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Canada- Sustainable Forest Biomass Supply Chains

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Douglas Bradley
President,
Climate Change Solutions

402 Third Avenue · Ottawa, Ontario · Canada K1S 2K7
phone · 613.321.2303 email · douglas.bradley@rogers.com
web site · www.climatechangesolutions.net

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NB: This study was undertaken to gain an understanding of the potential long-term costs to develop forest residue sources in Canada. It is not a detailed time and motion study of cost components of handling and transporting forest biomass in Canada. It is a 12-day study to assess cost experience in other countries, in particular Finland and Sweden, to assess for planning purposes what the long term anticipated costs might be to acquire forest residue in Canada, and use this assessment to estimate the amount of forest biomass that might be available for domestic purposes and exports.

Mill residue volume estimates reflect 2005 data accurate within 3-4%, and are updated for planned bioenergy projects in 2005-07. What is not reflected is the short term impact of a cyclical downturn in the US housing market which has caused a temporary reduction in the production of Canadian lumber and by extension mill residue. This production is expected to recover. Also not reflected is the impact of the rise in the $Canadian versus the $US, which has the potential to reduce Canadian lumber production.

All $dollars are stated in $Canadian unless otherwise specified.

Executive Summary

Canada had an estimated 2.7 million ODt of surplus residue from sawmills and pulp mills in 2005. In 2005-07 an estimated 0.9 million ODt of this surplus was committed to energy projects. On the positive side, a sizable proportion of residue production still goes to landscapers at low cost, residue that could be redirected to energy. Mill residues available for energy in 2007 may be 2.3 million ODt. 15.4 million ODt of bark in "heritage" piles is available also. In order to increase production of renewable energy, all of the major forest products provinces are seriously considering utilizing forest residues to supplement mill residues for energy. This source exceeds 16 million ODt annually.

Sweden has considerable experience with forwarding, comminuting and transporting energy wood, trying and testing several supply chains since 1980. Forest residue supply chains include; transporting uncomminuted residue, chipping and trucking, and bundling, both from roadside and in-forest. Sweden has experienced considerable cost reduction over 25 years due to equipment improvements, learning etc. In 1983-2003 costs fell 2% annually, the greatest cost reductions from forwarding, the least from transportation.

Finland also has tried and tested several supply chains, including loader/truck combinations, terminals, and bundling energy wood instead of chipping. Until recently, bundling had the lowest transportation cost of energy wood owing to the energy density achieved by bundling. However it is still a new technology and full supply chain costs are still high. While the bundling chain bears lower cost than full tree chipping, recent use of much larger trucks has reduced the delivered cost of loose residues, now the new lowest cost supply chain. In the meantime, two companies have built and begun testing new model bundlers, so costs are anticipated to come down, more so than chipping, which is well down the learning curve.

In the US, several trials with bundling have led to estimates of $31.50US/ODt for collecting and bundling, forwarding, transporting and chipping.

In Canada, approximately 90% of forest land is "Crown", that is owned by governments. Most of this is under the jurisdiction of the Provinces, which organize harvesting under Sustainable Forest Licenses. License holders are allocated an "annual allowable cut", and pay the province a stumpage charge based on roundwood taken from the stand. Thus Provinces own the harvest residues. No province has yet decided to charge a stumpage for residue. Ontario has indicated there will be no charge.

Canada is a major forest products producer. Approximately 90% of harvesting is full-tree to roadside, where trees are forwarded to roadside and delimbed, either to roundwood for sawmills, or chipped for pulp mills. Canada has extensive experience with full tree chipping, both in-forest and roadside, but very little experience with comminuting harvest residue or thinnings. Based on costs in existing supply chains and on evidence from recent trials, the estimated cost to pre-pile, chip and transport roadside residues, including costs related to forest management, is $46/ODt for 100 km. This should fall to under $44 by 2010 as the chain tightens up. Based on cost reductions experienced by Sweden and

Finland on the learning curve, Canadian supply chain costs for roadside chipping are projected to fall to $40/ODt by 2015. Estimated costs to bundle and transport roadside biomass 100 km are $50/ODt in 2007-08, $42/ODt in 2010, and $37/ODt by 2015, as the effects of learning and process and equipment improvements are felt.

While an estimated 16.4 million ODt of harvest residues are available annually, 12.9 million tonnes are already at roadside and are targeted first for bioenergy. The economic distance for roadside waste is generally about 150 km. On this basis approximately 11.3 million ODt of roadside waste are considered to be economic. Combined with excess mill residues and heritage bark, 17 million ODt are economic and available for energy.

In BC power prices are low and the pulp industry is unlikely to invest in internal heat and power. BC pellet exports are growing exponentially. Upwards of 85% of available biomass in BC, or 8.7 million ODt, may be available for export in the form of transportable bio-products. Half of Ontario biomass is in the North West, far from ports and unlikely destined for Europe, though US exports are possible. Ontario's power incentive will draw some biomass for internal power. An estimated 40% of Ontario biomass, chiefly from the North East and South, are available for export. Quebec biomass is closer to ocean ports and there is little incentive for local biomass power, so potentially over 70% of biomass could be exported. Overall, 11 million ODt biomass in Canada may be available for export.

Canada- Sustainable Forest Biomass Supply Chains

1. **Forest Biomass Volumes**

Forest biomass can be broadly separated into two categories; mill residue (bark, sawdust and shavings primarily from pulp mill and sawmill operations), and forest residue (tops, branches and leaves from harvest and thinning operations that are left in the forest or at roadside after delimbing). Mill residue bears a lower cost as it is already at a mill site and is partially comminuted. Bioenergy projects tend to use the lowest cost feedstock, usually 100% mill residue. Where mill residues are scarce or dispersed, an energy plant will try to find the lowest cost mix encompassing both mill residue and some forest residue.

1.1. Mill Residue

A 2005 mill residue survey[1] of Canadian pulp mills and sawmills indicated annual production of bark, sawdust and shavings of 21.2 million ODt[2] as shown in Table 1.1. Much of this biomass is committed to produce onsite energy, or sold to independent power producers, board and pellet manufacturers, farmers for animal bedding, and landscapers for garden beds. After considering domestic consumption and exports there was a surplus of 2.7 million ODt on Jan 1, 2005. The province of BC had a surplus at 1.8 million ODt, with .5 million ODt in Alberta, just over 100,000 ODt in each of Ontario and Quebec, and essentially zero elsewhere. Abundant mill residue, previously free for the taking, has become a commodity commanding a price of $0-25/ODt.

Table 1.1- Canada Surplus Mill Residues (ODt)

	2005				2005-07		
	Prod'n 000 BDt	Consump.	Exports	Surplus 000 BDt	Utilization	Recovery	Surplus 000 BDt
Province							
BC	6,554	4,389	350	1,815	-815		1,000
Alberta	2,406	1,924	0	481	-30		451
Saskatchewan	580	416	0	164			164
Manitoba	225	212		13			13
Ontario	2,602	2,480	0.54	121	-60	415	476
Quebec	6,669	6,400	169	100			100
New Brunswick	1,373	1,223	150	0		69	69
Nova Scotia	601	588	0	13		30	43
PEI	24	23		1			1
Nfld & Lab.	195	166	0	30			30
Total	21,229	17,821	669	2,738	-905	514	2,347

[1] Estimated Production, Consumption and Surplus Mill Wood Residues in Canada-2004, A National Report- NRCan & FPAC; Prepared by BW McCloy and Associates and Climate Change Solutions
[2] ODt- Oven Dry tonnes= Bone Dry tonnes

Known and anticipated new biomass projects are projected to reduce the estimated 2005 surplus by 0.9 million ODt, also shown on Table 1.1. Pellet and energy projects in BC alone will reduce the BC surplus by 0.8 million ODt[3]. A new pellet plant in Houston BC and a pellet plant expansion in Price George will utilize over 250,000 ODt of mill residue, and Canfor is contemplating pellet capacity also. A recent call for power by BC Hydro may eliminate the BC surplus in BC, if biomass power projects can compete with current prices. In Ontario, a bark boiler project at the Abitibi-Consolidated pulp & paper mill in Ft. Francis is in the final stages of approval. It would utilize 60,000 ODt.

