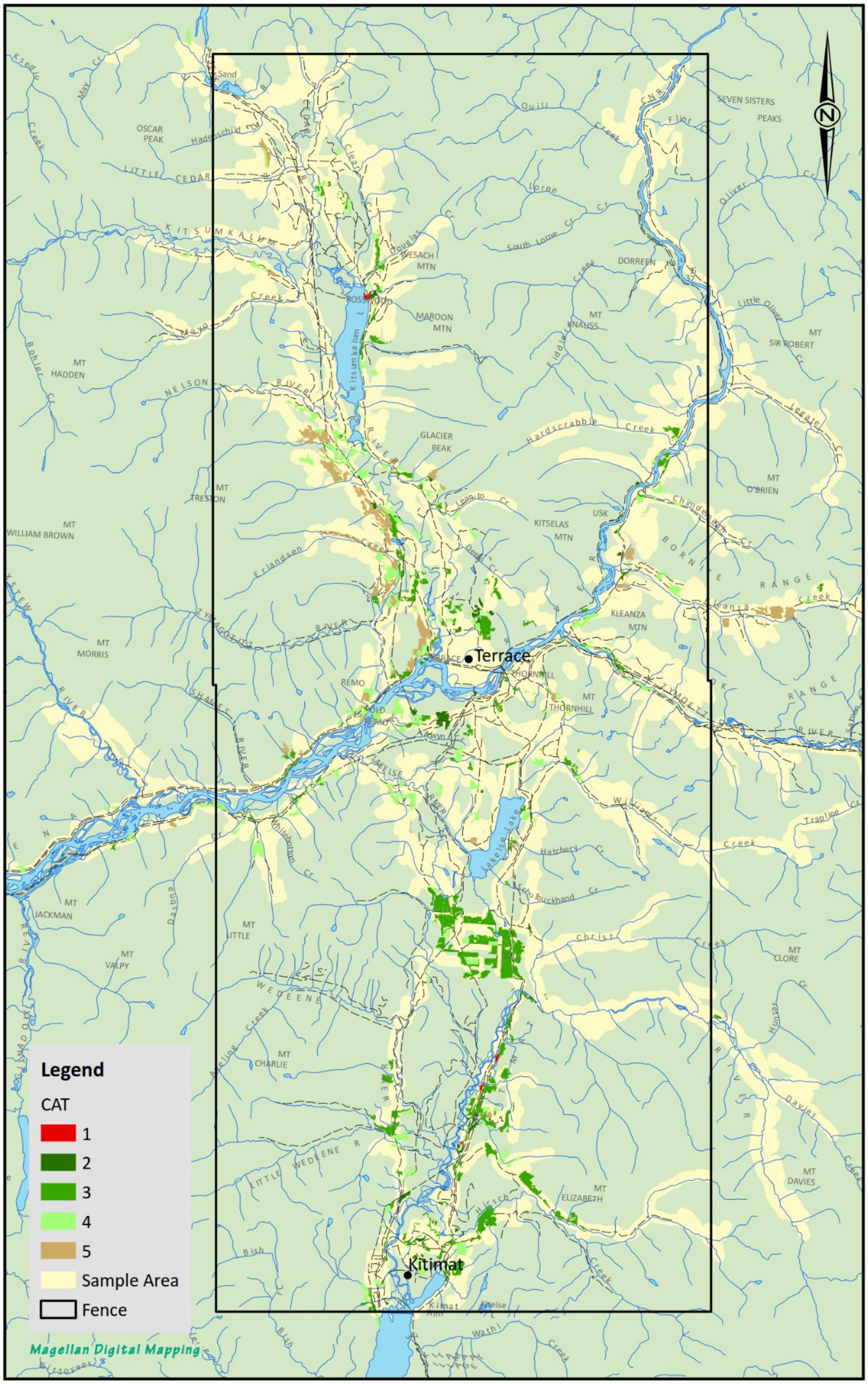
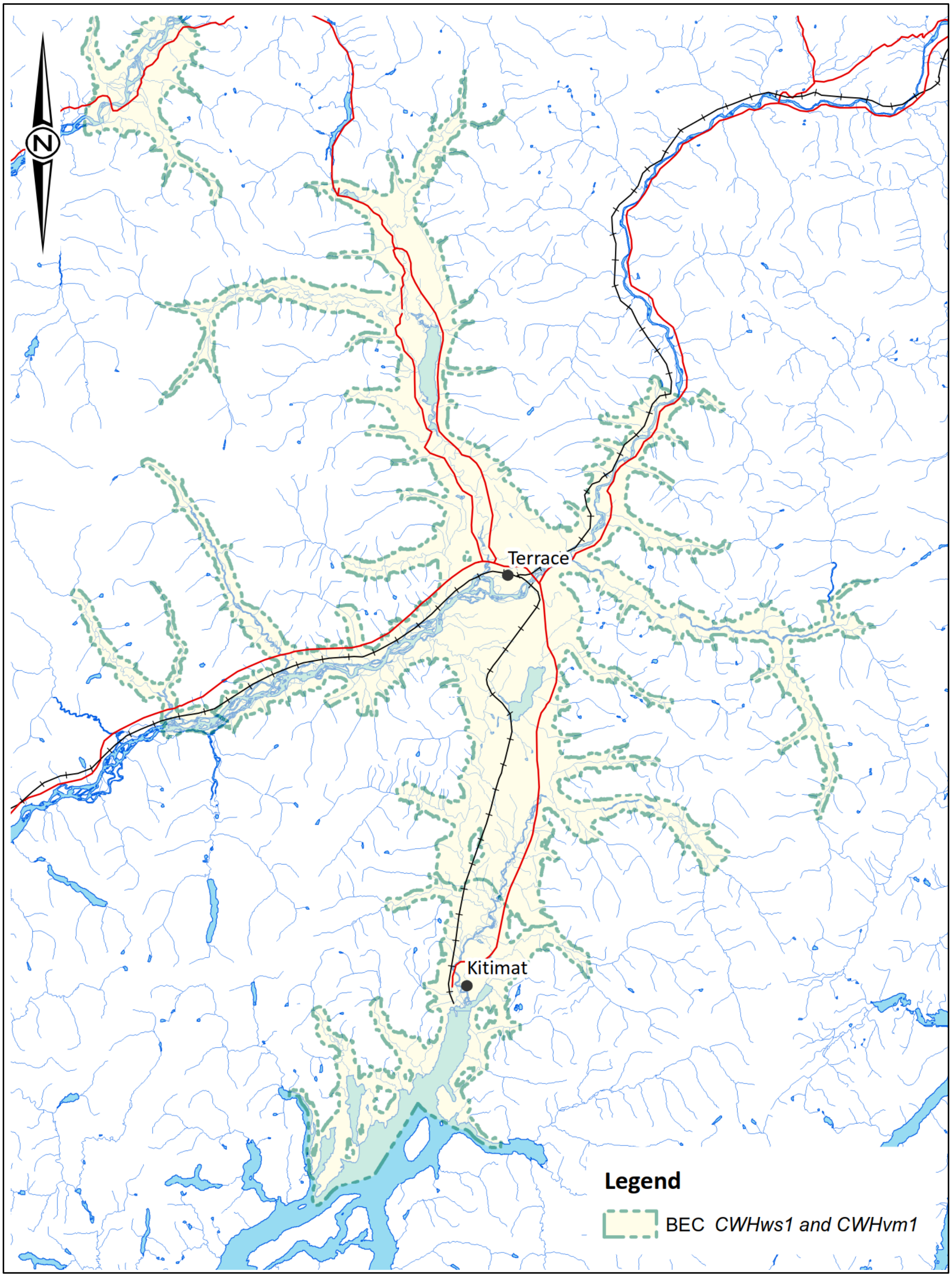
Appendix A: Second Growth Sample Area

The following map outlines the fenced area that was considered for sampling. According to VRI data, each polygon sampled was allocated to one of the five categories (CAT 1 to 5), which are colored coded on the following map. Only those polygons that contain a sample plot are identified on the map. Polygons available for sampling were those fully or partially located within 500 m of roads within the fenced area and meeting certain stand criteria. The fenced area was chosen based on the high rate of logging occurring within the Kalum and Kitimat valleys contained therein, which provides a high proportion of second growth stands to be sampled.


Legend
CAT
1
2
3
4
5
Sample Area
Fence
Magellan Digital Mapping
Terrace
Kitimat
THORNHILL
MT THORNHILL
REMO
ROSSWOOD
OSCAR PEAK
SEVEN SISTERS PEAKS
MT SIR ROBERT
MT O'BRIEN
MT HADDEN
MT TRESTON
MT WILLIAM BROWN
MT MORRIS
MT JACKMAN
MT VALPY
MT LITTLE
MT CHARLIE
MT CLORE
MT DAVIES
MT ELIZABETH
KITSELAS MTN
KLEANZA MTN
WESACH MTN
MAROON MTN
GLACIER PEAK
MT KNAUSS
DORREEN
USK
Kitsumkalum
Lakelse Lake
Hardscrabble Creek
Erlandsen Creek
Hatchery Cr
Williams Creek
Christ Creek
Little Oliver
Legate Cr
Davies Creek

Appendix B: Second Growth Area of Interest

The following map outlines the area of interest for second growth sampling: the lower elevation variants of the Coastal Western Hemlock (CWH) subzones of the onshore portion of the former Kalum Forest District. The CWH subzones are where the majority of forest harvesting has occurred within the region. Therefore, the sampling work done in this study can be used to extrapolate volume and inventory data to the forest polygons within these subzones. All the sampled areas are within the area of interest.


N
Terrace
Kitimat
Legend
BEC CWHws1 and CWHvm1

Appendix C: Second Growth Sampling Procedures

The following is a memorandum compiled for the field sampling portion of this study. The author, Kevin Hardy, RPF (ret), designed the field sampling techniques therein based on the scope and methodology of the 2018 *Vegetation Resources Inventory BC - Ground Sampling and Procedures* from the Ministry of Forests, Lands and Natural Resource Operations, except for the exclusion of some variables that were not considered relevant to this project.

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MEMORANDUM

Date: September 14, 2018

To: Tim Salkeld RPF, Forest Analysis and Inventory Branch

cc: Kevin Hardy RPF (ret); Sonny Jay RPF (ret); Gary Johansen RPF

From: Rick Brouwer RPF

Re: **Sample Plan for 2nd Growth Sampling to support the *Northwest BC Future Forest Products and Supply Streams* project**

The following plan for second growth sampling was prepared by Kevin Hardy, RPF (ret) and reviewed by Sonny Jay RPF (ret) and Rick Brouwer RPF:

A budget originally deemed to support 50 ground samples was the deciding factor in designing a sample plan that could focus sampling on target areas of second-growth hemlock and balsam stands in the road accessible areas of Kitimat, Terrace, Hazelton and Prince Rupert. The intent was to build on work done for a project[1] from 2016 which looked at forest inventory data to determine whether second-growth stands might be able to support either a sawmill or fibremill. The field work would allow refinement of the conclusions from this report about the amount of potentially available second growth by establishing ground samples to verify whether the inventory estimates were reasonable, and could support commercial activities related to potential forest products.

Strata of interest were pre-stratified based on classes of Quadratic Mean Diameter since log size was of particular interest and would be very important in investment decision making.

Target sampling errors, while discussed as approx. 15%, were not set at the beginning since the mean values for volume, Quadratic Mean Diameter (QMD) and log grade by the important larger diameter class strata were of most interest. Further sampling required to bring the precision around the lower confidence limit to a specific level would be considered with a bigger project in the future.

The population of interest for the 50 samples was defined as follows:

The initial data capture for second growth sampling included forest inventory polygons accessible by road between Kitimat, Terrace, Hazelton and Prince Rupert BC. The dataset was meant to feed into 2 projects, therefore, the initial project area is significantly larger than the second growth project requires.

Initial Project Area

The initial project area included the following:

- Kitimat Valley and tributaries
- Kitsumkalum Valley and tributaries
- Skeena Valley south side from Mount Jackman to Shelf Peak
- Skeena Valley north side from Port Edward to Kuldo River
- Portions of the Kitseguecla, Bulkley, Suskwa and Shegunia Valleys
- Nass Valley from Sharp Peak to Taylor River
- Excluding large parks and protected areas along the boundary

[1] Coast Mountains Natural Resource District and Silverwood Natural Resource Consultants. (2016): *Forest Investment Opportunities in Northwest British Columbia.* FLNR File 10005-40/GS16DCM007SF.

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Large voids in the 2017 forest inventory, Vegetation Resources Inventory (VRI), specifically within TFL 41 and Nisga'a Lands areas were filled with 1999 and 1998 Forest Cover data, respectively, which were aged up to 2017 (note: some voids remain within TFL 1, specifically most of mapsheet 103i.049 and unlogged portions of 93L). Smaller voids, polygons identified as Not Satisfactorily Restocked, were updated with tree species, ages, heights and site index from RESULTS Forest Cover Inventory where available.

Where overlap between the forest inventories occurred, VRI was given priority and the older forest cover layers were clipped to its edges.

Non-forested, private lands, Indian Reserves and Parks were removed from the dataset.

Second Growth Sample Area

The capture of potential sample areas was a 500m buffer of driveable roads. This road network consisted of and extended from Terrace, south to Kitimat along Highway 37, north to Sand Lake along Highway 113, west to McNeil River and east to Cedarvale along Highway 16. All roads tributary to these Highways that were permitted forest tenure roads or paved public roads were included in the network from which the buffer was built. All forest inventory polygons intersecting this buffer were captured for potential sampling.

Further, a rectangular fence was built along the heavily logged Kitimat and Kitsumkalum Valleys to focus future sample areas along that corridor. All forest inventory polygons captured by the buffer which intersected this fence formed the basis for second growth sampling dataset.

Crown Land Focus and Stand Categories

From the remaining polygons the following attributes were used to select and categorize the final list of potential sample areas:

- Hemlock Leading (Hemlock is species 1)
- Age >=25 and <=100 years
- Volume >=250 m3/ha

Categories:

1. quadratic mean diameter 35cm+
2. quadratic mean diameter 30 to 35cm
3. quadratic mean diameter 25 to 30cm
4. age greater than 40 years and not found in categories 1, 2 or 3.

Isolated slivers and polygons less than 2 hectares (ha) were removed leaving 9009.6 ha (1028 polygons) to potentially sample.

Sample Set Creation

The list of polygons was used to select 50 samples using PPSWR.

To set the sample location within each polygon:

- a 100m x 100m UTM grid was overlaid on the sample areas (amounting to 250,000+ points) using ET GeoWizards 'Create Point Grid Software'. The grid PoC was at the intersection of 2 lines representing the western most and southern most sample polygon boundary edges.

- points landing outside sample areas were removed.
- remaining Grid Points (1600) were assigned the polygon number of the sample area they fell within then given a unique Grid Point number (1 to 1600), after being sorted by polygon.
- Grid Points to be sampled were selected by polygon using a random number sequence generator (random.org) with the lowest and highest Grid Point values representing the sequence boundaries. The first number returned in the sequence was chosen as the sample location. If a polygon contained more than 1 sample then the second number in the sequence was chosen as the second sample, the third number was chosen as the third sample, etc.
- Auxiliary Plots sampling were located 50m in each cardinal direction from the original sample site.
- maps at 1:5,000 and 1:10,000 showing BING imagery, sample sites, aux plots, polygons and access roads were built for each sample site.
- Aux plots outside and on polygon boundaries were relocated or split in the polygon using VRI methodology.

Area Net Downs

	Item	Area (ha)		Net Area (ha)	Stage
	Initial data capture		=	2900456	A
minus	Non-forested/N.T.A.	1160418	=	1740038	B
minus	Private Lands/I.R.	65503	=	1674535	C
minus	Parks/Protected Areas	30280	=	1644256	D
minus	Age <25 and >100	656132	=	988124	E
minus	Non-Hemlock Leading	845171	=	142953	F
minus	Volume (12.5 utilization) <250m3/ha	16674	=	126279	G
minus	Outside of 500m road buffer	81247	=	45033	H
minus	Outside of fence	7564	=	37469	I
minus	Does not meet CAT 1-4 definitions	28459	=	9010	J

areas based on NAD 83 BC Environment Albers projection

Balsam Leading

Balsam Leading stands were pulled out of the dataset at Stage I, broken into the 4 stand categories (same as Hemlock leading) resulting in 2400.5 ha (141 polygons) of potential Balsam sampling and renamed to CAT5. This polygon list was used to select 10 samples and 10 replacements PPSWR. The same mapping procedures were used as for the Hemlock maps.

Area by Management Unit

The project manager requested the second growth area be broken out by Management Unit (TSA, TFL and others). The TSA boundary file is in a shambles, with gaps and overlaps not accounted for. The GIS person did his best to 'clean' it but problems still arise when used for area calculations. However, the problems amount to less than 1% by area, and given the state of the local forest inventories it is not expected that this will have much impact. The total area is not represented in the table above as it runs outside of the steps taken to drill down to CATs 1-4:

Management Unit	Area (ha)	% of Total
Cascadia TSA Block 11	3446	3.1%
Cascadia TSA Block 9	2525	2.3%
Kalum TSA	63570	58.0%
Kispiox TSA	1204	1.1%
TFL1	20472	18.7%
TFL41	18334	16.7%
Grand Total	109551	100.0%

Field Sampling Methodology

A standard VRI 5 point cluster was used for the 60 samples with the following variations on attribute collection:

Not Collected (as deemed not pertinent to project by VRI Certified project manager as well as not trainable in short period of time with specific crew members available):

- Tree Loss Indicator count and location or codes (used cruise loss indicators)
- Wildlife use
- Damage agents
- Small tree and stump data
- Stem mapping
- Ecological data
- Net Factoring % (except as defects or decay affects log grades)
- Remaining Bark %
- Wood condition
- GPS at IPC

Collected (on Cruise Cards*, not VRI cards***,** extra fields were used to collect log grades and TLSOX information):

- Aside from the first 2 days field work, where an initial BAF of 4 was used, BAF 9 prism or Relaskop was used for all samples.
- DBH High side for all trees IPC/Aux
- Live/dead standing/down
- Tree length for all trees IPC /Aux and Ht suitability
- Tree Class
- Crown Class
- Log Letter Grades for all IPC trees (and all Aux plots for ~ half the samples)
- Microscope counted Ages for T L S O X trees and age suitability
- Slope %
- Aspect
- Photos of Centre Plaque, Cardinals and vertical into canopy
- Location of Sample by Recreation GPS by Easting and Northing minus 15m and tight chain 15m North

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Table of Strata area and sampling intensity

2G Sampling Intensity				
Stratum	**Area**	**# of samples**	**Sample Intensity (ha/sample)**	**Comment**
CAT 1 Hw QMD 35cm+	27.9	3	8	(without 500m road buffer) 78 ha = 26 ha/sample: high interest stratum
CAT2 Hw QMD 30-35cm	253.6	12	21	(without 500m road buffer) 2819 ha or 235 ha/sample
CAT 3 Hw 25-30 cm	4463.5	30	149	(without 500m road buffer) 7619 ha or 254 ha/sample
CAT4 Hw >40 yrs <25 cm	4264.6	5	853	(without 500m road buffer) 16000 ha or 3200 ha/sample: low interest stratum
CAT 5 Ba 25-100 yrs >250 m3/ha	2400.5	10	240	
TOTALS	11410.1	60		

- RB

Appendix D: Second Growth Sampling Results Data

The following pages show the numerical results summarized from the raw data collected in the field. Full cruise compilations were executed on the field data to produce these results. Each page summarizes the findings within each CAT.

CAT 1

Hemlock Leading

Species Codes:
C = Western redcedar
H = Western hemlock
B = Balsam fir
S = Sitka spruce
PL = Lodgepole pine
AC = Poplar
D = Alder
E = Birch

CAT 1 Inventory Quadratic Mean DBH > 35cm		
Inventory Type Area (ha)	171.4	Within Area of Interest (Appendix B)
Inventory CON Volume/ha	487.0	Within inventory polygons sampled only
Inventory All Species Average DBH	39.0	Within inventory polygons sampled only
Inventory All Species Average Total Height	30.8	Within inventory polygons sampled only
Inventory All Species Average Projected Age	60	Within inventory polygons sampled only

Field Sample Information	
Plots	15
Volume/ha Coefficient of Variation	51%
Volume/ha Sampling Error 2 S.E.	43%
Trees/Plot	6.6
Average Age	47

	Conifer		**C**	**H**	**B**	**S**	**PL**	**AC**	**D**	**E**
Species %	74		0	43	10	21	0	13	13	0
	All	**Conifer**								
m3/ha	566.0	419.0		243.0	55.0	121.0		71.0	76.0	
SPH Live/DP	704.0	552.0								
Average DBH	33.5	33.0		35.7	50.3	28.5		54.8	29.3	
Net m3/Tree		0.8		1.0	2.4	0.4		2.6	0.6	
Ht/Tree	26.2	25.4		26.9	31.6	19.8		34.3	23.4	
Volume/5m		0.3								
Average Slope %	0									
Slope Range	0									

	H	**I**	**J**	**M**	**U**	**X**	**Y**
Percent Log Grades (Conifer)	17	3	60	0	11	9	0
(Ring counts not considered for H grades)							

Stem distribution 22.5 cm DBH and above

Diameter Class (All)	**22.5+**	**27.5+**	**32.5+**	**37.5+**	**42.5+**
Cumulative SPH	489	383	273	181	120
Cumulative Volume m3/ha	528	489	411	330	258

CAT 2

Hemlock Leading

CAT 2 Inventory 35cm > Quadratic Mean DBH > 30cm		
Inventory Type Area (ha)	562.7	Within Area of Interest (Appendix B)
Inventory CON Volume/ha	488.0	Within inventory polygons sampled only
Inventory All Species Average DBH	33.2	Within inventory polygons sampled only
Inventory All Species Average Total Height	28.2	Within inventory polygons sampled only
Inventory All Species Average Projected Age	69	Within inventory polygons sampled only

Field Sample Information	
Plots	40
Volume/ha Coefficient of Variation	26%
Volume/ha Sampling Error 2 S.E.	23%
Trees/Plot	7
Average Age	74

	Conifer		**C**	**H**	**B**	**S**	**PL**	**AC**	**D**	**E**
Species %	79		11	28	23	17	0	13	6	1
	All	**Conifer**								
m3/ha	659.0	524.0	75.0	184.0	154.0	112.0	0.0	83.0	42.0	9.0
SPH Live/DP	647.0	546.0								
Average DBH	35.2	34.5	30.9	32.8	43.9	33.3		50.9	30.4	34.6
Net m3/Tree	1.0	1.0	0.6	0.9	1.8	0.8	0.0	2.6	0.7	0.9
Ht/Tree	29.9	29.1	27.3	29.2	30.9	27.6		38.6	24.5	26.5
Volume/5m		0.3								
Average Slope %	3									
Slope Range	0-45									

	H	**I**	**J**	**M**	**U**	**X**	**Y**
Percent Log Grades (Conifer)	22	3	54	0	10	11	0
(Ring counts not considered for H grades)							

Stem distribution 22.5 cm DBH and above

Diameter Class (All)	**22.5+**	**27.5+**	**32.5+**	**37.5+**	**42.5+**
Cumulative SPH	502	385	273	183	119
Cumulative Volume m3/ha	624	574	490	409	321

CAT 3

Hemlock Leading

CAT 3 Inventory 30cm > Quadratic Mean DBH > 25cm		
Inventory Type Area (ha)	7293.1	Within Area of Interest (Appendix B)
Inventory CON Volume/ha	320.0	Within inventory polygons sampled only
Inventory All Species Average DBH	29.5	Within inventory polygons sampled only
Inventory All Species Average Total Height	21.5	Within inventory polygons sampled only
Inventory All Species Average Projected Age	56	Within inventory polygons sampled only

Field Sample Information	
Plots	148
Volume/ha Coefficient of Variation	14%
Volume/ha Sampling Error 2 S.E.	11%
Trees/Plot	5.7
Average Age	56

	Conifer		**C**	**H**	**B**	**S**	**PL**	**AC**	**D**	**E**
Species %	96		5	67	19	4	1	3	1	0
	All	**Conifer**								
m3/ha	411.0	393.0	22.0	275.0	76.0	15.0	5.0	12.0	5.0	0.0
SPH Live/DP	759.0	732.0								
Average DBH	28.7	28.7	29.2	28.4	29.6	32.6	22.4	32.7	24.2	
Net m3/Tree	0.5	0.5	0.4	0.5	0.6	0.8	0.3	0.9	0.4	
Ht/Tree	23.6	23.4	21.7	23.4	23.4	26.3	21.7	31.1	20.7	
Volume/5m		0.2								
Average Slope %	14									
Slope Range	0-80									

	H	**I**	**J**	**M**	**U**	**X**	**Y**
Percent Log Grades (Conifer)	4	1	66	0	19	9	1
(Ring counts not considered for H grades)							

Stem distribution 22.5 cm DBH and above

Diameter Class (All)	**22.5+**	**27.5+**	**32.5+**	**37.5+**	**42.5+**
Cumulative SPH	507	338	185	89	38
Cumulative Volume m3/ha	360	299	210	130	71

CAT 4

Hemlock Leading

CAT 4 Inventory 25cm > Quadratic Mean DBH; > 40 yrs		
Inventory Type Area (ha)	7233.0	Within Area of Interest (Appendix B)
Inventory CON Volume/ha	265.0	Within inventory polygons sampled only
Inventory All Species Average DBH	26.1	Within inventory polygons sampled only
Inventory All Species Average Total Height	20.1	Within inventory polygons sampled only
Inventory All Species Average Projected Age	58	Within inventory polygons sampled only

Field Sample Information	
Plots	25
Volume/ha Coefficient of Variation	24%
Volume/ha Sampling Error 2 S.E.	22%
Trees/Plot	6.4
Average Age	63

	Conifer		C	H	B	S	PL	AC	D	E
Species %	97		19	56	11	11	0	1	1	1
	All	Conifer								
m3/ha	512.0	501.0	98.0	286.0	58.0	58.0	0.0	4.0	3.0	4.0
SPH Live/DP	786.0	753.0								
Average DBH	30.5	30.8	38.3	28.2	35.3	31.4	0.0	25.6	28.2	20.0
Net m3/Tree	0.7	0.7	0.9	0.6	1.0	0.7	0.0	0.4	0.6	0.2
Ht/Tree	25.6	25.7	26.0	25.5	26.4	25.8	0.0	21.1	23.8	19.9
Volume/5m		0.2								
Average Slope %	18									
Slope Range	0-65									

	H	I	J	M	U	X	Y
Percent Log Grades (Conifer) (Ring counts not considered for H grades)	9	1	67	0	15	7	1

Stem distribution 22.5 cm DBH and above

Diameter Class (All)	22.5+	27.5+	32.5+	37.5+	42.5+
Cumulative SPH	546	362	204	125	81
Cumulative Volume m3/ha	465	391	292	221	166

CAT 5

Balsam Leading

CAT 5 Volume > 250 m3/ha		
Inventory Type Area (ha)	2383.5	Within Area of Interest (Appendix B)
Inventory CON Volume/ha	337.0	Within inventory polygons sampled only
Inventory CON Average DBH	27.7	Within inventory polygons sampled only
Inventory CON Average Total Height	21.7	Within inventory polygons sampled only
Inventory CON Average Projected Age	59	Within inventory polygons sampled only

Field Sample Information	
Plots	50
Volume/ha Coefficient of Variation	15%
Volume/ha Sampling Error 2 S.E.	13%
Trees/Plot	5.9
Average Age	63

