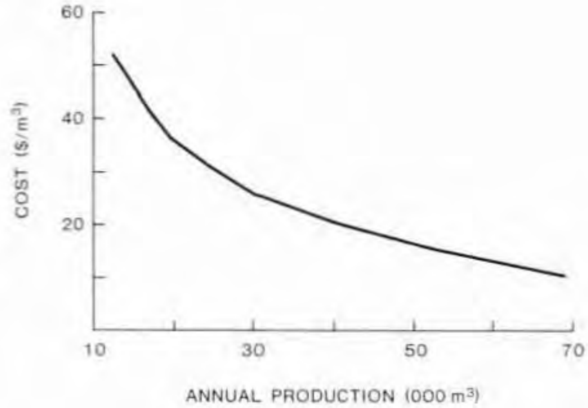


Figure 5. Relationship of chipping cost to machine utilization.

show the cost of chipping relatively long, straight pieces with one type of machine. A similar relationship exists for each of the defined systems — the machine and labor costs are relatively fixed, and the unit cost of production depends heavily on annual output.

The range of the costs shown in Figure 5 approximates the range of the estimated processing costs in the ten systems. Yard chippers can process residual materials for $10-$12/m³, while landing chippers generally cost more than $25/m³. The principal differences between these operations are the moving and set-up costs of the mobile landing chippers, the differing ability to feed the machine in each landing, and other factors which tend to depress annual output per machine.

Transport of incremental residual materials

British Columbia coast loggers have been on the technological frontier of truck-hauling of logs since the 1950's. Larger more powerful trucks with improved brakes have been continuously developed throughout the period. Improved tires, more fuel-efficient engines, improved loading and unloading systems and many other developments have been developed or have had their first trials on the B.C. coast. Although much of the technology is directly relevant to transporting residual materials, significant variation and modifications are also essential. The loading and handling of these smaller, generally more variable sized materials creates special problems. The normal long bunks used to transport full length logs are not well suited to residual transport, except in cases where residual materials can be added to the top of normal log loads.

Each of the described trials which form the basis for the selected systems used slightly different truck hauling methods. Chip vans, garbage bin vans, large gravel trucks and other similar configurations were used. Figure 6 shows the general range of these costs by type of system and distance.

Tugboat and marine transport operators in B.C. have also been among the leading innovators of the logging world for decades. A wide range of technologies varying from particular types of log raft and connectors to freighter-sized self-loading and self-dumping log barges have been developed in B.C. to transport logs up to 500 miles on the inland sea.

Residual materials create serious problems in normal log boom traffic. The rate of loss is high, and the problems in handling the normal logs are increased. Therefore only the attached residual material or the largest pieces can be transported in this manner. In general, containment within

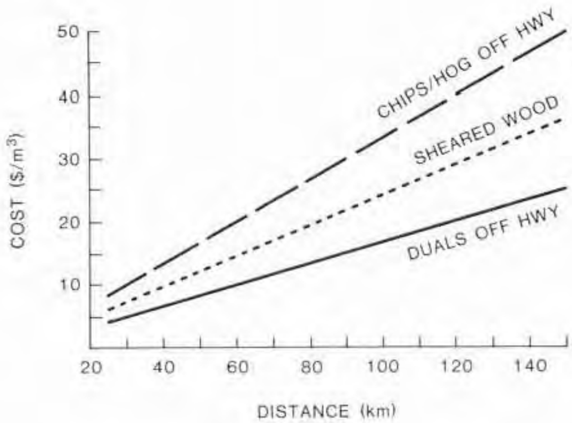


Figure 6. Total owning and operating costs of land transportation systems for residual materials.

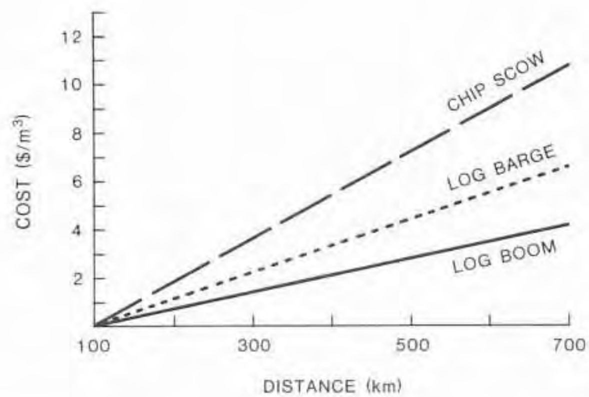


Figure 7. Total owning and operating costs of marine transportation systems for residual materials.

barges or scows is required for most residual materials. Figure 7 shows the range of marine transport costs estimated for different types of residual materials on different marine transport systems.

Summary cost analysis — system base cases

In order to develop a picture of each residual fuel and integrated fuel/fibre system as a "supplier," a base case has been developed for each as though an owner-operator held all rights to residual harvesting on 1000 ha of normal coast logging activity.

The base case assumes that 80% of the logged area was harvested using field tower cable systems, and 20% using grapple yarder systems. The base cases also assume residual volumes and transport distances equivalent to a roughly equal merger of South Coast Mainland and East Vancouver Island conditions. Figures 8 through 17 show the expected marginal and average cost of extraction and processing of the residuals for each system.

These simulated "suppliers" of fibre and hog fuel from forest residuals form the basis of the regional supply estimates developed later. However, before that stage, the financial and economic viability of each potential supplier must be investigated. This, of course, requires an analysis of projected demand and price for each product stream.

Fuel and fibre demand

The coastal forest industry of B.C. is entering a period of dynamic change. Some of the more important factors are high and rising raw material (log) cost, rapidly changing mill technology, increasing production of lumber in other areas closer to the traditional markets, the possibility of U.S. restrictions on forest product imports from Canada, and economic uncertainty throughout North America. Several recent reviews have attempted to deal with some of the more important issues (e.g., Woodbridge Reed and Associates Ltd. 1984; Nilsson 1985).

Although many of the problems and issues present serious challenges to the coast forest industry, we do not expect drastic shifts in the coast industry or its utilization pattern in the next decade. Many of the problems are not new. Most of the important problems are market-related and beyond the control of the industry. Change will likely be incremental and very much in line with traditional patterns. During the last peak period (1978-79) the disposition of the wood harvest on the B.C. coast resembled that shown in Table 8.

In 1978/79 both the pulp and paper and wood product segments of the industry were working at close to capacity. The coast industry at that time produced over 4800 million fbm of lumber

Table 7. Break-even cost of whole-tree chipping at different levels of machine utilization

Annual production[a/] (000 Green T)	Cost[a/] 1979 US $ per green T	Annual production (000 m³)	Cost[b/] 1985 Can $ per m³
61	5.00	69	10.40
46	7.50	52	15.60
35	10.00	40	20.80
26.5	12.50	30	26.00
21.5	15.00	24	31.20
17.3	17.50	20	36.40
15	20.00	17	41.60
13	22.50	15	46.79
11	25.00	12	51.99

a/ University of Washington, 1979
b/ Nawitka updated estimate

Table 8. Disposition of the total roundwood harvest on the B.C. coast during 1978/79

Product	Volume (000 Solid m³)	Proportion of total
Lumber and timbers	8400	0.268
Plywood	1030	0.033
Shingles and Shakes	660	0.021
Groundwood blocks	2560	0.082
Pulp chips	10 400	0.332
Hog fuel (sawdust, planer shavings, misc. wood, bark)	8300	0.265
TOTAL (Incl. bark)	31 350	1

Source: Nawitka estimates

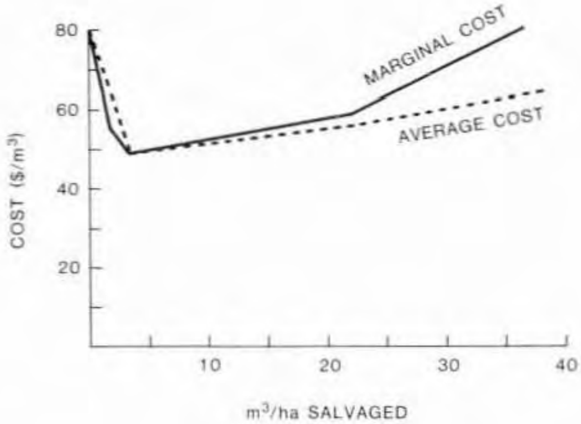


Figure 8. Average and marginal Costs of system 1 (hog chipper in landing).

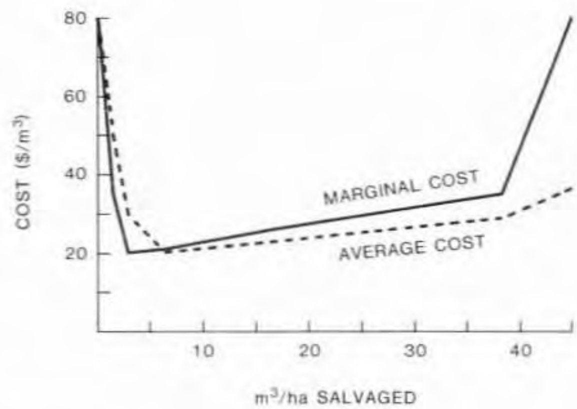


Figure 9. Average and marginal costs of system 2 (hog chipper in sortyard).

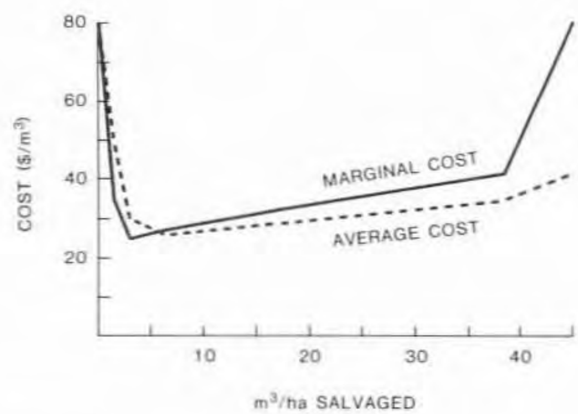


Figure 10. Average and marginal costs of system 3 (barker and chipper in sortyard).

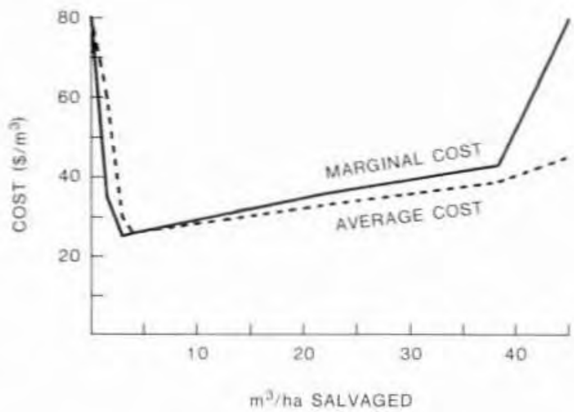


Figure 11. Average and marginal costs of system 4 (landing shear for millyard chipper).

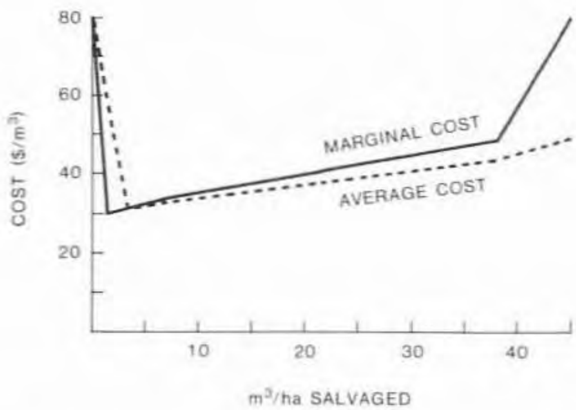


Figure 12. Average and marginal costs of system 5 (landing shear for millyard barker and chipper).