While surpluses are being absorbed, mill residue currently utilized may still be available for energy. A Jan 2007 survey of Eastern Ontario showed that while virtually all of mill residues were consumed, only 20% went to energy while 50% was sold or given away to landscapers. Prices ranged from 0 to $22.50/ODt, but much was sold for under $12/ODt. A sizable amount of biomass could be recovered for energy at reasonable cost. Estimated biomass recovery from landscaping to energy is; Ontario 415,000 ODt, New Brunswick 69,000ODt, and Nova Scotia 30,000 ODt. Thus the estimated amount of mill residue available for energy in 2007 is 2.3 million Odt, shown in Table 1.1.

1.2. Heritage Bark Piles

In BC, Alberta and Manitoba, sawmills are required to incinerate bark and sawdust that is not used internally or sold in the year it is produced. In Saskatchewan and the Eastern provinces incineration is disallowed and mills pile excess residue at the mill site. Only recently have mills been looking to this bark as fuel source. In some cases this bark is contaminated with rocks or soil, or is too wet or to be economically usable. However, many of these piles are excellent sources of biomass. Table 1.2 shows sawmill estimates in 2005 of bark volume, usable bark (fairly dry, little contamination), and bark available (not committed). In Canada in 2005 there were 15.9 million ODt of bark. Since then some piles have begun to be mined in Ontario and Quebec so that the volume today may be closer to 15.4 million ODt, equivalent to 1.5 million ODt annually, if mined over 10 years.

Table 1.2 Surplus Heritage Bark piles- 000ODt

	2005			2005-07	
	Estimated	Usable	Available	Utilized	Remaining
Saskatchewan	2,900	2,900	2,900		2,900
Ontario	12,000	8,012	6,712	80	6,632
Quebec	11,710	5,651	5,651	400	5,251
New Brunswick	300	257	257		257
Nova Scotia	213	206	148		148
PEI	30	30	30		30
Newfoundland	235	188	188		188
Total	27,388	17,244	15,886	480	15,406

[3] Latest estimate by Brian McCloy, BW McCloy and Associates

1.3. Forest Residue

With much of the mill residues consumed, forestry and energy companies and provincial governments are looking to harvest residues as the next fuel source, vast, and much of it burned at roadside. Table 1.2 estimates harvest residue available in the key forestry provinces. BC has the largest harvest, at 87 million M^3, and the most harvest slash. Quebec is next highest in harvest, with 40 million M^3. In most of the provinces slash is 9-14% of the harvest volumes, as shown in Table 1.2. However, in BC slash volumes are currently 20-40% of harvest, a phenomenon of the massive harvest of Mountain Pine Beetle wood. While bucking to a 4" top is normal, since MPB logs are often cracked and can' be used for lumber, BC is now bucking to a 6" top and leaving more slash behind. In BC an estimated 11.0 million ODt is at roadside. FPInnovations estimates that 7 million ODt of this is accessible MPB slash. In BC, Alberta and Ontario the harvest method is primarily full-tree to roadside, which leaves the slash at a roadside and thus relatively accessible. While Quebec has more slash than Ontario, a mixture of harvest methods yields only 940,000 ODt at roadside in Quebec, compared to 1.5 million ODt in Ontario.

Table 1.2- Harvest Residue- Annual Volumes & Methods

	Harvest Roundwood Mil M3	Slash %	Slash Mil M3	Slash 000 BDt	Roadside %	Roadside 000 BDt	Stump 000 BDt
BC	87.0	25%	29.0	11,600	80%	9,280	2,320
Alberta	23.5	10%	2.6	1,044	95%	992	52
Ontario	24.2	14%	3.9	1,576	95%	1,497	79
Quebec	39.6	9%	3.9	1,567	60%	940	627
New Brunswick	10.4	9%	1.0	411	35%	144	267
Nova Scotia	5.7	9%	0.6	225	0%	0	225
	190.4			16,424	78%	12,853	3,571

While Finland and Sweden have long utilized forest residue, serious interest has only begun in Canada. Potential forest biomass sources include residues from harvest, silviculture activity, natural disturbance (especially mountain pine infected stands), and non-merchantable wood. With so much experience gained in Sweden and Finland, what technologies should be applied in the Canadian context? What would be the long-term cost for harvest residue? How much could be deemed economically attainable?

2. Policy Support Framework

Both Sweden and Finland have high energy prices, and also effective policy frameworks to promote energy from biomass. Neither country has any oil reserves, a key driver for effective policies. Cost reduction in Scandinavian biomass supply chains has been a result of these policies. Canada can expect to make use of 25 years of learning by Scandinavia, but will not likely experience an equivalent pace of cost reduction without additional supportive policies and incentives.

The main driving forces for biomass use in **Sweden** were high oil prices beginning in the1970s and the subsequent policy by government to wean Sweden of imported oil. The oil crisis triggered biomass R&D programs, and in the 1980s and 90s investment subsidies of up to 25% on boilers or total investment costs were available for district heating systems and CHP plants. A carbon tax implemented in 1991 and taxes on NO_x from fossil fuels strongly improved the competitiveness of the use of biomass fuels for heat and power production[4]. The Solid Fuel Act and Wood Fibre Act further promoted the use of biomass fuel. A renewable electricity certificate system introduced in May 2003 may also promote increased biomass-based CHP capacity.

Finland also has many support mechanisms for energy from wood. A carbon-based tax on fuels used for heat production was imposed in 1990, but wood-based fuels are free of this tax. In 2004, the energy tax in €/MWh was coal 6.3, light fuel oil 6.0, heavy fuel oil 5.3, natural gas 1.9[5]. In addition, consumers of electricity pay a tax of 6.9€/MWh, which is refunded to producers of electricity from forest chips or wind. A subsidy of 5.5€/MWh is paid to chip producers that harvest small-diameter fuel wood from young thinning stands. A subsidy of typically 25% is paid on investments in new technology for forest chip production, including chippers, crushers, balers, felling heads, and biomass vehicles. Financial support is also provided to commercialize technology for renewable resources. Favourable incentives have resulted in considerable development of biomass systems.

In **Canada**, many historical programs focused on R&D and marketing, but very little support was provided for development, to the disappointment of developers. Much of the bioenergy development consisted of large cogeneration facilities at pulp plants, which enabled pulp companies to reduce purchases of fossil fuels and electricity. Also, many independent power producers began producing power using "free" sawmill residue. Lately, some provinces have introduced premiums for renewable power. Ontario, for example, now offers 11¢/KWh for power from renewable resources, 14.5¢ in peak hours. With the ongoing pulp & paper mill closures, provinces are finally beginning to promote the use of forest harvest residue for energy, although no incentive is given. Restrictive heritage legislation by provincial environment ministries has been a major barrier to bioenergy development, but this is expected to change. Ontario has drafted a "Biofibre policy" on allocation and usage of roadside harvest residue on Crown (provincially owned) land. New Brunswick also now promotes use of roadside slash, but there have been no requests to date.

3. Forest Residue Supply Chains

There are four main sources of forest biomass;

- Slash (tops and branches) left after stand harvesting
- Slash and small trees from thinnings and cleanings
- Unmerchantable wood

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[4] Technological learning and cost reductions in wood fuel supply chains in Sweden- M. Junginger etal 2005

[5] Developing technology for large scale production of forest chips. Technology Programme Report 6/2004 Tekes

- Wood impacted by natural disturbance, such as fire or insect infestation

The lowest cost and primary source of forest biomass is usually harvest slash since it is already on the ground and it is plentiful, usually 10% of tree volume. Slash from thinnings is also on the ground, but it is more costly to acquire since there is a lower volume per hectare than after harvest, and it is at the stump. Other sources involve an additional step of felling, which adds to the cost.

There are numerous slash supply chain options that might be categorized as follows[6];

1. Terrain chipping- Slash is chipped using a mobile chipper where harvesting has taken place. Chips are collected in a small container, and brought to the roadside where they are transferred to a truck.

2. Roadside chipping- Either trees are felled and forwarded to roadside (full tree harvesting, most common in Canada) for delimbing, or trees are delimbed in the field and slash is forwarded to roadside. Slash is chipped at roadside using either a mobile chipper or truck mounted chipper and transferred to a truck.

3. Terminal chipping- Uncomminuted slash is transported a short distance to a terminal where slash is comminuted and loaded onto large bulk trucks.

4. Bundling- Uncomminuted slash is compressed either in the field or at roadside into composite residue logs using a mobile bundler, and transported in standard logging trucks to the end user, where comminution takes place.

In addition, there are numerous loading and trucking options to handle and carry chips from the comminution point to the end user. Some are just standard trucks that carry and dump chips, some are purpose-built to load and compress chips to reduce costs, and some include a capability to tip at the end-user to further reduce handling costs.