	Conifer		C	H	B	S	PL	AC	D	E
Species %	99		2	38	56	3	0	0	1	0
	All	Conifer								
m3/ha	502.0	496.0	10.0	190.0	283.0	13.0	0.0	0.0	6.0	0.0
SPH Live/DP	671.0	660.0								
Average DBH	32.2	32.3	25.9	32.0	33.2	29.5	0.0	0.0	26.2	0.0
Net m3/Tree	0.8	0.8	0.4	0.7	0.9	0.4	0.0	0.0	0.5	0.0
Ht/Tree	26.6	26.6	26.7	26.0	27.4	18.2	0.0	0.0	24.1	0.0
Volume/5m		0.2								
Average Slope %	29									
Slope Range	0-75									

	H	I	J	M	U	X	Y
Percent Log Grades (Conifer) (Ring counts not considered for H grades)	13	2	66	0	10	9	0

Stem distribution 22.5 cm DBH and above

Diameter Class (All)	22.5+	27.5+	32.5+	37.5+	42.5+
Cumulative SPH	528	375	241	155	83
Cumulative Volume m3/ha	471	414	335	257	173

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Appendix E: Delivered Log Cost Data Methodology

The following is a description of the data management and geographic information system (GIS) methodology and steps taken to assemble the Delivered Log Cost (DLC) dataset and build the DLC spreadsheet:

1. Started with the forest inventory compilation file created for second growth sampling:
   - Replaced incomplete TFL 1 forest inventory data with newer Cascadia VRI. This covered TRIM mapsheets 93L071, 061, 052, 051, 041, 031 and 021.
   - Replaced some missing VRI polygons with a 2014 version of TFL 1 forest inventory which had been rolled into VRI by Inventory Branch for a separate project. Included parts of mapsheets 103I059 and 103P046
2. Added the following harvest netdowns to the file (100% netdown unless otherwise noted).
   - Ownership Class, i.e. private land
   - Parks and protected areas
   - Hanna-Tintina protected area
   - Managed Licences (e.g. Woodlots)
   - Terrain Class IV (50% netdown)
   - Terrain Class V (90% netdown)
   - Operability for TFL41, TFL1 – areas outside the operability line were subject to a 100% netdown
   - Harvest Method Mapping for Kalum and Nass TSAs – Areas not considered operable were subject to a 100% netdown
   - Kalum SRMP polygons, including
     - Kiteen-Cedar Partial Retention (50%)
     - Kiteen-Cedar Full Retention
     - Lakelse Lake Zone 1
     - Lakelse Lake Zone 2 (50%)
     - Upper Kitsumkalum
     - Miligit Creek Sensitive area
     - Williams-Thomas/Clore Landscape Corridor
     - Skeena Islands
   - Cranberry SRMP polygons, including
     - Water Management Units
     - Ecosystem networks
   - Growth and Yield plot, 50m buffer
   - RESULTS forest cover reserves
   - Grizzly bear WHA
   - Coastal tailed frog WHA
   - Goat Winter Range
   - Old Growth Management Areas
   - BEC
     - TFL1
       - AT *(now BAFA or CMA)*
       - ESSF
       - MH (50%)
     - TFL41
       - AT *(now BAFA or CMA)*

        - ESSF
        - MH
    - Kalum TSA
        - AT *(now BAFA or CMA)*
        - ESSF
        - MH (50%)
    - Nass TSA
        - AT
    - Cranberry TSA, Kispiox TSA
        - AT *(now BAFA or CMA)*
    - Remainder of Kispiox TSA: as for Cranberry TSA, plus
        - AT *(now BAFA or CMA)*
- Stand Related
    - TFL1
        - Deciduous leading
    - TFL41
        - Deciduous leading
    - Kalum TSA
        - SI<10
        - Deciduous leading
    - Nass TSA
        - SI<9
        - Deciduous leading
    - Cranberry TSA
        - Spruce SI<10
        - Pine SI<11
        - Deciduous leading
        - Hemlock leading with Cedar and Balsam and Site Index (SI) <9
    - Geographic units that were within the remainder of Kispiox TSA: as for Cranberry TSA, plus
        - Spruce SI<10
        - Pine SI<11
        - Deciduous leading
        - Hemlock with C and B SI<9
- Visual Landscape Inventory
    - Nass
        - Preservation VQO
        - Retention VQO
    - Cranberry
        - Preservation VQO
        - Retention VQO
    - Geographic units that were within the remainder of Kispiox TSA *(this group of netdowns are new and reflect the Cranberry TSA)*
        - Preservation VQO
        - Retention VQO

2a. For additional information, net downs were <u>not</u> applied to the following:

- Community Watersheds

- Recreation sites and trails that did not explicitly indicate they were reserved from harvest
  - U.R.E.P.
- Forest polygons > Age Class 6, Height Class 2 or less
- Forest polygons < Age Class 5, unless Pine
- Environmentally Sensitive polygons:
  - ESA
  - Es1, Ew1, Er1, Ep1, Ea, Ec1, Eh1
  - Es2, Ew2, Er2, Ep2
- Non-commercial brush (the original file contained only those inventory polygons which have a tree species component)
- Geographical areas not covered in this DLC project

3. Developed DLC unit boundaries, which are based on Region/Compartment boundaries, with a few changes to better reflect log transportation.
4. Intersected data with DLC units.
5. Export resultant data to spreadsheet format.
6. Data summarised from spreadsheet and utilised in development of a delivered log cost summary.

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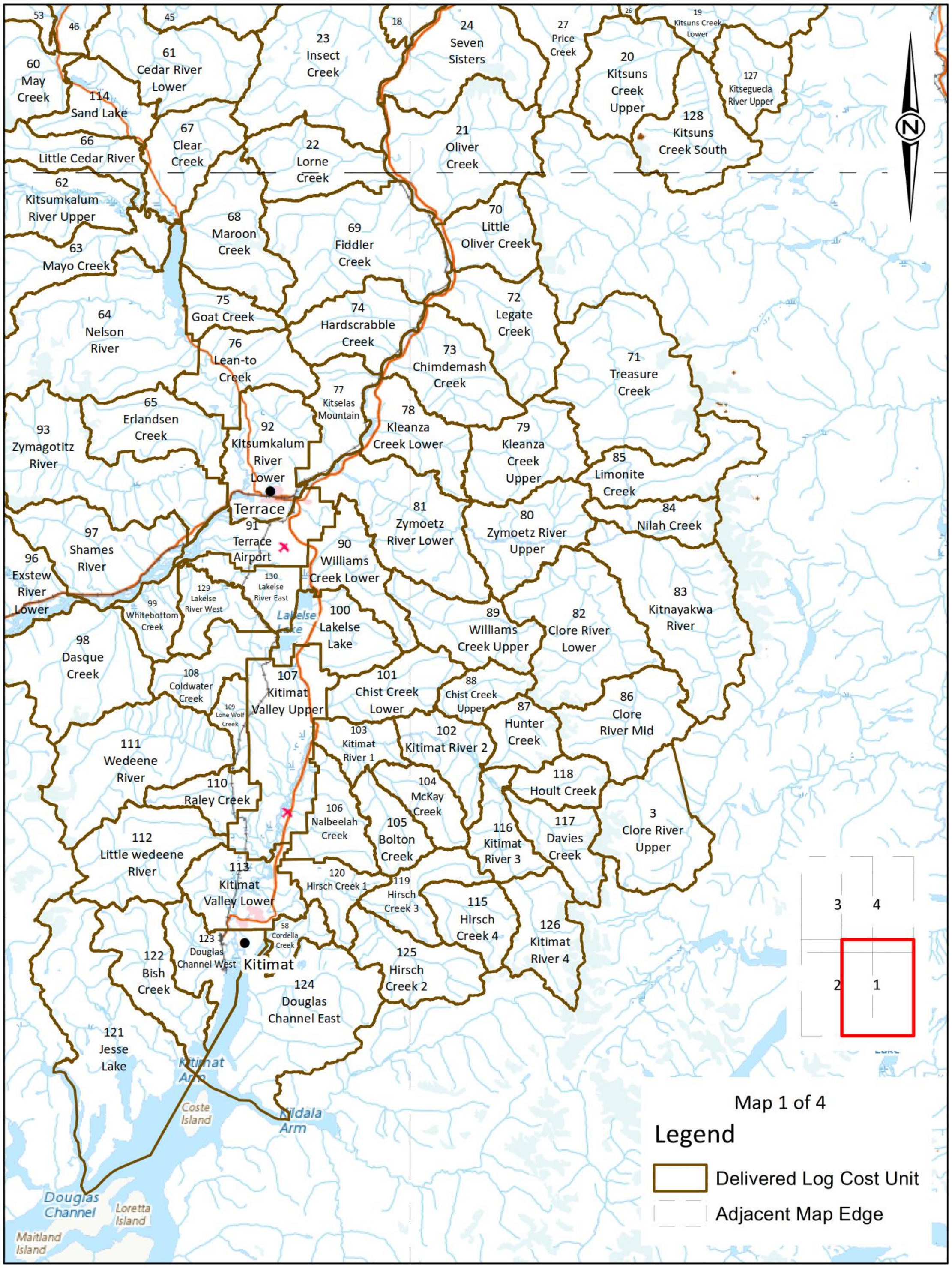
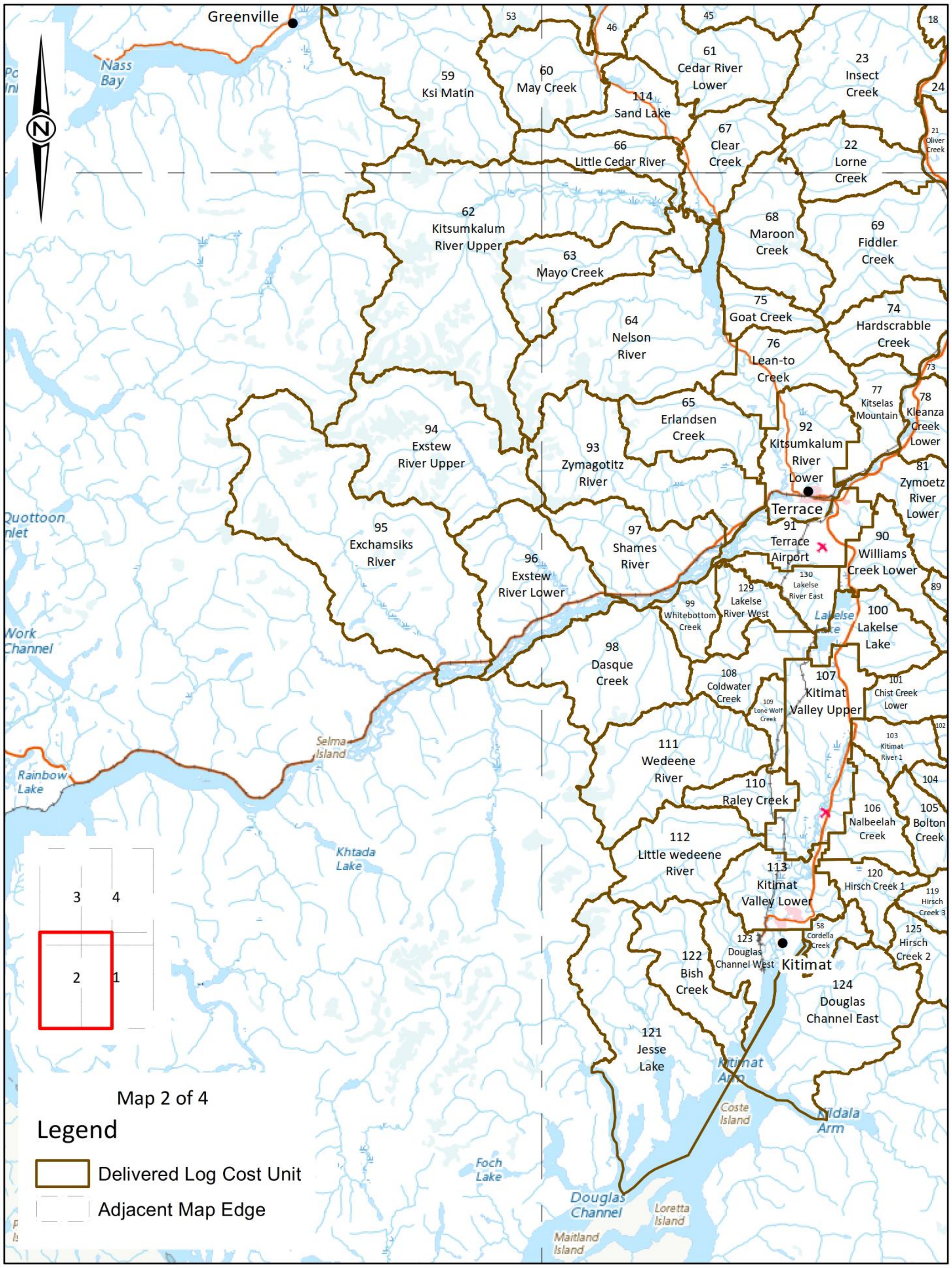
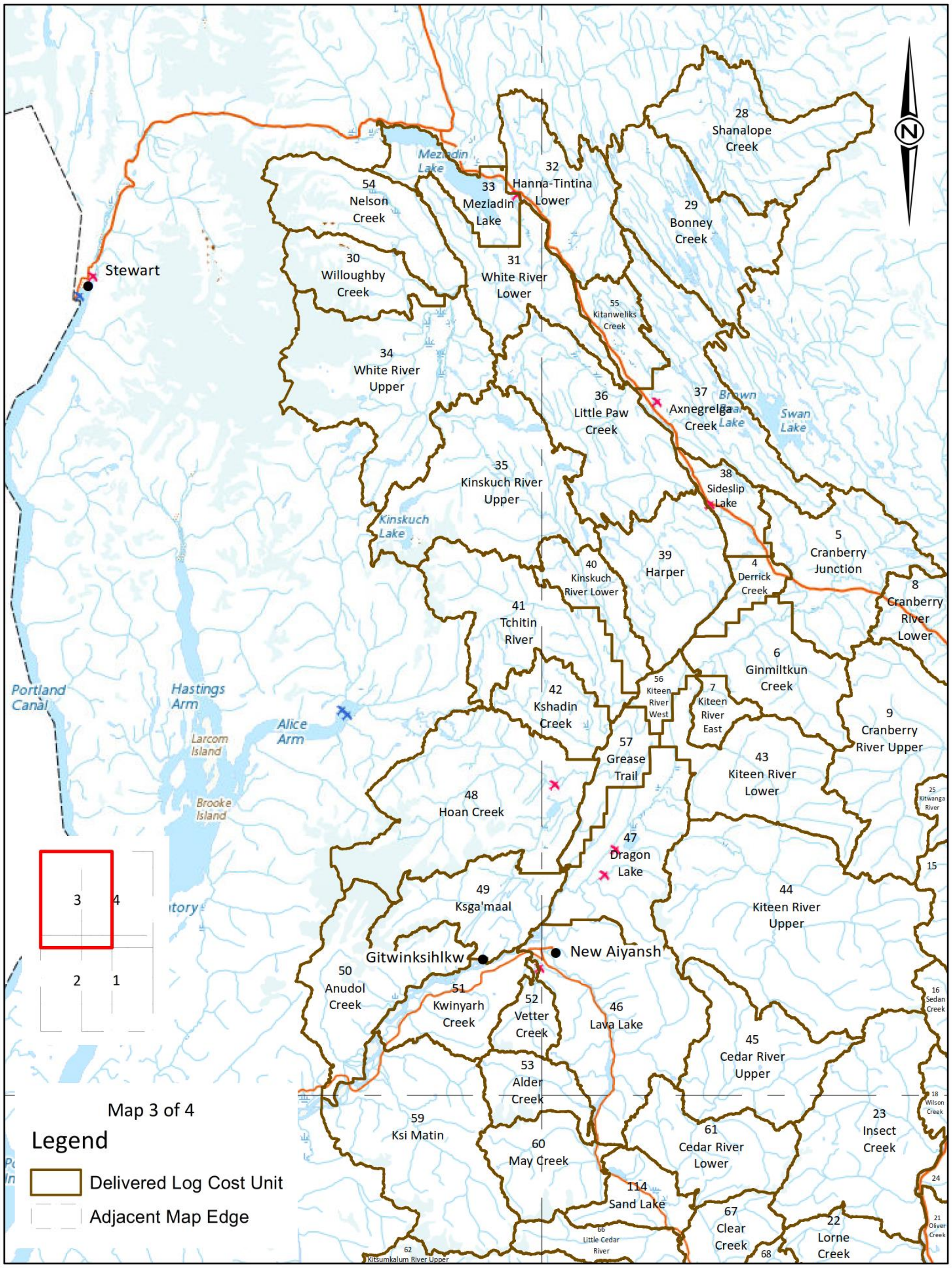
Appendix F: Delivered Log Cost Maps

The following maps show the locations of the Geographic Units that are used in the delivered log cost model.




Greenville
Nass Bay
Quottoon Inlet
Work Channel
Rainbow Lake
Selma Island
Khtada Lake
Foch Lake
Douglas Channel
Loretta Island
Maitland Island
Coste Island
Kitimat Arm
Kildala Arm
Lakelse Lake
Terrace
Kitimat
53
46
45
18
24
21 Oliver Creek
59 Ksi Matin
60 May Creek
61 Cedar River Lower
114 Sand Lake
23 Insect Creek
66 Little Cedar River
67 Clear Creek
22 Lorne Creek
62 Kitsumkalum River Upper
68 Maroon Creek
69 Fiddler Creek
63 Mayo Creek
75 Goat Creek
74 Hardscrabble Creek
64 Nelson River
76 Lean-to Creek
73
77 Kitselas Mountain
78 Kleanza Creek Lower
65 Erlandsen Creek
92 Kitsumkalum River Lower
94 Exstew River Upper
93 Zymagotitz River
81 Zymoetz River Lower
91 Terrace Airport
95 Exchamsiks River
97 Shames River
90 Williams Creek Lower
96 Exstew River Lower
130 Lakelse River East
89
129 Lakelse River West
99 Whitebottom Creek
100 Lakelse Lake
98 Dasque Creek
108 Coldwater Creek
107 Kitimat Valley Upper
101 Chist Creek Lower
109 Lone Wolf Creek
102
103 Kitimat River 1
111 Wedeene River
104
110 Raley Creek
106 Nalbeelah Creek
105 Bolton Creek
112 Little wedeene River
113 Kitimat Valley Lower
120 Hirsch Creek 1
119 Hirsch Creek 3
58 Cordella Creek
125 Hirsch Creek 2
123 Douglas Channel West
122 Bish Creek
124 Douglas Channel East
121 Jesse Lake
3
4
2
1
Map 2 of 4
Legend
Delivered Log Cost Unit
Adjacent Map Edge



28 Shanalope Creek
29 Bonney Creek
32 Hanna-Tintina Lower
33 Meziadin Lake
54 Nelson Creek
30 Willoughby Creek
31 White River Lower
55 Kitanweliks Creek
34 White River Upper
36 Little Paw Creek
37 Axnegrelga Creek
35 Kinskuch River Upper
38 Sideslip Lake
5 Cranberry Junction
39 Harper
40 Kinskuch River Lower
4 Derrick Creek
8 Cranberry River Lower
41 Tchitin River
6 Ginmiltkun Creek
42 Kshadin Creek
56 Kiteen River West
7 Kiteen River East
9 Cranberry River Upper
57 Grease Trail
43 Kiteen River Lower
48 Hoan Creek
47 Dragon Lake
44 Kiteen River Upper
49 Ksga'maal
50 Anudol Creek
51 Kwinyarh Creek
52 Vetter Creek
46 Lava Lake
45 Cedar River Upper
53 Alder Creek
59 Ksi Matin
60 May Creek
61 Cedar River Lower
23 Insect Creek
114 Sand Lake
67 Clear Creek
22 Lorne Creek
66 Little Cedar River
62 Kitsumkalum River Upper
68
25 Kitwanga River
15
16 Sedan Creek
18 Wilson Creek
24
21 Oliver Creek
Stewart
Gitwinksihlkw
New Aiyansh
Meziadin Lake
Brown Bear Lake
Swan Lake
Kinskuch Lake
Portland Canal
Hastings Arm
Alice Arm
Larcom Island
Brooke Island
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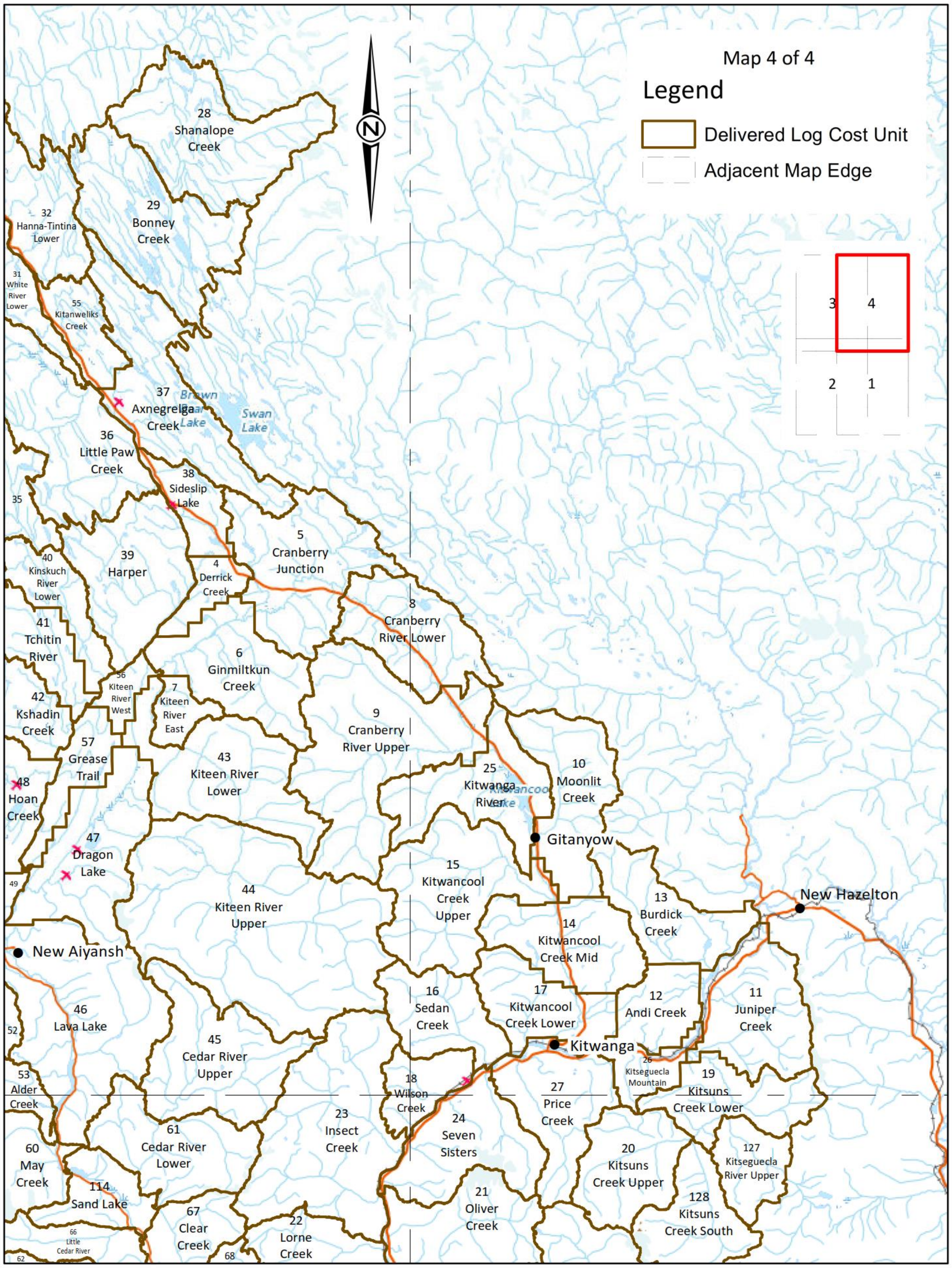
Map 3 of 4
Legend
Delivered Log Cost Unit
Adjacent Map Edge


Map 4 of 4
Legend
Delivered Log Cost Unit
Adjacent Map Edge
3
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28 Shanalope Creek
29 Bonney Creek
32 Hanna-Tintina Lower
31 White River Lower
55 Kitanweliks Creek
37 Axnegrelga Creek
Brown Bear Lake
Swan Lake
36 Little Paw Creek
38 Sideslip Lake
35
5 Cranberry Junction
40 Kinskuch River Lower
39 Harper
4 Derrick Creek
8 Cranberry River Lower
41 Tchitin River
6 Ginmiltkun Creek
56 Kiteen River West
7 Kiteen River East
42 Kshadin Creek
9 Cranberry River Upper
57 Grease Trail
43 Kiteen River Lower
25 Kitwanga River
Kitwancool Lake
10 Moonlit Creek
48 Hoan Creek
Gitanyow
47 Dragon Lake
49
15 Kitwancool Creek Upper
44 Kiteen River Upper
13 Burdick Creek
New Hazelton
14 Kitwancool Creek Mid
New Aiyansh
46 Lava Lake
16 Sedan Creek
17 Kitwancool Creek Lower
12 Andi Creek
11 Juniper Creek
52
45 Cedar River Upper
Kitwanga
26 Kitseguecla Mountain
53 Alder Creek
18 Wilson Creek
27 Price Creek
19 Kitsuns Creek Lower
23 Insect Creek
24 Seven Sisters
61 Cedar River Lower
60 May Creek
20 Kitsuns Creek Upper
127 Kitseguecla River Upper
114 Sand Lake
21 Oliver Creek
128 Kitsuns Creek South
67 Clear Creek
22 Lorne Creek
66 Little Cedar River
62
68

Appendix G: Detailed Delivered Log Cost Results for each Geographic Unit

The following tables provide information for each of the Geographic Units included in the Delivered Log Cost model. Table G1 summarises costs for each Unit and provides the delivered log cost based on the distribution of sawlogs and fibrelogs within each unit, which are sent to different destinations. The sawlog and fibrelog distribution is shown in Table G2. The units are arranged alphabetically. See the map in Appendix F to locate each unit.

Table G1. Costs for each geographic unit, including weighted delivered log cost.