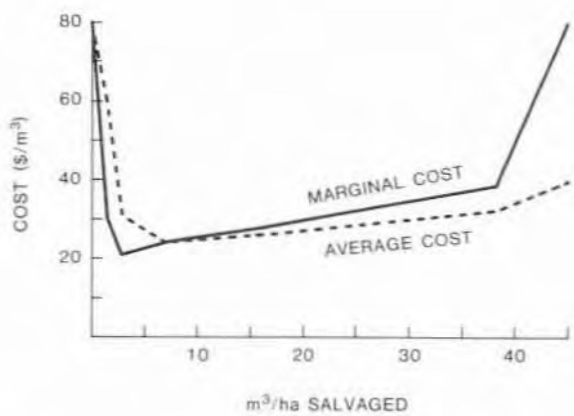


Figure 13. Average and marginal costs of System 6 (sortyard shear for millyard hog chipper).

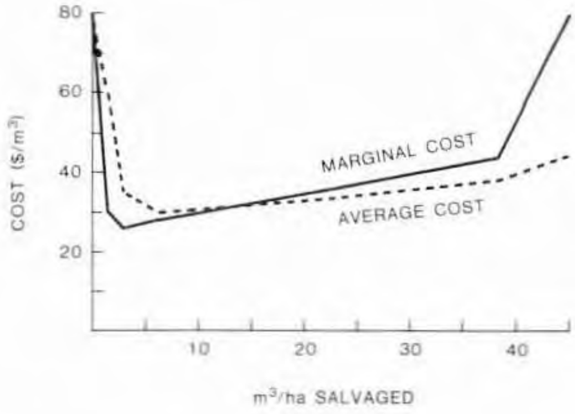


Figure 14. Average and marginal costs of system 7 (sortyard shear for millyard barker and chipper).

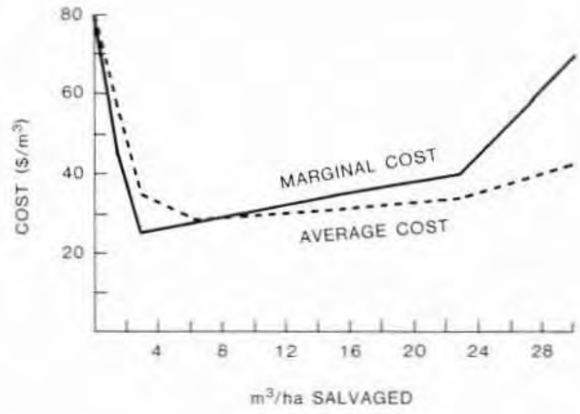


Figure 16. Average and marginal costs of system 9 (marine barker and chipper) accessible regions.

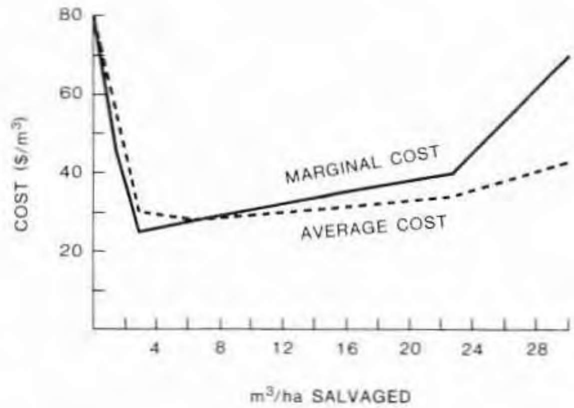


Figure 15. Average and marginal costs of system 8 (marine barker and chipper) inaccessible regions.

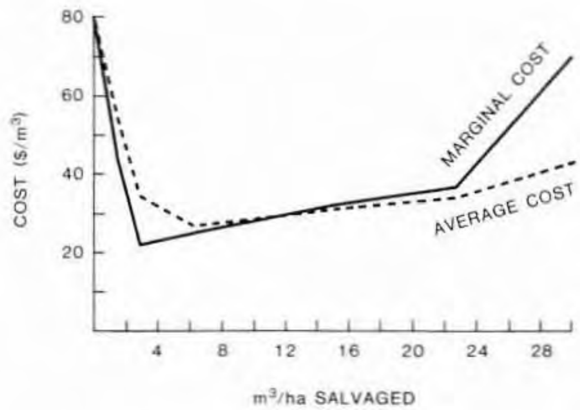


Figure 17. Average and marginal costs of system 10 (barker and chipper in sortyard) inaccessible regions.

per annum, 3.5 million squares of cedar shakes/shingles, about 1.4 million sq. ft. (3/8) of plywood, and about 1.4 million tonnes of market pulps. All of this was produced at prices which were generally profitable to the industry. Before turning to forecast balances and prices, it will be useful to review the situation in 1985.

Current (1985) fuel and fibre balances and prices

Fibre

A reduction in output in the wood products industry of the coast due to weak markets for lumber and plywood has led to a decline in the total production of chips and hog fuel available from this segment of the industry in 1984/85. The total coast harvest has declined 13% from the peak of 1978. A higher proportion of the total log harvest is being barked and chipped directly in roundwood form. Log exports are up, particularly to Japan and China.

The coastal fibre balance has been largely maintained by imports of whitewood chips from the booming sawmill industry of interior B.C. Some of these chips are also being exported to off-shore markets. The current (1985) price of whitewood chips in coastal markets is about $58 per volumetric unit, or $28.50 per solid cubic metre of wood. Douglas-fir chips usually bring about \$2.50 less per volumetric unit or about \$27.25 per solid cubic metre. On the export market, whitewood chips bring US \$85 per bone dry unit, or about \$43.40 per cubic metre of solid wood.

Production of other fibre products is almost insignificant in the B.C. coast industry. Flakeboard, fibreboard and other wood-based panels used an insignificant fraction of the total available fibre.

Hog fuel

Although wood waste burner capacity has been rising in the B.C. coast forest industry in recent years (McDaniels 1982; Robinson 1985). The current supply/demand balance is depressing hog fuel prices. Large volumes can currently (1985) be purchased for \$3.50 per volumetric unit, or about \$1.75 per cubic metre of solid material (miscellaneous wood, sawdust, shavings and bark). A more normal price level for this material is about \$10 per volumetric unit. During various short-run imbalances on the supply side the price can rise significantly. For example, during the period of construction of the major approaches to a new bridge in Vancouver, large volumes of hog fuel were demanded for fill. Spot prices at times rose \$20 per volumetric unit. The following section is an economic analysis of hog fuel values in terms of energy replacement cost and a forecast of these values.

Forecast fuel and fibre balances and prices

Energy consumption in the forest industry

The forest industry in B.C. accounts for approximately 80% of total industrial energy consumption (British Columbia, Ministry of Energy, Mines and Petroleum Resources, 1980). The pulp and paper sector accounts for most of this. Pulp and paper mills are able to generate a substantial proportion of their energy internally by burning waste liquors. However, the mills collectively are the largest consumers of fossil fuels in C. Heavy fuel oil (HFO) is the major fossil fuel utilized by the coastal forest industry. McDaniels (1982) estimated that the total pulp and paper industry could use an additional 5 million m^3 of hog fuel annually to replace HFO by 1990. This rate of growth in consumption would create local scarcities on the B.C. coast.

Energy equivalent value of hog fuel — A forecast

The energy equivalent value of hog fuel is defined here as the maximum imputed value of hog fuel assuming it is displacing heavy fuel oil after taking into account differences in boiler efficiencies and capital charges. The first step in estimating the energy equivalent value of hog fuel is to forecast the price of HFO.

The price of heavy fuel oil delivered to the mill averaged \$170/m^3 (\$27.00/BBL) during 1983. The fuel is purchased from lower mainland refiners. The price fluctuates in relation to general market conditions, the volume of the sale, and the cost of crude oil. The demand for HFO on the coast has declined in recent years with the conversion to hog fuel by the coastal pulp mills and the closure of the cement plant at Bamberton on Vancouver Island. Local refiners have reduced their HFO production in response. For the purposes of this study, we have adopted a low and high HFO price forecast. For a sensitivity analysis, a forecast that assumes a short-term supply disruption is also formulated. In the low price forecast, the price of HFO delivered to the mill remains constant in real terms at \$170/m^3 to 1986, then escalates at 0.50% per year to 2004. In the higher price forecast, a constant price to 1986 is again assumed with real price escalation of 2% per year thereafter.

The sensitivity scenario has no real growth to 1986 and then real price escalation of 20% in one year. This price shock is similar in magnitude to the price shock of 1979/80 in which the world crude price jumped from US \$28.50/BBL to US \$36.50/BBL. Following the price shock, the HFO price declines at an annual average rate of 2% until it equals the high price forecast. The three price forecasts are presented in Table 9.

The energy equivalent value of hog fuel is related to the cost of HFO, the moisture content and energy content of the wood, the respective boiler efficiencies, and the cost of utilizing the hog fuel. We have estimated the energy equivalent value of hog fuel from two perspectives. The first assumes no incremental costs of using additional hog fuel. This value would be relevant to relative-

Table 9. Heavy fuel oil price forecasts (constant 1984 Canadian dollars)

Year	Price scenario Low ($/m³)	High ($/m³)	Shock ($/m³)
1984	170.00	170.00	170.00
1985	170.00	170.00	170.00
1986	170.85	173.40	204.00
1987	171.70	176.90	199.90
1988	172.60	180.40	195.90
1989	173.40	184.00	192.00
1990	174.30	187.70	188.20
1991	175.20	191.40	191.40
1992	176.00	195.30	195.30
1993	176.90	199.20	199.20
1994	177.80	203.20	203.20
1995	178.70	207.20	207.20
1996	179.60	211.40	211.40
1997	180.50	215.60	215.60
1998	181.40	219.90	219.90
1999	182.30	224.30	224.30
2000	183.20	228.80	228.80
2001	184.10	233.40	233.40
2002	185.00	238.00	238.00
2003	186.00	242.80	242.80
2004	186.90	247.70	247.70

Table 10. Energy equivalent value ($/volumetric unit) of hog fuel (constant 1984 Canadian dollars)

Year	HFO Price scenario Low	High	Shock
1984	45.73	45.73	45.73
1985	45.73	45.73	45.73
1986	45.96	46.64	54.88
1987	46.19	47.59	53.77
1988	46.43	48.53	52.70
1989	46.64	49.50	51.65
1990	46.89	50.49	50.63
1991	47.13	51.49	51.49
1992	47.34	52.54	52.54
1993	47.59	53.59	53.59
1994	47.83	54.66	54.66
1995	48.07	55.74	55.74
1996	48.31	56.87	56.87
1997	48.55	58.00	58.00
1998	48.80	59.15	59.15
1999	49.04	60.34	60.34
2000	49.28	61.55	61.55
2001	49.52	62.78	62.78
2002	49.77	64.02	64.02
2003	50.03	65.31	65.31
2004	50.28	66.63	66.63

ly small volumes of hog fuel used to displace HFO assuming no incremental capital cost is required. The second method expresses the energy equivalent value of hog fuel assuming the construction of a new boiler.

The energy equivalent value of hog fuel, assuming no incremental capital costs, is presented in Table 10 for the three price scenarios. Given the low HFO price forecast, the energy equivalent value of hog fuel remains in the order of $45-$50 per volumetric unit over the forecast period. The high HFO price forecast implies an energy equivalent value of $45 per volumetric unit in 1984 increasing to nearly $67 per volumetric unit by 2004. Given the shock forecast, the value of hog fuel reaches nearly $55 per volumetric unit in 1986, then declines slowly through 1990 before rising again.