4. Supply Chain Experience

In Scandinavia several supply chain studies have been undertaken. Many will be examined to ferret out data that can be used in the Canadian context.

4.1. Sweden

The key findings in studies in Sweden that may be applicable to Canada are;

- The most common and lowest cost supply chain is roadside chipping
- Costs have declined at 2% p.a. over 25 years of forest residue harvesting
- A 13% cost reduction was achieved for each doubling in cumulative harvest
- Care is taken to reduce residue contamination by soil and gravel

In Sweden extensive research has been carried out on the collection and use of forest residues. Various supply chains have been tried, tested, rejected, improved etc. over a

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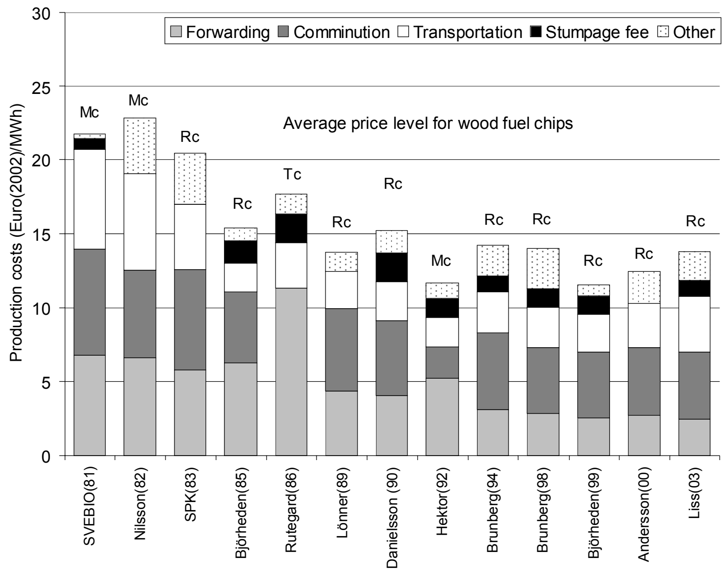
[6] Ibid 3

long period of time, and a number of supply chain studies have been published between 1981 and 2003. The predominant and most successful chain now is roadside chipping.

Since the 1980s there has been a significant reduction in production costs. Table 4.1 shows the production cost developments from 1982 to 2003 as reported in 13 studies[7]. Although these results cannot be compared directly due to dissimilarities in assumptions, some being roadside chipping, some terminal chipping etc, they indicate a definite improvement over time. Production costs have fallen 1.9% p.a., from 22€/MWh (6.1€/GJ) in 1980-82 to 12-14€/MWh (3-4€/GJ) in 2000-03.

Table 4.1- Production Costs €/MWh (2002)
Tc- Terrain chipping, Rc- Roadside chipping, Mc- Terminal chipping



The key cost factors in forest residue harvesting are forwarding, chipping, transportation and stumpage[8]. Felling costs are normally allocated to primary forest products, lumber and pulp, and do not apply to residue costs. Roundwood harvesters in Sweden are aware that slash is going to be harvested, so operators have learned to avoid driving over residues in order to reduce contamination by earth and rocks. Also, while slash used to lie randomly distributed, now it is piled next to the timber and pulpwood.

Forwarding costs have fallen chiefly by gaining experience and learning efficiencies over time. For example, once instructed to gather as much slash as possible, now forwarders only take the "cream off the top", which not only reduces time spent, but leaves nutrients at the harvest site. New equipment has been developed that increases slash carrying capacity, further lowering costs.

Comminution is primarily by chipping or grinding. Chippers tend to be less costly than grinders, but chippers are more affected by earth and rock contamination, which dulls

[7] Ibid 3
[8] Ibid 3

chipping blades and causes more downtime and maintenance. Over time, chipping costs have been reduced significantly, both by reducing contamination and by technical development of chippers, which have increased production capacity.

Transportation costs have remained relatively stable, with the predominant transportation as wood chips in container trucks. In seven studies between 1977 and 2000, neither fixed nor variable costs have changed significantly in real terms.

A last cost factor is stumpage, a fee for the forest owner. Table 4.2 illustrates the improvement in cost structure for roadside chipping. In 20 years real costs were reduced 32%, or 1.94% p.a. Forwarding achieved the greatest reduction at 58%, chipping at 33%.

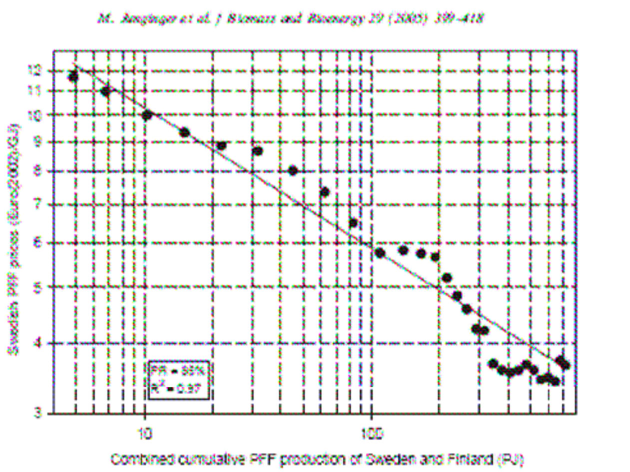
Table 4.2 Roadside Shipping costs €(2002)/GJ

	1983	2003	Reduction	Annual
Forwarding	1.61	0.68	58%	
Chipping	1.89	1.27	33%	
Transportation	1.23	1.04	15%	
Stumpage & other	0.95	0.85	11%	
	5.68	3.84	32%	1.94%

A 2005 study on technological learning[9] explored use of the experience curve concept whereby cost reductions of a product over time are investigated as a function of cumulative production. For example, in some industries production costs have been shown to decline 20% for each doubling in production as a result of learning by doing, innovations from research, product standardization, networking etc. In Sweden, over 10 cumulative doublings of forest residue production, a progress ratio of 87% was estimated with a correlation R^2 of .93, suggesting a 13% reduction in costs for each doubling in production. The report suggested circumstances in which this curve could be applied to project additional cost reductions for Sweden. While Canada would certainly experience a learning curve, it is unlikely that it would be the same as in Sweden.

Fig 4.1 Combined Forest Fuel Production- Sweden and Finland

[9] Ibid 3



4.2. Finland

The most extensive research in Finland has been on productivity in residue chipping, bundling, transportation, and terminals. Results that are most applicable to Canada are;

- Timberjack currently has the lowest cost of three bundling machines
- Bundling costs have averaged 20% lower with effective pre-piling of slash
- Transporting bundles has been lowest cost compared to all other methods
- Bundling is the highest cost when the whole supply chain is considered
- Bundling is still in its infancy and projections for cost improvement show that this method will be the lowest cost supply chain greater than 60 km
- Terminals add to a supply chain cost, but improvements to power plant operation may reduce overall cost
- Bundles can be stored far longer than chips, and may provide an effective feedstock "inventory"

4.2.1. Bundling

While slash bundlers were introduced in Sweden in the 1990s, it is Finland where most bundler research has been done and most bundlers operate, 30[10] as of 2005.

The Timberjack 1490D system is a bundler, originally Fiberpac technology, mounted on a Timberjack forwarder. It produces a "continuous 70-75 cm thick slash bundle which is cut into 3 m lengths by a chain saw. There are 25 such bundlers operating in Finland, and 10 others in the Czech Republic, Switzerland, Italy, Spain, and the US. A second bundler called the Wood Pac was developed and Partek Forest Oy bought the rights in 2002. The Wood Pac uses a batch system, like a cigarette roller, producing one bundle at a time about 80 cm thick and 3.5m long. In 2005 Komatsu introduced the Valmet WoodPac, of which there are three in use in Finland. In 2003 Pinox Oy introduced a third bundler system, the Pika RS 2000, a bundler mounted on a harvester-forwarder. It operates continuously, like the Timberjack, but it is detachable from the forwarder. There are three Pika machines operating in Finland.

[10] See Appendix- K. Kärhä, T. Vartiamäki

Matsäteho Oy undertook an extensive time and motion study comparing the productivity of bundler supply chains, and subsequently another study was done using only Timberjack bundlers[11]. The results[12] are summarized as follows;

- The Pika RS 2000 and Valmet WoodPac bear a higher supply chain cost, primarily due to smaller bundle size compared with the Timberjack, but also due to lower productivity. (However, the Pika and WoodPac machines are still prototypes and the operators used in testing were not experienced.) As shown in Table 4.2-1, Timberjack bundles were higher in volume (0.5 m^3), weighed more (418 kg), and had energy content (1.02 MWh), despite having a higher moisture content than the other two options.