Geographic Unit_Name	"Fixed" costs (Admin, O/H, Road mngt, post-log, stumpage) ($/m³)	Road Development Cost ($/m³)	On Truck Cost ($/m³)	Silviculture Cost ($/m³)	Sawlog Hauling Cost (Terrace) ($/m³)	Fibre log Hauling Cost (Kitimat or Stewart) ($/m³)	Profit & Risk ($/m³)	Weighted Delivered Log Cost (DLC) ($/m³)
Alder Creek	16.48	8.29	47.80	1.28	11.29	8.46	7.10	100.80
Andi Creek	16.48	4.63	28.50	2.18	14.99	27.08	5.35	77.20
Anudol Creek	16.48	7.75	46.30	1.76	24.75	20.51	7.71	109.10
Axnegrelga Creek	16.48	7.46	30.00	2.83	24.64	33.50	6.00	86.05
Bish Creek	16.48	11.02	39.00	2.64	17.59	33.88	6.40	91.33
Bolton Creek	16.48	9.88	39.00	0.96	12.50	10.72	5.81	83.42
Bonney Creek	16.48	5.66	29.25	2.68	27.59	23.67	6.23	89.11
Burdick Creek	16.48	4.65	28.50	2.03	15.26	31.02	5.62	80.81
Cedar River Lower	16.48	8.01	33.00	1.12	10.33	21.08	5.62	80.91
Cedar River Upper	16.48	8.36	44.80	1.13	21.93	39.86	7.11	100.91
Chimdemash Creek	16.48	9.57	47.80	1.32	12.91	22.84	6.66	94.88
Chist Creek Lower	16.48	8.18	39.00	0.71	10.81	9.43	5.61	80.73
Chist Creek Upper	16.48	8.88	43.40	1.06	7.51	17.63	6.05	86.61
Clear Creek	16.48	7.64	34.50	1.21	10.07	19.37	5.52	79.44
Clore River Lower	16.48	8.31	39.65	1.32	12.10	15.32	6.25	89.40
Clore River Mid	16.48	8.29	39.65	1.62	8.43	19.20	6.58	93.78
Clore River Upper	16.48	7.63	37.50	3.43	19.15	24.10	6.50	92.69
Coldwater Creek	16.48	9.19	47.80	0.75	11.29	8.46	6.56	93.59
Cordella Creek	16.48	9.41	47.80	2.79	13.19	24.57	6.52	93.02
Cranberry Junction	16.48	5.40	30.00	2.22	14.96	28.51	5.62	80.87
Cranberry River Lower	16.48	7.20	29.25	2.47	17.63	32.39	5.70	81.98
Cranberry River Upper	16.48	7.62	37.50	1.34	14.96	28.51	6.37	90.94
Dasque Creek	16.48	9.92	58.10	0.91	10.18	12.97	7.64	108.14
Davies Creek	16.48	8.99	47.80	0.82	16.37	14.45	6.60	94.08
Derrick Creek	16.48	5.21	28.50	2.70	18.55	26.26	5.52	79.54
Douglas Channel East	16.48	11.76	47.80	2.28	11.57	14.68	6.79	96.71
Douglas Channel West	16.48	11.84	47.80	3.80	17.59	33.88	6.81	96.88
Dragon Lake	16.48	8.51	43.30	3.13	16.13	34.52	7.30	103.54

Geographic Unit_Name	"Fixed" costs (Admin, O/H, Road mngt, post-log, stumpage) ($/m³)	Road Development Cost ($/m³)	On Truck Cost ($/m³)	Silviculture Cost ($/m³)	Sawlog Hauling Cost (Terrace) ($/m³)	Fibre log Hauling Cost (Kitimat or Stewart) ($/m³)	Profit & Risk ($/m³)	Weighted Delivered Log Cost (DLC) ($/m³)
Erlandsen Creek	16.48	7.12	41.80	0.89	10.07	19.37	5.87	84.27
Exchamsiks River	16.48	11.05	75.70	2.75	8.88	11.81	9.15	128.54
Exstew River Lower	16.48	9.85	39.00	0.84	9.53	12.59	5.97	85.54
Exstew River Upper	16.48	8.88	47.80	0.63	11.27	20.84	6.58	93.77
Fiddler Creek	16.48	8.42	43.30	1.19	10.17	19.49	6.31	90.19
Ginmiltkun Creek	16.48	7.26	33.00	1.79	15.36	31.16	6.15	87.95
Goat Creek	16.48	9.69	47.80	1.73	13.37	23.41	6.71	95.50
Grease Trail	16.48	5.52	27.75	1.82	14.09	25.68	5.66	81.40
Hanna-Tintina Lower	16.48	7.94	29.25	2.97	24.75	20.51	6.00	85.97
Hardscrabble Creek	16.48	9.49	47.80	1.01	10.78	20.24	6.70	95.37
Harper	16.48	7.44	31.50	2.88	25.87	40.07	6.46	92.23
Hirsch Creek 1	16.48	7.24	43.30	2.54	13.12	12.26	6.08	87.05
Hirsch Creek 2	16.48	11.07	47.80	2.80	8.43	19.20	6.87	97.75
Hirsch Creek 3	16.48	9.27	47.80	3.24	12.98	8.34	6.76	96.29
Hirsch Creek 4	16.48	8.88	47.80	2.99	11.92	10.79	6.71	95.59
Hoan Creek	16.48	6.63	43.30	1.63	15.38	25.33	7.46	105.68
Hoult Creek	16.48	9.07	47.80	0.89	11.29	8.46	6.61	94.24
Hunter Creek	16.48	8.13	43.40	0.68	6.53	15.52	6.17	88.25
Insect Creek	16.48	8.75	38.25	1.77	30.72	25.26	6.82	97.01
Jesse Lake	16.48	11.05	39.00	2.53	12.10	15.32	6.50	92.79
Juniper Creek	16.48	8.17	39.00	2.17	15.26	31.02	6.60	94.10
Kinskuch River Lower	16.48	8.11	36.00	2.93	18.05	30.52	6.90	98.16
Kinskuch River Upper	16.48	7.40	30.00	3.17	24.64	33.50	6.26	89.54
Kitanweliks Creek	16.48	5.77	29.25	3.02	15.38	25.33	5.82	83.60
Kiteen River East	16.48	8.36	37.50	2.70	14.44	28.49	6.90	98.15
Kiteen River Lower	16.48	8.14	46.30	1.94	26.91	36.28	7.43	105.32
Kiteen River Upper	16.48	7.71	46.30	2.00	26.91	36.28	7.92	111.96
Kiteen River West	16.48	7.01	29.25	2.13	12.20	23.37	5.86	84.09
Kitimat River 1	16.48	9.20	47.80	0.78	11.57	14.68	6.45	92.00
Kitimat River 2	16.48	9.21	47.80	0.76	10.67	13.57	6.45	92.00
Kitimat River 3	16.48	9.01	47.80	0.79	17.71	16.09	6.60	94.07
Kitimat River 4	16.48	10.88	47.80	1.34	0.00	0.00	6.79	96.67
Kitimat Valley Lower	16.48	7.23	31.50	3.97	12.10	15.32	5.14	74.33
Kitimat Valley Upper	16.48	5.58	39.00	1.51	12.50	10.72	5.58	80.27
Kitnayakwa River	16.48	8.24	39.65	2.29	9.53	12.59	6.72	95.72
Kitseguecla Mountain	16.48	6.60	33.00	1.86	28.07	17.89	5.79	83.16

Geographic Unit_Name	"Fixed" costs (Admin, O/H, Road mngt, post-log, stumpage) ($/m³)	Road Development Cost ($/m³)	On Truck Cost ($/m³)	Silviculture Cost ($/m³)	Sawlog Hauling Cost (Terrace) ($/m³)	Fibre log Hauling Cost (Kitimat or Stewart) ($/m³)	Profit & Risk ($/m³)	Weighted Delivered Log Cost (DLC) ($/m³)
Kitseguecla River Lower	16.48	6.23	31.50	1.87	11.97	31.19	5.83	83.66
Kitseguecla River Upper	16.48	7.48	28.50	2.13	0.00	0.00	5.90	84.59
Kitselas Mountain	16.48	8.95	46.30	0.98	13.37	23.41	6.44	91.93
Kitsumkalum River Lower	16.48	5.98	30.00	1.11	6.98	16.99	4.66	67.91
Kitsumkalum River Upper	16.48	7.94	46.30	0.95	10.33	21.08	6.88	97.85
Kitsuns Creek South	16.48	6.55	39.00	1.53	0.00	0.00	6.61	94.28
Kitsuns Creek West	16.48	7.90	36.00	2.09	18.55	26.26	6.53	93.11
Kitwancool Creek Lower	16.48	5.76	31.50	2.13	10.28	19.63	5.66	81.35
Kitwancool Creek Mid	16.48	4.74	28.50	1.95	15.43	31.24	5.37	77.41
Kitwancool Creek Upper	16.48	8.96	47.80	1.37	17.59	33.88	7.16	101.58
Kitwanga River	16.48	5.63	30.00	1.57	28.07	17.89	5.63	80.94
Kleanza Creek Lower	16.48	8.95	47.80	1.07	17.42	28.36	6.94	98.62
Kleanza Creek Upper	16.48	8.98	47.80	1.46	16.43	27.15	6.78	96.55
Ksga'maal	16.48	6.13	31.50	1.59	28.07	17.89	6.55	93.37
Kshadin Creek	16.48	7.30	34.50	1.77	18.30	31.32	6.62	94.41
Ksi Matin	16.48	8.91	47.80	1.42	9.10	19.58	7.90	111.61
Kwinyarh Creek	16.48	8.69	33.00	1.48	23.02	23.78	6.77	96.42
Lakelse Lake	16.48	8.86	46.30	0.90	10.18	12.97	6.22	88.96
Lakelse River East	16.48	5.85	30.00	0.85	0.00	0.00	4.83	70.22
Lakelse River West	16.48	6.47	43.30	0.93	0.00	0.00	6.00	85.98
Lava Lake	16.48	8.48	44.80	2.23	21.93	39.86	7.31	103.71
Lean-to Creek	16.48	9.08	47.80	1.10	10.87	20.35	6.44	91.98
Legate Creek	16.48	8.96	47.80	1.15	9.31	19.23	6.73	95.84
Limonite Creek	16.48	7.72	40.40	1.26	7.33	12.69	6.48	92.53
Little Cedar River	16.48	7.46	41.80	1.13	15.36	25.84	6.16	88.20
Little Oliver Creek	16.48	8.87	37.50	2.07	9.40	19.95	5.90	84.61
Little Paw Creek	16.48	7.42	30.00	2.80	24.64	33.50	6.00	85.97
Little wedeene River	16.48	9.17	47.80	2.64	12.10	15.32	6.63	94.51
Lone Wolf Creek	16.48	9.26	39.00	0.57	12.20	23.37	5.91	84.70
Lorne Creek	16.48	8.38	39.00	1.93	13.06	28.99	5.99	85.80
Maroon Creek	16.48	7.61	46.30	1.61	9.39	18.54	6.41	91.58
May Creek	16.48	8.95	47.80	1.34	7.55	17.68	7.12	101.05
Mayo Creek	16.48	7.78	47.80	1.34	9.46	20.02	6.89	98.04
McKay Creek	16.48	8.99	39.00	0.80	11.84	15.13	5.73	82.30

Geographic Unit_Name	"Fixed" costs (Admin, O/H, Road mngt, post-log, stumpage) ($/m³)	Road Development Cost ($/m³)	On Truck Cost ($/m³)	Silviculture Cost ($/m³)	Sawlog Hauling Cost (Terrace) ($/m³)	Fibre log Hauling Cost (Kitimat or Stewart) ($/m³)	Profit & Risk ($/m³)	Weighted Delivered Log Cost (DLC) ($/m³)
Meziadin Lake	16.48	8.42	34.50	5.53	21.21	20.94	6.76	96.19
Moonlit Creek	16.48	7.77	37.50	1.85	14.99	27.08	6.27	89.57
Nalbeelah Creek	16.48	7.37	39.00	0.76	11.84	15.13	5.50	79.23
Nelson Creek	16.48	9.85	46.30	5.87	21.93	39.86	7.84	110.85
Nelson River	16.48	7.11	41.80	0.95	10.28	19.63	5.93	85.03
Nilah Creek	16.48	7.94	33.75	1.34	10.72	16.83	6.06	86.82
Oliver Creek	16.48	5.71	30.00	1.55	13.06	28.99	5.55	79.90
Price Creek	16.48	6.51	33.00	2.29	26.73	17.00	5.76	82.68
Raley Creek	16.48	7.46	44.80	0.72	13.12	12.26	6.10	87.35
Sand Lake	16.48	8.46	34.50	0.92	13.12	12.26	5.76	82.80
Sedan Creek	16.48	11.63	39.00	2.23	11.97	31.19	6.87	97.77
Seven Sisters	16.48	7.34	37.50	2.03	30.72	25.26	6.24	89.25
Shames River	16.48	9.14	47.80	0.96	10.18	12.97	6.43	91.79
Shanalope Creek	16.48	5.68	29.25	2.84	28.07	17.89	6.25	89.30
Sideslip Lake	16.48	7.56	30.00	3.08	21.47	29.35	5.86	84.10
Tchitin River	16.48	8.05	33.00	2.14	16.13	34.52	6.59	94.00
Terrace Airport	16.48	4.99	39.00	1.10	9.20	19.70	5.55	79.86
Treasure Creek	16.48	8.44	37.50	1.29	7.53	17.66	6.43	91.78
Vetter Creek	16.48	8.39	37.50	2.39	18.30	31.32	6.73	95.90
Wedeene River	16.48	9.70	47.80	0.79	12.10	15.32	6.64	94.57
White River Lower	16.48	7.94	29.25	3.90	24.87	20.33	6.17	88.23
White River Upper	16.48	8.47	36.00	5.41	28.74	25.08	7.01	99.59
Whitebottom Creek	16.48	8.95	46.30	1.03	10.18	12.97	6.63	94.49
Williams Creek Lower	16.48	9.14	43.40	0.98	9.20	19.70	5.98	85.72
Williams Creek Upper	16.48	9.22	43.40	1.08	9.20	19.70	6.29	89.94
Willoughby Creek	16.48	8.38	47.80	5.19	27.59	23.67	7.79	110.14
Wilson Creek	16.48	7.28	34.50	2.05	27.45	21.19	6.09	87.18
Zymagotitz River	16.48	9.15	41.15	0.85	11.27	20.84	5.98	85.67
Zymoetz River Lower	16.48	8.67	46.30	1.21	16.35	27.04	6.59	93.92
Zymoetz River Upper	16.48	8.62	46.30	1.36	16.43	27.15	6.81	96.96

Table G2. Mature sawlog and fibre timber volume in each geographic unit.

Geographic Unit_Name	Weighted Delivered Log Cost (DLC) ($/m³)	Total Mature volume (m³)	% Sawlog Grade	% Fibrelog Grade	Sawlog volume (m³)	Fibre volume (m³)
Alder Creek	100.80	582614	55%	45%	320438	262176
Andi Creek	77.20	701135	60%	40%	420681	280454
Anudol Creek	109.10	2377633	65%	35%	1426580	951053
Axnegrelga Creek	86.05	3307882	65%	35%	2150123	1157759
Bish Creek	91.33	1354449	60%	40%	948114	406335
Bolton Creek	83.42	339213	60%	40%	203528	135685
Bonney Creek	89.11	2855863	65%	35%	1856311	999552
Burdick Creek	80.81	1299783	65%	35%	779870	519913
Cedar River Lower	80.91	1074657	55%	45%	644794	429863
Cedar River Upper	100.91	1476629	60%	40%	885978	590652
Chimdemash Creek	94.88	571759	55%	45%	343055	228704
Chist Creek Lower	80.73	702071	50%	50%	421243	280829
Chist Creek Upper	86.61	169752	55%	45%	101851	67901
Clear Creek	79.44	629834	50%	50%	409392	220442
Clore River Lower	89.40	1519579	60%	40%	911748	607832
Clore River Mid	93.78	812760	60%	40%	447018	365742
Clore River Upper	92.69	156899	65%	35%	86295	70605
Coldwater Creek	93.59	437423	55%	45%	262454	174969
Cordella Creek	93.02	925470	60%	40%	509008	416461
Cranberry Junction	80.87	2587832	65%	35%	1682091	905741
Cranberry River Lower	81.98	1393512	60%	40%	905783	487729
Cranberry River Upper	90.94	1562652	60%	40%	937591	625061
Dasque Creek	108.14	871732	60%	40%	523039	348693
Davies Creek	94.08	739708	70%	30%	443825	295883
Derrick Creek	79.54	476346	60%	40%	309625	166721
Douglas Channel East	96.71	2940568	60%	40%	2058397	882170
Douglas Channel West	96.88	436558	60%	40%	261935	174623
Dragon Lake	103.54	3109194	55%	45%	1554597	1554597
Erlandsen Creek	84.27	451329	60%	40%	248231	203098
Exchamsiks River	128.54	1105271	55%	45%	663163	442109
Exstew River Lower	85.54	942927	60%	40%	565756	377171
Exstew River Upper	93.77	150239	60%	40%	90144	60096
Fiddler Creek	90.19	1910094	60%	40%	1050552	859542
Ginmiltkun Creek	87.95	1216094	60%	40%	790461	425633

Geographic Unit_Name	Weighted Delivered Log Cost (DLC) ($/m³)	Total Mature volume (m³)	% Sawlog Grade	% Fibrelog Grade	Sawlog volume (m³)	Fibre volume (m³)
Goat Creek	95.50	217254	60%	40%	141215	76039
Grease Trail	81.40	1040712	55%	45%	572392	468321
Hanna-Tintina Lower	85.97	2113234	65%	35%	1373602	739632
Hardscrabble Creek	95.37	974239	55%	45%	584543	389695
Harper	92.23	2378867	60%	40%	1546264	832604
Hirsch Creek 1	87.05	740803	55%	45%	407442	333361
Hirsch Creek 2	97.75	384372	65%	35%	211405	172968
Hirsch Creek 3	96.29	427688	70%	30%	235228	192459
Hirsch Creek 4	95.59	308883	55%	45%	169885	138997
Hoan Creek	105.68	3707683	55%	45%	2409994	1297689
Hoult Creek	94.24	426800	60%	40%	256080	170720
Hunter Creek	88.25	10195	65%	35%	6117	4078
Insect Creek	97.01	102732	65%	35%	61639	41093
Jesse Lake	92.79	2210657	60%	40%	1547460	663197
Juniper Creek	94.10	307720	60%	40%	184632	123088
Kinskuch River Lower	98.16	1158563	60%	40%	753066	405497
Kinskuch River Upper	89.54	2818236	65%	35%	1831853	986382
Kitanweliks Creek	83.60	975171	60%	40%	633861	341310
Kiteen River East	98.15	312065	60%	40%	124826	187239
Kiteen River Lower	105.32	1912387	65%	35%	1051813	860574
Kiteen River Upper	111.96	4146473	55%	45%	2487884	1658589
Kiteen River West	84.09	443302	60%	40%	243816	199486
Kitimat River 1	92.00	698045	60%	40%	418827	279218
Kitimat River 2	92.00	726196	50%	50%	435718	290478
Kitimat River 3	94.07	1161859	70%	30%	697115	464743
Kitimat River 4	96.67	149069	0%	0%	89441	59628
Kitimat Valley Lower	74.33	1000381	60%	40%	550210	450171
Kitimat Valley Upper	80.27	420004	60%	40%	210002	210002
Kitnayakwa River	95.72	1480425	60%	40%	814234	666191
Kitseguecla Mountain	83.16	281948	65%	35%	169169	112779
Kitseguecla River Lower	83.66	779069	60%	40%	467441	311627
Kitseguecla River Upper	84.59	608107	0%	0%	364864	243243
Kitselas Mountain	91.93	676069	60%	40%	439445	236624
Kitsumkalum River Lower	67.91	912340	60%	40%	593021	319319
Kitsumkalum River Upper	97.85	1387248	65%	35%	762987	624262
Kitsuns Creek South	94.28	634656	0%	0%	380793	253862

Geographic Unit_Name	Weighted Delivered Log Cost (DLC) ($/m³)	Total Mature volume (m³)	% Sawlog Grade	% Fibrelog Grade	Sawlog volume (m³)	Fibre volume (m³)
Kitsuns Creek West	93.11	363006	60%	40%	217804	145203
Kitwancool Creek Lower	81.35	757046	60%	40%	454227	302818
Kitwancool Creek Mid	77.41	1824757	60%	40%	1094854	729903
Kitwancool Creek Upper	101.58	472600	60%	40%	283560	189040
Kitwanga River	80.94	722378	65%	35%	433427	288951
Kleanza Creek Lower	98.62	1152704	55%	45%	633987	518717
Kleanza Creek Upper	96.55	817322	55%	45%	449527	367795
Ksga'maal	93.37	2999750	65%	35%	1649862	1349887
Kshadin Creek	94.41	1000008	50%	50%	650005	350003
Ksi Matin	111.61	1677402	65%	35%	1006441	670961
Kwinyarh Creek	96.42	1809225	55%	45%	995074	814151
Lakelse Lake	88.96	719368	60%	40%	395652	323716
Lakelse River East	70.22	509719	0%	0%	331317	178402
Lakelse River West	85.98	490454	0%	0%	294272	196182
Lava Lake	103.71	2546863	55%	45%	1400775	1146089
Lean-to Creek	91.98	729453	60%	40%	474145	255309
Legate Creek	95.84	814302	65%	35%	407151	407151
Limonite Creek	92.53	798433	55%	45%	518981	279452
Little Cedar River	88.20	250861	40%	60%	137974	112888
Little Oliver Creek	84.61	340035	65%	35%	204021	136014
Little Paw Creek	85.97	4524674	65%	35%	2941038	1583636
Little wedeene River	94.51	569035	60%	40%	341421	227614
Lone Wolf Creek	84.70	320881	60%	40%	160440	160440
Lorne Creek	85.80	44904	65%	35%	26943	17962
Maroon Creek	91.58	433044	60%	40%	281478	151565
May Creek	101.05	653199	55%	45%	391920	261280
Mayo Creek	98.04	584796	65%	35%	350878	233918
McKay Creek	82.30	852885	50%	50%	511731	341154
Meziadin Lake	96.19	570007	65%	35%	370505	199503
Moonlit Creek	89.57	678778	60%	40%	441205	237572
Nalbeelah Creek	79.23	634796	60%	40%	317398	317398
Nelson Creek	110.85	573563	60%	40%	372816	200747
Nelson River	85.03	1050308	55%	45%	682700	367608
Nilah Creek	86.82	348092	55%	45%	191450	156641
Oliver Creek	79.90	416357	60%	40%	228996	187361
Price Creek	82.68	359613	65%	35%	233749	125865
Raley Creek	87.35	429537	55%	45%	257722	171815

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Geographic Unit_Name	Weighted Delivered Log Cost (DLC) ($/m³)	Total Mature volume (m³)	% Sawlog Grade	% Fibrelog Grade	Sawlog volume (m³)	Fibre volume (m³)
Sand Lake	82.80	549663	55%	45%	329798	219865
Sedan Creek	97.77	6234	55%	45%	3740	2493
Seven Sisters	89.25	418536	65%	35%	251122	167415
Shames River	91.79	802702	60%	40%	481621	321081
Shanalope Creek	89.30	3233103	65%	35%	2101517	1131586
Sideslip Lake	84.10	930133	55%	45%	604586	325547
Tchitin River	94.00	1943718	55%	45%	1263416	680301
Terrace Airport	79.86	474500	60%	40%	284700	189800
Treasure Creek	91.78	3419865	65%	35%	1367946	2051919
Vetter Creek	95.90	973578	55%	45%	535468	438110
Wedeene River	94.57	180180	60%	40%	108108	72072
White River Lower	88.23	2540629	65%	35%	1651409	889220
White River Upper	99.59	856810	65%	35%	556927	299884
Whitebottom Creek	94.49	516447	60%	40%	309868	206579
Williams Creek Lower	85.72	1111395	60%	40%	611267	500128
Williams Creek Upper	89.94	356645	60%	40%	196155	160490
Willoughby Creek	110.14	63403	65%	35%	41212	22191
Wilson Creek	87.18	372583	60%	40%	242179	130404
Zymagotitz River	85.67	1063781	60%	40%	585079	478701
Zymoetz River Lower	93.92	1169575	55%	45%	701745	467830
Zymoetz River Upper	96.96	1101518	65%	35%	660911	440607
Total		**135,148,068**			**81,466,177**	**53,681,891**

Appendix H: Potential Products Results

The findings of the market analysis were summarized into an excel spreadsheet where the results were numerically assigned and the products were numerically graded according to their compatibility with production in Northwest BC. Each numerically assigned value has been hyperlinked to the most relevant source for that data. The excel version of these results is available as a supporting document to this report. The excel version also contains pop-up comments for each of the values providing justification for the ranking given. The excel version is also editable to allow potential investors and other interested users to modify the gradings and weights assigned to each category to produce a product ranking tailored to the user's priorities.

The values listed within this table are extrapolated upon and described in more detail in Appendix I.

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Product Category	Product	Capital Investment	Profit Margin Ratio	Local Abundance of Required Species or Materials	Maximum Allowable Moisture Content	Extent of Research and Past Market Success	Available Market	Job Creation	Wood Source	Sustainability	TOTAL	Rank
Biofuels	Biomethane	2	4	4	1	3	4	4	5	6	33	1
Biofuels	Combined Heat and Power	1	6	4	2	3	3	2	5	4	29	2
Non-Timber Forest Products	Conifer Essential Oils	5	2	4	3	2	2	1	5	4	28	3
Pulp and Paper	Northern Bleached Softwood Kraft	0	6	4	3	3	2	4	3	2	27	4
Biomaterials	Lignin Pulp Moulded Products	1	2	4	3	4	2	4	3	3	26	5
Biofuels	Wood Pellets	1	2	4	0	4	3	3	5	4	26	6
Non-Timber Forest Products	Berries	5	1	4	3	1	4	1	3	4	26	7
Pulp and Paper	Bleached Chemithermo Mechanical Pulp	0	3	4	3	2	3	4	3	4	26	8
Pulp and Paper	Recycled Pulp	1	2	4	3	3	2	4	3	4	26	9
Biomaterials	Nanocrystalline Cellulose	0	6	4	3	1	3	3	1	4	25	10
Non-Timber Forest Products	Culinary Plants (i.e. Fiddleheads)	5	1	4	3	1	3	1	3	4	25	11
Non-Timber Forest Products	Floral Greenery and Native Plant Landscaping	5	1	4	3	1	3	1	3	4	25	12
Non-Timber Forest Products	Medicinal Plants	5	1	4	3	1	3	1	3	4	25	13
Non-Timber Forest Products	Wild Mushrooms	5	1	3	3	1	4	1	3	4	25	14
Other	Lightweight Aggregates with Pulp Sludge	4	4	0	3	2	2	4	3	3	25	15
Biochemicals	Lignin Extraction	2	3	4	3	2	3	2	1	4	24	16
Engineered Wood Products	Laminated Strand Lumber	1	3	2	3	4	3	3	1	4	24	17
Engineered Wood Products	Laminated Veneer Lumber	1	3	2	3	4	3	3	1	4	24	18
Engineered Wood Products	Parallel Strand Lumber	1	3	2	3	4	3	3	1	4	24	19
Engineered Wood Products	Plywood	1	2	4	3	4	3	3	1	3	24	20
Pulp and Paper	Dissolving Pulp	0	3	3	3	3	3	4	2	3	24	21
Pulp and Paper	Mechanical Pulp	0	2	4	3	3	3	4	2	3	24	22
Engineered Wood Products	Particle Board	0	6	4	0	3	2	4	3	2	24	23
Biomaterials	Biochar	2	3	4	1	2	2	2	3	4	23	24
Biomaterials	Wood-Plastic Composites	2	3	3	0	2	2	4	3	4	23	25
Engineered Wood Products	Cross-Laminated Timber	1	3	3	1	4	3	3	1	4	23	26
Engineered Wood Products	Oriented Strand Board	0	4	4	0	4	3	4	1	3	23	27
Sawn Wood	Firewood	5	3	3	0	2	3	1	5	1	23	28
Sawn Wood	Trusses	3	3	3	1	3	3	3	1	3	23	29
Value Added Alternative Forest	Millwork	2	3	3	1	4	2	3	3	2	23	30
Biochemicals	Hemicellulose-Based Sweeteners	0	6	2	1	1	2	2	5	4	23	31
Biochemicals	Lignin Micro- and Nanoparticles	0	4	4	3	1	3	2	1	4	22	32
Biochemicals	Lignin Resin	1	3	4	3	1	3	2	1	4	22	33
Biochemicals	Lignin Thermoplastics	1	3	4	3	1	3	2	1	4	22	34
Engineered Wood Products	I-Joists	0	3	3	1	4	3	2	2	4	22	35
Pulp and Paper	Northern Bleached Hardwood Kraft	0	6	1	3	3	0	4	3	2	22	36
Sawn Wood	Polymer-Impregnated Wood Products	2	3	2	0	2	4	3	3	3	22	37
Value Added Alternative Forest	Prefabricated Homes/Structures	2	3	4	1	4	2	3	1	2	22	38
Engineered Wood Products	Glue-Laminated Timber	2	3	4	1	4	2	2	1	2	21	39
Engineered Wood Products	Medium Density Fiberboard	0	2	2	3	3	2	4	3	2	21	40
Sawn Wood	Viscoelastic Thermal Compressed Wood	2	2	4	0	1	1	3	3	4	20	41
Value Added Alternative Forest	Cabinets	4	1	4	1	3	3	1	1	2	20	42
Value Added Alternative Forest	Furniture	4	2	3	1	4	3	2	0	1	20	43
Sawn Wood	Machine Stress-Rated	4	3	4	1	3	2	0	1	1	19	44
Biomaterials	Wood-Cement Composites	2	3	2	1	1	2	2	3	2	18	45
Sawn Wood	Energy-Production Flooring	2	2	2	0	1	2	2	3	4	18	46
Value Added Alternative Forest	Log Homes	2	3	3	1	3	3	2	0	1	18	47
Value Added Alternative Forest	Shakes and Shingles	4	2	2	1	3	2	2	0	2	18	48
Sawn Wood	Tonewood	2	3	2	1	2	2	2	0	1	15	49
Engineered Wood Products	High Density Fiberboard	0	2	1	0	1	2	4	3	2	15	50

No Sources

Appendix I: Potential Products Research

This appendix describes in detail the market information identified for each potential wood product that pertains to or is comparable to Northwest BC. Information was organized into SWAT (Strengths-Weaknesses-Advantages-Threats) formatting for ease of comparison. Following each potential product's SWAT is a summary of the important considerations for Northwest BC according to the market analysis.