The energy equivalent value of hog fuel, assuming the construction of new boilers, is less than the imputed value presented above. This is because of the significant capital costs involved in constructing the new facilities. The energy equivalent value of hog fuel for the three price scenarios is presented in Table 11 for a range of discount rates. Long-range bond yields, and recent proposals for inflation-indexed mortgages, suggest a real discount rate from the private perspective of about 4%. In this case, the maximum energy equivalent value of hog fuel could reach $26 per volumetric unit.

One of the major uncertainties in forecasting the future petroleum replacement values of hog fuel and the regional economic impacts is government policy regarding the supply of natural gas to Vancouver Island and other coast forest industry centers. An aggressive policy of construction subsidy and gas pricing could significantly alter the energy balances of the coast forest industry and

Table 11. Energy equivalent value ($/volumetric unit) of hog fuel at various discount rates (constant 1984 Canadian dollars)

Real discount rate	HFO Price scenario		
	Low	High	Shock
0	25.26	33.25	34.34
0.01	23.49	31.21	32.40
0.02	21.62	29.09	30.37
0.03	19.66	26.88	28.25
0.04	17.60	24.58	26.05
0.05	15.47	22.21	23.77
0.06	13.25	19.76	21.42
0.07	10.95	17.23	18.99
0.08	8.57	14.64	16.50
0.09	6.13	11.98	13.95
0.10	3.62	9.28	11.34

likely make the incremental use of forest-based residuals uneconomic as fuels for the foreseeable future.

Pulp and raw material balances and prices

The coast pulp and paper industry may be on the verge of major structural change. Some analysts (e.g. Nilsson 1985) have forecast the closing of some facilities. Some mills have already reduced production. It is beyond the scope of this study to attempt to forecast the outcome of these events in detail. It seems unlikely that any decline in demand for pulp chips in relation to supply will occur. In Scandinavia and parts of the U.S. where supply/demand has tightened over time, the price of chips from any source comes to approximate the cost of round pulpwood. Woodbridge, Reed and Associates Ltd. (1984) have forecast that the real cost of softwood residuals in B.C. will continue to rise, and that by 1990 chips will command a price of $40 per solid cubic metre.

For the purposes of analysis of the prospects of individual forest residue chip suppliers and a regional industry of this sort, a value of $\$40/m^3$ is treated as a maximum and $\$30/m^3$ as a working minimum price for the clean chip fraction of the production.

Financial viability of residue operations

Operator revenues versus costs

Using the base production cases, the microeconomics of such operations can be analyzed under different price scenarios for fuel and fibre. Each operator would be unable to affect the market price for either fuel or fibre, and therefore a horizontal price line would represent the market supply and demand faced in any period. The level of the line would reflect the price of fuel and of fibre products in the period, and the proportion of each which this system could produce.

The proportion of fuel and fibre likely would vary with the degree of residue utilization. With smaller pieces (recovered at the high end of the utilization spectrum) the fraction of recoverable clean chips would probably be lower, and therefore the average revenue from this portion of the incremental material would be lower, than that from the larger pieces (recovered at the medium utilization level). Table 12 shows the estimated marginal and average revenues at each level of utilization for each of the systems examined using a combined East Vancouver Island and South Coast Mainland region species composition.

A few examples of the likely financial viability of different operations will clarify the approach taken in developing regional supply estimates.

System 1 (hog chipper in the landing) is unlikely to be economic at any probable value of hog fuel (Figure 18). The base average revenue line shown is that implied by a 4% rate of return being adequate for all investments in wood energy utilization equipment. The maximum average revenue line shows the value to a user with a burner system in place (paid for or sunk cost) under oil-shock conditions.

System 2 (hog chipper in sortyard) is also only marginally economic, showing a loss even on its lowest cost outputs, at $\$13/m^3$ (Figure 19). If a lower cost of capital were appropriate or if the purchasing company already had a boiler paid for and in place, the price could be driven up as high as $25 in a short-run energy shock (Table 10),

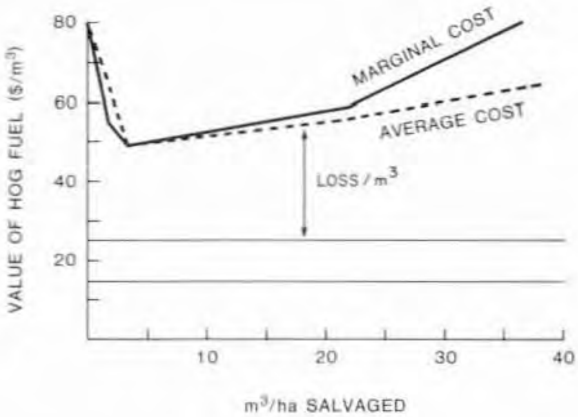


Figure 18. Marginal and average costs and maximum and base average revenues of system 1 (hog chipper in landing).

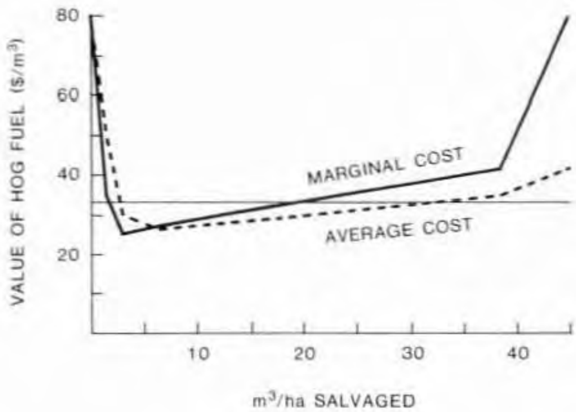


Figure 20. Marginal and average costs and base average revenues of system 3 (barker and chipper in sortyard).

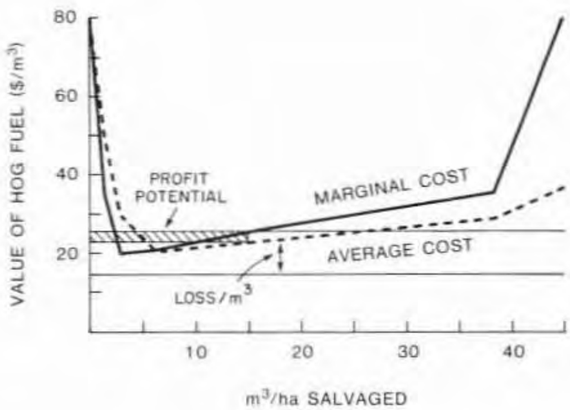


Figure 19. Marginal and average costs and maximum and base revenues of system 2 (hog chipper in sortyard).

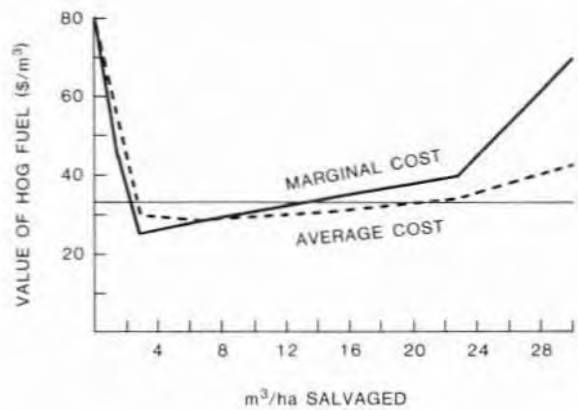


Figure 21. Marginal and average costs and base average revenues of system 8 (marine barker and chipper).

depending on the bargaining power of the residue supply industry.

System 3 (barker and chipper in a sortyard) (Figure 20) produces both chips for pulp and hog fuel. If the price of chips were $40/m³ and the value of hog fuel $13/m³, and the product proportions chips:hog was 70:30, the average product price faced by this operator would be $31.90/m³. Such a price would give operators of this system some latitude for profitable production.

Figure 21 portrays a similar situation for a marine-based system producing chips and hog fuel under the same price conditions.

Potential for a residue industry on the B.C. coast

Using the criterion that a successful industry is made up of profitable firms, there is potential for a new type of industry on the B.C. coast to produce fuel and fibre products from logging residuals. Although current prices do not provide much encouragement, price forecasts for the early 1990s indicate that it is not too early to begin

Table 12. Estimated marginal and average revenues for each system at different levels of utilization

		SYSTEM 1				SYSTEM 2			
Utilization Level		Landing	Low	Medium	High	Landing	Low	Medium	High
Proportion Chip Recovery		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	VALUE								
Fir Chips	$37.50	0	0	0	0	0	0	0	0
Whitewood Chips	40.00	0	0	0	0	0	0	0	0
Cedar Chips	19.00	0	0	0	0	0	0	0	0
HW Chips	19.00	0	0	0	0	0	0	0	0
Total Chips		0	0	0	0	0	0	0	0
Hog Fuel Value	$13.00	$3,392	0	$18,472	$16,527	$3,392	$2,917	$16,527	$15,555
		Scenario	1+2	1 to 3	1 to 4				
Marginal Revenue		$13.00	$0.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00
Average Revenue			$13.00	$13.00	$13.00		$13.00	$13.00	$13.00
Gross Revenue/Level		$44,091	0	$240,133	$214,586	$44,091	$37,916	$214,856	$202,218
Total Rev All Levels		$499,080				$499,080			

		SYSTEM 3				SYSTEM 4			
Utilization Level		Landing	Low	Medium	High	Landing	Low	Medium	High
Proportion Chip Recovery		0.65	0.90	0.65	0.40	0.00	0.00	0.00	0.00
	VALUE								
Fir Chips	$37.50	661	787	3223	1867	0	0	0	0
Whitewood Chips	40.00	1168	1391	5694	3298	0	0	0	0
Cedar Chips	19.00	353	420	1719	996	0	0	0	0
HW Chips	19.00	22	26	107	62	0	0	0	0
Total Chips		2205	2625	10743	6222	0	0	0	0
Hog Fuel Value	$13.00	$1,187	$292	$5,785	$9,333	$3,392	0	$18,472	$16,527
Marginal Revenue		$27.24	$33.41	$27.74	$22.07	$13.00	$0.00	$13.00	$13.00
Average Revenue			$30.36	$28.47	$25.88		$13.00	$13.00	$13.00
Gross Revenue/Level		$94,090	$97,449	$458,503	$343,334	$44,091	0	$240,133	$214,856
Total Rev All Levels		$993,377				$499,080			

		SYSTEM 5				SYSTEM 6			
Utilization Level		Landing	Low	Medium	High	Landing	Low	Medium	High
Proportion Chip Recovery		0.65	0.90	0.65	0.40	0.00	0.00	0.00	0.00
	VALUE								
Fir Chips	$37.50	661	0	3602	1983	0	0	0	0
Whitewood Chips	40.00	1168	0	6364	3504	0	0	0	0
Cedar Chips	19.00	353	0	1921	1058	0	0	0	0
HW Chips	19.00	22	0	120	66				
Total Chips		2205	0	12007	6611				
Hog Fuel Value	$13.00	$1,187	0	$6,645	$9,916	$3,392	$2,917	$16,527	$15,555
Marginal Revenue		$27.74	$0.00	$27.74	$22.07	$13.00	$13.00	$13.00	$13.00
Average Revenue			$27.74	$27.74	$25.30		$13.00	$13.00	$13.00
Gross Revenue/Level		$94,909	0	$512,445	$364,793	$44,091	$37,916	$214,856	$202,218
Total Rev All Levels		$971,327				$499,080			

		SYSTEM 7				SYSTEM 8			
Utilization Level		Landing	Low	Medium	High	Landing	Low	Medium	High
Proportion Chip Recovery		0.65	0.90	0.65	0.40	0.65	0.90	0.65	0.40
	VALUE								
Fir Chips	$37.50	661	787	3223	1867	661	787	3223	0
Whitewood Chips	40.00	1168	1391	5694	3298	1168	1391	5694	0
Cedar Chips	19.00	353	420	1719	996	353	420	1719	0
HW Chips	19.00	22	26	107	62	22	26	107	0
Total Chips		2205	2625	10743	6222	2205	2625	10743	0
Hog Fuel Value	$13.00	$1,187	$292	$5,785	$9,333	$1,187	$292	$5,785	0
Marginal Revenue		$27.24	$33.41	$27.74	$22.07	$27.74	$33.41	$27.74	$0.00
Average Revenue			$30.36	$28.47	$25.88		$30.36	$28.47	$0.00
Gross Revenue/Level		$94,090	$97,449	$458,503	$343,334	$94,090	$97,449	$458,503	0
Total Rev All Levels		$993,377				$650,042			

		SYSTEM 9				SYSTEM 10			
Utilization Level		Landing	Low	Medium	High	Landing	Low	Medium	High
Proportion Chip Recovery		0.65	0.90	0.65	0.40	0.65	0.90	0.65	0.40
	VALUE								
Fir Chips	$37.50	661	787	3223	0	661	787	3223	0
Whitewood Chips	40.00	1168	1391	5694	0	1168	1391	5694	0
Cedar Chips	19.00	353	420	1719	0	353	420	1719	0
HW Chips	19.00	22	26	107	0	22	26	107	0
Total Chips		2205	2625	10743	0	2205	2625	10743	0
Hog Fuel Value	$13.00	$1,187	$292	$5,785	0	$1,187	$292	$5,785	0
Marginal Revenue		$27.24	$33.41	$27.74		$27.74	$33.41	$27.74	
Average Revenue			$30.36	$28.47			$30.36	$28.47	
Gross Revenue/Level		$94,090	$97,449	$458,503	0	$94,090	$97,449	$458,503	0
Total Rev All Levels		$650,042				$650,042			

detailed consideration of the shape and viability of such an industry.