Table 4.2-1 Bundle Properties

	TimberJack 1490D	Pika RS 2000	Valmet WoodPAc
Solid Volume (m3)	0.5	0.37	0.43
Weight (kg)	418	295	328
Energy Content (MWh)	1.02	0.81	0.97

- The greatest influence on bundling productivity is the organization of the logging operation. Cutting for recovery of logging residues only added only 0.5€/m^3 to the cost of cutting, but improved bundling productivity by 20%. When piles were stacked in parallel and not driven over by machinery, 68m^3/ha were removed compared with 50m^3/ha for poorly prepared or crushed piles. Residue removal was 29% of roundwood removal (1 m^3 residue per 3.5 m^3 roundwood).
- The next most important cost factor was operator experience level. Average productivity was 18.1 bundles per hour, but varied from 13 to 26 per hour. Some were better than others, but all improved with learning.
- Loading residues from one side of the road is more effective than two sides, since two sides require lifting the bundle over top of the bundler.
- The freshness of the residues affect removal costs; the fresher the residue, the higher volume removed
- Load method was more important than pile quality
- When comparing the total supply chain cost for three extraction methods (loose residues, roadside chipping and bundling), bundling is the highest cost especially at short haul distances, as shown in Fig 4.2. However analyses of supply chain components suggests that with an "optimized" supply chain costs can be reduced over 30% from 9.3€/M^3 to 6.4€/M^3 (shown on Table 4.2-2) by increasing the size of the bundle, improved operator training, achieving higher slash density per ha, and achieving a better residue layout. The optimized bundling supply chain should be the most competitive for transportation distances of more than 60 km.

Fig 4.2

[11] Ibid 10

[12] Ibid 10

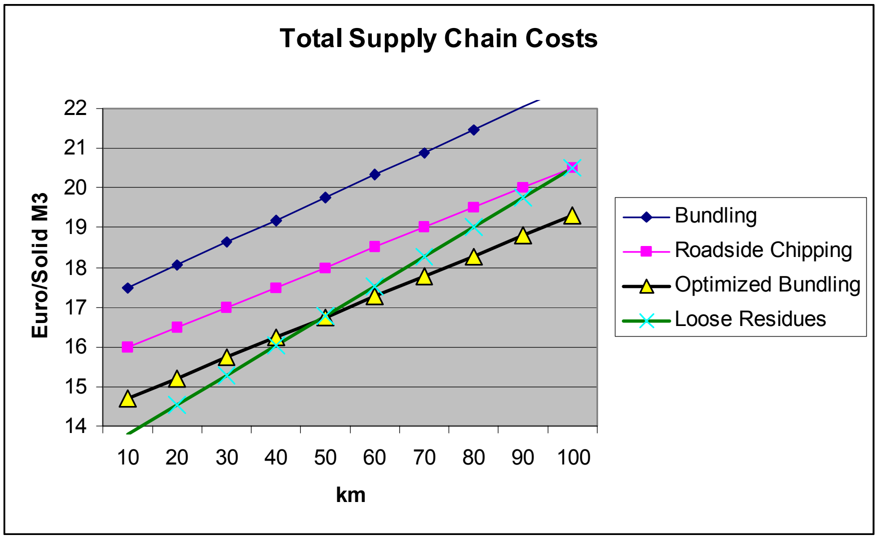


Table 4.2-2 Optimizing Bundling

	Bundling	Optimized Bundling	
Working hours	2,650	3,000	
Size of bundle	0.5	0.6	
Cord cost (€ solid M3)	0.75	0.30	
Operating Hour cost (€/E15)	84	77	
Bundling cost (€/solid M3)	9.31	6.41	-31%

4.2.2. Transportation

Finnish researchers have done considerable analysis on cost improvements for different components of forest biomass supply chains including; alternative truck trailer combinations, use of terminals, bundling technology, and shipping by inland waterway. These options are summarized in a Task 40 publication[13], and relevant results are discussed below.

A road transportation study[14] examined systems to increase bulk density by compacting or chipping, or increasing loads by extending load space. It was found that by chipping solid volume content could be increased from 15-20% for loose logging residues and 35-40% for chipped residue. A 2004 study examined profitability and efficiency of 10 truck-trailer combinations for loose residues, with truck capacities up to 145m^3. When considering four truck-trailer combinations transporting residue, bundles had the highest load (80-93 MWh), the lowest loading time (45-50 min.), and second lowest unloading time (50-55 min.) compared with other methods, as shown in Table 4.2.

[13] Biomass Supply Chains- Experiences and Lessons in Five Several Countries- Bradley D, Ranta T, Heinimo J, Perry M, Leistad O. 2007

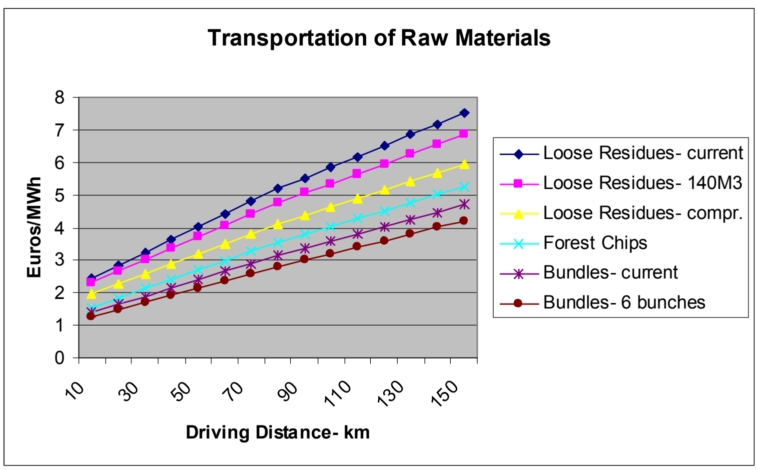
[14] Transportation Options and Profitability for Logging Residues in Finland- Ranta T, Rinne S 2004

Table 4.3- Transportation Data for Alternative Raw Materials

	Bundles		Loose Residues			Forest
	5 bunch	6 bunch	124 M3	140 M3	Compressed	Chips
Investment (000€)	225	228	250	260	280	235
Load, MWh	80	93	56	64	79	78
Loading time (min)	45	50	75	80	85	90
Unloading time (min	50	55	60	65	65	35

Looking at transportation alone, Fig 4.3 shows that in 2005 loose residues were the costliest to transport, and bundles the lowest for all distances. Costs per MWh for 100 km were; loose residues 5.8€, compressed residues 4.6€ bundles 3.6€ (or 1€/GJ).

Fig 4.3- Transportation Costs of Alternative Raw Material Options



Furthermore, bundling had the lowest cost increase per added km, making it more competitive at long distances. For transporting bundles average speed fluctuates with distance, since long distances usually involve more highway travel. For example, as shown in Table 4.4, for a 50 km trip the average speed over all roads is 52 kph.