Note that in some digital versions of this report, the contents of this appendix may be provided separately.

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Future Products and Supply Streams

SWOT Analysis for Forest Products Development in NWBC

Sorted by Grading in **Market Analysis** *Spreadsheet*

Biomethane (Renewable Natural Gas)

Product Information: Biomethane, which is more commonly referred to as renewable natural gas, is completely interchangeable with traditional natural gas such that refineries, transport facilities, pipelines or products that use traditional natural gas (furnaces, power stations) would not need to be modified in order to switch to renewable natural gas (RNG) (Canadian Gas Association, 2014). RNG can be produced by a number of processes, the two most common of which are anaerobic digestion and gasification (Li, Mehmood, Thorin, & Yu, 2017). In addition, RNG can undergo a treatment process to be converted into oil-derived products such as gasoline/petrol, diesel, jet fuel, etc, which have a significantly reduced carbon footprint comparted to fossil fuel-derived counterparts (Green Car Congress, 2014). Through the gasification process, forestry residues can produce biomethane (Canadian Gas Association 2014. Start-up capital ranges from US$ 2.5 million – 3.8 million (approximately CAD$ 3.9 million – 5.0 million) (Li, Liu, Farahani, Gao & Huo, 2017). Profit margin ratios vary from 16% to 45% depending on size (Iaquaniello, Centi, Salladini, & Palo, 2018). An RNG plant would directly employ approximately 85 people (Andersson, 2013).

Strengths: There is a large available market due to the interchangeability of RNG with traditional natural gas and the more sustainable nature of RNG (Canadian Gas Association, 2014). A number of successful project plants have been established since 2008, including GoBiGas in Sweden and Carbonarius in the UK (ETIP Bioenergy, n.d.). RNG production capitalizes on waste products such as forestry and agricultural residues, which could offer significant and sustainable feedstocks. RNG has the potential to supplement the oil-based fuel industry (i.e. diesel, petrol, and jet fuel) as well through Oxidative Coupling of Methane (OCM) and Ethylene-to-Liquid (ETL) conversions, two proprietary processes recently unveiled by Siluria Technologies (Green Car Congress, 2014). This conversion can also be achieved using Steam Reforming and Fischer-Tropsch Gas-to-Liquid (Hamilton, 2008). The environmental footprint of RNG is much lower than that of its traditional counterpart (Canadian Gas Association, 2014). Research to date focusses mainly on using spruce, aspen or birch for gasification, however, in theory, any species can be used (Odhner, Horváth, Kabir, & Schabbauer, 2012). Latest technologies allow for conversion of RNG into methanol or acetic acid, which opens up a large range of further opportunities (Shan, Li, Allard, Lee, & Flytzani-Stephanopoulos, 2017).

Weaknesses: As of 2014, there were no RNG production in Canada's forest industry to compare to because "the upgrading of gasified biomass to RNG is still an imperfect process requiring strategic technology investments" (Canadian Gas Association, 2014). In order to produce a viable amount of methane from woody residues, further pre-treatment processes are required, which would increase production costs (Canadian Gas Association, 2014).

Opportunities: British Columbia has the largest potential for renewable natural gas due to its large biomass resource base (forest industry; Canadian Gas Association, 2014). Not only can transportation costs of shipping natural gas to Northwest BC be minimized with a local facility, current plans and proposals for new natural gas pipelines in the region, such as the TransCanada Coastal GasLink Pipeline and the Chevron Pacific Trails Pipeline, may provide opportunity for an expanded market. Northwest BC's forestry residues currently see minimal utilization, which may suggest an opportunity for a large sustainable feedstock supply.

Threats: Delivered costs of RNG feedstocks are variable and may pose a financial challenge for a local facility. Inconsistencies in woody residues such as moisture and species used may impact RNG production efficiency (Canadian Gas Association, 2014).

Considerations for Northwest BC: RNG production in Northwest BC appears to be highly feasible, especially considering the current and future natural gas infrastructure in the region. Methods for RNG production from pulp and paper mill residues would require lower investment costs (Andersson, 2013), however, there are currently no pulp or paper mills in Northwest BC to capitalize on this opportunity. Feedstock costs and market pioneering are potential challenges to consider, but we recommend further research including a localized cost-benefit analysis to determine the potential for real application in Northwest BC.

Combined Heat and Power

Product Information: Combined Heat and Power (CHP) is a long-standing technique for energy generation and can utilize a number of different fuels (Zafar, 2019). In terms of using woody residues as the fuel source, Clarke, Freihaut, Lin & Fletcher (2012) indicate that steam turbines, Stirling Engines and the Organic Rankine Cycle are the only prime movers capable of utilizing this type of fuel. Steam turbines as the prime mover (creator of mechanical energy), are useful in power plants and industrial applications, but less so for residential or commercial buildings because of the high heat output and low mechanical/electrical energy output (Clarke et al., 2012). Stirling engines work by using waste heat to expand and contract a working fluid to produce mechanical energy. Leftover heat makes up the heat output in the CHP process (Clarke et al., 2012). The heat source is not internal to the system and therefore any type of fuel can be used (Clarke et al., 2012). Stirling engines have few moving parts and are therefore relatively easy to maintain, however, they are very expensive and have fairly low electrical efficiency (Clarke et al., 2012). Therefore, they are not ideal in CHP systems unless there is a large quantity of low-cost heat source available (i.e. woody residues) (Clarke et al., 2012). Stirling engines typically operate at 1 to 25 kW (Clarke et al., 2012). The Organic Rankine Cycle is another process that can use any type of heat source, and uses a compressor to pressurize the working fluid (usually water) and a turbine to depressurize the

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working fluid as it is heated (Clarke et al., 2012). This system, like the Stirling Engine, also suffers from high capital costs and low electrical efficiency (Clarke et al., 2012). It is an inefficient CHP system unless it has a large quantity of low-cost fuel/heat source that is not ideal for any other CHP system (Clarke et al., 2012).

Generally, case-studies of CHP facilities utilizing woody biomass, as indicated by Clarke et al., have been successful. Some important factors to keep in mind to improve the likelihood of success for a woody residue CHP facility include: Taking advantage of feasibility studies and grants, selling excess energy to the grid, and analyzing the market for how much biomass fuel is available in the area and at what cost (Clarke et al., 2012).

Amber, Day, Ratyal, Kiani, & Ahmad (2018) indicate that the capital investment for a 230 kW CHP project is $680,000 (converted to CAD). Although no sources indicating profit margins were found, Amber et al. determine that over $100,000 (converted to CAD) in electricity costs can be saved per year when switching from grid electricity and natural gas boilers to a natural gas CHP unit of 230 kW capacity. Because the CHP facility runs on natural gas, we can extrapolate and presume that savings may be even higher when using woody residues as the feedstock, since costs for biomass in the form of cut and dried firewood are generally on par with natural gas (Connors, 2016; Engineering ToolBox, 2003; Kijiji, 2019: PNG, 2019), and one can expect that costs for biomass in the form of woody residues would be even lower. Any tree species can be used in a biomass CHP system, although different species have different heating efficiencies, and moisture content will also inversely affect heat output (Clarke et al., 2012). Biomass CHP systems are being successfully used in a number of pilot and full-scale projects (Better Building Initiatives, 2017). Demand for biomass-based energy sources is increasing significantly, especially as grid energy prices rise (Transparency Market Research, 2016). Approximately six to eight people would be employed for a 3,100 kW capacity CHP system utilizing wood waste as fuel (EPA CHP Partnership, 2015).

Strengths: CHP units are much more efficient than Separate Heat and Power (SHP) (Clarke et al., 2012). CHP systems offer flexible fuel options, allowing one to capitalize on wood wastes such as sawdust, pulp, shavings, chips, and harvesting residues. A CHP unit providing the heat and electricity to a proponent negates the need for an additional stand-by power backup system in the event of power outages, since a CHP system has an “off-grid” configuration and can run even when grid power goes down (Clarke et al., 2012). A CHP unit can provide excess thermal/electrical energy back to the grid, to utility companies and/or nearby energy users for additional energy savings. These systems are very efficient when utilizing load shifting, which can customize total load to meet the changing requirements of the users (Clarke et al., 2012). Because of the high efficiency of CHP systems, emissions are usually lower than traditional energy sources (Clarke et al., 2012).

Weaknesses: CHP units have higher set-up costs than SHP, although these are usually justified by higher returns-on-investment (Clarke et al., 2012). They are more complex to run and maintain than equivalent SHP systems and therefore requiring more specialized training for employees. Additional costs exist if feedstock needs to be transported to CHP facility (EPA CHP Partnership, 2015).

Opportunities: Logging is a primary industry in Northwest BC and as such woody residues are abundant. Currently there is minimal utilization of harvesting residues, and most slash piles ae burned within a year of harvesting to mitigate fire hazards. It may be economically feasible for logging companies to transport their wood wastes to a local facility in order to eliminate the burning costs, in which case costs for CHP feedstock would be relatively low. One study even estimates that logging companies may even pay a tipping fee to the CHP facility for the opportunity to eliminate burning obligations (EPA CHP Partnership, 2015). CHP facilities could meet the energy demands of many small communities, subdivisions, or facilities in Northwest BC, given the variable sizes of CHP facilities that could be employed. BC has a number of funding opportunities available for clean energy projects (GovBC, 2019). It is common and efficient to have a CHP facility paired with a lumber mill that can provide the feedstock in the form of mill wastes to the CHP facility, which in turn provides for all of the energy demands of the mill; this is especially innovative when costs of natural gas are increasing and heat output from CHP can replace the natural gas heating used in Kilns (Austin, 2011). A biomass heating project is proposed for the Upper Skeena Recreation Centre in Hazelton (Gareau, 2018).

Threats: Due to the relatively high moisture content in Northwest BC wood, the efficiency of a CHP facility would be lower than standard unless a pre-use drying process is employed. The image below illustrates the inverse relationship between wood moisture content and combustion efficiency (Clarke et al., 2012).

Table 4: Combustion properties of hardwood

Moisture content – oven dry basis	As-fired heat value	Assumed combustion efficiency	Usable heat
[%]	[Btu/net lbm]	[%]	[Btu/net lbm]
0	8,300	80	6,640
15	7,218	78	5,630
30	6,385	76	4,853
60	5,188	72	3,735
100	4,150	67	2,780

Source: Haygreen & Bowyer, 1982

Consideration for Northwest BC: CHP energy shows many advantages over traditional energy sources, especially in Northwest BC where natural gas prices are rising and woody residues are underutilized. There are a number of lumber mills in Northwest BC that would benefit from the addition of a CHP unit, in terms of energy cost savings and environmental footprint. Not only could local sawmills and other facilities benefit from a CHP facility, but many small communities as well, such as those on the coast, in the Nass, along Highway 37 North, and many others where access to electricity and/or natural gas heating is limited.

Conifer Essential Oils

Product Information: Essential oils are volatile oils that hold the fragrance of the plants from which they are extracted. The essential oils extracted from conifers are used in aromatherapy and medical/pharmaceutical applications. It is commonly produced by steam distillation of the needles and twigs up to one cm in diameter, cut into pieces 1 cm or shorter, and can even utilize sawdust. Oil from cedar foliage has been used for room sprays, talcs, insecticides, embalming fluids, microscope slide slips, industrial cleaners, deodorants, pharmaceuticals, cleaning fluids, salves and cold remedy salves, liniments, reodorized sawdust logs or instant fire logs, perfumes, shoe polishes, and soaps (Food and Agriculture Organization of the United Nations, 1995). Oils from the Pinaceae family are used for fresheners, disinfectants, colognes, bath preparations, leather products, soaps, deodorants, inhalants, detergents, and vaporizer liquids. It also has uses in aromatherapy, such as in saunas, steam baths, and during massages. Oil from these species can be produced from steam distillation or volatile solvent extraction from the needles, twigs, or crushed cones. Oil from hemlock is used in purposes similar to the other species mentioned above. Conifer essential oils are relatively easy to produce compared to other medicinal plants.

Strengths: The production of conifer essential oils could provide year-round work since conifers retain their leaves throughout the year and forest harvesting also occurs year-round. For instance, fresh harvesting residues for oils could be gathered before or after logging.

Weaknesses: Conifer essential oil production does not create a lot of jobs, generally one person or family can run a small distillation business. However, it could potentially employ more people for acquisition of forest residues needed for distillation. The profit margin is relatively low and is more adequately suited for a secondary source of income (Check, 2003). Extraction techniques have been thoroughly researched but feasibility in BC relatively undocumented.

Opportunities: Conifer essential oil extraction creates the opportunity to utilize local forest residues. Many local tree species are known for their desirable essential oils and the higher moisture content is actually an advantage. Start-up costs are manageable, with a small-scale distillation unit costing around $22,000 (converted to Canadian dollars with inflation), whereas large-scale operations can cost up to and potentially over $4 million for a large distillation plant (converted to Canadian dollars with inflation) (Thomas et al., 1993). An inexpensive home-made distilling apparatus could also be used for small-scale local sales if purity and efficiency are not a concern.

Threats: It is a difficult market to get into unless very small-scale and local, larger-scale production is highly monopolized (Thomas et al., 1993). Furthermore, some people may avoid the use of some conifer essential oils such as cedar leaf oil due to possible toxicity from thujone, a ketone found in some plant species. Thujone is a neurotoxin which can cause seizures and brain damage when taken orally, however it is unknown if dermal application or inhalation of the fumes has detrimental effects (Check, 2003).

Considerations for Northwest BC: The availability of conifer boughs needed to make conifer essential oils are plentiful in Northwest BC and could be combined with forestry practices to reduce waste. A First Nation or small community approach may provide a lever with larger health and beauty corporations if buyers can be secured.

Northern Bleached Softwood Kraft

Product Information: Northern Bleached Softwood Kraft (NBSK) is a high-grade type of pulp with characteristic features such as long fibers and large fiber diameters. It is used as a reinforcement fiber for typical pulp applications such as paper, or can be used to make kraft paper, tissue paper, and other paper products (Catalyst Paper, 2015). It can be made from lodgepole pine, white spruce, red cedar, douglas fir, hemlock, and larch (Nanko, Button, & Hillman, 2005).

Strengths: NBSK is the second largest pulp produced in the world (by tonnage), second to eucalyptus pulp from Europe, Asia, and Latin America, and has high market demand (Numera Analytics, n.d.). A large mill can be highly profitable and can employ up to 400 people (United States Environmental Protection Agency, 1997).

Weaknesses: According to a United States Environmental Protection Agency report (1997), kraft mills are extremely expensive to start up, to the order of billions of dollars. It is also costly to produce due to the chemical treatment and bleaching process (Numera Analytics, n.d.). From an environmental standpoint the primary concerns with kraft pulping are the use of chlorine-based bleaches and toxic emissions to air, water, and soil. In addition, the pulping process only utilizes 50% of input wood. One solution is to use an oxygen-base, closed loop process which helps minimize chemical discharge, but effluent damage to the environment still occasionally occurs (Broten, & Ritchlin, 2012).

Opportunities: BC has a relatively long growing season compared to the rest of the country, which allows for BC wood products to have the long fibers and larger diameters that are characteristic in quality NBSK. There are high pulp prices in the US ($1300 USD/metric tonne) compared to Europe ($1170 USD/metric tonne) and China ($915 USD/metric tonne), and the demand for NBSK is considerably high (Natural Resources Canada, 2019).

Threats: There are numerous NBSK mills in BC, such as Prince George, Quesnel, Hinton, Duncan, and Kamloops. As of 2016, the market was facing an oversupply, resulting in reduced value (Marzouk, 2016). Consequently, as a commodity priced product the pulp markets are very sensitive to swings in the macro economy, and NBSK is the second most volatile commodity after oil as measured by standard deviation of market pricing (Rosenberg, 2011).

Consideration for Northwest BC: NBSK is considerably stronger than bleached hardwood kraft, and Northwest BC has an abundance of softwoods that could be used. It can also be produced from sawmill wastes (Catalyst Paper, n.d.). This industry is not without its problems, for example, issues from the increased export of raw logs means the supply for local mills is going away (Parfitt, 2017).

NWBC also has a relatively high raw material cost compared to other regions, as well as nearby competition from existing pulp and paper mills like Canfor in Prince George, and Cariboo Pulp & Paper Co in Quesnel which is a West Fraser company. Additionally, the past history of corporate pulp mill failures in NWBC should be examined, including the 2010 Eurocan pulp and paper mill closure in Kitimat, and the 2004 Skeena Cellulose pulp mill closure in Prince Rupert. Risks include shrinking markets, wood fiber supply issues, potential tariffs, environmental restrictions and mill inefficiencies with high costs (Fastmarkets RISI, n.d.).

Lignin Pulp Moulded Products

Product Information: Lignin Pulp Moulded Products (LPMP) are eco-friendly packaging materials that can replace plastic and styrofoam. They can be produced from virgin pulp or post-consumer paper products (recycled pulp), which are dissolved into a pulp and then pressed into packaging forms. The process has been around since the mid 90’s and has gained commercial importance in recent years (Didone et al., 2017). Michelson Packaging (Personal communication, November 19, 2018) and Pacific Pulp (Personal communication, November 19, 2018) said a manufacturing facility can employ anywhere from 50 to over 100 employees. In 2017, Esco Technologies Inc. (2017) reported their EBITDA margin at $8.5 million US dollars for their technical packaging division, with 10.3% of net sales for the large company. Information on the size of this facility could not be found.

Strengths: One of the greatest draws to this product is its ability to satisfy a growing demand for eco-friendly packaging, and its ability to be recycled or composted. For instance, it is a sustainable replacement for EPS (Styrofoam) in many applications. It can also be made from recycled pulp. Furthermore, production is a relatively simple process, and its presence in the industry since the early 90’s is “tried and tested”. There is a variety of production techniques to meet the specifications of the resulting desired product. One of the relatively new production techniques, flashing-assisted displacement dewatering, offers solutions to the common fallbacks of typical molded pulp problems, including energy input requirements, tensile strength, and delamination (Didone et al., 2017). The future looks promising for this product since the market in North America is expected to continue to grow past 2022 (Meges, 2018).

Weaknesses: While lignin pulp moulded products are an eco-friendly packaging solution, it is lacking in certain properties in comparison to its non-sustainable alternatives (like Styrofoam), such as resistance to thermal or moisture-induced degradation. The capital investment for a LPMP facility is in the multi-millions of dollars (Pulp Packaging, 2018), and if the pulp processing and pulp molding facilities are not integrated, energy costs and environmental impacts will increase and potentially devalue the feasibility.

Opportunities: The global markets for LPMP are growing (Meges, 2018).

Threats: LPMP could be made from post-consumer paper products sourced from a local recycling program, however, anonymous sources claim that all BC municipal recyclables have been acquired by Cascades Recovery+ in Vancouver (Personal communication, 2018). Also, pulp from post-consumer paper products can only be recycled a finite number of times. Although it is a highly desired product, it is already well-established in worldwide markets with abundant production and competition from large companies.

Consideration for Northwest BC: The largest obstacle for LPMP production in some areas of Northwest BC is the lack of a local pulp mill. Due to the high capital investment, the most efficient system would be to integrate the paper molding facility into a pulp and paper plant, where the lignin byproducts could be recovered for making moulded products. Existing pulp and paper mills include Canfor Prince George, and Cariboo Pulp & Paper Co. in Quesnel which is a West Fraser company. Paper products are dissolved in an aqueous solution to produce pulp, so moisture content does not negatively impact the process.

Wood Pellets

Product information: Wood pellets are a renewable fuel source, made of compact wood fiber products such as sawdust. A pellet plant can cost around $18 million in capital investments for a 75,000 metric tonne/year plant (converted to 2019 CAD), employ approximately 90 people, and turn a profit margin of 11% or more (Pirraglia, Gonzalez, & Saloni, 2010). Pellet plants can utilize many wood sources, from saw logs to pulp logs to sawmill wastes to forestry residues (Huan, 2016). The pellet quality is dependent on low ash content and a moisture quality below 10%; tree species has very little effect on pellet quality and the raw material is put into a dryer to reduce its moisture content (Middleton, n.d). The market faced an oversupply despite increasing demands in 2017 and early 2018, but new industrial demands have soaked up excess supply and the demand for wood pellets is expected to continue growing (Strauss, 2017).

Strengths: Wood pellets are made from renewable resources and can replace fossil fuels in a number of applications. Their density makes them an efficient energy source and this density also helps cut costs for transportation. This volume capacity of transport is much higher than that of other wood products due to the condensed nature of pellets.

Weaknesses: The cost of wood pellets has been fluctuating and is not always cheaper than fossil fuel alternatives, which causes low motivation for consumers and industries to switch to pellets (Wood Pellet Association of Canada, n.d.). It also requires modified systems to use wood pellets, so it is not an easy or cheap switchover from fossil fuels or other alternatives (Murray, 2015). In addition, the transportation efficiencies are subject to moisture, for instance wet pellets break apart, therefore, pellet need to be shipped and stored in a dry space.

Opportunities: There is a significant amount of forest residue that could be used for pellet production, depending on costs. Currently there are not many other uses of forest residues, which means high resource availability, provided it is at affordable prices.

Threats: The process to make pellets requires dry wood products, and since local sourced wood has a high moisture content, the process would require a potentially costly drying process, or

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outsourced wood products (if part of a large-scale pellet production facility; small scale facilities can be supplied by sawdust from local sawmills, which may or may not need to be dried). It would also require a large storage facility.

Considerations for Northwest BC: There is a good potential market as there is an increasing trend in Northwest BC of use of pellet stoves and provincial initiatives are in place to promote homeowners to switch to higher efficiency wood heating appliances (Millar, 2006). However, the production costs of wood pellets are slightly higher for moist raw material, which would put the production in Northwest BC at a slight disadvantage due to the wood's higher moisture content (Sénéchal & Grassi, 2009). There is also local competition, as there is already a number of pellet plants in the area (Newpro in Smithers, Pinnacle Pellet in Burns Lake, Premium Pellet in Vanderhoof, Pacific BioEnergy in Prince George) as well as a new pellet plant currently being built in Terrace. Another proposed plant to be built in South Hazelton (Bakker, 2018) will produce biocoal, also known as torrefied pellets, that can be used as a clean alternative to coal. A major advantage of torrefied pellets is the fact that they are weather resistant which allows them to be stored outside in a pile and is also more cost effective for transportation (Airex E, n.d.).

Berries

Product Information: Berry picking is abundant in BC, and a number of species have been officially identified as being picked commercially (BC Ministry of Forests and Range, 1995). These species are blackberry, blackcurrant, highbush-cranberry, blueberry, huckleberry, and saskatoon berry. Many other species, including salmon berries, thimbleberries, elderberries, red currants, soopalallie, and kinnikinnik are picked unofficially for home-based businesses such as selling canned or baked goods. Little data exists regarding commercial wages, markets, or distribution channels, but it is expected that capital investment for a commercial berry picking business would be minimal, to the order of a few thousand dollars at most, for transport and manpower.

Strengths: Demand is steadily increasing for sustainably harvested, organic, and wild products (BC Ministry of Forests and Range, 1995). It can be paired with the forest industry when possible to harvest berries before the cutblock is harvested, therefore acquiring resources that would have otherwise been lost during harvest. Berry production can temporarily increase after harvest while the forest is regenerating and there is additional light and reduced competion for berry producing shrubs. Appropriate silvicultural practices can maintain and enhance berry production by providing more sunlight to the berry producing shrubs (Burton, 2006).

Weaknesses: One venture would not employ a large number of people, nor would it likely provide income sufficient for living, given the seasonality of it. Therefore, such a venture would need to complement another part-time business.

Opportunities: There is a significant supply of wild berries in Northwest BC, especially blueberries, huckleberries, salal (in some areas), thimbleberries, salmonberry and elderberry.

Threats: Entrepreneurs may be hesitant to start up such a venture because of the small payoff and seasonal variations in growing stock.

Considerations for Northwest BC: The Wilp Sa Maa'y Harvesting Co-operative is a berry harvesting enterprise started by the Gitxan First People and is an example of a regional co-operative working together to form a successful venture in Northwest BC (Burton, 1999).

Bleached Chemithermo Mechanical Pulp

Product Information: Bleached chemithermo mechanical pulp (BCTMP) is a high yield pulp that can be produced from softwoods or hardwoods, and is far less costly to produce that NBSK. One source provides a capital investment estimate of $163 million (converted to 2018 CAD) and a profit margin ratio over 15% for a 100,000 metric tonne per year facility (Harpole, Leatham, & Myers, 1989). Another source claims a 200,000 air-dried metric tonne per year facility with zero liquid effluent costs $377 million (converted to 2018 CAD) in start-up (Cannell & Cockram, 2000). BCTMP can be made from any tree species although the properties of the pulp vary according to which species are used (Fibre Lab, n.d.).

Strengths: BCTMP is a less expensive alternative to NBSK. It can also be produced more sustainably and produce high grade pulp sufficient to replace NBSK. Millar Western's BCTMP mill was the first and only zero-effluent market pulp mill in 2000. An article claims that "the mill uses about 10% of the fresh water that a traditional mill of this type would use and only about 2.5% of the water a kraft mill would use" (Pulp & Paper Canada, 2000). It can be made from pulp logs or sawmill wastes (International Labour Office, n.d.).

Weaknesses: Similar to NBSK, BCTMP also requires advanced technology to produce high grade pulp (Pulp & Paper Canada, 2000). Unlike NBSK, BCTMP contains lignin, which reduces the photostability of BCTMP products (Cannell & Cockram, 2000).

Opportunities: There is a strong growing market demand for BCTMP in China (Hein, 2017). A factory can employ a large workforce of 100 people or more (International Labour Office, n.d.).

Threats: It is projected that global pulp products supply will outweigh market demand until at least 2020 (Hein, 2017).