This will require development of at least a crude definition of regional supply potential, including a rough supply curve (quantities which could be made available at different fibre and fuel price levels) for major supply zones. Figure 22 outlines the basic steps of the study and a model to develop these supply estimates.

Other requirements include a forecast of logged area, salvagable proportion of the area, residual volume by species, estimates of weighted transportation distances from regional supply centers to various regional demand centers, and the likely structure of a regional residual supply industry (in terms of the ten systems evaluated here), given local conditions in each major region.

Regional supply estimates

Regional harvest and transportation patterns

The allowable annual cut (AAC) of the defined regions of the B.C. coast is presented in Table 13. The most important regions are the most accessible ones — the South Coast of the Mainland, the East Coast of Vancouver Island, and the West Coast of Vancouver Island. In total they account for over 75% of the medium-term wood supply potential of the B.C. coast.

Using the average old-growth volume per hectare from B.C. Forest Service inventory estimates for each region (Appendix 3), the AAC level is translated into an estimated total area logged in each region for the medium term (Table 13). Each of the large southern regions will harvest

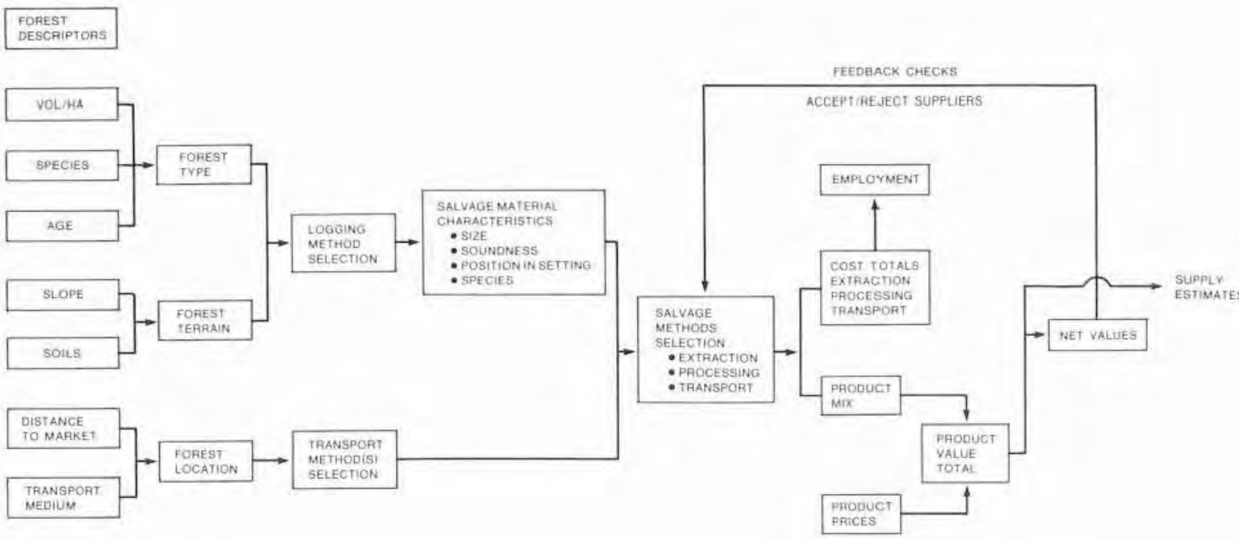


Figure 22. Process flow for development of regional fibre supply curves.

9000 to 10 000 ha each year for the next 20 years, while the three northern zones in total will harvest 10 000 to 12 000 ha per year. These areas define the maximum residue supply area potential of each region.

The volume harvested in each supply region flows in varying proportions to other regions as well as to internal mill centers. Most pulp and paper mills on the coast are in the three southern regions (Figure 23).

Estimate of the wood requirements of each major center are presented in Table 14. Based on known tenure arrangements and broad regional information, a rough source/destination table has been developed (Table 15). Only four of the six regions have significant demand centers: the South Coast Mainland, East Vancouver Island, Western Vancouver Island, and the North Coast of the Mainland.

A weighted average land and water distance travelled by raw material feeding the mills of each region is shown in Table 15. The total estimate for the B.C. coast shows a weighted land distance of 31 km and a weighted average water distance of 183 km (to weighted regional import centers for raw materials as shown in Figure 24). In regional residual supply estimates it is assumed that the incremental materials will follow basically the same paths as the normal log flows.

Defining regional residual fuel and fibre supply industries

The largest regions of supply and demand are East Vancouver Island and the South Coast of the Mainland. These regions are also among the most closely linked of the regions by well-established water transport systems. Therefore, in terms of supply potential, these two regions are considered as one large zone. The western portion of Vancouver Island is also a distinct supply/demand zone, although linked to the inland waterway region by many forest product movements. A third major region for supply is the North Coast zone made up of North Coast Mainland, Queen Charlotte Islands and the Mid Coast Mainland. This zone has the highest cost of support for logging crews, and higher overall transport costs to major demand centers.

In order to define regional residue supply industries, the total area logged in each zone was netted down as shown in Table 16. Further, the most profitable systems were selected as shown on the right side of Table 16, according to general local conditions in each zone. These coefficients, together with the detailed cost estimates for each type of supplier, defined the supply patterns of the residual supply industry in each of the three major zones.

Figure 25 illustrates how the residual fuel and

Table 13. Annual allowable cut in each region of the B.C. coast

Region	AAC (000 m³)	Vol per ha (m³)	Estimated Total area logged (ha)
Queen Charlotte Islands	2550	545	4679
North Coast Mainland	2521	543	4643
Mid Coast Mainland	1575	638	2469
South Coast Mainland	7651	725	10 553
East Vancouver Island	6373	647	9850
West Vancouver Island	7076	865	9150
TOTAL*	28 546		41 299
	Weighted average	691	

* for all lands regulated by the Ministry of Forests (TSA,TFL,CTF) B.C. Forest Service 1984

Table 14. Location, capacity, products and roundwood requirements of pulp and paper mills on the B.C. coast

	Mill Location	Annual Capacity (000 tonnes)		Product[a/]	Roundwood Requirement
		Pulp	Paper	Types	(000 m³)
Belkin Packaging Ltd.	Burnaby	0	150	recycled pbd	0
B.C. Forest Products Ltd.	Crofton	657	436	news, BKP, gwd spec pap	1600
Canadian For Products Ltd.	Port Mellon	180	0	BKP	810
Crown Forest Ind. Ltd.	Duncan Bay	770	510	news, BKP, K pap	1820
Eurocan P & P Co. Ltd.	Kitimat	300	300	liner, K pap	1500
Island Paper Mills Ltd.	Annacisis	0	112	fine pap	0
MacMillan-Bloedel Ltd.	Harmac	340	0	BKP	1350
MacMillan-Bloedel Ltd.	Port Alberni	452	382	news, semi-BKP, gwd spec pap	1020
MacMillan-Bloedel Ltd.	Powell River	670	620	news, semi-BKP, gwd spec pap	1600
Scott Paper Co. Ltd.	New Westminster	26	90	tissue, sanit pap	75
Tahsis Pacific Co. Ltd.	Gold River	230	0	BKP	1200
Westar Timber Ltd.	Prince Rupert	369	0	BKP	1600
Western Pulp Ltd.	Squamish	150	0	BKP	750
Western Pulp Ltd.	Port Alice	140	0	sulphite pulps	700

[a/] Recycled pbd — recycled paperboard
BKP — bleached Kraft pulp
K pap — Kraft paper
fine pap — fine paper
tissue — tissue
sulphite pulps — sulphite pulps
news — newsprintr
gwd spec pap — groundwood specialty paper
liner — linerboard
semi-BKP — semi-bleached Kraft pulp
sanit pap — sanitary paper

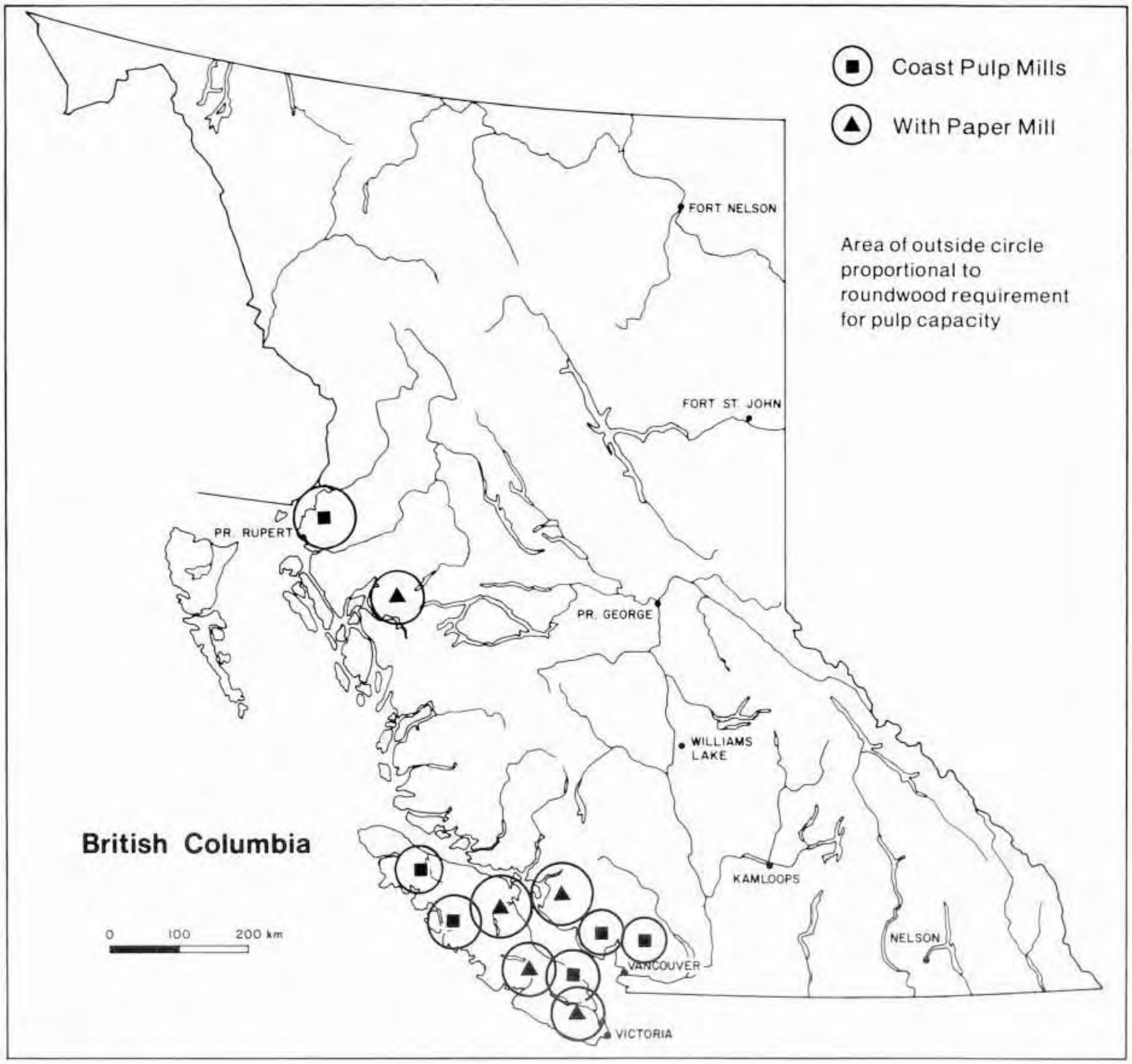


Figure 23. Location and relative wood requirements of pulp and paper mills on the B.C. coast.