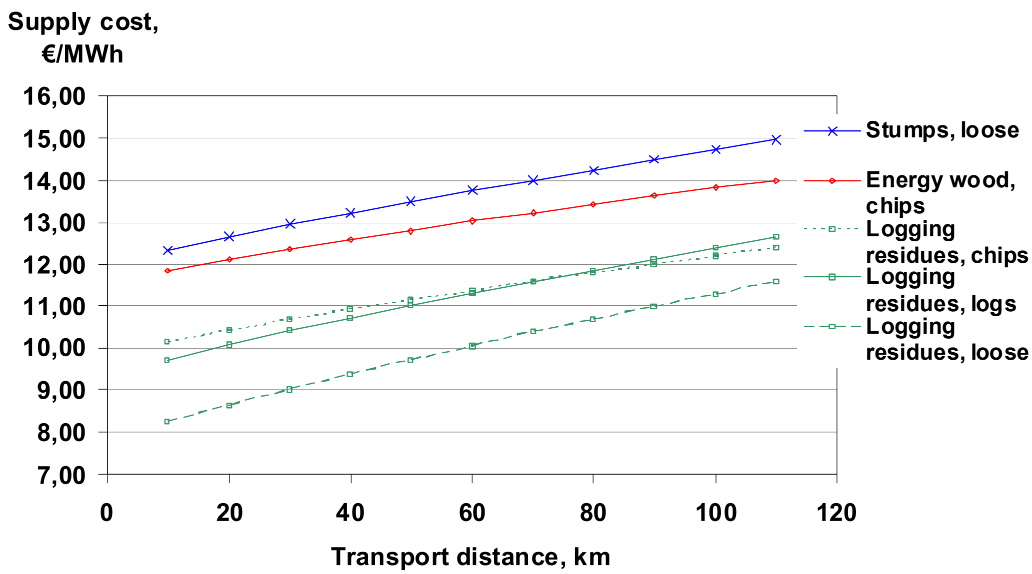
Table 4.4

Distance Km	Avg Speed kph
50	52
100	60
150	73

4.2.3. Full Supply Chain

While bundling appears to have transportation advantages, the equipment is expensive to buy and operate. Its competitiveness falls when other costs are included, such as felling, baling, forwarding, stumpage and overheads. As shown in Fig 4.4[15], the full cost of bundling is lower than stumps and energy wood (chipped from full trees), but is approximately the same as chipping logging residues. In fact recent use of large 160m^3 trucks has made the supply chain for loose residues the lowest cost option. Residue logs are transported by using normal timber trucks containing typically a maximum of 60 composite residue logs per load, at 0.4-0.5 m^3 per log. Bundling is still in its infancy, and will benefit from experience, learning, and equipment improvements. Even though the full cost of transporting loose residues has been reduced to below the cost for bundles, shown above, Fig 4.2 indicates that supply chain improvements will reduce the cost of bundling so that it will the be lowest cost chain beyond 60-km.

Fig 4.4 2007 Supply Costs in Finland



4.2.4. Use of Terminals

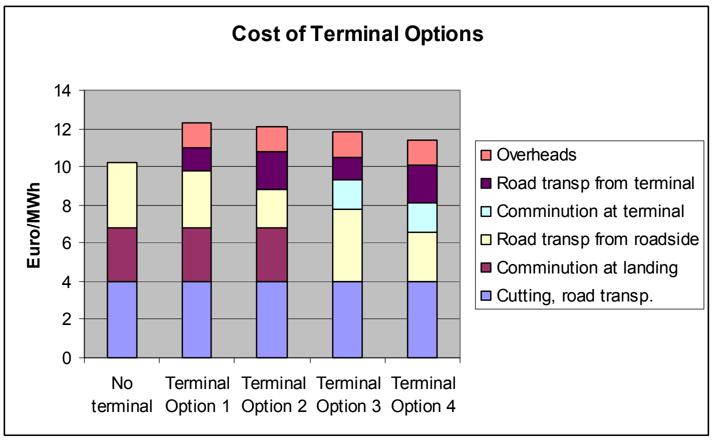
Finnish researchers have also examined the impact of using terminals to store energy biomass, to resolve supply problems both at the plant and in the field. Energy plants require a continuous supply of forest chips and they favour consistent biomass quality. Yet their experience is to have uneven deliveries, causing backlogs in receiving and congestion in the storage area. Variations in the quality of forest chips have caused difficulties in optimal operation of power plants. The amount of biomass used by energy plant fluctuates during the year with emphasis on winter, and often energy plants will not receive chips if the plant is down or the receiving area is full. In the field too many trucks on the road often cause queuing for either chippers or chip trucks. Chipper breakdowns impeded delivery of chips.

[15] Tapio Ranta, Lapeenranta University of Technology, 2007

Analysis showed that a terminal can solve many supply chain problems. It can store and make available differing qualities of chips according to an energy plant's needs. It can act as a buffer storage area for both the supplier and end user. Chip trucks can be loaded at the terminal if field chippers break down. Forest chips comminuted at a landing can be transported to the terminal, even if the power plant is not receiving. Fig 4.5 shows costs of supply chains without a terminal and four options with a terminal. Terminal costs are minimized with option 4 where the terminal is located closer to the biomass source rather than the power plant, and chipping is undertaken at the terminal instead of at the landing.

In fact, supply chain costs were higher with a terminal than without because of the added cost of unloading, handling, and reloading. However, these are supplier costs only, and do not reflect the efficiency benefits to the energy plant. It is likely that overall costs would be less when factors such as power plant downtime savings and efficient chipping at the terminal are included. Without this data, terminals cannot be evaluated properly.

Fig 4.5 Supply Chains Using Terminals



Bundles have an advantage over chips when storing in terminals. Once material is chipped it is recommended to use the fuel as soon as possible to prevent excessive microbial activity[16]. The latter causes health hazards through spore emission, energy losses, and even spontaneous combustion. Bundles do not display these drawbacks, and form a relatively uniform handling unit.

4.3. US

Bundling trials in the US have applicability to Canada, partially due to similar tree species. Some applicable learning includes;

- Don't attempt to take all the harvest residue, only the "cream"
- Alternate butts and tops, and don't bundle too dry

In the US large volumes of forest residues became available as a result of the Health Forest Restoration Plan and the National Fire Plan. Recognizing the energy potential in forest thinnings, in 2004 a study was undertaken to test the effectiveness of bundling

[16] Transport and Handling of Bundles- Johansson, Gullberg and Bjorheden

technology in the US[17], following a Swedish study that showed bundling to be competitive with roadside chipping at $US8.88-11.33/m^3 ($19-24/ODt). In the US, in-woods chipping was recognized as the most cost-effective system to recover forest residues, but it was best suited for situations with full-tree skidding to roadside, good road access for chip vans and chippers, and sufficient biomass volume per hectare.

In the US study, data was taken from 8 locations in Idaho, Oregon, Montana and California. It was found to be unproductive to collect all the residue so scattered material was left, consistent with requirements to leave a certain amount of slash. The best bundles were those that contained various lengths of slash, not too dry, and with alternating butts and tops. Machine specifications were 10-30 bundles/hour, and the highest achieved in trials was 24. Slash arrangement was found to be critical. Productivity fell when the operator picked up less than full grapple loads, causing more swings per bundle, and more time per bundle. Residues aligned at harvest in a bundle trail with grapple-sized piles, yielded production of 26 bundles/hour. (The best output achieved by the skilled operator after a clear-cut was 38 bundles per hour.)

Owning costs for a Timberjack were $US58/scheduled machine hour (SMH), operating costs $US50/SMH, including fuel, lube, repair and maintenance, chainsaw, twine etc, and labour $US22/SMH, for a total cost of $US130/SMH. At 26 bundles, this is $US5.00 per bundle. Little data was collected for transportation and chipping, so assumptions were made. Table 4.3 shows estimated costs assuming 20 bundles per hour (8 ODt). (The Finnish average was 18.1 and the optimized rate is 20.1) In the US, average supply chain costs would be $31.50/ODt, not including stumpage or profit margins.

Table 4.3 Full costs Slash

USA- Bundler

$US/ODt

	Low	Hi	Avg
Collect & Bundle	16.00	16.00	16.00
Forwarding	5.00	5.00	5.00
Haul 80 miles	5.00	10.00	7.50
Chip at plant	3.00	3.00	3.00
	29.00	34.00	31.50

[17] Forest Residue Bundling Project- New Technology for Residue Removal- May 2004- Rummer B, Len D, O'Brien O.

5. Forest Ownership and Stumpage Charges

Section 4 deals with alternative methods and costs of harvesting forest residue. Before assessing full costs, it is prudent to look at wood fibre ownership in Canada. Section Table 5.1 illustrates the forest area, harvest volume and forest ownership in each Province. BC, Alberta, Ontario and Quebec are the largest forest products provinces. BC has 64.3 million hectares of forest, and a harvest volume of 87 million m^3 annually. Newfoundland has about 1/3 of the forest area of BC, but less than 3% of BC's harvest, since Newfoundland is not a major forestry province.

Canada was generally colonized from East to West. In the colonial period, before the existence of provinces, much land was given away or sold to individuals or companies. So with the exception of Newfoundland, land in the Eastern provinces reflects a much higher level of private ownership, increasing in Provincial ownership as one moves west. For example, In PEI forests are 91% privately owned, while in BC only 3% is private and 96% is "Crown", that is owned by the Provinces or the Federal government.