Considerations for Northwest BC: When compared to other high-quality pulp producing processes, this product has lower capital and manufacturing costs, produces higher yields and is more environmentally friendly (Cannell & Cockram, 2000), making it an attractive option for Northwest BC. Since the shutdown of the NBSK mill in Prince Rupert, expectations for the success of another mill of its kind in the region have not been high. However, the financial advantages of BCTMP and its comparable value to NBSK suggest that it may be a potential alternative to other pulp mills. The moisture content in the local wood is not an issue for pulp mills.

Recycled Pulp

Product Information: Recycled pulp takes consumer paper recyclables and re-processes it to produce post-consumer paper. Virgin papers can be recycled up to five times, and the recycling process is comparatively more environmentally friendly than producing virgin paper (Arjowiggins, n.d.*a*). By reusing pulp and paper, demand for virgin fibers (via tree harvesting) is reduced. Waste paper is first sorted by type and then dissolved in a water mixture with soap to remove inks and impurities (Arjowiggins, n.d.*b*). The pulp is then prepared into sheets, treated with a coating if required, dried, and rolled onto jumbo reels (Arjowiggins, n.d.*b*).

Few to no new mills have been constructed since the mid to late 1900s because of the continuous shut downs of mills across the province (FLNRORD, 2019). Any new mill operations that start up take advantage of pre-existing infrastructure and revitalize it (FLNRORD 2019). In this way, capital costs for a recycled paper mill would consist of purchase costs of a suspended mill and upgrading costs. A mill designed for production of 300,000 metric tonnes per year, utilizing 70 to 100% deinked recycled paper is valued at $290 million (converted to 2018 CAD; Pulp & Paper Canada, 2003).

Strengths: Recycling pulp, as opposed to producing virgin pulp, uses a fraction of the energy, produces half as much CO_2, prevents landfill buildup where more greenhouse gas emissions would occur, takes 35,000 less liters of water per tonne, and can produce one tonne from 1.2 tonnes of waste paper vs 2.5 tonnes of wood for virgin paper (Arjowiggins, n.d.*a*). Deinking sludge can be recycled to provide agricultural composting or produce cement and bricks (Arjowiggins, n.d.*c*). Recycled papers can be of comparable quality to virgin papers (Arjowiggins, n.d.*a*).

Weaknesses: Fibers are too far degraded after five recycles, but there is no way to tell how many times paper has been recycled (Papernet, n.d.). Recycled materials may also be prone to increased bacterial content, making them unsuitable for use in the food industry (Papernet, n.d.).

Opportunities: Moisture content does not affect the recycling process of reclaimed paper, since recycled fibers are dissolved in an aqueous solution (Arjowiggins, n.d.*d*).

Threats: Starting up a sorting yard and pulp mill is a costly undertaking, and there are few mill sites in Northwest BC that are available and suitable for milling recycled pulp.

Considerations for Northwest BC: A large portion of BC's municipal paper recycling currently goes to Cascades Recovery+ in Vancouver, according to any anonymous source (Personal communication, 2018). However, the Regional District of Kitimat Stikine is not part of this agreement, and Do Your Part Recycling in Terrace BC, who collects the district's recycling, claims that it is a constant challenge to find firms that can financially justify the purchase costs of recycled paper (Do Your Part Recycling, personal communication, December 06, 2018). With the right local recycled paper mill, however, this may be a viable source for feedstock.

Nanocrystalline Cellulose

Product Information: Nanocrystalline Cellulose (NCC) is a pulp product that is valued for its nanoscopic, chiral nematic fibre orientation that exhibits durable, flexible, hydrophilic, magnetic, and iridescent properties (Natural Resources Canada, 2016). Using NCC in composites adds improved strength, flexibility, and permeability to a wide range of products, including paper products, films, biosensors, security devices, specialty packaging, magnetic paper, and electronics (Natural Resources Canada, 2016). There are a number of ways to produce NCC from bulk cellulose, including mechanical, chemical (acid hydrolysis), and enzyme treatments (George & Sabapathi, 2015). This product is renewable, nontoxic, biocompatible, and sustainable (George & Sabapathi, 2015). Prices range from $3.30/g to $33.00/g of NCC, depending on product type (Cellulose Lab, 2018). CelluForce Canada produces 300 tonnes per year (one facility; Miller, 2018). Estimates of production costs are $4,800 to $21,190 per tonne and profit margins have been noted around 30% (Abbati de Assis et al., 2017). Capital investments are estimated up to $250 million, and staff is around 42 staff per facility (Abbati de Assis et al., 2017). On February 05, 2019, CelluForce received $6.4 million in funding to upgrade its nanocrystalline cellulose plant in Quebec to become a full commercial, demonstration-scale plant (Natural Resources Canada, 2019).

Strengths: NCC is a renewable resource; specifically, cellulose is the most abundant organic material on the planet (Song et al., 2014). It is environmentally safe and biodegradable, and is easy to produce from both softwood and hardwood (Dufresne, 2013; Song et al., 2014). When using certain production processes such as enzymatic hydrolysis coupled with sonification, a biproduct is cellulosic ethanol, which is an eco-friendly petroleum alternative (Song et al., 2014). There is an immense range of potential applications of NCC (Lyne, 2013).

Weaknesses: If using the acid hydrolysis method of cellulosic extraction, high quantities of acid products are required, and acid resistant equipment is required, resulting in high production costs (Song et al., 2014). Production is very costly, and large-scale facilities have been limited due to the current lack of cost-effective production methods (Transparency Market research, 2019).

Opportunities: Moisture content does not appear to have an effect on NCC production, since pulp (water matrix) is the primary feedstock (Peresin et al., 2010).

Threats: Currently methods of production use wood pulp as input source (Asim, 2017; Song et al., 2014). If using enzymatic hydrolysis, hardwood more readily digests than softwood (Song et al., 2014). There are a number of global producers established, however, their productions capacities are generally quite low (Figure 1; ISO/TC 6/TG 1 – Cellulose Nanomaterials, 2017; Miller, 2015). Because NWBC is fairly isolated, shipping costs of NCC to buyers may be a disadvantage, although market is generally international anyway.

Considerations for Northwest BC: Nanocrystalline cellulose is a relatively new product, whose broad range of uses is still being realized. More and more industries and consumers are realizing the superior qualities of NCC, and market demand has been steadily on the rise with further increases expected due to the recent technological advancements in production equipment (Transparency Market Research, 2019). The vast range of end users combined with the unsaturated market provides a lucrative opportunity for a new venture to establish its product on the market. Capital and production costs are expected to be high, but the isolated nature of Northwest BC is not expected to impact transportation costs, since end-users are virtually everywhere. The greatest disadvantage to Northwest BC for producing Nanocrystalline cellulose is the need for pulp as the feedstock; there are currently no pulp mills in Northwest BC. Whereas research to date has focused on the production of NCC from pulp, exploration into the production of NCC from other wood sources such as saw mill wastes of forestry residues may provide an alternative production method that may better suit Northwest BC.

Cellulose Nanocrystals (CNCs)

CELLULOSE NANOCRYSTALS (CNC) CAPACITY CURRENT AND ANNOUNCED 2015 (kg per day)

CelluForce, Canada	1,000
American Process, U.S.	500
Holmen (Melodea), Sweden *	100
Alberta Innovates, Canada	20
US Forest Products Lab	10
Blue Goose Biorefineries, Canada	10
India Council for Ag. Research	10
FPInnovations, Canada	3
Melodea, Israel	Pilot

*2016

Cellulose Nanofibrils (CNFs)

CELLULOSE NANOFIBRILS (CNF) CAPACITY CURRENT AND ANNOUNCED 2015 (kg per day)

Paperlogic	2,000
University of Maine	1,000
Borregaard, Norway	500
American Process	500
Nippon Paper, Japan	150
Innventia, Sweden	100
CTP/FCBA, France	100
Oji Paper, Japan	100
Stora Enso, Finland	Pre-commercial
UPM, Finland	Pre-commercial
FPInnovations, Canada	Pilot
Norske Skog	Pilot
SAPPI, Netherlands	Pilot
VTT	Pilot
Daicel, Japan	Lab
Luleå University of Technology, Sweden	Lab
US Forest Products Laboratory, USA	Lab

Figure 1.Nanocrystalline Cellulose Production Capacity. Retrieved from Miller (2015).

Culinary Plants

Product Information: Botanical forest products (BFPs) include plants and fungi used for a variety of reasons other than timber products. Some of these plants and fungi can be considered culinary plants and can be profitable. Examples include sap (birch, bigleaf, douglas) for syrup, wild berries(cloudberries, strawberries, trailing dewberries, cranberries, bunchberries, raspberry, blackberry, huckleberry, blueberry, salmonberry, thimbleberry, currant, high bush cranberry, soopalalie, elderberry, chokecherry, salal, saskatoon, and Oregon grape), wild greens/grasses (stinging nettle, asparagus, watercress, fireweed shoots, mint, and dandelion greens), wild onions, fiddleheads, and mushrooms (Hamilton, 2012).

Strengths: There is minimal capital investment involved in starting up a business gathering and selling culinary plants because only manpower, a good knowledge base, and minimal equipment are required for a small operation. There are many forest species that have market potential in BC and there is an increased interest in their use (BC Ministry of Forests and Range, 1995). The harvest of BFPs is sustainable because it utilizes plants from the understory of established forests.

Weaknesses: Profit margins would likely be low for such an industry, although no concrete data has been found in regards to capital investment or generated income. Job creation is low because only a few people would be employed on a part-time basis, per business. Some of the products can easily be affected by weather and time of year. There is currently very little integration of BFP harvesting and industrial forestry, although this may be a window for opportunity. Certain products may have a limited shelf-life, and therefore gathering and selling practices have to be well coordinated with clients.

Opportunities: Mushroom and salal harvest is a multi-million-dollar commercial activity in coastal BC (Olivotto, 2009). Provincial revenue for BFPs is valued at $680 million (Gagné, 2004). In 1994, pine mushrooms harvested in the Nass Valley earned close to $4 million (Mitchell, 1998). Northwest BC has abundant vegetation for the harvesting of culinary herbs.

Threats: Issues with sustainable management, land ownership and who has rights to harvest may pose complications (Turner, 2001). Lack of government revenue, potential over-harvesting of the resource, and infringement of aboriginal rights and First Nations' traditional use of BFPs are some of the issue that arise due to the lack of regulations for harvesting BFPs in BC (Gagné, 2004). On the other hand, this could also be an opportunity to liaison with local First Nations and create new opportunities to market and/or harvest BFPs and incorporate cultural values.

Considerations for Northwest BC: Because of the value of BFPs to First Nations, the gathering and marketing of culinary plants may be an economical opportunity for First Nations groups, as well as an opportunity to promote and support First Nations cultures. The gathering of culinary herbs could be coordinated with the regional forest industry by harvesting understory species before logging occurs. Northwest BC has a relatively long growing season which means extended opportunities for harvesting of culinary herbs. Despite the advantage, a venture such as this one would still provide limited income due to its seasonal nature and would need to be paired with other income earned during the down season.

Floral Greenery and Native Plant Landscaping

Product Information: Another way that botanical forest products (BFPs) can be used is through the harvest and sale of floral greenery used to make crafts and decorations, and the use of salvaged plants for landscaping. Some examples include decorative boughs, moss and grasses for flower arrangements, Christmas trees, ferns and trees for landscaping, conifer seeds for reforestation and shrub and wildflower seeds for gardening (Hamilton, 2012). Many crown areas ideal for harvesting

BFP's are not regulated, however, a permit is required for the harvest and sale of botanical forest products on Nisga'a lands (Nisga'a Lisims Government, n.d.).

Strengths: There is minimal capital investment required for gathering floral greenery because mainly manpower and a good knowledge base is required. There are many species in NWBC that have market potential. The harvest of BFPs is sustainable because it utilizes understory species of established forests (Gagné, 2004).

Weaknesses: Profit margins would likely be low for such an industry, although no concrete data has been found in regards to capital investment or generated income. Job creation is low because only a few people would be employed on a part-time basis per business. Some of the products can easily be affected by weather and time of year. There is currently very little integration of BFP harvesting and industrial forestry, although this may be a window for opportunity. Certain products may have a limited shelf-life, and therefore gathering and selling practices would have to be well coordinated with clients. Salal, one of the most successful AFPs for floral greenery and landscaping, is only abundant in a few areas of Northwest BC.

Opportunities: The collective gross revenue in BC for floral greenery was $55-$60 million in 1997 with 13,000 estimated commercial pickers, who sold to Europe, Hong Kong, Japan and the United States (Gagné, 2004; Wills, 1999). Native art also generates significant income with the use of floral greenery. A single birch tree can make over $1,000 in masks, bowls, spoons and baskets (Turner, 2001). Co-management options have been suggested between the forest and salal industries as salal pickers can prune trees for the forest company, and the salal growth benefited from the fertilizer used on young strands which increased the salals value up to $2,500/ha (Wills, 1999). Around 12,000-15,000 people harvest salal foliage in BC (Wills, 1999).

There is also a growing demand for native plants for restoration projects and urban landscaping. In addition, seeds can be harvested for forest nurseries (BC Ministry of Forests and Range, 1995). A trial conducted on Vancouver Island showed that salvaging ferns from proposed logging roadways was economically viable even though the harvest period only lasted a few months; the profit potential per day was high (BC Ministry of Forests and Range, 1995). A total of 44 native BC plant species have been identified for landscaping, and their use is increasingly preferred because they are naturally adapted to the local climate and have a greater tolerance to disease and insects (BC Ministry of Forests and Range, 1995).

Threats: Lack of regulations to harvest BFPs in BC creates issues like lack of government revenue, over-exploitation of the resource, infringement of aboriginal rights, and concerns over land ownership and rights to harvest (Turner, 2001).

Considerations for Northwest BC: Because of the value of BFPs to First Nations, the gathering and marketing of floral greenery may be an economical opportunity for First Nations groups, as well as an opportunity to promote and support First Nations cultures. The gathering of floral greenery could be coordinated with the regional forest industry by harvesting understory species before logging occurs. Northwest BC has a relatively long growing season which means extended opportunities for harvesting of BFPs. Despite the advantage, a venture such as this one would still potentially provide insufficient income without being paired with another venture that can be undertaken during the down season.

Medicinal Plants

Product Information: Medicinal plants are botanical forest products (BFP) with uses as general tonics, purgatives, laxatives, salves, antiseptics, anti-inflammatories, medicines for respiratory and internal ailments, and many other uses (Gagné, 2004). Medicinal plants can be made into essential oils (cedar oil, wild rose oil), herbal teas, tinctures, balms and salves (yew, wild rosehip, elderberry, hawthorn, bee pollen, horsetail, valerian, plantain, devil's club, snakeroot, wild ginger, pipsissewa, stinging nettle, and veratrum; Hamilton, 2012). Fungi are also considered to have medicinal properties (Keefer, Ehlers & Macpherson, 2008). Many crown areas ideal for harvesting BFP's are not regulated, however, a permit is required for the harvest and sale of botanical forest products on Nisga'a lands (Nisga'a Lisims Government, n.d.).

Strengths: There is minimal capital investment required for gathering medicinal plants because mainly manpower and a good knowledge base is required. There are many species in Northwest BC that have market potential. The harvest of BFPs is sustainable because it utilizes understory species of established forests (Gagné, 2004). In addition, some herbs and shrubs favor post-logging conditions that allow more sunlight (Gagné, 2004).

Weaknesses: Profit margins would likely be low for such an industry, although no concrete data has been found in regards to capital investment or generated income. Job creation is low because only a few people would be employed on a part-time basis per business. Some of the products can easily be affected by weather and time of year. There is currently very little integration of BFP harvesting and industrial forestry, although this may be a window for opportunity. Certain products may have a limited shelf-life, and therefore gathering and selling practices would have to be well coordinated with clients. For example, a fungus such as Chaga can be stored for only six to nine months in prepared form and six weeks in natural form (Wills & Lipsey, 1999). If the storage or shipping time gets extended the price drops (Wills & Lipsey, 1999).

Opportunities: The world market for herbal medicines is around $14 billion annually (Wills & Lipsey, 1999). In 1997, the gross revenues paid to 15-20 Canadian commercial collectors was $2-$3 million, gatherers were paid on a per pound basis and made around $100 per day, with premium prices being paid for organically grown or wildcrafted produce (Wills & Lipsey, 1999).

Threats: Certain food safety regulations may apply where herbals must be sold as either food (no health claims permitted) or drugs (and have to undergo clinical testing) (Wills & Lipsey, 1999). Lack of regulations to harvest BFPs in BC creates issues like lack of government revenue, over-exploitation of the resource, infringement of aboriginal rights, and concerns over land ownership and rights to harvest (Turner, 2001).

Considerations for Northwest BC: Because of the value of BFPs to First Nations, the gathering and marketing of medicinal herbs may be an economic opportunity for First Nations groups, as well as an opportunity to promote and support First Nations cultures. The gathering of medicinal herbs could be coordinated with the regional forest industry by harvesting understory species before logging occurs. Northwest BC has a relatively long growing season which means extended opportunities for harvesting of BFPs. Despite the advantage, a venture such as this one would likely still provide insufficient income without being paired with another venture that provides income.

Wild Mushrooms

Product Information: There are 33 species of wild edible mushrooms that are harvested in British Columbia (BC Ministry of Forests and Range, 1995)**.** Preferred growing conditions vary between species, for example pine mushrooms prefer stands of trees around 100 years old whereas chanterelle host trees need to be at least 10-40 years old (Ehlers & Hobby, 2010). Between 2,000 and 5,000 people harvest pine mushrooms in British Columbia (BC Ministry of Forests and Range, 1995). In 1993, $3.4 million was paid to harvesters in the Terrace-Nass valley area with 110,000 kg of pine mushrooms being harvested (Wills & Lipsey, 1999). Mushrooms are a significant BFP in Nisga'a traditional territories and a permit is required for the harvest and sale of botanical forest products on Nisga'a lands (Nisga'a Lisims Government, n.d.).

Strengths: There is minimal capital investment required for gathering mushrooms because mainly manpower and a good knowledge base is required. There are many species in Northwest BC that have market potential. The harvest of BFPs, including mushrooms, is sustainable because it utilizes understory species of established forests (Gagné, 2004).

Weaknesses: No concrete data has been found in regards to capital investment or profit margins, although it is expected that capital investment costs would be low, and generated income moderately low because of the seasonal nature of the product. Job creation would be low because only a few people would be employed on a part-time basis per business. Some of the products can easily be affected by weather and time of year. There is currently very little integration of BFP harvesting and industrial forestry, although this may be a window for opportunity. Certain products may have a limited shelf-life, and therefore gathering and selling practices would have to be well coordinated with clients. For example, mushrooms such as Chaga can be stored for six to nine months in prepared form and only six weeks in natural form (Wills & Lipsey, 1999). If the storage or shipping time gets extended the price drops (Wills & Lipsey, 1999). Successful mushroom growth can be impacted by weather and profit could vary greatly from year to year. For instance, an average to good year can yield around 392,000 kg of pine mushrooms in BC, but in a less-than-average year this figure falls to 250,000 kg (Wills & Lipsey, 1999). Most mushrooms prefer mature stands, and clear-cuts can eliminate mushroom habitat for decades (BC Ministry of Forests and Range, 1995).

Opportunities: One study looked at morels, a fire-adapted species, and saw a potential to use broadcast or scattered burns in order to deal with post-harvest timber slash to create more morel habitat (Gagné, 2004). They found that adding inoculum or calcium fertilizer might encourage fruiting and minor disturbance of sites prior to harvest (e.g. skid trails) may actually stimulate fruiting (Gagné, 2004). Gathering and selling mushrooms can be a lucrative seasonal industry, with a good day earning a gatherer hundreds of dollars.

Threats: According to Wills & Lipsey (1995):

> *We were able to identify sixteen active companies exporting wild food mushrooms (of several species) from BC. Over 90% of all exports from Vancouver to Japan of pines are controlled by seven companies, (six of which are Canadian-owned). In a good fruiting year for pines, these seven companies have collective before-tax revenues from pines and other mushrooms of approximately Can. $40-$45 million but in a bad year this figure can fall to around Can. $25 million. Individual mushroom revenues of these seven companies ranged in a good year from Can. $22 million to under Can. $1 million. We have identified only three BC companies involved in the export of nutraceutical and medicinal mushrooms, however there are dozens in Oregon and Washington states.*
>
> *Although over the past decade, the pine harvest has approximately doubled, the average price paid to exporters has remained the same ---around US$19.00-$20.00/lb. In 1997 there was a brief price war for pine mushrooms in the Nass valley. Some companies which had been inactive for several years re-entered the pine market and when this happened, several large, established companies raised the field price paid to harvesters to the range of Can.$35.00-$50.00/lb, driving the new entrants from the field. (When this occurred, some companies lost in excess of Can. $50,000 in a two-week period). At the same time the wholesale price for pines in Tokyo and Osaka was around yen 5,300 –an anomalous situation in which the field price paid to pickers was almost twice the landed price in Tokyo. Canadian pine exports have grown at roughly 10% annually since 1993, and the combined Oregon and Washington state wild food mushroom industry has grown at an average annual rate of around 12% since 1987.*

From the excerpt above, it is likely that there is significant competition in the mushroom harvesting industry, and that new ventures may be pushed out by larger established companies who possess the capital to do so. Lack of regulations to harvest BFPs in BC creates issues like lack of government revenue, over-exploitation of the resource, infringement of aboriginal rights, and concerns over land ownership and rights to harvest (Turner, 2001).

Considerations for Northwest BC: Because of the value of BFPs to First Nations, the gathering and marketing of mushrooms may be an economic opportunity for First Nations groups, as well as an opportunity to promote and support First Nations cultures. The gathering of mushrooms could be coordinated with the regional forest industry by harvesting understory species before logging occurs. Northwest BC has a relatively long growing season which means extended opportunities for harvesting of BFPs. Despite the advantage, a venture such as this one would likely still provide insufficient income without being paired with another venture that provides income.

Lightweight Aggregates with Pulp Sludge

Info: Wastewater sludge from pulp and paper mills can be used to create glass aggregates such as tiles, roof shingles, asphalt paving, sandblasting media, and cement materials (Bajpai, 2018). Currently, the sintering process requires very high heats to turn traditional materials into glass aggregates, and this is becoming increasingly costly as fuel costs rise (Chen et al., 2016). When combining paper pulp sludge with standard green clay materials (50-90%), the sintering temperature and energy requirements reduce significantly (Chen et al., 2016). One study indicates that a fly-ash brick facility (i.e. cement materials) could employ around 146 people, with capital investment being relatively low around $380,000 (converted to 2018 CAD) and an EBITDA margin of 45% (Building Materials & Technology Promotion Council, 2007). This may be comparable to the statistics for a pulp sludge aggregate brick facility, except for a few unknown factors, namely: the input materials (pulp sludge) may need further processing in order to be used in the same processes as fly-ash brick manufacturing; the costs of raw goods (pulp vs fly-ash) may vary between the two products; and the lower sintering temperature required for pulp sludge may reduce the energy requirements compared to that for fly-ash bricks.

Strengths: Aggregate markets may favour the reduced energy costs associated with using pulp sludge to produce glass aggregates. Particle densities of resulting lightweight clay and pulp sludge are within the range of acceptable density specifications for glass aggregates.

Weaknesses: Glass aggregates created solely from pulp sludge without a partial clay composition are not feasible due to the chemical composition of pulp sludge.

Opportunities: There are currently no glass aggregates facilities in Northwest BC that utilize pulp sludge in their manufacturing processes. This may be an opportunity for a local start-up, considering the reduced energy costs associated with pulp sludge – glass aggregates compared to conventional aggregates.

Threats: Unknown market for glass aggregates in the area, as there may be resistance by consumers to transition to a new product that is not yet widely known about. Generally, the construction industry in Northwest BC is steadily increasing, and the demand for lightweight aggregates should proportionately increase. There are no pulp or paper mills in Northwest BC who’s pulp sludge could be utilized for lightweight aggregates. Conventional aggregate plants currently exist in Quesnel, 100 Mile House, and Williams Lake (United Concrete and Gravel), Sechelt (Lehigh Materials), and many smaller operations throughout Northwest BC.

Lignin Extraction (Biorefinery)

Product Information: Lignin extraction consists of extracting lignin from the black liquor that is a waste product of pulp and paper mills. Extraction of lignin from cellulose is either done via the traditional technique of sulfite pulping, or the more modern kraft process of lignin separation through acid precipitation (Fatehi & Chen, 2016). Specialists are optimistic and excited about the upcoming market for lignin. With extensive research taking place on lignin applications, it is believed that the pulp and paper's most abundant waste product may soon find economically viable opportunities (Fatehi & Chen, 2016; Mabrouk et al., 2017; McCoy, 2016; Natural Resources Canada, 2016; Natural Resources Canada, 2013). Some lignin applications include substituting phenol in phenolic resins, replacing carbon black in rubber reinforcements, and substituting for polyacrylonitrile as a precursor to carbon fiber (Fatehi & Chen, 2016).

When paired with a pulp mill: Adding a biorefinery decreases volume constraints on the recovery boiler, allowing pulp production to increase (Kasurinen, 2016). Three new income streams are generated when a biorefinery is added to a pulp mill: increase in pulp production, decrease in lime kiln fuel costs, and lignin sales (Kasurinen, 2016). One study suggests mill expansion costs to range between $14 and $33 million (Natural Resources Canada, 2016). The WestFraser mill in Hinton, AB created 7.5 new full-time positions at their new lignin co-located plant (Natural Resources Canada, 2016). The upgrade to the pulp mill to add the recovery plant cost $30 million, and the capacity of the lignin extraction plant is 30 tonne/day (ProcessWest, 2016).

When not paired with a pulp mill: Approximate start-up cost (total capital investment) is $4.87 million for a plant with a capacity of 2.54 tonne/day of feedstock, which is a relatively low capacity (Mabrouk et al., 2017). There does not appear to be a lot of literature on biorefineries that are not extensions of pre-existing pulp mills. It would appear that the pairing of a pulp mill and biorefinery is the most economic opportunity, since the pulp mill benefits in increased capacity, and the biorefinery benefits from immediate no-cost feedstock access.

Strengths: There is an abundance of lignin that can be extracted from pulp and paper waste products, and the value of the lignin, when extracted, is much higher than when it is burned for local heat and power (Natural Resources Canada, 2013). Lignin has a chemical structure similar to petroleum products, which means it holds the potential to replace a large number of fossil-fuel based products, therefore lowering the environmental impacts of these products (Berlin & Balakshin, 2014). Lignin extraction from black liquor will also improve capacity of pulp mill recovery boilers by approximately 15% (McCoy, 2016).

Weaknesses: While there is extensive research taking place on lignin applications, there have been very few products that have earned a stable position in the market. In certain markets, lignin cannot compete with lignosulfonates, which are produced via the traditional sulfite pulping, because lignosulfonates are water soluble whereas industrial lignin is not (Fatehi & Chen, 2016).

Opportunities: The closest lignin recovery facility is in Hinton, AB at West Fraser's pulp mill (ProcessWest, 2016). The only other two, as of 2016, were in Plymouth, NC, and Finland, as well as a pilot-scale project in eastern Canada.

Threats: Lignin extraction facilities are most economically effective when paired with a pulp mill because the lignin extraction phase occurs before the black liquor goes to the recovery boiler in the pulp mill. There are no pulp mills in Northwest BC to which an extraction plant can be added.

Considerations for Northwest BC: A small-scale stand-alone plant may be feasible for Northwest BC (Mabrouk et al., 2017), whereas a co-located plant with a pulp mill is unfeasible for Northwest BC due to the lack of active pulp mills in the region. If a dormant pulp mill in the region were to be reactivated (see BCTMP section), that may be an opportunity for the mill to consider a lignin recovery expansion. Utilization of lignin is relatively new, and only increasing in demand quite recently, which means there may be some added risks involved in the production of it. However, green alternatives to petroleum-based products are only expected to increase in demand in the future, in which case a lignin biorefinery in Northwest BC may be a jump start into an upcoming market.