fibre industry might develop on the South Coast over time, if the least expensive systems were introduced first. However, this is not necessarily the pattern which would emerge, depending on which companies were purchasing fuel and fibre, which companies had access to sortyards, mill yards, booming grounds and so on. It will be more meaningful to describe the regional incremental production possibilities in ascending order of increased cost and derive an industry average cost curve from this data.

This average cost function for the industry will approximate the industry supply curve over time, assuming relatively free entry/exit and trading patterns (Baumol 1963). An element of profit and risk should be added, since this has been excluded from our cost estimates.

Supply estimates for three major zones of the B.C. coast

The B.C. Forest Service's normal allowance for profit and risk in B.C. Coast logging operations is about 16-18%. Although discussion about its rea-

Table 15. Destination of pulpwood on the B.C. coast, by region of origin, volume, and distance travelled by mode of transportation.

Sources	Destination NCM	QCI	MCM	SCM	EVI	WVI	Total volume
NCM							
%	0.34			0.01	0.03	0	
VOLUME (000 m³)	1265	0	0	40	189	0	1494
Land distance (km)	30	–	–	30	30	30	
Water distance (km)	40	–	–	700	660	540	
QCI							
%	0.15			0.09	0.07	0.02	
VOLUME (000 m³)	596	0	0	363	440	67	1465
Land distance (km)	22	–	–	22	22	22	
Water distance (km)	160	–	–	720	680	520	
MCM							
%	0.26			0.04	0.04	0.01	
VOLUME (000 m³)	968	0	0	161	251	34	1414
Land distance (km)	26	–	–	26	26	26	
Water distance (km)	210	–	–	450	410	380	
SCM							
%	0.24			0.48	0.3		
VOLUME (000 m³)	893	0	0	1933	1886	0	4712
Land distance (km)	40	–	–	40	40	40	
Water distance (km)	700	–	–	60	240	240	
EVI							
%	0			0.27	0.35	0.11	
VOLUME (000 m³)	0	0	0	1088	2200	370	3658
Land distance (km)	35	–	–	35	35	35	
Water distance (km)	660	–	–	120	30	270	
WVI							
%	0			0.11	0.21	0.86	
VOLUME (000 m³)	0	0	0	443	1320	2896	4659
Land distance (km)	24	–	–	24	24	24	
Water distance (km)	380	–	–	240	270	60	
Average Distances							
WTD Land (km)	30	–	–	35	33	25	WTD AVG LAND km 31
WTD Water (km)	262	–	–	177	187	96	WTD AVG WATER km 183

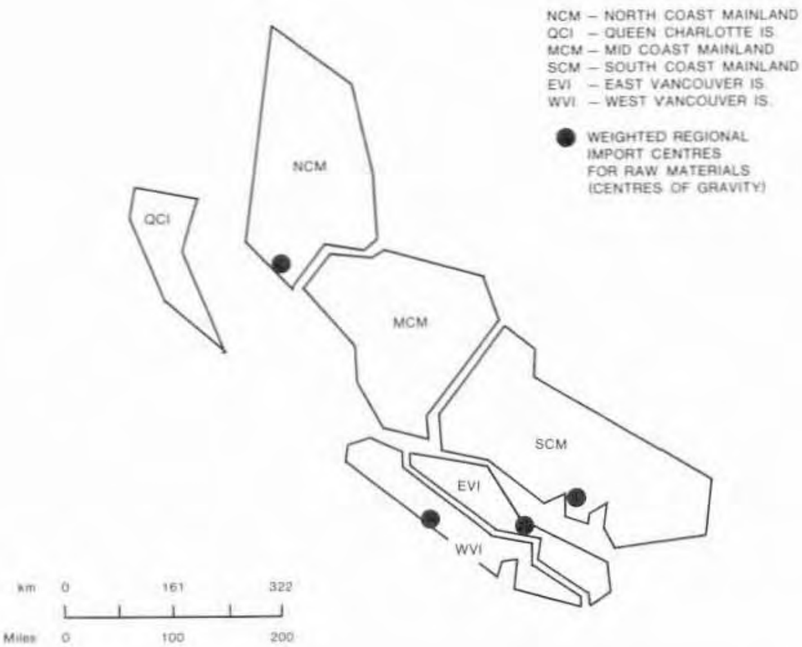


Figure 24. Location of weighted regional import centres for residual fibre on the B.C. coast.

Table 16. Allocation of salvage area by system and region on the B.C. coast

SUPPLY ZONE	Total Annual ha Logged	Net Availability Factor	Salvage areas allocated to systems by region			
			SYST3 (4)[a]	SYST7 (5)	SYST8 (3)	SYST9
South coast, Mainland and East Vancouver Island	20 400	0.75	0.30 6120	0.25 5100	0.20 4080	–
West Vancouver Island	9100	0.60	0.20 1820	0.40 3640	–	–
North coast mainland, Mid-coast Mainland and Queen Charlotte Islands	11 800	0.40	–	0.10 1180	0.20 2596	0.80 944
TOTAL	41 300		7940	9920	6676	944
Total availability	25 480					
WTD Factor B.C. Coast		0.62				

[a] Numbers in parentheses are the estimated numbers of machines.

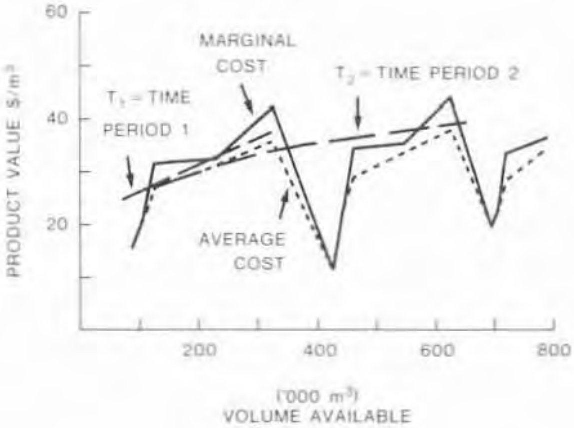


Figure 25. Development of a residual fuel and fibre industry on the south coast over time.

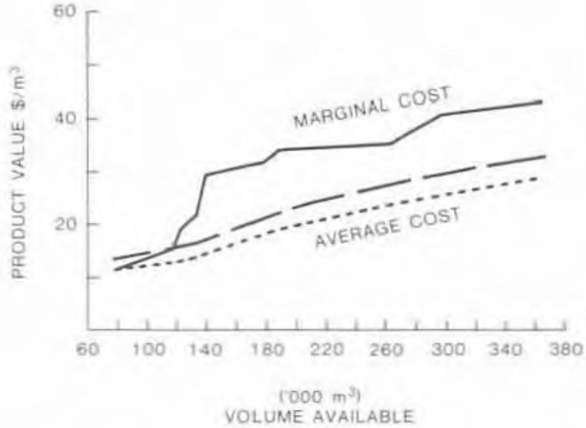


Figure 27. Estimated supply of fuel and fibre from a residuals industry in the West Coast Vancouver Island zone of B.C.

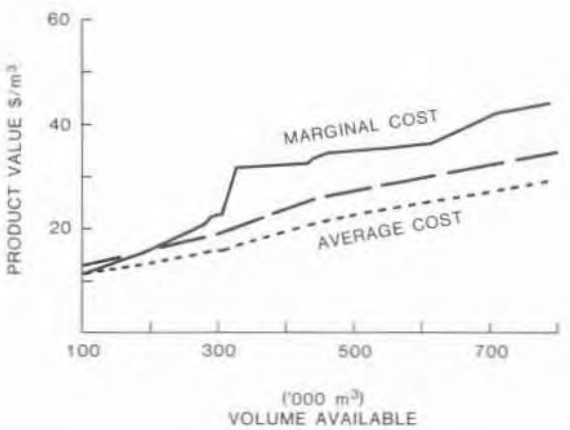


Figure 26. Estimated supply of fuel and fibre from a residuals industry in the South Coast zone of B.C.

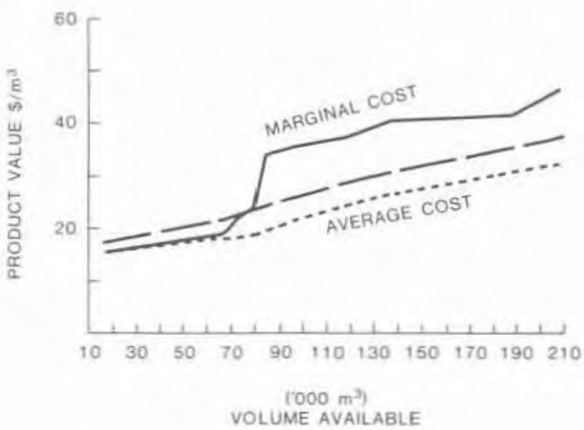


Figure 28. Estimated supply of fuel and fibre from a residuals industry on the North Coast zone of B.C.

sonableness, basis for measurement and other issues have gone on for decades, it will serve as an acceptable measure of profit and risk for these supply estimates.

In Figure 26 the barred line is the expected supply of fuel and fibre residuals in the South Coast zone through the defined residue-based industry. This line represents the average cost curve of the industry plus 18% for profit and risk.

Figure 27 shows the supply function (barred line) for the residuals from the West Coast of Vancouver Island, and Figure 28 shows the supply potential (barred line) defined for the North Coast zone. Such supply estimates can be used for analysis of a number of public policy questions.

Regional economic considerations

Efficient use of forest resources

The "waste" left behind in logging each hectare on the coast of B.C. has been the subject of much forest policy discussion for several decades (e.g., Sloan 1945, 1956; Pearse 1976). Foresters from Europe and Japan express shock at the amount of material remaining on the ground after logging in a typical B.C. coast logging setting. Slash burning is still practiced in many areas to reduce the long-term fire hazard of this material lying on the ground.

In fact, an increasing proportion of the material has been removed from each hectare logged on the B.C. coast since the turn of the century. The economic process described in this report (incremental revenue = incremental cost) has been gradually moving the margin of recovery up each tree in stands with large trees, out into stands with less desirable species and smaller average tree size, and down into the smaller understory trees which traditionally were broken or left in normal coast logging practices. Reverses, such as the recent relaxation of utilization standards (B.C. Forest Service public announcements in 1984), are only temporary and are due to short-term market constraints.