Table 4.1

Forest Ownership

	Forest Land	Harvest Volume	Forest Ownership Provincial	Federal	Private
	mil ha	m^3	%	%	%
Province					
BC	64.3	87.0	96%	1%	3%
Alberta	36.4	23.5	89%	8%	3%
Saskatchewan	24.3	6.1	90%	4%	6%
Manitoba	36.4	2.1	95%	2%	3%
Ontario	68.3	25.2	91%	1%	8%
Quebec	84.6	43.3	89%		11%
New Brunswick	6.2	11.4	48%	2%	50%
Nova Scotia	4.4	6.9	29%	3%	68%
PEI	0.3	0.7	8%	1%	91%
Newfoundland & Lab	20.1	2.3	99%		1%
Total	345.0	208.5	77%	16%	7%

While the Crown owns 93% of Canada's forests, the rights to the wood fibre are distributed to companies, or groups of companies under arrangements called Sustainable Forest Licenses. These licenses allow harvesting of a defined amount of timber each year, called the Annual Allowable Cut. The license holder pays a fee called "stumpage" for the wood, and the license holder is responsible for forest management.

On Crown land the province owns the harvest residue. Currently all of the forest products provinces are examining options to allow harvest residue to be taken away for energy.

Ontario recently tabled a proposed policy on harvest residue for review by stakeholders, and is expected to finalize a policy in the next few months. It is the intent of the Province to allow applicants to take away harvest residue essentially at "no charge". However, favour will be shown to those biomass projects that can show they provide the most jobs within the local community. While no stumpage charge is expected, it is likely that the license holder could charge a fee for use of roads, forest management etc.

Quebec is also expected to allow taking away of harvest residue. The Canadian Forest Service is now mapping Quebec to assess what areas can ecologically support the harvest of forest residue, and which should not. Quebec does not yet have a policy, but it is very much under discussion. Even now, Quebec will entertain applications for harvest residue utilization.

New Brunswick has a policy, and has already done the work on eligibility of sites based on site ecology, however due to low power prices in the Province there has not been a strong demand for forest residue.

In BC, there are growing piles of roadside slash owing to the high cull rate of Mountain Pine Beetle fibre. To promote using the fibre, the government has indicated that even though some of the fibre is merchantable, it will not charge the license holder against its Annual Allowable Cut if this fibre is hauled to a pulp mill or energy facility. To date there is only one instance of a company making use of this provision and hauling slash to a mill.

6. Canada- Harvest Residue Cost Estimates:

Canada has had decades of experience with in-forest full-tree chipping to supply fibre to pulp mills, and has improved supply chain efficiencies over time. However, experience with chipping and grinding slash has been limited to trials, although these have been going on for several years. In 2005 trials for a Timberjack bundler were undertaken at several locations across Canada. Many trials and studies were undertaken by the Forest Engineering Research Institute of Canada[18], now part of FPInnovations. How can we integrate knowledge of offshore supply chains with what is known in Canada to produce a usable estimate for long term domestic forest residue supply chains?

Table 1.2 shows that 95% of harvesting in Canada is full tree to roadside, thus 95% of harvest residues are at a roadside. While it is possible that future in situ residue harvesting will occur, roadside slash is so much more plentiful and costs should be so much lower than in situ that only roadside chipping and roadside bundling are examined.

6.1. Chipping & Grinding Roadside Slash:

As indicated in 4.4, experience comminuting roadside slash has been limited to trials. Field trials are interesting for examining new processes and getting broad estimates of

[18] In early 2007, Feric merged with Forintek (National Wood Products Research Group) and Paprican (Pulp and Paper Research Institute of Canada) to become FPInnovations, and Feric is now known as FPInnovations- Feric Division

costs, but very few operating efficiencies are expected in trials. For example, trucks and other machinery are often rented on a one-time basis at high cost, operators may be inexperienced, or may be experienced in different terrain. Also, slash is often disbursed, whereas an efficient system would integrate harvesting and residue processes by preparing slash in a particular way. For this reason costs in trials over-estimate what can be achieved. FPInnovations commonly takes results of trials and other known cost factors and subsequently models processes to get a more accurate assessment of costs.

FPInnovations estimated the achievable cost of the roadside slash supply chain with roadside grinding. Three cases were developed; realistic, optimistic, and pessimistic, with details provided in Appendix 1. Briefly a **realistic case** assumed slash pre-piling arrangements with the harvester, charges for road use and other forest management by the license holder, comminution of 25 ODt/hour, and 100 km chip transportation on highways and tertiary and secondary roads. The **optimistic case** assumes fewer license charges, comminution at 30 ODt/hour, and only 50 km transportation. The **pessimistic case** assumes no integration with harvest operations, extra road charges due to graveling on tertiary roads, low comminution productivity, and 150 km transportation. These cases are based on knowledge of Scandinavian systems and technologies, some existing configurations of forestry equipment, and Canadian wage and fuel rates. Table 6.1-1 illustrates the cases, showing a projected realistic cost of $43.60/ODt, while the optimistic estimate is $24.11, the pessimistic $61.54.

Table 6.1-1 Recovery of Roadside Residues- Ontario ($/ODt)

	Optimistic	Realistic	Pessimistic
	50 km	100 km	150 km
Pre-piling	2.64	2.64	0.00
Comminution (grind)	10.25	13.04	18.56
Transport	12.4	21.51	30.02
Stumpage	0	0.00	0.00
Road Improvement	1	3.00	7.96
Planning & Supervision	1	2.25	2.25
Overhead	0	2.25	2.25
Compliance	0	0.50	0.50
Silviculture Rebate	-3.18	-1.59	0.00
	24.11	43.60	61.54

How will costs improve? Looking at cost components, pre-piling may not occur initially, but the potential for efficiencies will drive integrated harvest and residue recovery early on, reducing costs.

Using current methods, slash at roadside is likely to contain significant amounts of contamination from soil and rocks, both as a result of forwarding trees over the ground, and also with slash placed on the ground at roadside. Sand and gravel dull chipper blades quickly, resulting in chipper downtime. Thus, initially comminuting will likely be done with grinders, which are more costly to operate than chippers, but are more robust and forgiving to contamination. Contaminated chips cause problems in boilers, chiefly glassing, which subsequently has to be cleaned out. In Europe, clean chips command a higher price than contaminated chips, and systems have been developed to eliminate sand, dirt and other contaminants. If the marketplace mimics Europe, residue prices will promote elimination of contamination, and systems may switch to lower cost chippers. In the long run, better forwarding systems and ground cover at roadside will reduce contamination, and lower cost chippers to replace grinders, reducing comminution costs. Chip transportation will improve with the use of larger, more efficient trucks.

In all likelihood, residue systems will not pay costs for forest management or overhead initially, but these systems will soon have to bear these costs. Road costs will depend on local terrain.

Table 6.1-2 projects costs through 2015. The estimated achievable cost (from Table 6.1-1 above) is $43.60/ODt for a 100 km distance with no stumpage, or $34.49 for 50 km (FPInnovations). In the next year or two, costs are expected to be higher than that as the supply chain starts up, estimated at $46/ODt for 100 km, and $35.84/ODt for 50 km. In 2007-09, operators should reduce costs quickly simply by learning aspects of the chain, such as slash piling, loading etc. Knowledge will be shared. By 2010 the cost should drop to the achievable $43.85/ODt. The long-term Swedish experience was to reduce costs by 2% p.a. over 20 years from equipment and procedure improvements and learning. Canada will borrow from additional Scandinavian learning, operators will gradually determine which equipment will excel in Canada and will improve Canadian procedures. Equipment will also improve. A long term cost reduction of perhaps 1.8% p.a. is not unreasonable. The cost in 2007 dollars for Ontario and Quebec is thus projected at $39.79/ODt for 100 km, and $31.32 for 50 km.