Laminated Strand Lumber

Product Information: Laminated strand lumber (LSL) is one of three Structural Composite Lumber (SCL) products (European Wood, n.d.). It is similar to parallel strand lumber (PSL) and laminated veneer lumber (LVL), except that the strands are not produced from veneers (European Wood, n.d.). Instead, LSL shreds smaller logs and faster growing species like aspen, birch and poplar into strands approximately 1ft in length (Louisiana-Pacifica Corporation, 2011). LSL can either be made with all of the strands oriented along the major axis for applications such as beams, rafters, sills and columns; or with some of the strands aligned along the minor axis, for applications such as walls, floors, and ceilings (Libertatis, n.d.). An average sized LSL mill of 85,000m^3 annual production would require capital investment around $50 million, with profit margins around 20% (Jahromi, 2006; Ross, 2006; U.S. Environmental Protection Agency, 2002*b*). An average sized plant would employ 30-40 people (Vancouver Island Economic Alliance & MNP LPP, 2017).

Strengths: LSL is stronger, straighter, and more uniform than dimension lumber (as is LVL and PSL), and is often made from smaller, faster growing, lower-value trees like aspen and poplar, which means less stress on older, slower growing forests (Libertatis, n.d.; Louisiana-Pacific Corporation, 2011). LSL products are typically less expensive than other Engineered Wood Products because of their simpler production techniques (Hoesly, n.d.). LSL has a higher shear strength than LVL and PSL, and has a larger utilities-hole allowances than its two relatives (Landreman, 2012). It does not split as easily as dimension lumber or LVL, and is better than LVL in that the strength of the material may be better matched to the application instead of being too strong, which is common for LVL. This means saving money where it doesn't need to be spent.

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Weaknesses: Like LVL and PSL, LSL is bonded with phenol-formaldehyde adhesives, which raise health concerns due to their off-gassing (European wood, n.d.). These adhesives are also not considered environmentally friendly because they are produced from non-renewable petroleum sources. LSL is not considered as strong as LVL or PSL and is therefore not as ideal for long spans, although still stronger than dimensional lumber (Hoesly, n.d.).

Opportunities: Relatively simple to make like LVL and PSL, LSL is a much newer innovation with fewer manufacturers. LVL has already paved the way for similar Engineered Wood Products to become widely accepted, creating a market that is ready to integrate LSL. Only one manufacturer is currently listed with the American Plywood Association – The Engineered Wood Association (APA) directory and they are located in Houlton, Maine (APA, n.d.).

Threats: Many consumers still use sawn lumber in applications where LSL could be used, and are unaware of the opportunity for using lower cost, higher sustainability engineered wood products.

Considerations for Northwest BC: Soaking the logs prior to processing is part of the production of LSL and, therefore, the high moisture content of Northwest BC trees is not a setback (U.S. Environmental Protection Agency, 2002*b*). There is minimal logging of Aspen, Birch or Poplar in NWBC, although this may change if there is a market for these species, as they are present in moderate quantities. Northwest BC has been experiencing increasing levels of construction due to new industries and increased populations, and this may be an opportunity for a prominent LSL market in the region.

Laminated Veneer Lumber

Product Information: Laminated veneer lumber (LVL) is one of three Structural Composite Lumber products (SCL; European wood, n.d.). It is an engineered wood product designed to replace dimensional lumber in virtually any application with improved physical properties (Vlosky et al., 1994). It is made by bonding thin wood veneers together under heat and pressure (Canadian Wood Council, n.d.). It is produced the same way as plywood, except that all veneer layers run in the same direction grain-wise, whereas in plywood they are cross laminated. In LVL the thickness of each veneer can range from 2.5 to 4.8 mm. Commonly used species are douglas fir, pine, larch, spruce and poplar (Vlosky et al., 1994). Sometimes LVLs can have a few veneers arranged perpendicular to the typical direction to add strength in perpendicular axes. Developed in the 1940s, the market for LVL took off in the early 1990s (Hiziroglu, n.d.). Production of LVL is sometimes separated into two different process facilities—one that produces the veneer sheets by rotary peeling logs (often a lumber mill), and one facility that compiles those sheets into billets (Vlosky et al., 1994). As of 1992, North America and Finland had the most developed LVL markets (Vlosky et al., 1994). An average sized LVL mill of 85,000m^3 annual production would require a capital investment around $50 million, with profit margins around 20% (Jahromi, 2006; Ross, 2006; U.S. Environmental Protection

Agency, 2002*b*). An average sized plant would employ 30-40 people (Vancouver Island Economic Alliance & MNP LPP, 2017).

Strengths: Large LVL members can be made from smaller trees, providing better forestry utilization than sawn lumber (StructureCraft, n.d.). LVL can support heavier loads than dimension lumber and span longer distances. It is also less prone to shrinking or warping because of the pre-drying and treatment of each veneer before compilation (Vlosky et al., 1994). LVL can be cut, sawn and handled like regular lumber and is therefore very versatile in what shapes it can take. It can also be produced in virtually any size (length, width, and depth), limited only by manufacturing equipment and transportation restrictions (U.S. Environmental Protection Agency, 2002*b*). Some claim that LVL is comparable in strength to concrete or steel, and energy requirements for production of LVL is markedly lower than that of steel, plastic, concrete, stone and brick (Stora Enso, 2016). LVL is a better use of resources than dimension lumber in that material is not lost in the production of the billets in the way that material is lost when a round log is cut into a rectilinear shape (Busta & Honesty, 2013). It is also a better use of resources because wider dimensions of LVL can be produced from smaller trees, reducing the demand for large old growth logs (StructureCraft, n.d.). Uniformity of LVL physical properties compared to sawn lumber is another distinctly favorable quality, where low quality veneers that contain knots or other structural impurities are removed (Busta & Honesty, 2013). Job site waste is also reportedly reduced from 11% with dimensional lumber to less than 1% with LVL (Vlosky et al., 1994).

Weaknesses: LVL is significantly more expensive than dimension lumber of comparative load capabilities. LVL is generally not considered a good product for visual applications; however, recent innovations have led to unique visual applications of LVL (Vlosky et al., 1994). For example, vertically laminated veneer lumber is oriented so that the veneer grain edges are exposed on the face of the product instead of the surface grain of the topmost veneer (StructureCraft, n.d.). Because all veneers are oriented in the same direction, LVL tends to shrink and swell like dimensional lumber, although LVL appears to exhibit more uniform swelling compared to solid lumber. LVL is usually bonded with phenol-formaldehyde, which, although better than urea-formaldehyde, is considered a health hazard for the emissions it releases (Canadian Wood Council, n.d.). Formaldehyde based adhesives are petroleum products, contributing to Greenhouse Gas emissions and the heavy demand for non-renewable fossil fuels (APA, 2015). New innovations are allowing the use of more ecofriendly lignin-based resin adhesives, which are more sustainable and less toxic (Kalami et al., 2017; Wood Based Panels International, 2017).

Opportunities: There is a strong market for LVL in the construction industry because of its superior strength-to-weight ratio (Hiziroglu, n.d.). In 1990, the price point was considered high enough to justify transportation costs from manufacturing regions to distant demand markets (Hiziroglu, n.d.). Price stability is much higher than for dimension lumber because of the flexible options of log size used to make LVL (Hiziroglu, n.d.). In 1992 demand in North America exceeded supply (Hiziroglu, n.d.). In the 90’s, LVL showed high profit margins, and it was estimated that this trend would continue as improvements in manufacturing and production cost reductions would occur (Hiziroglu, n.d.). Moisture content is not an issue as trees undergo soaking, steaming and drying as part of the manufacturing process (U.S. Environmental Protection Agency, 2002*b*).

Threats: Boise Cascade, Weyerhauser, Louisiana-Pacific, Roseburg, Universal Forest Products, Georgia-Pacific (Wallender, 2018) are all BC companies currently producing LVL. Another potential threat to a new production line is the high capital investment necessary(Hiziroglu, n.d.). Markets are fairly regional, in that there are high costs associated with shipping large or awkward LVL shapes and sizes long distance (Natural Resources Canada, 2016). This can also be an opportunity if there is not yet a strong regional supply in NWBC. In BC there is currently Crisco Manufacturing in Brisco, BC, (Kootenays) and LP in Golden, BC, manufacturing LVL (APA, n.d.; Brisco Manufacturing, 2015). There is also West Fraser LVL manufacturing in Rocky Mountain House, AB, Global LVL Inc in Quebec, and Forex Amos in Amos, Quebec(APA, n.d.; West Fraser, 2019). Birch and other fast growing second growth species are not often logged in Northwest BC however these species are present in the region in moderate abundance and could be harvested if there is a market for them. Second growth conifer can also be used for LVL.

Considerations for Northwest BC: There is currently no manufacturing of LVL in Northwest BC, and, because it is a relatively regional product, this may present an opening for production in the region. The construction industry, which is the primary consumer of LVL, has been steadily increasing in the region. There may also be a research opportunity to further explore the feasibility of lignin-based resins, which could make LVL an even more attractive product to replace dimension lumber.

Parallel Strand Lumber

Info: Parallel strand lumber (PSL) is one of three Structural Composite Lumber (SCL) products. It is similar to Oriented Strand Board (OSB) except that it forms lumber of various width and sizes, as opposed to OSB which is just produced in sheets (Libertatis, n.d.). PSL is formed through a similar production process as LVL except that after peeling a log into veneers, the veneers are clipped into strands that can be up to 8 feet long (Smart Growth, 2016). PSL did not enter the market until 1988 (Landreman, 2012). Similar to the other engineered wood products capital investment is high at around $50 million (Ross, 2016), with profit margins of around 20% (U.S. Environmental Protection Agency, 2002*b*), and direct employment around 30-40 people per manufacturing plant (Vancouver Island Economic Alliance & MNP LLP, 2017).

Strengths: Parallel strand lumber can easily utilize edge wastes and more of the rotary-peeled log than LVL (Jahromi, 2006). Like LSL and LVL, PSL is stronger, straighter, and more uniform than dimensional lumber of the same dimensions (Jahromi, 2006). PSL is better at absorbing preservatives and is more fire retardant than LVL (Libertatis, n.d.).

Weaknesses: Like LVL and LSL, PSL is bonded with phenol-formaldehyde adhesives, which raise health concerns due to their off-gassing (Canadian Wood Council, n.d.). These adhesives are also not considered environmentally friendly because they are produced from non-renewable petroleum sources. However, the use of more ecofriendly lignin-based resin adhesives is beginning to be used (Wood Based Panels International, 2017). PSL is generally more expensive than LVL and LSL (Libertatis, n.d.).

Opportunities: Relatively simple to make like LVL and LSL, PSL is a much newer innovation with fewer manufacturers (Libertatis, n.d.). LVL has already paved the way for similar Engineered wood products to become widely accepted, creating a market that is ready to integrate PSL. The percentage of fibre utilization in PSL is higher than in LVL and this could be enhanced by running the PSL and LVL plants at one site (Busta & Honesty, 2013). Moisture content is irrelevant since logs are soaked as part of the manufacturing process (Busta & Honesty, 2013). Trees used include douglas fir, larch, western hemlock and poplar (Smarth Growth, 2016); Hemlock is commonly found in Northwest BC.

Threats: Weyerhaeuser has a parallam (PSL) plant on Annacis island, BC (near Vancouver; Weyerhaeuser, n.d.).

Considerations for Northwest BC: Like LVL and LSL, PSL is not yet manufactured in Northwest BC, which may be an opportunity for development. Construction in the region has been steadily increasing, a further indication of the potential for LVL demand in the region. There is also a research opportunity to further explore the feasibility of lignin-based resins for use in SCL products.

Plywood

Product Information: Plywood is a manufactured board made of crossbanded veneers glued together and compressed under heat (Russel, n.d.). Plywood is often used for things like furniture and paneling, and sometimes flooring. One source claims that profit margins are 12-15% per sheet (Quora, 2018). The same source claims startup costs are $13 to $26 million and running capital is around $26 million CAD. Startups require approximately 1800 square metres of land for a production plant (NextWhatBusiness, 2019).

Strengths: These boards are lighter than solid wood and much stronger (Wood Work Basics, n.d.). They resist cracking, bending, warping and shrinking, and can be produced from smaller trees because of the rotary-cut process of producing veneers (Wood Work Basics, n.d.). They can be produced in a variety of widths and dimensions, and are useful in eliminating localized weaknesses typical of solid wood (Wood Work Basics, n.d.).

Weaknesses: Some consumers find the edges of plywood unattractive which can limit its potential uses (Wood Magazine, n.d.). It can be fairly expensive, sometimes as expensive as a solid wood equivalent, depending on quality (Wood Magazine, n.d.). Thicknesses may vary from their specified dimension, making it difficult to work with in high-precision scenarios (Wood Magazine, n.d.). Glue usually contains formaldehyde, which has significant health concerns (U.S. Environmental Protection Agency, 2002*d*). However, innovative alternatives are becoming more common and feasible (see Lignin Resin section).

Opportunities: Using Terrace as an example, one study shows that although new housing construction in Terrace reached a low in 2010, it appears to be consistently climbing since, which means an increasing demand in local building materials such as plywood (Thomson & White, 2014).

This may be representative of Northwest BC's trends as a whole. Plywood manufacturing establishments in 1997 employed an average of 60 employees per establishment, although this number is likely to be lower now due to increased automatization of machinery (U.S. Census Bureau, 1999). Plywood can be made from any softwood species (The Wood Database, n.d.). Northwest BC's wood's high moisture content is not a setback because wood resources are used green, not dried (Russel, n.d.).

Threats: Plywood exports have been experiencing an abrupt drop in volume, possibly due to the US softwood duties (Indexbox, 2018). Production has also been relatively slow, and demand has remained steady (Indexbox, 2018)

Considerations for Northwest BC: With multiple industrial projects moving into Northwest BC, it can be expected that construction in the region will face a steady increase, raising the demand for building materials like plywood. Since moisture content of the feedstock is not an issue, producing plywood in Northwest BC is an ideal venture for the region's wood. With the increasing volume of second growth coming available for harvest in the near future, products such as plywood will be some of the few that can utilize smaller trees for production. However, there may be potential impacts to plywood exports to the US due to their softwood lumber duties. This may negatively affect Canada's plywood production.

Dissolving Pulp

Product Information: Dissolving pulp (DP) is bleached wood pulp that is used in chemical matrices where no fibrous structures of the wood remain (Välimaa, 2015). The dissolved pulp can then be spun into textile fibers or to create plastic like materials (Välimaa, 2015). DP is primarily used for Viscose Staple Fiber (VSF), modal, and lyocell, which are types of rayon used for clothing and textiles. Cash costs are on average $1000/tonne (Pulp & Paper Canada, 2013). Between 2006 and 2017, VSF had the fastest growth in volume of any textile, including cotton, natural fibers, and synthetics (Fortress Global Enterprises, 2018). Total growth in the volume of VSF in that time was 86% (Fortress Global Enterprises, 2018). Extremely high capital investments are required for a dissolving pulp plant, to the order of hundreds of millions of dollars (Pulp & Paper Canada, 2012). Profit margins for DP production are usually quite high, and consistently higher than that of paper mills (Bhuckory, 2014). Further research into utilizing hemicellulose byproducts would be valuable in considering pairing a dissolving pulp plant with another product to increase revenue and offset costs. The Thurso Mill in Quebec employs 336 employees (Euwid, 2017).

Strengths: New technology allows for closed-loop production of dissolving pulp which sharply reduces chemical wastes (Välimaa, 2015). Dissolving pulp has a number of intermediate and end products, resulting in a versatile market. One product, viscose, or VSF, is a textile with a steadily growing demand due to its appealing qualities such as texture, softness, drape, lustre, etc. While hardwoods are currently primarily used to make dissolving pulp, it can also be made with softwoods, which in fact are more ideal in that they have more cellulose and less hemicellulose than hardwoods (cellulose is the primary ingredient in dissolving pulp; hemicellulose and lignins are removed; Freitas & Mathews, 2017). The market for dissolving pulp is growing annually at a rate of 9-12% (Pulp & Paper Canada, 2013). New technologies offer the opportunity to retrieve hemicellulose biproducts from the pre-hydrolysis process in DP production; hemicellulose can be used for a number of other applications and products (Shen et al., 2015).

Weaknesses: The production of DP is still somewhat unsustainable in that it is an energy intensive process and has a number of air and water emissions, although a number of advancements are being made, such as the new closed-loop process (Freitas & Mathews, 2017). Canadian DP prices have dropped from US$ 2,200 per Tonne in 2011 to US$500 in June 2018 (Shen et al., 2015).

Opportunities: According to Brian McKay of Brian McKay and Associates Market Intelligence Consulting in Quebec in 2017, dissolving pulp holds tremendous growth potential over the long term (Hein, 2017). Wood feedstock can be either wet or dry (Freitas & Mathews, 2017). BC's western hemlock is particularly well suited to producing dissolving pulp (Naturally:Wood, 2019). Another opportunity is that dissolving pulp can be made from second-growth forests (Hatton, 1997).

Threats: There is a dissolving pulp mill in Vancouver (Fortress).

Considerations for Northwest BC: Northern BC may be particularly well suited for a DP plant in that we have extensive amounts of Western Hemlock and second growth (in the near future), both of which are suitable for dissolving pulp production. The high moisture content of Northwest BC's wood would not be a disadvantage in producing this product, since wet wood can be used as feedstock. However, the remoteness of our region may be a disadvantage, considering the globalized market of DP, although this idea needs further research for support. Neucel's specialty cellulose plant in Port Alice, BC, has yet to reopen it's doors, and there is talk that it may not reopen (Thomas, 2019).

Mechanical Pulp

Product Information: Mechanical pulp is similar to chemically treated pulp but produced via mechanical means. Includes Stone Groundwood (SGW) pulping which produces a high yield of short fibers, Refiner Mechanical Pulping (RMP), which produces a high yield of slightly longer fibers (can utilize wood wastes), and Thermomechanical Pulping (TMP), which is high energy input but produces the longest fibers (Industrial Efficiency Technology Database, n.d.). Another type is CTMP (see Bleached Chemithermo Mechanical Pulp section). Mechanical pulp can produce twice as much pulp from a given number of trees compared to the krafting (chemical) alternative process (Conservatree, n.d.). It requires substantial capital investment around $172 million (converted to 2019 CAD; Harpole, Leatham & Myers, 1989). More research is required to find adequate profit margin estimates. For the purpose of this study, a modest estimate of *Category 2 – 5% to 15%* was used.

Strengths: Mechanical pulp is easier and more cost-effective to produce than chemically-treated pulp. It also has much higher yields than in chemical processes. Mechanical pulp can be produced entirely from recycled or waste materials; in 2006, 45% of wood sources for the pulp industry were sawmill residues, 21% logs and chips, and 34% recycled paper (Sixta, 2006). Mechanical pulping has minimal environmental concerns besides forest degradation; the only chemicals used in the process are hydrogen peroxide and sodium dithionite, which have benign byproducts (Hu, 2013). A pulp mill in Nova Scotia directly employs over 300 people, and including indirect jobs created, provides over 2,000 full-time equivalent jobs (Macdonald, 2015). The global market demand for pulp has been steadily increasing from 2006 to 2016, with China's demand doubling in that time (McClay, 2017). As of 2016, China and Europe have the highest demand globally, each at over 30% (McClay, 2017). North America comes in third at 12% in 2016, which has declined from 18% in 2006 (McClay, 2017). Transportation costs are relatively low compared to wood costs (Börjesson & Ahlgren, 2015).

Weaknesses: Mechanical processes often damage the cellulose, which reduces the strength of the produced pulp. Purity is usually lower than that of chemically produced pulps, and therefore the age resistance of mechanical pulp is low. As a result, mechanical pulp is generally lower in value than chemical pulp. Mechanical production of pulp has a high electrical demand compared to chemical pulp (Börjesson & Ahlgren, 2015).

Opportunities: Canada has been a leading source of market pulp, providing 21% to the global markets in 2006 (Sixta, 2006). Conifer tree species are preferred because of their longer fibers (How Products are Made, n.d.). In particular, Fir and hemlock are both common species used in pulp production (Geman, 2014). Mechanical pulp is usually produced at a final moisture content of about 10%, reached via air drying (Nanko, Button & Hillman, 2005). Further uses of pulp such as paper making usually start by mixing the pulp in a water solution, therefore making the moisture content irrelevant (Nanko, Button & Hillman, 2005).

Threats: Pulp is generally a global, commodity-type product, and as such, markets are volatile and high-risk. The start-up costs for a pulp mill are very high. Depending on feedstock source, there may be a high cost associated with the feedstock (i.e. round logs versus forestry residue)

Considerations for Northwest BC: Pulp mills have had low success in the past in this region. Should an investor choose to startup a mechanical pulp mill in Northwest BC, there are a number of old mill sites across the region that could be recommissioned.

Particleboard

Product Information: Although OSB is technically a type of particleboard, the term particleboard is generally used to refer to boards with smaller wood components than OSB (Displays2Go, 2015). Particleboard can also be called Low Density Fibreboard (Rouge, 2015). Typical materials include sawdust and planer shavings from sawmills (Natural Resources Canada, 2016). Particleboard is a non-structural material, and competes with Medium Density Fiberboard (MDF) in the same markets

(Natural Resources Canada, 2016). Particleboard is made by mixing wood particles with glues and resins and sealing them into sheets under high heat and pressure (International Timber, 2015). Fibers are often stratified by size, with the coarser particles in the middle and the finest particles on the surfaces, to create the smooth surface for which particleboard is known (International Timber, 2015). Common species used in particleboard include fir, pine, poplar, and spruce, and, less commonly, hemlock (Dettmer, 2013). Startup costs have been identified as $300 million (converted to 2019 CAD) for a 186 million ft^2/year capacity mill (Spelter, 1994). The same source also estimates $100 million (converted to 2019 CAD) in startup costs for a 100 million ft^2/year capacity plant (Spelter, 1994). Around 173 employees would be needed for a mill with this capacity (Spelter, 1994). As of 2000, there was a high demand on particleboard from western Canada and the US (Columbia Engineering International Ltd., 1993). Gross profit margins can be higher than 50% (Ababa, 2008).

Strengths: Particleboard with veneer is often used in ready-to-assemble furniture and cabinets, especially because particleboard's defining quality is its smooth surface that allows for coating (Jones, 2016). Particleboard is lower cost than MDF and often considered of lower quality (Jones, 2016). Unlike plywood, particleboard can be made from mill scraps and forestry residues; this makes it more environmentally sustainable than plywood (Jones, 2016). The smooth surface allows for the application of thin sheets of veneer or plastic laminate to mimic the look of solid wood, and therefore can be a cheap alternative to solid wood in cabinet and furniture applications (Jones, 2016).

Weaknesses: Particleboard is usually made with non-waterproof glue, which makes it unsuitable for exterior and high-humidity environments (Natural Resources Canada, 2016). As a result, it tends to swell more than MDF when exposed to water (Jones, 2016). Particleboard usually contains formaldehyde in its adhesives or coatings, and this, in addition to the fine sawdust created, raises health concerns when cutting these boards (Natural Resources Canada, 2016). While particleboard can be considered more eco-friendly than plywood because of its second-hand ingredients, many argue that it is actually less eco-friendly because of the greater amounts of toxic adhesives (formaldehyde) that are used to make it (Natural Resources Canada, 2016).

Opportunities: Newpro is currently upgrading its particleboard plant in Smithers BC into a pellet plant, which may open up market opportunities in Northwest BC (Vandenberg, 2017). However, this is also likely an indicator of a failing market for particleboard. Siempelkamp offers a range of services and products for building a particleboard mill (Siempelkamp, n.d.).

Threats: There appears to be a declining market for particleboard, as associated mills and production are slowly declining (International Timber, 2015). Feedstock particles need to be at a moisture content of 2.5% or less for particleboard production (International Timber, 2015), therefore, wood from the Northwest BC would require significant drying costs. Other mills include Canfor in New Westminster BC and a number of mills in Ontario and Quebec (Company Listing, n.d.).

Considerations for Northwest BC: Use of particleboard appears to be slowly declining, and the health concerns of the resins used may be a significant contributor to this concern. If lignin resin production becomes a viable alternative, production of particleboard in Northwest BC may be feasible. The species used for particleboard production are all present in the region, and there are sawmill and forestry residues available to be utilized. The conversion of Smithers' mill from particleboard to pellets may be an indicator of a failing market for particleboard in the region. Conversely, it may have opened up a supply opportunity for the region to replace Smithers' retired supply.

Biochar

Product Information: Biochar is similar to activated charcoal, except that it is produced from woody biomass that has been heated to high temperatures in an anoxic environment, and is used for soil supplementation, growing media for plants, and water filtration (Crane Management Consultants, 2018). A carbon offset revenue stream would help make the production of biochar more economically feasible (Crane Management Consultants, 2018). Total capital investment costs could range from $2.8 million to $8.4 million depending on size and location in Northwest BC (Barlow et al., 2017). Marketing staff would be one person (Crane Management Consultants, 2018), and regular staff would amount to 11 people (seven fulltime and four seasonal; Barlow et al., 2017). Production volumes could reach around 970 tonnes by year four, at a suggested value of US$100 per cu. yd (Crane Management Consultants, 2018). Fourth year revenue would be $688,800 according to Crane Management Consultants (2018). In a theoretical mill in Thornhill BC, annual operation and maintenance (O&M) costs are $1.21 million and gross revenue is $3.31 million (Barlow et al., 2017). From this we can calculate EBITDA margins as [($3.31M - $1.21M) / $3.31M] * 100% = 36.5%. Rate of return for this theoretical, mid-sized facility is 21% and an after-tax payback period would be approximately 10 years (Barlow et al., 2017).

Strengths: Production of biochar is environmentally sustainable because it is making use of wastes and residues and is storing carbon in the soil as opposed to it being released to the atmosphere from burning (Crane Management Consultants, 2018). Biochar production can be paired with biomass energy-generating facilities (Barlow et al., 2017).

Weaknesses: There is currently only a small market because of lack of awareness and endorsement, lack of sustainability initiatives, and the large start-up cost associated with a biochar production facility (Barlow et al., 2017).

Opportunities: Can produce refined biochar to provide to several market sectors where established end-product producers can use Northwest BC biochar (Crane Management Consultants, 2018). This would allow the Northwest BC facility to stream into multiple markets, enhancing stability through a variety in clients (Crane Management Consultants, 2018). Biochar could be marketed to businesses that make the following: gardening growth supplies, landscaping supplies, farm supplies, stormwater filtration supplies, soil remediation supplies and livestock feed supplies (Crane Management Consultants, 2018).

Threats: There is currently a low feasibility for biochar production as a filtration media or barbeque charcoal/briquette product because of alternative production methods (Crane Management Consultants, 2018). Additionally, those markets are already well established and monopolized by larger companies or cheaper companies from Asian countries (Crane Management Consultants, 2018). Moisture content is a concern for biochar production, therefore the high moisture content in Northwest BC feedstocks may be a disadvantage (Barlow et al., 2017).

Considerations for Northwest BC: The heavy reliance on forestry in Northwest BC means that there is a large amount of forestry residue that can be utilized for a biochar facility, provided that feedstock costs are feasible. The high moisture content in the wood of Northwest BC means that further processing of feedstock will be required to meet ideal feedstock conditions, thereby raising costs associated with a biochar facility in this region. However, if sawmill wastes were utilized, this obstacle would be bypassed. A highly useful feasibility study was completed on the potential for a bioenergy facility in Thornhill BC that would produce biochar as its main product as well as energy to power the facility (Barlow et al., 2017). This report concludes that a bioenergy facility in Thornhill BC would appear to be very feasible.