It is the ups and downs of residual economics which have inhibited the development of an industry. Being at the margin, all fluctuations affect this portion of the resource more severely than the bulk of the normal wood flows. Nonetheless, present trends indicate that it will be economically feasible in the late 1980s and 1990s to harvest up to one million m^3 of fuel and fiber material from within the normal logged area of the B.C. coast.

If feasible, this will make better use of the total forest estate which underlies the regional economy. Costs of forest protection, roading, administration and research are all fixed. Further economic output from this basic set of inputs increases the efficiency of the most important sector of the economy.

Further, the value of old-growth forest in other uses, such as wilderness and environmental protection, continues to increase. Obtaining more economic fibre from each hectare logged, together with more intensive management of the most productive sites, may permit the relegation of a larger fraction of the old-growth resource to wilderness and environmental protection over several decades.

The removal of the material analyzed in these estimates would probably not degrade the forest site. The removal of all material, including branches needles and tops, could have an effect over several rotations. Further research is needed in this area, but if removal of further woody material reduces the need for slash burning, there could be a positive effect on the remaining forest site under certain specific conditions such as shallow soils or steep slopes.

In general, although difficult to quantify in many dimensions, an incremental fuel and fibre industry would improve the efficiency of the use of the B.C. coast forest estate, as long as the removal costs were offset by the revenues.

Economic prices and costs

Market prices in the short run do not always accurately reflect real economic costs. A most significant example has already been discussed in which the oil replacement value of wood fuel was compared with the current market value of hog fuel on the B.C. coast.

A relatively sophisticated calculation of the expected frequency of oil shocks and the expected cost to a company being caught in a petroleum squeeze would be required to analyze the capital investment and extra burning costs required to use wood fuels. Different companies have come to different conclusions in the course of such analysis: some elect to gamble on relatively stable petro-energy supplies; some elect to provide strategic defenses through hog fuel burners.

For the B.C. economy, there is no doubt that the petroleum energy value of the hog fuel burned is the economic gain from the process of using these wood-based fuels in the coast forest industry.

A second major departure of market prices from economic values may occur in the current labor market of B.C. With unemployment approaching 15% at times and disturbingly stable at high levels, the opportunity cost of an unemployed laborer on the B.C. coast is not likely to be $16/hour, which is what a B.C. company would have to pay a worker (under current forest industry contracts) hired in an incremental fuel/fibre operation.

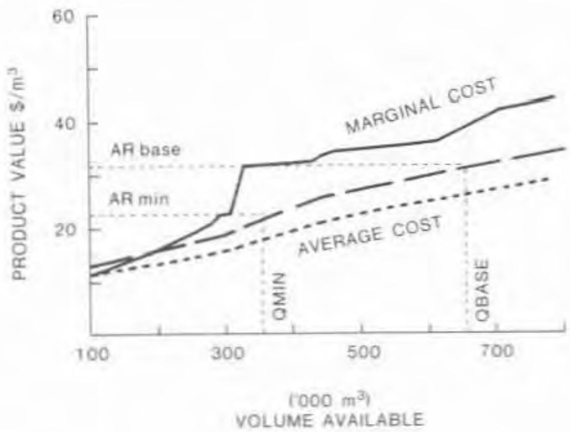


Figure 29. Economic viability of a residue-based fuel and fibre industry on the South Coast zone of B.C.

A third significant departure of market values from economic values can occur in exchange rates. If central government interventions are sustaining artificially high or artificially low rates of exchange between the Canadian dollar and other major currencies, this effect should be considered in an economic analysis. In general, the high export content of the pulp and paper industry, and the import replacement value of the hog fuel, would make a residual fuel and fibre industry a desirable addition to the regional economy in terms of foreign exchange effect.

Potential impact in the economy of the coast region

Two basic scenarios are used to define the likely residual supply industry on the B.C. coast. The first (base case) assumes a pulp chip price equivalent to the export price (US $85 per volumetric unit). Assuming a realistic exchange rate for the Canadian dollar is US $0.75, the equivalent price per solid cubic metre is $40 Canadian. In our view, this represents a realistic pulp fibre value for the B.C. coast in the late 1980s and 1990s. The base case assumes a petro-energy equivalent value of $26 per volumetric unit, or $13 per solid cubic metre. This could be equated to a 4% real return on boiler investment, or to an industry where perhaps one-half of the necessary boiler capacity is already in place.

The second major case should provide a floor for the expectations of the residue-based fuel/fibre industry. Chips are valued at $30 per solid cubic metre, hog fuel at $5 per solid cubic metre. These levels reflect normal market prices on the B.C. coast over the past five years (1980-85). Figure 29 illustrates the range of likely output from the residual fuel and fibre industry under the two basic scenarios for the major supply zone — the South Coast. Table 17 shows the volumes available from this analysis and for a similar analysis of the West Coast Vancouver Island and North Coast supply zones. At the minimum (e.g. South Coast zone only, minimum case) 355 000 m³ of residual fuel and fibre material could be obtained. At the base case level with all zones in operation, about 1.1 million m³ of additional material could be produced from salvage operations in normal logging.

No body of data exists, under comparable conditions, for the normal measure of industrial activity within a residue-based fuel and fibre industry. However, using Statistics Canada data for the logging segment of the B.C. coast, together with manpower and equipment estimates for various system trials, a set of estimates have been developed of the employment, wages and salaries, value added and gross value of shipments for residue-based fuel and fibre operations on the B.C. coast. Appendix 4 shows the derivation of these estimates for each cubic metre processed through such an industry. Economic impacts of residual fuel/fibre production within the coast economy are summarized in Table 18. These esti-

Table 17. Expected operating levels of a residual fuel and fibre industry on the coast, 1986-2000

Potential supply	Base case	Minimum case
Average revenue	$31.90	$22.50
Output (000 m³)		
South Coast Zone	655	355
West Coast Zone	317	183
North Coast Zone	143	70
Potential Supply	1115	608

mates show the potential for an industry with $19-$36 million of annual shipment values, paying $9-$17 million in total wages and salaries for 300 to 570 jobs and generating value added of $11-21 million dollars.

Under conditions of serious scarcity of raw materials for coast pulp mills, the provision of chips from forest residuals would defend existing industry values and employment. Similarly if demand were rising against scarce raw material, the residual fibre could be a necessary key to industrial expansion. Although the manufacturing value-added should not be attributed to the wood in an economic sense, the presence or absence of the wood could control feasibility of a total regional benefit flow.

In this sense, 250 to 470 manufacturing jobs and $17-32 million in manufacturing value-added could be strategically defended by an effective residue-based fuel and fibre supply industry (Appendix 4).

In total, residual fuel and fibre production represents a significant industrial opportunity for the B.C. coast. More detailed policy and feasibility studies will likely be necessary to investigate ways to facilitate its establishment.

Table 18. Annual economic impact of a residual fuel and fibre industry on the B.C. coast, 1986-2000

Total (all zones)	Jobs (Person years)	Wages & salaries (000$)	Value added (000$)	Total value shipments (000$)
Base case	569	17 265	20 635	35 569
Min. case	310	9414	11 252	19 395

Regional Distribution of Impacts (Percent)

	South Coast	West Coast Vancouver Island	North Coast
Base case	0.59	0.28	0.13
Min. case	0.58	0.30	0.12

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Appendix 1: Waste for cut control by management unit, Vancouver Region

Table A1-1. Waste for Cut Control by Management Unit, Waste Surveys, Vancouver Forest Region, 1981 and 1982[a]

Regional management unit	Net area (ha)	Waste left (000 m^3)	Production cut (000 m^3)	Total cut charged (000 m^3)	% Waste of production cut	Waste per unit area (m^3/ha)
1981						
Fraser	922.9	43	662	705	6	46.1
Kingcome	1071.3	58	818	876	7	54.0
Nootka	1083.5	69	893	962	8	63.5
Quadra	1436.9	86	1095	1180	8	59.7
Soo	702.0	21	413	434	5	29.7
Regional TSA's	5216.2	277	3881	4157	7	52.9
1982						
Fraser	1539.5	50	892	942	6	32.3
Kingcome	1209.1	56	1021	1078	5	46.1
Nootka	1632.1	80	1050	1130	8	49.2
Quadra	1667.9	112	1041	1153	11	67.2
Soo	548.4	15	452	468	3	27.9
Regional TSA's	6597.0	313	4456	4771	7	47.5
Regional[b] TFL's	9619.6	694	8966	9661	8	72.2
Region Total	16 216.6	1007	13 422	14 432	7.5	62.1

[a] Unavoidable plus avoidable waste; for trees having a minimum 13 cm butt radius i.b. at 0.3 metre stump, to a top radius i.b. of 8 cm.

[b] Data were available only for 1982.

Appendix 2: Per hectare volumes and species, average coast logging operation

Table A2-1. Per Hectare Volumes and Species Average, Coast Logging Operation 1981-82[a]

Timber supply area	Total volume (m^3/ha)	Cut control waste (m^3/ha)[b]	Waste by species (%)[c] F	H	C	B	Cy	Other
Nootka	770	55	0	44	39	12	5	0
Kingcome	857	50	0	29	50	10	9	2
Soo	722	29	4	49	30	17	0	0
Quadra	751	64	12	29	43	15	1	0
Fraser (East half)	669	37	13	34	11	30	6	6
(West half)			29	24	35	10	0	2
All T.S.A.'s	756	50	5	41	34	15	3	2
Regional T.F.L.'s	1004	72						

[a] Utilization standard: 13 cm stump radius inside bark and 8 cm top radius inside bark.

[b] Waste for cut control purposes by definition is not exactly the same as waste for utilization purposes.

[c] Estimate only based on Nawitka subsample.

Source: Waste Survey and Cut Control Records, Vancouver Forest Region, 1981 and 1982.

Appendix 3: Average mature volumes per hectare, B.C. coast, by species mix and supply area

Figure A3-1. Prince Rupert Forest Region Timber Supply Areas

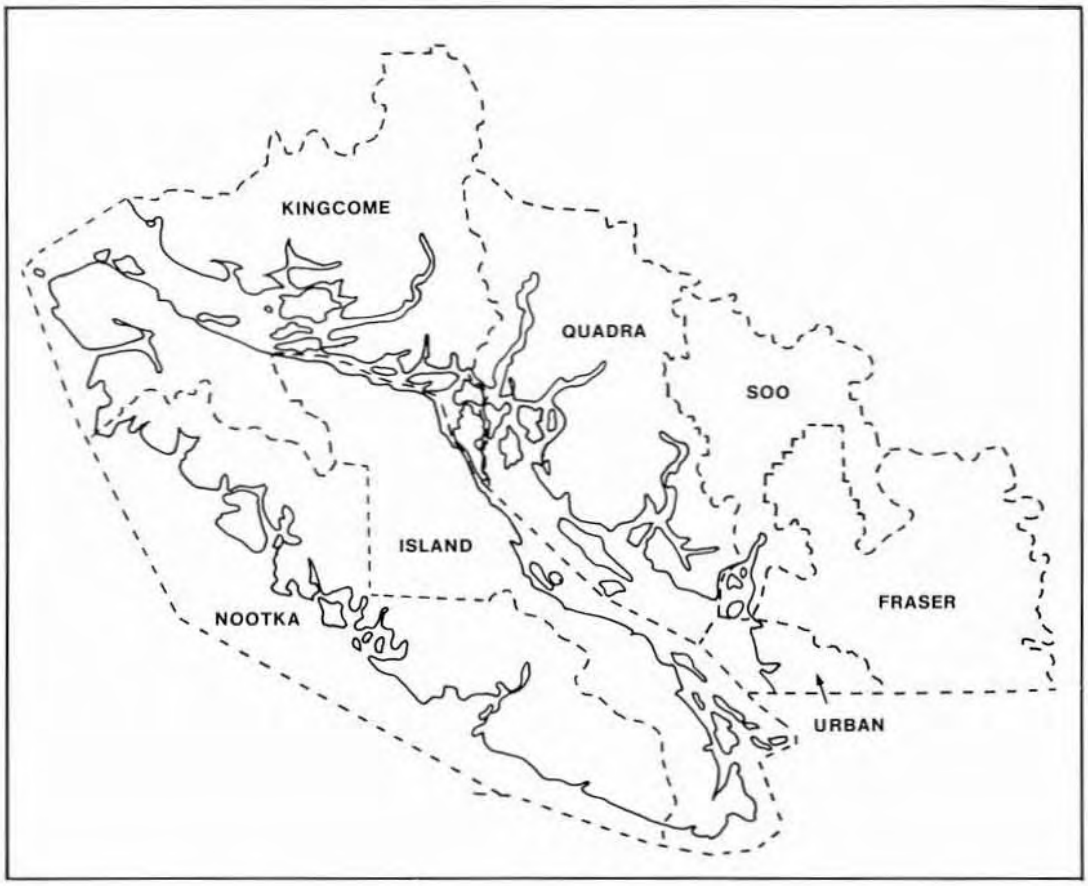

Figure A3-2. Vancouver Forest Region Timber Supply Areas

Table A3-1. — Queen Charlotte TSA
Mature Volume per Hectare, by
Major Forest Types & Species*
(m^3 per ha)