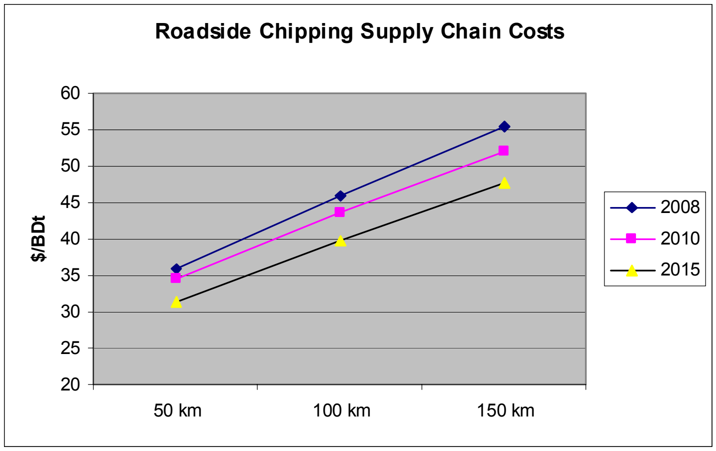
Table 6.1-2

Roadside Slash- Chip- to Energy Plant

	$/ODt	Timed Cost Curve			
	Base	2007-08	2010	2015	Improve
Forwarding	0		0		
Prepiling	2.64	4.00	2.64	2.16	-18%
Chipping	13.04	14.00	13.04	11.21	-14%
Transportation- 100 km	21.51	24.00	21.51	20.00	-7%
Stumpage	0	0	0	0	
Roads, for mgt…	6.41	4.00	6.41	6.41	
Total 100 km	43.6	**46.00**	**43.60**	**39.79**	8.7%
Transportation- 50 km	12.4	13.84	12.4	11.53	-7%
Total 50 km	34.49	35.84	34.49	31.32	

Fig 6.1 illustrates how cost by distance is projected to fall over time. Residues that cost $56/ODt to comminute and transport in 2008 is projected to cost $48/ODt by 2015.

Fig 6.1



6.2. Bundling In Situ Slash

Bundler trials were undertaken in several locations across Canada in 2005. FPInnovations undertook some of the trials, however as their association members funded the trial, some of the detailed data is not available. FPInnovations indicates that bundling costs should not be radically different from those in Europe and the US, and without supplying exact data confirms that collecting, bundling and forwarding estimates from the US are very similar to Canadian assessments, shown in Table 6.2-1. Since the US study did not develop accurate hauling and chipping costs, Canadian costs were used for these components. For comparability, the same forest management and stumpage costs as the chipping case are reflected. The estimated achievable cost of bundling with a 100 km transport is $51.14/ODt.

Table 6.2-1

Canada Bundling Estimates $/ODt

	50 km	100 km	150 km
Collect & Bundle	17.20	**17.20**	17.20
Forwarding	5.38	**5.38**	5.38
Haul	13.46	**17.15**	19.16
Chip at plant	5.00	5.00	5.00
	41.04	44.73	46.74
Forest Mgt etc	4	6.41	6.41
Stumpage	0	0	0
	45.04	51.14	53.15

How can these costs be expected to improve over time? As indicated in Fig 4.1, the relationship between costs reductions and cumulative production is linear when plotted on a logarithmic scale. While the impact on costs over time depends on the time it takes to double production, intuitively costs are expected to decline at a slower rate over time, such as that shown in Fig.6.2. Chipping residues has been going on for decades and the process benefited from years of learning in Sweden and Finland. The supply chain is well down the learning curve. While cost reductions will occur, they will be relatively small compared to the past as it will take longer to achieve doublings in production. Bundling is new to Scandinavia and essentially unknown in North America, and is higher up the learning curve. Larger cost reductions can be expected to occur in the early stages. The technology has only begun to be improved, with the advent of new bundler designs, and there are notions to integrate the bundling process with the actual harvest, which could reduce costs. Indeed, even with the same equipment learning is expected to reduce costs.

Fig 6.2

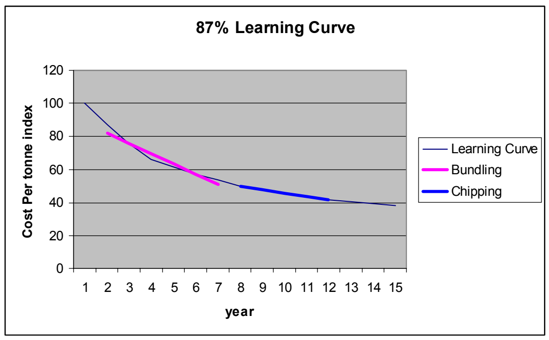


Table 6.3 projects achievable costs over time. Initially, with no local experience, but with experience picked up from Scandinavia, costs can be expected in the range of $61/ODt for 100 km. Familiarity with equipment, experimenting with procedures, and effectively integrating roundwood harvesting with slash harvesting should enable costs to fall to the achievable level of $51/ODt by 2010, reflected in Table 6.3-1 and 6.3-2.

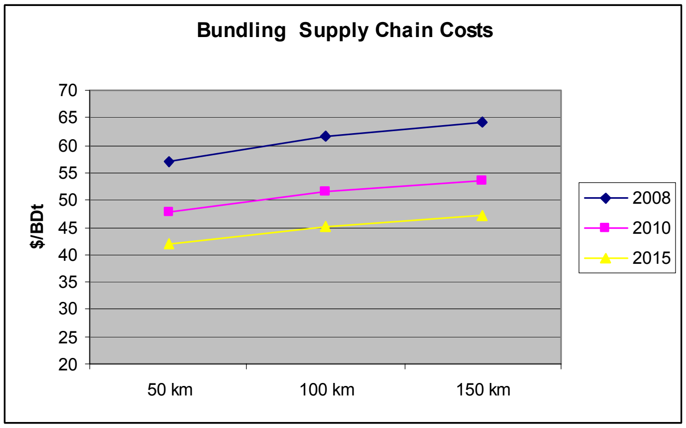
Table 6.3-2

Bundle Slash- Truck to Energy Plant

	$/ODt	Timed Cost Curve			2010-15
	Base	2007-08	2010	2015	Improve
Collect and Bundle	17.20	20.00	17.20	13.76	-20.0%
Forward	5.38	7.00	5.38	4.41	-18.0%
Transportation- 100 km	17.15	22.00	17.15	15.92	-7.2%
Stumpage	0.00	0.00	0.00	0.00	
Chip at Plant	5.00	6.00	5.00	4.50	
Roads, for mgt…	6.41	6.41	6.41	6.41	
Total 100 km	51.14	**61.41**	**51.14**	**45.00**	12.0%
Transportation- 50 km	12.4	17.26	13.46	12.52	-7%
Total 50 km	46.39	56.67	47.45	41.60	12.3%

With new bundler designs, and increasing experience it is projected that a cost reduction of 12% can be easily achieved by 2015, compared to 9% for chipping roadside slash, which is further down the learning curve. As indicated in 4.2.1, Finnish analysis estimates that an optimized bundling supply chain can be reduced by 31% from current cost levels. A 12% reduction by 2015, or 2.5% p.a., is conservative. The cost for 100 km should be in the range of $45/ODt, $47.45 for 50 km. Fig 6.3 illustrates how cost by distance is projected to fall over time for the bundling supply chain. For example, residue logs delivered from 150 km and chipped at the energy plant that cost $64/ODt in 2008 are projected to cost $47/ODt by 2015.

Fig 6.3



6.3. Bundling Roadside Slash

Table 6.3 shows the estimated supply chain cost of bundling from roadside. There is no forwarding cost since the residue is already at roadside. Collecting and bundling has been reduced by $4/ODt from insitu bundling owing to the relative ease of working on roads. Achievable costs are $41.76 for 100 km in 2010, and $37/ODt by 2015.

Table 6.3-1

Bundle Roadside Slash- Truck to Energy Plant

	$/ODt	Timed Cost Curve			2010-15
	Base	2007-08	2010	2015	Improve
Collect and Bundle	13.20	16.00	13.20	10.56	-20.0%
Transportation- 100 km	17.15	22.00	17.15	15.92	-7.2%
Stumpage	0.00	0.00	0.00	0.00	
Chip at Plant	5.00	6.00	5.00	4.50	
Roads, for mgt…	6.41	6.41	6.41	6.41	
Total 100 km	41.76	**50.41**	**41.76**	**37.39**	10.5%
Transportation- 50 km	12.4	17.26	13.46	12.52	-7%
Total 50 km	37.01	45.67	38.07	33.99	10.7%
Transportation- 150 km	12.4	24.58	19.16	17.82	-7%
Total 150 km	43	52.99	43.77	39.29	10.2%

7. Economic Volumes of Forest Residues

As estimated in Section 1, there are approximately 2.3 million ODt of available mill residue annually, 15.4 million ODt of bark in heritage piles and 12.9 million ODt of roadside residue annually. If bark piles are mined over an average of 8 years, supply would be 1.8 million BDt annually. The total forest biomass available for development is estimated at 17 million BDt, as shown in Table 7.1.