Wood-Plastic Composites

Product Information: Wood-plastic composites (WPCs) refers to any product that is a combination of wood materials and thermosets or thermoplastics (Clemons, 2002). Traditionally, plastic performance modifiers usually consisted of talc, calcium carbonate, mica, glass, or carbon fibers (Clemons, 2002). Currently, however, wood is becoming a significant competitor as a plastic filler (Clemons, 2002). Wood in WPCs is generally in particulate (flour) form or very short fibers (Clemons, 2002). Common WPC products include primarily decking, as well as flooring, interior car parts, and window and door component profiles (Natural Resources Canada, 2016). Wood usually comprises 30%-65% of WPCs (Natural Resources Canada, 2016). The total capital investment of a WPC manufacturing plant has been estimated around $38.7 million (converted to CAD) for a plant of 3840 kg/day capacity (NIIR Project Consultancy Services, n.d.*a*). The estimated rate of return on investment of a plant of this size would be approximately 43% (NIIR Project Consultancy Services, n.d.*b*). Another source estimates total capital investment (TCI) at $1 million (converted to CAD), with a payback period of 2 years and 3 months (NIIR Project Consultancy Services, n.d.*b*). A plant would employ around 60 people (Ghasem, 2013).

Strengths: Using wood fibers instead of conventional fillers means using a less expensive and renewable resource. Wood fibers are also lighter and less abrasive to equipment than conventional materials (Clemons, 2002). WPCs have improved fungal resistance, lower maintenance, and improved dimensional stability in the presence of moisture compared to solid wood alternatives (Clemons, 2002). They also have improved strength and durability and decreased thermal expansion compared to conventional plastic alternatives (Clemons, 2002). Global WPC demand was $4 billion in 2017, growing at a compound annual growth rate of 9.3% (NIIR Project Consultancy Services, n.d.*b*).

Weaknesses: Unlike conventional materials, wood fiber has a low bulk density, low thermal stability, and tends to absorb moisture (Clemons, 2002). Even 1 to 2 percent moisture content can be too high to produce quality plastic composites (Clemons, 2002). The processing temperature for most plastics, including those with low melting points, is usually high enough to cause thermal degradation of wood fibers (Clemons, 2002). Generally, however, there are plastics such as polyethylene, polypropylene, PVC, Polystyrene, and acrylonitrile-butadiene-styrene that can be melted below critical temperatures for wood (200°C) and are therefore often used in wood-plastic composites (Clemons, 2002). Light stability and fire resistance have yet to be determined (Clemons, 2002). WPCs are generally not used for structural purposes, because of the slight creeping properties inherent in plastics (Clemons, 2002).

Opportunities: Because wood is usually used in particulate form, all types of woody residues can be used, including slash piles and sawdust from mills. Shantex, a manufacturer of WCPs, uses wood mill residues (Shantex, 2014).

Threats: Wood must be dried to 0.5% moisture and then used quickly before it reabsorbs moisture (Natural Resources Canada, 2016). One study states that moisture content, thermal degradation and thermal stress, and lack of homogeneity are the main challenges in producing WPC via the extrusion process (Toghyani et al., 2016). Common species used for WPCs are pine, maple, and oak, although others may be useable as well (Clemons, 2002).

Considerations for Northwest BC: The primary woods used in WPCs are pine, maple, and oak, and only pine is present in Northwest BC, and even then, only in limited amounts. Because humidity is such a concern in WPCs, Northwest BC wood would require processing to produce acceptable feedstock for WPCs. There are significant amounts of forestry and sawmill residues in the region, and therefore feedstock transportation costs may be relatively low. Construction and housing in Northwest BC is steadily increasing, and as a result there may be a significant market in the region for WPCs.

Cross-Laminated Timber

Product Information: Cross-laminated timber (CLT) consists of sawn planks layered on top of each other in an alternating perpendicular fashion and glued together to create a panel or timber (Canadian Wood Council, n.d.). CLT is manufactured as panels that are generally cut to specification during the manufacturing process, not after (Canadian Wood Council, n.d.). The capital investment for a CLT plant is estimated around $10-$25 million, with profit margins around 20% (Collins & Hankins, 2017). This plant would create around 43 jobs (Collins & Hankins, 2017).

Strengths: CLT is extremely strong, durable, and highly fire resistant and can replace masonry, concrete and steel (Northwest Hardwoods, 2017). CLT comes from renewable resources, is quite easy and economically efficient to produce, can be sustained by second-growth wood, and can replace timbers and other lumber that comes from old-growth forests (Koberstein, 2017). Emissions from a building project can be reduced by as much as 70% when replacing concrete and steel with CLT (Koberstein, 2017). In one building example, "the Crossroads estimated the total potential carbon benefit of the wood used just in the CLT portion of the building at 692 metric tons of CO_2 (equivalent), which compares to keeping 132 cars off the road for a year, or providing total energy to operate a home for 59 years" (Evans, n.d.). CLT has been approved in the National Building Code of Canada in the 2016 Supplement (Structurlam, n.d.), and was added to the International Building Code in 2015 (American Wood Council, 2015). CLT eliminates a lot of noise, dust, and worksite wastes during construction phases that are present under traditional building practices (Northwest Hardwoods, 2017). CLT has a high decrement delay (the time it takes for heat to pass through a building structure) which means greater insulation (400x more insulative than steel and 10x more insulative than concrete and masonry; Northwest Hardwoods, 2017). Wall loads such as cabinets are no longer constricted by stud location when using CLT because the entire CLT panels are sufficient for anchoring (Greenspec, n.d.). Construction time is much faster with CLT than with steel, concrete, and/or masonry, thermal bridging is eliminated, and scaffolding is rarely needed (Greenspec, n.d.). CLT can be used for walls, floors and roofing—an entire building could theoretically be made from CLT (Saxena, 2016). CLT structures are extremely resilient to seismic damage, and structural parts are usually prefabricated using Computer Numeric Controls machines resulting in high precision and tight-fitting joints which improves insulative ability (Evans, n.d.).

Weaknesses: CLT requires design specifications prior to production and cannot be modified to shape on site like traditional building products (Greenspec, n.d.). CLT usually requires a crane to build with (Greenspec, n.d.). Traditional glues within CLT are not environmentally friendly, however, benign alternatives do exist (see Lignin Resin section; Greenspec, n.d.). CLT is currently more expensive to purchase than using concrete because the market and supply is still new (Greenspec, n.d.). CLT panels are unsuitable for belowground construction and do not perform well in acoustically sensitive areas (Saxena, 2016). Currently there appears to be a lack of research into the production of CLT from hemlock and balsam.

Opportunities: Currently, most CLT production exists overseas, which is very costly to transport to North America building sites (Greenspec, n.d.). The allowable moisture content is around 12%, which is easily achievable for Northwest BC lumber (KLH, 2012).

Threats: There may not be much awareness in the area yet of this new product, not to mention that new building materials require new building techniques. This may result in some hesitancy of the local market to switch to building with CLT. Significant startup costs exist for specialized equipment to make custom CLT. Mills exist in Okanagan Falls and Penticton, BC (Structurlam; APA, n.d.*a*), Chibougamau, Quebec (APA, n.d.*b*) and Devlin, Ontario (Leaf Engineered Wood Products, n.d.).

Considerations for Northwest BC: With a number of lumber mills in the area, and the fact that CLT can be made from both softwood or hardwood, we would have an abundant local supply of lumber to produce CLT, provided Asian markets do not outcompete local demand for feedstock. The construction industry in Northwest BC is steadily rising, and as CLT slowly starts being integrated into the industry, demand for CLT is expected to continue rising in the region. In addition, Mayor

Leclerc of Terrace BC is advocating for increased wood use in commercial buildings, including the upcoming Mills Hospital in Terrace (Link, 2019). Further research should be done to determine the value of CLT made from hemlock and balsam. If these two species are effective in producing high quality CLT, there may be an untapped opportunity in Northwest BC for Hem-Bal CLT.

Oriented Strand Board

Product Information: Oriented Strand Board (OSB) is a wood product that is made of rectangular shaped wood strands that are arranged in cross-oriented layers. The average capacity of a new OSB plant is 350 million ft^2 (Spelter, 1994). The cost of a new 100 million ft^2 capacity OSB plant would be approximately $114 million (converted to 2019 CAD; Spelter, 1994). In 1993, OSB plants had profit margins over 50% (Spelter, 1994). In 1993, a 150 million ft^2 OSB plant had approximately 150 employees (Ondro, 1991). Total sales per year for said plant was $84 million (converted to 2019 CAD; Ondro, 1991). Any variety of tree species can be used, including fast-growing species (APA, 2009).

Strengths: OSB boasts many of the same properties of solid wood alternatives (APA, n.d.). They are strong, dimensionally stable panels that resist deflection, delamination, and warping (APA, n.d.). They are made with waterproof adhesives and are relatively lightweight compared to their quality (APA, n.d.). OSB can be produced in large continuous mats that allow for reduction in joints where heat and noise can leak through (APA, n.d.). The panels are easy to produce in a variety of shapes and sizes, and have excellent thermal insulation (APA, 2009). OSB can be used for virtually all aspects of construction, including roofing, flooring, wall panels, ceiling panels, decking, furniture, and limitless Do-it-Yourself projects (APA, 2009). APA-certified OSB boasts low formaldehyde emissions from the adhesives (APA, 2009). OSB outperforms plywood in that soft spots and delamination are virtually non-existent (APA, 2009). Wood fiber is also used more efficiently in OSB than in plywood because size of tree or wood components used is generally irrelevant for OSB (APA, 2009). OSB also has twice the shear value of plywood across thickness (APA, 2009). Resins have decreased from 5% of a boards weight to less than 2%, and continue to decline as technologies evolve (Spelter, 1994).

Weaknesses: Standard adhesives in OSB are made from formaldehyde and considered a health hazard (Kraemer, 2011). Unlike its competitor, plywood, OSB is prone to the phenomenon called ghost lines in roofing, where the edges of the OSB swell in response to moisture when roofing shingles are thin or underperforming (Wardell, 2013). The problem of edge swelling is a serious one for OSB, and one that is difficult to prevent, especially if living and building in a humid climate (Wardell, 2013). However, with proper installation and protection, the concern for edge swelling can be eliminated (Wardell, 2013). OSB is not a good subfloor for tiling, because if the OSB receives any moisture, it will transfer the stress and cause the local tiles to fail (Wardell, 2013). It is also often advised against as a subfloor for vinyl sheet flooring because any edge swelling that may occur will be apparent through the vinyl flooring (Wardell, 2013). However, as stated before, edge swelling is rare if proper installation standards are met (Wardell, 2013).

Opportunities: OSB is an established product with multiple successful operations to learn from. In 2004, veneer and OSB mills were the second largest contributors to the log and fiber industry in British Columbia, second to lumber mills (Ministry of Forests and Range, 2005). Siempelkamp offers a range of products and services for building and starting up an OSB plant as part of their machine and plant engineering business unit (Siempelkamp, n.d.).

Threats: Other OSB mills: Norbord Lumber in 100-Mile House, Canadian Forest Products in Fort Nelson, Louisiana Pacific Canada Ltd. in Fort St. John and Dawson Creek (Ministry of Forests and Range, 2005), and Weyerhaeuser OSB mill in Edson, AB (Weyerhaeuser, n.d.). There are also a number of other OSB mills in Alberta and farther east. OSB has a somewhat negative reputation because of its edge-swelling tendencies.

Considerations for Northwest BC: In May 2018, the OSB mill in 100 Mile House temporarily shut down for about a month due to lumber shortages caused by the excessive damage to logging areas by the 2017 wildfires (Norbord Inc., 2018). Similar shortages may be experienced in 2019 from the previous year's fires. Because OSB can be made from any species, and can utilize smaller logs like those of second growth, such a mill in Northwest BC would potentially have a sustainable supply of feedstock as the region moves towards second growth logging.

Firewood

Product Information: Firewood is usually sold by the cord. Currently, prices in the region vary from $175 to $200 per cord, depending on the species and whether or not it is delivered and/or split (Kijiji, 2019). In Victoria a cord ranges from $300 to $500 depending on species and drying technique (Used Victoria, 2019).

Strengths: Startup costs for a firewood business are relatively low, as generally a chainsaw, an axe, a hook, and manpower are all that is needed (Marsinko, 1984). Suitable transportation is also necessary. A study in the late 1980s in the US showed that using a chainsaw and hydraulic splitter versus a chainsaw and hand tools was more efficient, and hauling with a mid-sized truck versus a pickup was also more profitable (Marsinko, 1984). In fact, using a pickup for both hauling (before processing) and delivery (after processing) resulted in a net deficit or near zero net income (Marsinko, 1984). In this article, total revenue ranged from 95% to 140% of costs associated with producing one cord (Marsinko, 1984). A firewood business can be very successful with the right marketing (Madden, n.d.), and can employ from 1 to 20 people (Marsinko, 1984).

Weaknesses: Preferred species for wood burning are not largely present in Northwest BC (maples and other hardwoods), but local species are still effective (Government of Canada, 2012). Airborne contaminants from wood burning are considered greater than from gas powered fireplaces (Millar, 2006).

Hardest (long burning)	**Density of Common Tree Species**
Ironwood Rock elm Hickory Oak Sugar maple Beech Yellow birch Ash Red elm Red maple Tamarack Douglas fir White birch Manitoba maple Red alder Hemlock Poplar Pine Basswood Spruce Balsam	Here is a list of the tree species commonly used for firewood, according to their relative densities. Trees at the top of the list have the most energy per cord, while those toward the bottom of the list have the least energy per cord. Although they are less dense, the species in the lower half of the list can make excellent firewood for spring and fall because they make heat control easier and don't tend to overheat the house.
Softest (shorter burns)	

Opportunities: In Northwest BC, there is fairly extensive access to slash piles for firewood collection. More than 27% of the Skeena and Bulkley Vallely Lakes District population depends on wood heat for heating their homes (Millar, 2006; Xue et al., 2006). The number of wood heat users in the region is also expected to increase (Millar, 2006).

Threats: Moisture content of firewood must be low, and therefore cut wood from local sources must be seasoned before selling, which can take time (Marsinko, 1989).

Considerations for Northwest BC: Because forestry is such a prominent industry in Northwest BC, there is considerable access to firewood stores. This availability comes in the form of forestry road access to crown areas where firewood gathering is permitted, recent cutblocks where logs from slash piles are often taken for firewood, or wood lots and forested properties that can be purchased and harvested for firewood. There is a large proportion of firewood users in Northwest BC, especially in rural subdivisions and communities (Millar, 2006). There are currently not very many professional sources of firewood for purchase in Northwest BC, according to Kijiji. This may be an opportunity for a moderate to large scale business providing full time firewood services.

Trusses

Product Information: Wood trusses are prefabricated wood products composed of joined lumber to make triangular shapes that have high strength-to-weight ratios (Canada Wood, n.d.). More research is needed to identify capital investment and profit margins for truss building. A truss facility could employ around 30 people (U.S. Census Bureau, 1999). Trusses are typically built from pre-cut softwood lumber (SBCA, n.d.).

Strengths: Wood trusses allow for long spans without supporting walls, which offers greater flexibility in floorplans (Canada Wood, n.d.). Trusses are custom built allowing for freedom in building design. Their load-transfer design allows for great strength in roofing systems (Canada Wood, n.d.). The open web configuration allows for ease of installation of plumbing, electrical, and mechanical services (Canada Wood, n.d.). Trusses allow for attractive vaulted ceiling designs, and the prefabricated nature of trusses means structures are made with a high degree of accuracy (Canada Wood, n.d.). Insulation can be easily installed in truss cavities (Canada Wood, n.d.). Floor trusses are less prone to shifting than dimension floor joists, which means the floor is much more stable and will not develop creaks or soft spots (Canada Wood, n.d.). Wood trusses are far more economic and ecofriendly than steel or concrete roofing alternatives (Canada Wood, n.d.). Wood trusses are generally less expensive than rafters because individual wood components can be much smaller than rafters (Canada Wood, n.d.). Because trusses are built at a specialized site, trusses are generally much higher quality than rafters, which are built on site with varied equipment and non-specialized carpenters (Canada Wood, n.d.). Where trusses may take up to a day to install, rafters can take up to a week (Canada Wood, n.d.).

Weaknesses: Trusses require more lead time in designing than rafters, and time for prefabrication to be completed (Armchair Builder, n.d.). Trusses often require cranes and other heavy equipment to install and transport, whereas rafters are built one board at a time (Armchair Builder, n.d.). Trusses take up more room in attic space that could otherwise be used as additional floor space when rafters are used (Armchair Builder, n.d.).

Opportunities: The majority of new houses in Canada (95%) are being built with trusses, resulting in an extensive market (Canada Wood, n.d.). Trusses are usually built by many smaller companies as opposed to a few large companies, which means there is less of a monopoly over the industry (Canada Wood, n.d.).

Threats: There are many small to mid-sized truss businesses in BC, including: Skeena Truss in Thornhill (Facebook, 2019); Tricon Truss and Millwork in Smithers (Supply Chain Connector, n.d.); Cameo Truss in Williams Lake (Cameo Truss, 2017); Surrey Truss in Surrey (Alliance Truss, n.d.); Winton Truss in Prince George (Winton Engineered Wood, n.d.); Alpha Truss in Oliver (Alpha Truss, n.d.); AcuTruss in Vernon, Kelowna, and Winfield (AcuTruss Industries, n.d.); Hi-Tec Industries on Vancouver Island (Hi-Tec, n.d.); Lake Country Truss in Spallumcheen (Lake Country Truss, n.d.); and many more.

Considerations for Northwest BC: Although there are a number of businesses already in place in the region, this may be an indicator of the success of such a business. These businesses are all small to mid-sized, suggesting minimal monopolization of the industry in Northwest BC. Construction and housing in the region is high and consistently expanding, which will likely further the demand for trusses in the region. Trusses require sawn lumber, and there are a number of saw mills in the region that could supply such material.

Millwork

Product Information: Millwork is a broad term that can include architectural wood working, exterior doors, flooring, flush doors, garage doors, interior doors, moldings/trim, paneling, staircases, stile and rail doors, turnings, wood windows, and many other construction parts (Vodden & Kuecks, 2003). Both hardwoods and softwood can be used in millwork, depending on homeowner/customer preferences (Vodden & Kuecks, 2003). Millwork requires sawn lumber from old growth or second growth, or Engineer Wood Products (EWP) with a low moisture content. Cedar, pine, fir, and spruce are all common wood species used (Nisbet Brower, n.d.). Capital investment and profit margins would vary according to which millwork equipment is incorporated (Vodden & Kuecks, 2003). Most economically effective millwork businesses are part of an existing saw mill (Vodden & Kuecks, 2003). In Manitoba, an existing millwork plant was purchased and upgraded for $4.7 million (converted to 2019 CAD), and created 55 new jobs (Manitoba, 1999). However, a smaller operation of 1-2 people could have a much smaller investment cost around $8000 (Ecotrust, 2008). The chart below indicates the relative number of jobs created per unit of wood processed (Vodden & Kuecks, 2003).

For every million board feet of wood processed[20]

Operation Type	Jobs Created
Primary (sawmill)	3
Moulding/Millwork	18-20
Furniture	80

Strengths: More research is needed for the pros and cons of such a broad value-added wood operation.

Weaknesses: A millwork business would need to be flexible and change with market needs and demands (Forth, 2014).

Opportunities: The millwork market is fairly saturated in BC, but increased housing construction projected for BC, especially in the Northwest, will increase market demand (Government of Canada, 2016).

Threats: Other millwork businesses in the region include CMP Manufacturing Ltd. in Terrace, Tricon Truss & Millwork Ltd. in Smithers, Heavenly Millwork in Telkwa, and over 300 other businesses around British Columbia (Manta, 2019).

Considerations for Northwest BC: There is an abundance of lumber to be used as feedstock for millwork in the region, stemming from the varied number of lumber mills. However, competition for these products with more lucrative Asian markets may be challenging. As construction and housing increase in the region, there may be increased demand for millwork. Conversely, there may be an oversaturation of millwork products produced in the region, and a new venture would have to seek out non-local markets, requiring access to transportation infrastructure (variable depending on the destination). Currently, there is transportation to Asian markets and to the east coast North America by rail. However, there is little economically manageable transportation infrastructure to the lower west coast of North America.

Hemicellulose-Based Sweeteners

Product Information: Xylitol and erythritol are two alternative sweeteners that can be produced from the hemicellulose in agricultural and wood residues (Leech, 2018; Sussman, 2010). Xylitol can be produced via chemical or biological methods (Menon, Prakash, & Rao, 2010). In both methods, hemicellulose must first go through acid hydrolysis to produce hemicellulosic hydrolysates (Menon, Prakash, & Rao, 2010). They must then also undergo detoxification using activated charcoal, over-liming, or ion exchange resins (Menon, Prakash, & Rao, 2010). Xylitol has a number of beneficial properties, including its capability for preventing otitis and upper ear and respiratory infections, its prebiotic nature, its anticariogenic, tooth hardening, and remineralization properties, and its ability to inhibit the growth of oral microorganisms (Ur-Rehman et al., 2015). The same source indicates that metabolism of xylitol and erythritol is independent of insulin, and is therefore an excellent sugar alternative for hyperglycemic/diabetic individuals, and is also not digestible by *Candida*, and will therefore help prevent *Candida* overgrowth in the digestive system (Ur-Rehman et al., 2015). A proposed xylitol demonstration plant in Quebec will cost $33 million to construct (Fortress Global Enterprises Inc., 2018). A full-scale project cost is estimated at ~$430 million (converted to 2019 CAD), with profit margins that can be higher than 50%, and market prices for xylitol that were $5.37/kg (converted to CAD) in 2014 (Gerbrandt, 2014). There is a steadily growing market for sugar alternatives (Gerbrandt, 2014). See the table below for the financials of a theoretical hemicellulose sweetener (xylitol) mill. Amounts are in 2014 USD.

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Table D - 13: Fermentation 10% EC LT TVR Cash Flow Statement – Best Case ($MM)

Year	Capital Cost	Revenue	Operating Costs	EBITDA	Depreciation	Interest	GP	Taxes	Net Profit	ATCF
0	-$239.0	$143.5	$0.0	-$95.7	$0.0	$0.0	$0.0	$0.0	-$95.7	-$95.7
1	$0.0	$46.4	$6.9	$39.5	$12.0	-$11.5	$16.1	$4.0	$12.0	$24.0
2	$0.0	$92.7	$13.7	$79.0	$12.0	-$10.7	$56.4	$14.1	$42.3	$54.2
3	$0.0	$92.7	$13.7	$79.0	$12.0	-$9.8	$57.2	$14.3	$42.9	$54.9
4	$0.0	$92.7	$13.7	$79.0	$12.0	-$8.9	$58.1	$14.5	$43.6	$55.6
5	$0.0	$92.7	$13.7	$79.0	$12.0	-$7.9	$59.1	$14.8	$44.4	$56.3
6	$0.0	$92.7	$13.7	$79.0	$12.0	-$6.8	$60.2	$15.1	$45.2	$57.1
7	$0.0	$92.7	$13.7	$79.0	$12.0	-$5.7	$61.4	$15.3	$46.0	$58.0
8	$0.0	$92.7	$13.7	$79.0	$12.0	-$4.4	$62.6	$15.7	$47.0	$58.9
9	$0.0	$92.7	$13.7	$79.0	$12.0	-$3.1	$64.0	$16.0	$48.0	$60.0
10	$0.0	$92.7	$13.7	$79.0	$12.0	-$1.6	$65.5	$16.4	$49.1	$61.1
11	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2
12	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2
13	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2
14	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2
15	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2
16	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2
17	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2
18	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2
19	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2
20	$0.0	$92.7	$13.7	$79.0	$12.0	$0.0	$67.0	$16.8	$50.3	$62.2

Figure 2. Source: tspace.library.utoronto.ca

Strengths: Biological methods of xylitol production have higher yields than chemical methods, are less costly and more ecofriendly (Gerbrandt, 2014). Biological methods include D-xylose metabolism by yeasts (Gerbrandt, 2014). Microorganisms capable of producing xylitol include a number of *Candida* species and *Debaromyces hansenii* (Gerbrandt, 2014). Fortress Global's Specialty Cellulose plant will have the potential for up to US$ 40 million EBITDA/yr (Fortress Global Enterprises Inc., 2018). Around 15 people will be employed for a xylose hydrogenation or fermentation plant (Gerbrandt, 2014). Xylitol can be produced from solid wood, particulates, or wood byproducts (Gerbrandt, 2014).

Weaknesses: Chemical methods of xylitol production are costly and not ecofriendly, although biobased production can be very ecofriendly (Menon, Prakash, & Rao, 2010). Xylitol and erythritol are considered very toxic to dogs (Sussman, 2010).

Opportunities: Xylitol has a growing market because of its health benefits as a sweetener, and also for use in the pharmaceutical industry for products like toothpaste (Sussman, 2010). S2G BioChemicals Inc. has a unique, patented process for effectively producing xylitol from softwoods (Fortress Global Enterprises Inc., 2018). Extensive research has been conducted on the production methods of Xylitol, dating back to the mid to late 1900's, primarily using hardwoods and agricultural residues (Hajny, 1981). The market value of xylitol is expected to reach US$ 1 billion by 2020, and go for US$ 20/kg supermarket selling price by 2020 (Ravella et al., 2012).

Threats: There is very little research on production of xylitol from softwood, as most case studies have targeted hardwoods or agricultural residues; however, Fortress Global and S2G BioChemicals Inc. have patented an effective production method for softwoods (Fortress Global Enterprises Inc., 2018). Fortress Enterprises bought S2G BioChemicals Inc. of BC and plans to open a demonstration mill in Quebec that will take cellulose mill wastes and produce xylitol (Fortress Global Enterprises Inc., 2018). More research is needed to determine the impacts of feedstock moisture content on production efficiency.

Considerations for Northwest BC: Northwest BC currently has untapped residues available for the production of xylitol. More research required to determine further relevancy to Northwest BC.

Lignin Micro- and Nanoparticles

Product Information: Lignin micro- and nanoparticles (LMNP) are produced from lignin byproducts and are useful in a variety of applications that replace traditional compounds derived from petrochemicals (Abbati de Assis et al., 2018). These applications include veneer protection, cosmetics, emulsion stabilizers, polymer reinforcement, drug delivery, pesticide protection, natural rubber filler, phenolic foam reinforcement, phenolic resins, feedstock for carbon fiber production, and many others (Abbati de Assis et al., 2018). Capital investment for an LMNP facility can be up to $28 million (Converted to CAD; Abbati de Assis et al., 2018). Net income after capital costs are cleared may be as much as $700/t (Converted to CAD; Abbati de Assis et al., 2018). At a calculated production volume of 150 t/day, this equates to $28 million net income per year (Abbati de Assis et al., 2018). An estimate of 12 employees would be required in an LMNP plant (Abbati de Assis et al., 2018). EBITDA profit margins would be ($1,559 US/t MPSP)/($1,168 OPEX and SG&A/t)*100 = 25% (Abbati de Assis et al., 2018). These estimates are all generated under the assumption that the facility would be co-located with a pulp mill, which would provide dried lignin (Abbati de Assis et al., 2018). Lignin solutions (before drying) might also be used, which would reduce costs considerably (Abbati de Assis et al., 2018).

Strengths: Lignin, a pulp and paper byproduct, is currently used as a fuel to heat and power pulp and paper mills, but its value can increase more than 10-fold if used to produce LMNP (DOE & Oak Ridge National Laboratory, 2012).