Species	Forest types							
	CCy CyC CyC C CyPl Cy	CH CyH CS CyS	H	HC HCy	HS	S SCy	SH SC	Weighted Average all types
C	176	292	15	180	27	1	110	185
H	37	116	562	354	490	67	340	210
S	7	36	35	40	195	821	522	110
Cy	88	25	–	31	–	10	10	32
Pl	14	12	–	1	–	1	–	8
Total	322	482	613	607	712	901	981	546
Type %**	20	40	2	10	15	1	10	98

* — Base year 1967; 7.1" close utilization , 4" top, gross, not including hardwoods, applicable to 100% of the TSA and 98% of the mature areas in the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1967 Unit Survey of the Queen Charlotte PSYU, and Forest Industry Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-2. — North Coast (Hecate) TSA
Mature Volume per Hectare, by
Major Forest Types & Species*
(m³ per ha)

Species	Forest types											
	CCy	CH CyH	H	HC HCy	HB	HS	BH	S	SH	SB	PlCCy PlH	Weighted average all types
C	154	266	7	178	123	19	66	10	56	7	36	148
H	44	110	433	280	387	447	247	55	322	144	16	243
B	7	29	21	41	218	25	404	23	45	275	–	65
S	6	27	21	24	34	159	11	763	495	467	1	44
Cy	78	48	12	59	8	8	–	–	5	–	23	40
Pl	12	2	2	1	–	–	–	–	1	–	49	3
Total	300	481	495	582	771	659	728	850	924	894	124	543
Type %**	17	21	8	22	18	8	1.5	.2	2	.3	1.5	99.5

* — Base year 1965; 7.1" close utilization, 4" top, gross, not including hardwoods; based on Hecate PSYU which comprises most of the TSA and is applicable to over 99% of the mature areas in the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1965 Unit Survey of the Hecate PSYU, and Forest Inventory Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-3a. — Mid Coast TSA, Northern Portion (Dean)
Mature Volume per Hectare, by
Major Forest Types & Species*
(m³ per ha)

Species	Forest Types																		Weighted average all types
	F	FC	FH	FCH	CCy CyC C Cy	CF	CH CS CB CyH CyB	H HPl	HF	HC HCy	HB	HS	B BPl	BH BC	BS	SH SC	SB	Pl	
F	437	257	260	92	–	74	3	11	158	28	7	9	4	3	–	–	–	2	21
C	86	406	106	119	247	567	325	78	92	200	75	154	1	41	5	140	27	1	191
H	92	80	238	92	61	116	136	501	352	340	368	367	34	217	88	281	201	–	236
B	–	–	9	–	15	–	41	67	21	56	193	80	378	354	271	83	303	33	89
S	8	20	18	17	9	50	24	13	15	36	44	163	8	17	168	394	513	1	41
Cy	–	–	–	–	43	13	16	–	–	16	4	2	–	6	2	–	–	–	14
Pl	2	–	6	8	8	3	2	–	1	–	–	–	44	–	5	–	–	111	2
Total	625	764	636	327	384	822	547	671	640	675	691	775	470	638	540	898	1044	149	595
Type %**	1.2	.4	2.4	.2	15.5	.1	25	3.5	1.7	15.5	20.8	4.4	1	3.9	.5	2.3	.3	.7	99.4

* — Base years 1962-63 and 1968; 7.1" close utilization, 4" top, gross; not including hardwoods; based on the Dean PSYU which comprises the northern portion of the TSA and is applicable to over 99% of the mature areas in the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1962-63 & 1968 Unit Surveys of Dean and Rivers Inlet PSYU, and Forest Inventory Division, BCFS Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-3b. — Mid Coast TSA, Southern Portion (Rivers Inlet)
Mature Volume per Hectare, by
Major Forest Types & Species*
(m³ per ha)

Species	Forest Types															
	FC	FH	CCY C CPl Cy CyC CyPl	CH CyH CyB CS CB CyS	H	HF	HCy HC	HB	HS	BH BCy BC	BS	S	SH SC	SB	PlCy PlC	Weighted Average all types
F	607	616	1	3	7	270	11	14	11	–	2	–	1	–	–	12
C	273	167	333	322	130	107	118	64	80	34	23	34	51	67	62	230
H	141	290	57	176	466	442	339	449	571	378	182	146	481	378	3	218
B	11	8	5	39	39	47	69	323	75	500	588	93	258	297	15	106
S	4	10	3	15	33	9	3	12	284	51	350	1138	422	421	–	23
Cy	–	–	113	166	5	1	90	7	1	12	–	–	–	–	46	85
Pl	2	3	20	2	4	1	2	–	–	–	–	1	–	–	126	8
Total	1038	1104	533	724	685	877	632	870	1022	975	1145	1413	1212	1163	252	683
Type %**	.3	.5	40.3	19.4	2.2	.8	8.6	21.8	.9	2.6	.2	.4	1.2	.3	.3	99.8

* — Base years 1962-63 and 1968; 7.1" close utilization, 4" top, gross; not including hardwoods; based on the Rivers Inlet PSYU which comprises the southern portion of the TSA and is applicable to nearly 100% of the mature areas in the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1969 Unit Survey of Rivers Inlet PSYU, and Forest Inventory Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-4. — Nootka TSA
Mature Volume per Hectare, by
Major Forest Types & Species*
(m^3/ha)

Species	Forest Types									
	FH FB	C CyC	CyH CB CS CyB	H HPl	HF	HC HCy	HB	BH BC BCy	SH SC	Weighted Average all types
F	636	9	21	28	253	34	6	4	–	29
C	128	453	487	24	53	212	48	42	227	266
H	467	89	243	915	742	410	630	374	549	388
B	7	13	71	43	4	68	289	559	18	133
S	16	1	6	8	56	7	12	1	705	13
Cy	5	49	39	23	34	44	6	19	–	32
Pw	2	1	5	1	2	2	–	1	–	1
Pl	–	22	3	2	1	1	–	–	–	3
Total	1261	638	874	1045	1145	779	992	1001	1499	866
Type %**	1.1	11.9	32.2	3.5	2.3	16.6	24.5	4.7	.9	97.7

* — Base year 1970; 7.1" close utilization, 4" top, gross; not including hardwoods; based on Nootka PSYU which comprises most of the TSA and is applicable to nearly 98% of the mature areas in the TSA.

** — The percent the respective type groups is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1970 Unit Survey of the Nootka PSYU, and Forest Inventory Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-5. — Kingcome TSA
Mature Volume per Hectare, by
Major Forest Types & Species*
(m³ per ha)

Species	Forest Types																Weighed average all types
	F	FC	FH	C CCy Cy CyC CyPl	CH CyH CyB CB CS	H HPl	HF	HC HCy	HB	HS	B BPl BF	BH BC BCy	S	SH SC	Pl	PlCy PlC PlH	
F	461	448	493	1	4	5	237	8	5	1	2	3	–	–	2	–	11
C	19	217	102	439	455	58	69	213	54	39	1	58	49	126	–	42	314
H	19	116	300	87	216	677	478	342	503	600	24	293	77	322	–	16	229
B	10	19	13	5	44	70	16	52	228	44	382	425	7	590	2	–	65
S	–	10	–	1	6	43	6	4	21	271	7	7	906	522	1	–	11
Cy	–	–	–	135	97	1	3	73	31	8	–	17	6	–	–	60	87
Pl	–	–	–	15	2	2	3	4	3	–	6	1	–	–	80	97	7
Total	508	811	908	684	825	857	813	697	845	963	433	804	1045	1029	85	215	724
Type %**	.6	.3	.6	36.8	27.1	2.6	.5	8.7	16.1	.4	1	1	.2	.4	.5	.8	97.6

* — Base years 1966, 1969, 1971 and 1974; 7.1" close utilization, 4" top, gross: not including hardwoods; based on Kingcome PSYU which comprises most of the TSA and is applicable to nearly 98% of the mature areas in the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1966, 1969, 1971 and 1974 Unit Surveys of the Kingcome PSYU, and Forest Inventory Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-6. — Soo TSA.
Mature Volume per Hectare, by
Major Forest Types & Species*
(m^3 per ha)

Species	Forest Types																Weighted average all types
	F FPw	FC FCy	FH FB	FPl	CF	CH CyB CB CyH CS	H HPl HPw	HF	HC HCy	HB	B BF BPl BPw	BC BH BCy	BS	Pl	PlF	PlB PlS PlH PlPw	
F	424	356	329	138	268	54	64	189	67	25	10	21	4	3	43	8	145
C	45	330	76	3	476	397	27	52	236	42	1	24	16	–	4	8	56
H	26	117	187	21	37	274	450	377	325	390	63	246	78	–	6	5	188
B	3	25	36	–	1	109	48	34	112	248	590	473	429	3	1	14	251
S	–	–	3	2	3	14	–	3	1	1	1	1	182	–	2	9	4
Cy	–	–	1	–	–	49	12	8	–	18	3	39	3	–	–	5	14
Pw	2	17	7	–	–	5	1	6	–	1	1	3	3	–	2	–	3
Pl	2	7	2	52	–	–	–	–	–	–	1		3	66	77	84	4
Total	502	852	641	216	785	902	603	669	741	725	670	808	719	73	135	134	665
Type %**	15.5	4.8	10.7	1.5	.7	.8	.9	4.8	2	13.5	12.6	26.7	1.5	.7	1.6	.5	98.8

* — Base year 1975; 7.1" close utilization, 4" top, gross; not including hardwoods; based on Soo PSYU nearly 99% of the mature areas in the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1975 Unit Survey of the Soo PSYU, and Forest Inventory Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-7. — Quadra TSA
Mature Volume per Hectare, by
Major Forest Types & Species*
(m^3 per ha)

Species	Forest Types: F	FC FCy	FH	FPl	C CCy Cy CyC	CF CyF	CH CyH CF CyB CS	H	HF	HC HCy	HB	B BPw	BH BCy BC	Pl	Weighted average all types
F	402	402	329	161	28	216	21	31	163	35	10	4	8	1	105
C	50	329	83	3	639	538	378	30	99	111	64	7	42	–	124
H	42	120	195	37	1289	94	260	467	336	322	430	45	378	–	295
B	–	2	3	1	27	20	67	71	18	68	249	566	440	3	155
S	–	–	1	12	9	6	4	7	1	1	–	1	2	2	1
Cy	–	–	3	–	126	9	121	13	25	135	51	12	42	–	57
Pw	1	–	3	–	2	1	1	3	1	3	2	9	1	–	2
Pl	3	–	1	92	1	–	–	1	–	–	–	2	–	119	1
Total	499	853	618	307	960	885	852	624	642	676	806	646	914	126	740
Type %**	10.4	3.8	6.8	.5	1.7	1.3	9.5	3	5.3	16.9	23.8	1.5	14.7	.3	99.5