Table 7.1- Annual Forest Biomass -000BDt

Province	Mill Residue	Bark Piles	Roadside	Total	Total Econ.
BC	1,000	0	9,280	10,280	10,280
Alberta	451	0	992	1,443	1,195
Saskatchewan	164	181		345	345
Manitoba	13	0		13	13
Ontario	476	839	1,497	2,812	1,989
Quebec	100	707	940	1,746	1,276
New Brunswick	69	32	144	245	245
Nova Scotia	43	19	0	62	62
PEI	1	0		1	1
Nfld	30	2		32	32
Total	2,347	1,780	12,853	16,980	15,438

While a large amount of roadside residue is available, not all of it may be economic. Based on costs in section 6, it is assumed that slash can be transported economically within 150 km, although the economic radius will vary by location, depending on roads, tree species, harvest locations etc. The Finnish experience is to consider 150-200 km as the outside range for this biomass.

BC has 72% of available roadside waste, partly because BC is the largest forestry province, but also because annual harvest has been increased to utilize Mountain Pine Beetle wood before it rots or burns, and because the rate of slash in BC is much higher than other provinces owing to the already deteriorated condition of the Pine Beetle wood. BC harvesters are now having success transporting roadside waste on a buggy using the same truck used to transport roundwood. Essentially all of the 9.3 million ODt harvest waste in BC can be considered economic.

In Ontario and Quebec, harvest distances vary considerably. Today wood hauls are longer than the historical average as much of the close-in wood has been harvested. In Ontario 45% of roundwood and thus 45% of harvest waste is within 150 km, and therefore considered economic. In Quebec 50% of harvest waste is within 150 km. New Brunswick is a small province and it is rare that wood is more than 150 km from a saw mill. For Canada, considering only economic harvest residue, the total economic biomass available for development is estimated to be 15.4 million BDt, shown in Table 7.1.

How much can be considered for export, and how much will likely be used domestically? It depends on a number of factors including; proximity of biomass to a port, the magnitude of biomass concentrations, domestic vs offshore incentives for bioenergy, climate change policies, provincial energy prices, investment capital sources etc.

In BC for example, owing to its considerable hydro capacity and wind power potential, electricity prices in the province are comparatively low. Bioenergy is not a meaningful component of BC's power plan. Pulp and paper companies may use some biomass to lower their fossil fuel costs, but large investment by the industry is likely to be low. Accordingly, internal use of biomass is anticipated to be low in BC. In 2006, 600,000 tonnes of pellets were exported to Europe, mostly from BC. As shown in Table 7.2, perhaps 85% of biomass, or 8.7 million tonnes, may be available for export in the form of transportable bio-products.

Alberta and Saskatchewan are far from ports, but they can export bio-products to the US West Coast or possibly the East Coast. Electricity prices are comparatively high in the Prairie Provinces, and there are pulp and paper mills that may utilize more biomass for heat and power to reduce fossil fuel costs. In these provinces a notional 30% may be available for export.

Under the new Standard Offer Program, Ontario now pays 11¢/KWh for new power from renewable sources, thus improving the economics for new cogeneration projects. Much of the available biomass is in the North West, far from ports. Perhaps 40%, or 825,000 tonnes, of Ontario's forest biomass might be considered for export. In Quebec biomass is not a major component of the province power plan, and the struggling pulp industry is unlikely to invest in internal energy. Forest operations are close to ocean going ports. Upwards of 70%, or 894,000 tonnes of Quebec forest biomass might be available for export.

Overall perhaps 11 million ODt of Canada's economic forest biomass might be made available for export, as shown in Table 7.2.

Table 7.2- Domestic Use and Export- 000ODt

	Biomass	Domestic	Export	% Export
BC	10,280	1,542	8,738	85%
Alberta	1,195	837	359	30%
Saskatchewan	345	242	104	30%
Manitoba	13	13	0	0%
Ontario	1,989	1,193	795	40%
Quebec	1,276	383	894	70%
New Brunswick	245	196	49	20%
Nova Scotia	62	6	55	90%
PEI	1	1	0	0%
Nfld	32	3	29	90%
Total	15,438	4,416	11,022	71%

The above estimate is based on mill residue surpluses, bark piles, biomass diverted from landscaping markets, and economic roadside biomass. Not included are other biomass sources including;

- Insitu harvest residue
- Unharvested annual allowable cut (aac)
- Harvest residue from unharvested aac
- Salvage wood from fires, insect infestation, blowdown etc
- Non-commercial stands
- Standing Mountain Pine Beetle wood

As energy prices rise and ocean transport costs decline, more of these sources may become economic in future.

Douglas Bradley
President,
Climate Change Solutions

402 Third Avenue · Ottawa, Ontario · Canada K1S 2K7
phone · 613.321.2303 email · douglas.bradley@rogers.com
web site · www.climatechangesolutions.net

Appendix 1
FPInnovations Supply Chain Assumptions

FPInnovations estimated costs for three scenarios; realistic, optimistic, and pessimistic.

General: In all cases the mix is assumed to be 80% Black Spruce, 5% Jack Pine, 10% Aspen, and 5% White Birch. Slash is an 8 cm top diameter and 45% moisture. Recovery is 9 ODt/ha for the realistic and optimistic cases, and 7 ODt/ha for the pessimistic owing to loss from lack of pre-piling. Roadside operations consist of pre-piling with an excavator and comminution with a tracked horizontal grinder. Transportation is by way of 4-axle live-floor chip van, including 5% for overhead. The labour rate for all equipment is $32/hr, and no assumption is made for stumpage paid to the wood owner.

Realistic: Although not currently practiced in Canada, this case assumes that an operator prepiles the residues in order to maximize efficiency for a grinder, and charges the residue system $2.64/ODt. In Canada, Crown land is divided into Sustainable Forest Licenses, and the license holder is responsible for forest management and associated costs. In the realistic case, it is assumed that the license holder will save costs by not having to pile and burn the residues, and therefore will provide the residue system with a silvicultural rebate of $1.59/ODt. It is assumed that the license holder will charge the residue system for normal ancillary costs including; $3/ODt for road use (assuming no graveling is necessary to access biomass recovery blocks), $2.25/ODt full forest management and planning charges plus $0.50/ODt regulatory compliance, and $2.25/ODt of company overhead for biomass recovery. Comminution is at 25 ODt per productive machine hour (PMH), reflecting grinder utilization at 60%. Transportation is 10 km on tertiary roads, 40 km on primary or secondary roads, and 50 km of highway, for a total of 100 km.

Optimistic: An operator prepiles the residues and charges the residue system $2.64/ODt. The residue system receives a full silvicultural rebate of $3.18/ODt, the cost not having to pile and burn the residues. The system is asked to pay only $1/ODt for the costs of road maintenance, and $1/ODt for incremental planning and forest management on biomass recovery, but no company overhead. Comminution is at 30 ODt/PMH, reflecting grinder utilization at 65%. Transportation is 10 km on primary or secondary roads, and 40 km of highway, for a total of 50 km.

Pessimistic: The harvest is not integrated with the recovery operation so there is no prepiling of residues to facilitate the grinder operation. Gravel is required on tertiary roads to access biomass, so the system is asked to pay $7.96/ODt for road use. The residue system pays overhead and forest management charges as in the realistic case, but there is no silvicultural credit. Comminution is at 19 ODt/PMH, reflecting grinder utilization at 55%. Transportation is 10 km on tertiary roads, 70 km on primary or secondary roads, and 70 km of highway, for a total of 150 km.

Appendix 2
Data Sources

Europe:
Developing technology for large scale production of forest chips (Tekes-Finland- 2004)

Technological learning and cost reductions in wood fuel supply chains in Sweden (Junginger et al- 2004)

Estimation of Energy Wood Potential in Europe (Karjaleinin- 2004)

Large-scale forest fuel supply solution through a regional terminal network in Finland (T. Ranta)

Profitability of transporting uncomminuted raw materials in Finland (T. Ranta)

Transportation options and profitability for logging residues in Finland (Lappeenranta U.)
Productivity and costs of slash bundling in Nordic conditions- K.Karha, T.Vartiamaki- 2005

Canada:
Identifying Environmentally preferable uses for biomass resources- BC Bugwood (Envirochem Services)

Field testing by FPInnovations- Feric Division

Field testing by Ontario Ministry of Natural Resources

Timberjack Field Data

US:
Fuel to Burn: Economics of Converting Forest thinnings to Energy Using BioMax in Oregon (Skog et al)

Forest Residues Bundling Project- (Forest Operations Research Unit- Alabama-2004)

Abbreviations:

ODT – Oven Dry tonnes = 0% moisture