* — Base years 1962, 1966-68; 7.1" close utilization, 4" top, gross; not including hardwoods; based on the Quadra PSYU which comprises most of the TSA and is applicable to over 99% of the mature areas in the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1962, 1966-68 Unit Surveys of the Quadra PSYU, and Forest Inventory Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-8. — Island TSA (Crown portion of E & N only)***
Mature Volume per Hecate, by
Major Forest Types & Species*
(m^3 per ha)

Species	Forest Types										
	F	FC	FH FB	CH	H	HF	HC	HB	BH	PlF	Weighted average all types
F	398	324	476	9	6	295	74	34	10	97	318
C	15	166	116	341	7	101	245	45	64	1	60
H	20	66	235	156	539	558	597	601	250	–	216
B	1	4	29	32	59	19	76	186	465	3	31
S	–	1	4	8	3	4	2	1	11	8	2
Cy	–	–	–	55	55	8	10	22	16	–	5
Pw	3	1	5	2	6	9	2	–	3	–	5
Pl	2	–	–	3	–	–	–	–	3	302	10
Total	439	563	863	606	674	994	1006	890	822	411	646
Type %**	43.6	3.8	15.2	1.1	3.4	18.1	1.4	6	1.6	3.1	97.5

* — Base year 1970; 7.1" close utilization, 4" top, gross; not including hardwoods; based on the E&N portion unit survey or about half of the TSA and is applicable to over 97% of the mature areas in the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

*** — Sayward block of the Quadra not included.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1970 Unit Survey of the Island TSA (Crown portion E & N only), and Forest Inventory Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-9a. — Fraser TSA - East Portion (Dewdney)
Mature Volume per Hectare, by
Major Forest Types & Species*
(m^3 per ha)

Species	F FPw	FC	FH FB	FPl	CH CB CyH CyB CS	H HPw	HF	HC HCy	HB	BH BPw BPl	BH BCy BC	BS	SB	Pl	Weighted average all types
	Forest Types														
F	407	350	276	145	29	28	189	29	10	12	5	5	31	4	94
C	33	177	101	3	510	63	114	207	45	12	20	10	10	–	63
H	37	67	175	38	319	584	396	437	431	51	250	36	22	–	223
B	12	16	38	1	123	78	36	98	259	554	437	329	191	12	237
S	9	6	12	5	6	5	5	2	5	37	5	99	375	–	26
Cy	–	–	8	–	53	10	16	66	22	17	30	4	–	–	19
Pw	7	2	8	–	6	10	10	1	5	3	2	10	6	–	5
Pl	4	–	–	81	–	1	–	–	–	2	–	3	6	182	4
Total	508.48	619.35	617.86	272.98	1044.6	799.13	766.39	839.23	776.57	688.94	749.04	496.28	640.45	198.59	670
Type %**	10	2.5	8.7	1.2	2.3	2.5	5	6.6	16.1	10.4	21.5	6.2	3	.9	96.9

* — Base year 1974; 7.1" close utilization, 4" top, gross; not including hardwoods; based on the Dewdney PSYU which comprises most of the eastern portion of the TSA and is applicable to nearly 97% of the mature areas of the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1974 Unit Survey of the Dewdney PSYU, and Forest Inventory Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Table A3-9b. — Fraser TSA - West portion (Vancouver)
Mature Volume per Hectare, by
Major Forest Types & Species*
(m^3 per ha)

Species	Forest Types												
	F	FC FCy	FH FB	C CCy Cy Cyc	CF CyF	CH CB CyH CyB	H	HF	HC HCy	HB	B BF	BCy BC	Weighted average all types
F	529	516	557	6	200	27	27	296	19	1	7	3	73
C	92	213	87	620	390	378	29	105	170	38	3	16	149
H	75	109	233	99	63	277	561	406	381	440	82	255	307
B	–	14	24	37	20	88	46	34	76	183	784	541	205
S	2	1	–	2	–	1	5	1	2	–	6	–	1
Cy	–	–	5	169	52	151	9	3	143	38	3	48	77
Pw	1	–	0	1	–	–	2	2	1	–	3	–	–
Pl	1	–	0	2	–	–	3	–	–	–	1	–	–
Total	701.42	853.62	907.10	935.85	724.10	921.67	681.89	847.28	791.05	699.95	889.92	863.70	812
Type %**	3.3	2.1	4.1	2.3	2.6	18.4	2	2.3	17.5	21.5	2.3	21	99.4

* — Base year 1970; 7.1" close utilization, 4" top, gross; not including hardwoods; based on the Vancouver PSYU which comprises most of the western portion of the TSA and is applicable to over 99% of the mature areas in the TSA.

** — The percent the respective type group is of the total mature forest area in the TSA.

Source: Derived from Forest Inventory Statistics of B.C., 1970, the 1970 Unit Survey of the Vancouver PSYU, and Forest Inventory Division, BCFS, Unofficial Zonal Diameter Conversion Factors, 1974.

Appendix 4: Regional economic impact statistics

REGIONAL ECONOMIC IMPACT
Base Case and Min Case
NORTH COAST ZONE

	INCREMENTAL FUEL & FIBRE VOLUME (m^3)		JOBS (Pers.Yr)		WAGES & SALARIES (000$)	
	Base Case	Min Case	Base Case	Min Case	Base Case	Min Case
Logging	143 000	70 000	61	30	1746	855
Hogfuel Mfr	42 900	21 000	2	1	90	44
Chip Mfr	100 100	49 000	10	5	378	185
Pulp & Paper Mfr	100 100	49 000	60	29	1781	872
	Total Production F&F		73	36	2214	1084 Production
	Total Mill Defense		60	29	1781	872 Mill Defense

	VALUE ADDED (000$)		TOTAL VALUE OF SHIPMENTS (000$)	
	Base Case	Min Case	Base Case	Min Case
Logging	1886	923		
Hogfuel Mfr	159	78	558	273
Chip Mfr	602	294	4004	1990
Pulp & Paper Mfr	4043	1979	11 512	5835
Total Production F&F	2647	1295	4562	2233 Production
Total Mill Defense	4043	1979	11 512	5835 Mill Defense

REGIONAL ECONOMIC IMPACT
Base Case and Min Case
SOUTH COAST ZONE

	INCREMENTAL FUEL & FIBRE VOLUME (m^3)		JOBS (Pers.Yr)		WAGES & SALARIES (000$)	
	Base Case	Min Case	Base Case	Min Case	Base Case	Min Case
Logging	655 000	355 000	278	151	7996	4334
Hogfuel Mfr	196 500	106 500	11	6	413	224
Chip Mfr	458 500	248 500	46	25	1733	939
Pulp & Paper Mfr	458 500	248 500	275	149	8157	4421
	Total Production F&F		334	181	10 142	5497 Production
	Total Mill Defense		275	139	8157	4421 Mill Defense

	VALUE ADDED (000$)		TOTAL VALUE OF SHIPMENTS (000$)	
	Base Case	Min Case	Base Case	Min Case
Logging	8639	4682	2555	1395
Hogfuel Mfr	727	394	18 340	9940
Chip Mfr	2756	1493	52 728	28 578
Pulp & Paper Mfr	18 519	10 037	52 728	20 578
Total Production F&F	12 122	6570	20 895	11 325 Production
Total Mill Defense	18 519	10 037	52 728	28 578 Mill Defense

REGIONAL ECONOMIC IMPACT
Base Case and Min Case
WEST COAST ZONE

	INCREMENTAL FUEL & FIBRE VOLUME (m^3)		JOBS (Pers.Yr)		WAGES & SALARIES (000$)	
	Base Case	Min Case	Base Case	Min Case	Base Case	Min Case
Logging	317 000	183 000	134	78	3970	2234
Hogfuel Mfr	95 100	54 900	5	3	200	115
Chip Mfr	221 900	128 100	22	13	839	484
Pulp & Paper Mfr	221 900	128 100	133	77	3948	2279
	Total Production F&F		162	93	4908	2834 Production
	Total Mill Defense		133	77	3948	2279 Mill Defense

	VALUE ADDED (000$)		TOTAL VALUE OF SHIPMENTS (000$)	
	Base Case	Min Case	Base Case	Min Case
Logging	4181	2414		
Hogfuel Mfr	352	203	1236	714
Chip Mfr	1334	770	8876	5124
Pulp & Paper Mfr	8963	5174	25 519	14 732
Total Production F&F	5867	3387	10 112	5838 Production
Total Mill Defense	8963	5174	25 519	14 732 Mill Defense

REGIONAL ECONOMIC IMPACT
Per Cubic Metre Utilized

Activity	TOTAL FOREST IND B.C. COAST[1]			INCREMENTAL FUEL/FIBRE PRODUCTION					TOTAL VALUE OF SHIPMENTS	
	Employment (Jobs/m^3)	Wages & Sal ($/$m^3$)	Value added ($/$m^3$)	Work (net factor)	Jobs	Wages & Sal ($/$m^3$)	Value (net factor)	Value added ($/$m^3$)	Base Case ($/$m^3$)	Low case ($/$m^3$)
Logging	0.00053	$15.26	$25.38	0.80	0.000424	$12.21	0.50	$13.19	n.a.	n.a.
Hogfuel Mfr	0.000055	$2.10	$3.70	1.00	0.000055	$2.10	1.00	$3.70	$13.00	$5.00
Chip Mfr	0.0001	$3.78	$6.01	1.00	0.0001	$3.78	1.00	$6.01	$40.00	$30.00
Pulp & Paper Mfr	0.0006	$17.79	$40.39	1.00	0.0006	$17.79	1.00	$40.39	$115.00	$115.00

REGIONAL ECONOMIC IMPACT
Base Case and Min Case
TOTAL ALL ZONES

	INCREMENTAL FUEL & FIBRE VOLUME (m^3)		JOBS (Pers.Yr)		WAGES & SALARIES (000$)	
	Base Case	Min Case	Base Case	Min Case	Base Case	Min Case
Logging	1 115 000	608 000	473	258	13 612	7422
Hogfuel Mfr	334 500	182 400	18	10	702	383
Chip Mfr	780 500	425 600	78	43	2950	1609
Pulp & Paper Mfr[2]	780 500	425 600	468	255	13 885	7571
	Total Prodn F&F		569	310	17 265	9414 Production
	Total Mill Defense[3]		468	2551	13 885	7571 Mill Defense

	VALUE ADDED (000$)		TOTAL VALUE OF SHIPMENTS (000$)	
	Base Case	Min Case	Base Case	Min Case
Logging	14 707	8020	n.a.	n.a.
Hogfuel Mfr	1238	675	4349	2371
Chip Mfr	4691	2558	31 220	17 024
Pulp & Paper Mfr	31 524		89 758	48 944
Total Production F&F	20 635	11 252	35 569	19 395 Production
Total Mill Defense	31 524	17 190	89 758	48 944 Mill Defense

1. Source: Derived from Statistics Canada, No. 25-201 and 36-204; J. Dobie, Statistics Canada, Vancouver; Crown Forest Industries, Vancouver; Nawitka Consultants, Victoria.
2. Not including hog fuel or chip manufacture.
3. Under conditions of **serious** scarcity of raw material for Coast pulp mills, the provision of chips from forest residues would defend existing industry production values and employment. Similarly, if demand were rising against scarce raw material, the residual fibre could be a necessary key to expansion. Although the manufacturing value should not be attributed to the wood in an **economic** sense, the presence/absence of the wood could control the feasibility of a total regional benefit flow.