Weaknesses: The technology for LMNP production is fairly new, with few real-world applications to date (DOE & Oak Ridge National Laboratory, 2012). The best source for lignins is the black liquor from pulp and paper mills, which the Northwest BC area does not have.

Opportunities: LMNP products are an emerging market, with opportunities for new suppliers to become established. If LMNP can utilize forestry residues, this would provide an opportunity for relatively low-cost feedstock in addition to utilizing a forestry waste material. However, using feedstock instead of pulp mill byproducts may be less economically feasible, although more research is needed to confirm this.

Threats: Established pulp mills outside of the region may be better positioned to take advantage of this opportunity.

Considerations for Northwest BC: Unfortunately, Northwest BC does not have any pulp or paper mills whose black liquor could be utilized for an LMNP facility. However, there are a number of old mills in the region that could be recommissioned, at which point an LMNP facility that would utilize the mill's waste products would be a paired business venture to consider. If it becomes economically effective to utilize forestry residues for an LMNP mill, then Northwest BC may be an ideal location for such a facility, since the region has a large forestry industry whose residues are currently not being utilized at significant scales.

Lignin Resin

Product Information: Lignin-epoxy resins and lignin-based phenolic resins are adhesives that can be produced from biomass (Li et al., 2018; Siddiqui, 2013). Traditionally, adhesives in industries such as carpentry and construction are usually formaldehyde-based, which poses a health concern (Hemmilä, Trischler, & Sandberg, 2013). Lignin-based alternatives are non-toxic, eco-friendly, and competitive in all the desired properties of traditional adhesives (Hemmilä, Trischler, & Sandberg, 2013). There are a number of ways to produce resins or adhesives from lignin, and each method has its associated benefits and drawbacks (Hemmilä, Trischler, & Sandberg, 2013). More research is needed to identify capital costs and profit margins.

Strengths: Lignin is widely available, since it is one of the primary waste products in the pulp and paper industry, and is commonly burned to produce local heat and power for mills. As of 2017, a process using hydrogenolysis and glycidylation produces a lignin-derived epoxy resin that outperforms traditional petroleum resins (Van de Pas & Torr, 2017). As of 2018, another method was confirmed that produces a formaldehyde-free lignin epoxy resin/thermoset that also out-performs traditional chemicals (Zhao et al., 2018). Another bio-based method claims to be even more effective than other bio-based resins (Wang et al., 2018). Kumar et al. (2018) appears to provide a great review about the bio-based alternatives and methods, but this source was not thoroughly reviewed for this study. One study shows that bio-chemical adhesives have a 22% lower environmental impact compared to petrochemical adhesives (Yang & Rosentrater, 2015). In this same study it was shown that lignin resins created 39% less fossil fuel changes than petroleum-based resins, 9% lower climate change effects (reduced transportation emissions), 40% less resource depletion, and 59% more ecosystem quality impact (Yang & Rosentrater, 2015).

Weaknesses: As of 2013, viable production methods for lignin-based resins were lacking (Hemmilä, Trischler, & Sandberg, 2013). Further research is required to determine if modern methods have been attained. Also, there are no local pulp mills to produce a source of lignin wastes.

Opportunities: There is an emerging market for lignin resins, with viable methods of production only recently becoming available (see above). There is a strong consumer resistance to formaldehyde resins, and this may assist the lignin resin industry in gaining a foothold in the markets. Excessive forestry residue in Northwest BC is available to be utilized. Production does not appear to be dependent on moisture content, which is high in this region, and therefore does not pose a threat to the feasibility of this kind of product.

Threats: Because the science behind lignin resin production is quite new, business ventures would be pioneers in the market and would have to take on the associated risks. The closest operation of a similar product is West Fraser's demonstration plant in Hinton, AB, which extracts lignin from the black liquor of pulp plants. West Fraser's short-term objective is to produce lignin-based adhesive, and from there to expand their market to encompass other lignin-based products (Bioplastics Magazine, 2016; Sustainable Development Technology Canada, 2014). The best source for lignin is the black liquor from pulp and paper mills, of which the Northwest BC region has none.

Considerations for Northwest BC: Unfortunately, Northwest BC does not have any pulp or paper mills whose black liquor could be utilized for a lignin resin facility. However, there are a number of old mills in the region that could be recommissioned, at which point a lignin resin facility that would utilize the mill's waste products would be a paired business venture to consider. If it can be economically successful to utilize forestry residues for a lignin resin mill, then Northwest BC may be an ideal location for such a facility, since the region has a large forestry industry whose residues are currently not being utilized at significant scales.

Lignin Thermoplastics (Bioplastics/Biopolymers)

Product Information: Lignin thermoplastics are products that can replace plastics in many applications (Oak Ridge National Laboratory, 2016). VTT of Finland takes Kraft lignin and grafts and plasticizes it with fatty acids, and then applies it to natural and pulp fiber composites (VTT, n.d.). The Oak Ridge National Laboratory has patented a thermoplastic that is an unmodified solvent-extracted melt-stable lignin combined with non-lignin thermoplastic polymer segments (Oak Ridge National Laboratory, 2016). There is a 2016 review of the production methods of lignin thermoplastics currently available that was not reviewed in any detail for this study but may provide further insight (Wang, Kelly, & Venditti, 2016). Lignin biopolymers can be used for a wide range of applications in replacing their petroleum-based equivalents, including vulcanized rubber replacement; adhesives, sealants, and coatings; polymer blends; bitumen modification; and modifiers for thermosets (Saito et al., 2012). More research is needed to determine total capital investment and profit margin estimates.

Strengths: Unlike thermosets, which are usually used in permanent solutions such as resins and adhesives, thermoplastics are reversible after curing, which means they can be recycled and are reusable (Saito et al., 2012). Lignin thermoplastics would not only be completely recyclable, but potentially biodegradable as well (Saito et al., 2012). Lignin, a pulp and paper byproduct, is currently used as a fuel to heat and power pulp and paper mills, but its value can increase more than 10-fold if used to produce thermoplastics (Science News, 2012). Some processes (hydrothermal liquefaction) perform better with wet feedstocks, and therefore no pre-drying is needed (Johnson & Hart, 2016).

Weaknesses: Like lignin resins, lignin thermoplastics are still a new product, with production processes that are still being widely researched and perfected. The best source for lignin is the black liquor from pulp and paper mills, of which the Northwest BC region has none.

Opportunities: There is an emerging market for lignin thermoplastics, with viable methods of production only recently becoming available. There is a strong consumer resistance to single-use plastics, and this may assist the lignin thermoplastic industry in gaining a foothold in markets. Excessive forestry residue in Northwest BC is available to be utilized. Production of lignin thermoplastics does not appear to be dependent on moisture content, which is high in this region, and therefore does not pose a threat to the feasibility of this kind of product.

Threats: Because the science behind lignin thermoplastic production is quite new, a business venture producing this product would have to bear the risks of entering an untested market. The closest operation of a similar product is West Fraser's demonstration plant in Hinton, AB, which extracts lignin from the black liquor of pulp plants. This plant's short-term objective is to produce lignin-based adhesive, and from there to expand their market to encompass other lignin-based products (Bioplastics Magazine, 2016; Sustainable Development Technology Canada, 2014). The pulp mills outside of the region are in a better position to take advantage of a lignin thermoplastic opportunity.

Considerations for Northwest BC: Unfortunately, Northwest BC does not have any pulp or paper mills whose black liquor could be utilized for a lignin thermoplastics facility. However, there are a number of old mills in the region that could be recommissioned, at which point a lignin resin facility that would utilize the mill's waste products could be a paired business venture to consider. If it can be economically successful to utilize forestry residues for a lignin thermoplastics mill, then Northwest BC may be an ideal location for such a facility, since the region has a dominant forestry industry whose residues are currently not being utilized at significant scales.

I-Joists

Product Information: Wood I-joists are similar in design to steel I-beams and are intended to replace standard lumber alternatives in floor and ceiling joists (Fisette, 2000). They were first designed in 1969 (Fisette, 2000). I-joists consist of an OSB web and two flanges made up of either sawn lumber or LVL. The webs and flanges are joined with the web inset into the flanges and glued (Fisette, 2000). Unlike traditional lumber joists, I-joists allow for long clear spans typical of open layouts, because their load-carrying ability is much higher than lumber joists (Fisette, 2000). Where LVL has physical properties that outperform solid wood, solid wood can make up for this with larger cross-sections (Fisette, 2000). The reason solid wood flanges are often chosen over LVL comes down to cost—solid wood is often cheaper than LVL (Fisette, 2000). US production of I-joists is 4 times that of Canada. A proposed I-joist plant for Kamloops would staff 14 people and produce 1.8 million board feet per year (Whispering Pines Forest Products, 2002). Capital investment for an I-joist plant is around $28 million (converted to 2019 value) or more (Ontario Forest Products, 2001).

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Profit margins for I-joist production are high, around 25% (Spelter, McKeever, & Durbak, 1997). A small plant would employ 14 or more people (Okun, Hillman, & Miller, 2003).

Strengths: I-joists are more stable than traditional planks because of the wide flanges, and are less susceptible to twisting, shrinking and warping caused by the slowly evaporating moisture naturally found in solid wood products (Georgia-Pacific Wood Products, 2012). The nature of this wood product means it will have a much lower moisture content than traditional solid wood beams (Georgia-Pacific Wood Products, 2012). I-joists have a number of advantages over dimension lumber. Not only do I-joist have greater design flexibility, they also have improved strength and stiffness; more uniform size, appearance and performance; improved dimensional stability; lighter weight for improved handling; and are more ecofriendly in that they require less material than dimension lumber, and the material is composite, reducing the demand on old growth lumber (Georgia-Pacific Wood Products, 2012). Another advantage of I-joists over dimensional lumber is that I-joists can be produced in lengths up to 60 feet, whereas dimensional lumber is generally available up to 16 feet (Fisette, 2000). This means less joints across floor spans. Because of their structural integrity, I-joists can also have on-center spacing up to 24”, as opposed to 16” for lumber joists (Fisette, 2000).

Weaknesses: I-joists are more complicated to install in roofing and flooring than traditional sawn lumber (Fisette, 2000). The biggest competitor in the I-joist industry is not other I-joist manufacturers, but actually dimension lumber (Fisette, 2000). As of 2000, I-joists were more expensive than their dimension lumber alternatives (Fisette, 2000). In addition, the unfamiliarity of the construction industry to I-joists also limited their favorability as of 2000 (Fisette). Currently, a 16’ (11-7/8’ depth) I-joist costs between $34 (Converted to CAD; Menards, 2018) and $67 (Converted to CAD; Lowe’s, 2018), and a dimensional lumber 2x10 of equal length is $23 CAD (The Home Depot, 2019).

Opportunities: As of 2007, the wood I-joist industry was one of the fastest growing sectors in Canadian forestry for the previous decade (Pirzada & Chui, 2007). The industry has many years of research under its belt, and therefore production is well established and documented. In the early 2000s, I-joists accounted for most of the value of the American engineered wood products industry (Fisette, 2000). Pinkwood is the only I-joist producer in western Canada that has long-length, high-speed production machines, and their plant is based out of Calgary (Pinkwood, 2016).

Threats: As of 2000, around 5 manufacturers dominated the US market, selling 80% of all I-joists (Fisette, 2000). The top three American I-joist producers are Trus Joist (Weyerhaeuser), Boise Cascade, and Louisiana-Pacific (United States International Trade Commission, 2003). In Canada, I-joist plants are across New Brunswick, Quebec, Ontario, Alberta, and BC (United States International Trade Commission, 2003). In 2002, the I-joist market, especially in eastern Canada, suffered from overcapacity (United States International Trade Commission, 2003). I-joists are manufactured in Williams Lake, BC by Cameo Truss (Cameo Truss, 2015), Winton Engineered Wood Products in Prince George, BC (Winton Engineered Wood, 2015), AcuJoist in Winfield, BC (AcuJoist, n.d.), and Pinkwood in Calgary, Alberta (APA, 2018).

Considerations for Northwest BC: Like trusses, I-joists are generally produced by small to mid-sized manufacturers, resulting in a less monopolized market. Williams Lake and Prince George appear to be the closest manufacturers, which means there may be an opening for Northwest BC to start a supply of I-joists. An I-joist producer could pair with a lumber mill in the region.

Northern Bleached Hardwood Kraft

Info: Northern Bleached Hardwood Kraft (NBHK) is similar to NBSK except that the fibres are shorter, which means lower grade durability and strength, and a softer finish (Numera Analytics, n.d.). Capital investment is very high (over $1 billion) and a plant can employ over 400 workers (U.S. Environmental Protection Agency, 1997). More research is needed to determine profit margins. Production of NBHK can use sawmill wood wastes (Numera Analytics , n.d.). Forestry residues are not preferable due to their size and compositional variations (Numera Analytics, n.d.).

Strengths: More research is needed to determine the relative strengths of NBHK to NBSK.

Weaknesses: The pulping process of NBHK production only utilizes 50% of the input wood (Ababa, 2008). The latest closed loop process minimizes chemical discharge from an NBHK plant, but there is still a lot of environmental concern from an NBHK mill (Broten & Ritchlin, 2012). Although the production process of NBHK has been fairly well studied, there is still a lot of progress to be made on the efficiency and eco-friendliness of the production process.

Opportunities: There is limited to no NBHK production in BC. Some hardwoods are available for harvest in the region including alder, aspen and cottonwood in the Nass and Kispiox regions. Further research is required to determine if there is an adequate supply for hardwood kraft.

Threats: Regulatory frameworks of BC/Canada/North America restrain the region from producing NBHK as effectively as Asian and African countries, whose regulations are different than ours.

Considerations for Northwest BC: There are a limited amount of hardwood species of considerable volume available in Northwest BC to utilize for NBHK. The major lumber that is produced from the region is generally softwood pulp logs, which suggests that a softwood kraft mill would be a more feasible venture than a hardwood kraft mill.

Polymer Impregnated Wood Products

Product Information: Polymer impregnated wood products (PIWP) can made from nearly any solid wood or composite wood product (Schneider, 1994). The wood product is first impregnated with a prepolymer which is then cured into a solid (Schneider, 1994). PIWPs are made via vacuum and pressure of low and medium viscosity treating fluids to force them into the wood (Schneider, 1994). Higher viscosity fluids can be used for impregnation using flow and diffusion-displacement techniques (Schneider, 1994). Flooring and decking are the most prominent markets for PIWPs (Schneider, 1994). Capital investment for a PIWP facility in 1968 was estimated around $4.7 million (converted to 2018 CAD), with around 22 jobs (International Atomic Energy Agency, 1968).

Strengths: PIWPs have increased surface hardness and dimensional stability compared to the parent product, and also have a more appealing surface finish without the need for staining or other coating (Schenider, 1994). PIWPs can be prepared from already manufactured wood products (Schneider, 1994).

Weaknesses: Depending on the polymer, some chemicals are not environmentally friendly (Schneider, 1994). The heartwood of softwood lumber does not impregnate well (Schneider, 1994). Drier wood is preferred as wood moisture content reduces penetrability (Schneider, 1994).

Opportunities: Local species that have can be used for PIWPs include *Alnus* spp., *Betula* spp., *Populus* spp., and *Prunus* spp (Schneider, 1994). According to Kebony, demand for these products began to exceed supply in 2015, and continues to grow (Kebony, 2019).

Threats: Hardwoods are preferably used for PIWPs because the heartwood of most softwoods does not impregnate well, and softwoods a lower density than hardwoods (Schneider, 1994). This means that softwoods require more treatment to reach comparable properties to hardwood PIWPs (Schneider, 1994).

Considerations for Northwest BC: Hardwoods for PIWPs are preferred, and Northwest BC's forest industry is dominated by softwood harvesting, and therefore available feedstock for PIWP production is limited.

Prefabricated Homes/Structures

Product Information: Prefabricated buildings include a variety of different structures, including the commonly known "mobile homes", as well as many other structures with a wide range in value and quality. Capital investment for a prefabricated facility is estimated around $7 million (Converted to CAD, reference year unknown), although this will vary depending on the type of prefabricated structures being produced (Embassy of Ethiopia, n.d.). One case study found that profit margins were around 22% and 35 people are employed in a prefabricated facility (Embassy of Ethiopia, n.d.).

Strengths: Prefabricated structures can help with the time-efficient construction of much needed housing in BC because of it's fast, easy, and cost-effective assembly (Rippon, 2011). Prefabricated buildings, compared to standard housing, provides an enclosed work environment, reduced labour hours, reduced waste material, computer optimization, and cost effectiveness (Rippon, 2011).

Weaknesses: Construction material requires low moisture content. Although high quality homes can be prefabricated, there is still a stigma against them because modular homes are often seen as low quality and lacking creativity (Rippon, 2011). There are also transportation limitations, shipping constraints, and transport costs that limit the market success of prefabricated structures (Rippon, 2011).

Opportunities: There is an increasing demand from first time home buyers and downsizers for prefabricated homes because of their simplicity and low cost (Holloway, 2018).

Threats: North Coast Modular Homes and General Northwest Homes are two prefab companies in Terrace, BC (General Northwest Homes, n.d.; North Coast Modular Homes, 2019). There are also Hart Modular Homes and Blackstone Homes in Prince George (Blackstone Homes, 2018; Hart Modular Homes, 2019).

Considerations for Northwest BC: Construction and housing rates are steadily increasing in Northwest BC, and as a number of industrial projects move into the region, there may be a rush for new housing. Prefabricated homes are well suited to meet growing housing demand because of their fast and simple installation.

Glue-Laminated Timber

Product Information: Glue-laminated timber (glulam) is made from two or more boards laminated together with their grains running in the same direction (Canadian Wood Council, n.d.). Common species used are Douglas fir, western larch, hemlock, amabilis fir, all spruces except Sitka, lodgepole pine and Jack pine (Canadian Wood Council, n.d.). Glulam can be made from old growth or second growth (Canadian Wood Council, n.d.). Feedstock wood must be dried to a moisture content of 15% (Canadian Wood Council, n.d.). Capital investment for a glulam facility runs between $1 million and $5 million (Collins & Hankins, 2017).

Strengths: One of the most unique benefits of glulam is the ability to produce curved beams without cutting (Canadian Wood Council, n.d.). Glulam is stronger than steel and dimensional lumber (Canadian Wood Council, n.d.). It is very visually appealing and often used in applications where building designs are open to expose architectural features (Canadian Wood Council, n.d.). Glulam is also impressive in that it shows high earthquake and fire resistance (Canadian Wood Council, n.d.). As a replacement to steel, glulam is much lighter with markedly better thermal insulation (Canadian Wood Council, n.d.).

Weaknesses: Glulam usually requires relatively large dimensional lumber and, therefore, the options for using second growth lumber are limited. Adhesion of feedstock lumber requires formaldehyde-based resins, which have health and environmental concerns (although these can be replaced with lignin resins; Canadian Wood Council, n.d.).

Opportunities: Glulam is already well integrated into the construction industries, and is often the feature piece in community and commercial buildings. There is a high demand for glulam but there are also a significant number of suppliers already in the market. This industry is not monopolized but consists of a number of small and medium-sized companies, making entry into the market less challenging.

Threats: According to the APA directory, there are glulam mills in Chibougamau, Quebec (Nordic Structures); Homedale, Idaho (Boise-Cascade); Vancouver, Washington (Calvert Company); Devlin, Ontario (LEAF Engineered Wood Products); Okanagan Falls and Penticton, British Columbia (Structurlam Mass Timber); Saint-Jean-Port-Joli, Quebec (Art Massif Structure De Bois); Louiseville, Quebec (Goodlam/Goodfellow); Boissevain, Manitoba and Edmonton, Alberta (Western Archrib); and Squamish, British Columbia (FraserWood Industries; APA, 2018).

Considerations for Northwest BC: Although there are a number of glulam providers in BC already, this simply indicates the sufficient demand in place for the product. As construction and housing steadily rise in the region as more industrial projects move in, it is expected that demand for wood products such as these will also rise, making room for new glulam suppliers.

Medium Density Fiberboard

Product Information: Medium Density Fiberboard (MDF) is a non-structural panel composed of wood fiber and urea-formaldehyde adhesive (Rouge, 2015). It sometimes also contains paraffin wax and other treatment chemicals (McCallum, 1996). Compared to plywood and particleboard, MDF is very dense and heavy, although can vary in density (Rouge, 2015). Unlike particleboard, fiberboard requires processing of woody materials into fibers before producing panels (Rouge, 2015). Hardboard is a similar product to MDF, although its use has been slowly decreasing (Rouge, 2015). A new MDF mill will cost approximately $1140 (converted to 2019 CAD) per thousand ft^2 of capacity, or $150 million (converted to 2019 CAD) for a 100 million ft^2 complex, and would employ about 100 workers (Spelter, 1994). Another source estimates capital costs to be around $187 million for a 120 million ft^2/yr plant (Columbia Engineering International Ltd., 1993). Gum, alder, hickory, as well as softwoods like pine and fir, are commonly used for MDF feedstock (U.S. Environmental Protection Agency, 2002*c*). The moisture content of the fibers during production is 12% (McCallum, 1996).

Strengths: MDF can be made from logs, recycled paper, mill and forestry residue, bamboo, and a number of other materials, making it a very versatile product in terms of production (McCallum, 1996). This means that waste materials can be utilized in the production of MDF, lowering the carbon footprint. MDF is a good substrate for veneers because of its smooth surface finish (Natural Resources Canada, 2016). MDF can be cheaper than solid wood alternatives, and is more uniform in density and quality (Natural Resources Canada, 2016). Because of its composition, MDF has smoother surfaces than particleboard and can be worked like solid wood, whether beveling, routering, moulding or producing a straight-edge panel (Natural Resources Canada, 2016).

Weaknesses: MDF does not hold nails or fine-pitch screws very well, and does not hold any fasteners well near the edges (McCallum, 1996). Like particleboard, MDF is prone to swelling from moisture (McCallum, 1996). It also poses a health concern due to the high formaldehyde content, which becomes airborne when cutting MDF (Baumann et al., 2000). Also, MDF emits formaldehyde at a consistent rate even when not cut (Baumann et al., 2000). Painting MDF, even that which has been primed, with latex is difficult because of the high-water absorption of MDF (Baumann et al., 2000). Paint finishes are usually very uneven and patchy (Baumann et al., 2000). MDF is more expensive than particleboard (Natural Resources Canada, 2016). MDF plants are very expensive to start up, usually in the hundreds of millions of dollars (Ontario Forest Products, 2001).

Opportunities: Production of MDF can utilize forestry and mill residues (McCallum, 1996). Siempelkamp offers a range of services and products for building an MDF mill (Siempelkamp, n.d.).

Threats: China has undergone significant production expansion and now monopolizes a large portion of the MDF market (Natural Resources Canada, 2016). Specifically, 40% of the world's MDF is produced in China (Natural Resources Canada, 2016). There are two West Fraser plants in Western Canada, one in Quesnel, BC (Westpine) and one in Blue Ridge, AB (Ranger Board; West Fraser, 2019). Pembroke MDF is another plant, located in Pembroke, ON (Roseburg, 2016).

Considerations for Northwest BC: Species that are commonly used to make MDF that are found in Northwest BC are pine, fir, and alder. Together, these species make up a significant portion of the logging focus in the region, although pine and alder are harvested at much lower quantities than fir. Generally, the most economically feasible feedstock used for MDF production is sawmill chips and sawdust. There are a number of saw mills in the region that could potentially supply this feedstock. More research should be done to confirm the feasibility of using forestry residues as feedstock. If this is a feasible option, there may be significant opportunity in the region to utilize forestry residues, which are abundant in the region due to the heavy focus on forestry, and currently underutilized.

Viscoelastic Thermal Compressed Wood

Product Information: Viscoelastic thermal compressed wood (VTC) is a high-density wood product that is made from low density wood by applying consistent pressure in the transverse direction, which does not damage cell walls (Kamke & Sizemore, 2008).

Strengths: This process is often used in conjunction with polymer impregnation of the wood to provide superior physical properties such as strength, hardness, stability and durability (Kamke & Sizemore, 2008).

Weaknesses: If untreated, compressed solid wood and veneers tend to spring back when exposed to moisture (Kamke & Sizemore, 2008).

Opportunities: There is fairly minimal research and understanding on VTC to date. More research is needed for this product. There is a potentially useful article on the commercialization potential of VTC wood, which was not reviewed for this study (Macias et al., 2011).

Threats: More research is needed.

Considerations for Northwest BC: This product has very little accessible information online regarding its potential for commercialization. Further research is needed on its consideration for production in Northwest BC.

Cabinets

Product Information: Cabinetry products can include bath vanities, case goods, commercial fixtures, home entertainment, kitchen cabinets, parts/components, and others (Vodden & Kuecks, 2003). For a small company the start-up cost can be relatively low (from $2000-$10000; How to Start an LLC, n.d.), however the profit margins can also be as low as 5% (Dunn, 2015). A small company generally only has one or two employees (Dunn, 2015). Sustainability of cabinet production depends on the materials used, manufacturing practices and transport, and length of use of the product (Abbas, 2018).

Strengths: Local timber can be used to produce cabinets; hardwoods, softwoods, and composite sheets and boards can all be used (Shaddy, n.d.).

Weaknesses: A small custom cabinet company may have difficulty competing with larger manufacturers who can offer competitive pricing (Dunn, 2015).

Opportunities: There is a large local market and high demand in Asian markets as well (Government of Canada, 2017).

Threats: Wood needs to have a low moisture content around 6% to 9% (Loffer, n.d.). In Terrace alone there is: Ewald Cabinets & Renovations Ltd., Price R & Sons Ltd., Benches Custom Woodworking and CMP Manufacturing Ltd. Furniture stores and larger stores like Timber Mart, Your Décor and Concept Floor & Kitchen Centre also offer cabinetry. There are many more in the Northwest BC region, both local and chain companies. Cabinetry can also be shipped from other locations around BC like Ikea and numerous other small and large companies.

Considerations for Northwest BC: Generally, the cabinetry industry is not monopolized by larger companies, which means starting a cabinetry business in Northwest BC should not have the challenge of competing purely with production giants; however, there are certainly some larger brands and companies that are large enough to offer competitive rates that cannot be met by smaller companies. On the other hand, consumers are often willing to pay more for a local custom build because of the higher quality wood sources. There appear to be a large number of local cabinetry businesses in the region, which indicates the high feasibility of cabinetry production for Northwest BC, but it may also be an indicator of a relatively saturated market, and new startups may have difficulty becoming established. With industrial projects moving into the region and increasing the rates of construction and new housing, the market for furniture may increase.

Furniture

Product Information: When starting a furniture business, capital investments are generally low, with the opportunity for high profit margins for premium products (Buisson, 2006). A small store startup can be between $2,000 and $10,000; however, a larger box store could easily cost $500,000 to $3 million (Gleeson, 2017). Job creation is highly variable depending on the size of the business. The chart below indicates the relative number of jobs created per unit of wood processed (Vodden & Kuecks, 2003).

For every million board feet of wood processed[20]

Operation Type	Jobs Created
Primary (sawmill)	3
Moulding/Millwork	18-20
Furniture	80

Strengths: Canada is one of the top 10 producers of furniture in the world, with high-quality products and expert craftsmen, especially in solid wood furniture (Buisson, 2006). The furniture industry in Canada was steadily growing between 2011 and 2015, and appears to continue to do so. There is a large market locally, and demand for shipping to Asia is high as well (Government of Canada, 2017).

Weaknesses: Wood for furniture needs to have a low moisture content around 6% to 9% to prevent warping (Loffer, n.d.). Lacquers and glue and paint fumes are not usually ecofriendly (Buisson, 2006). Usually old growth furniture is considered premium, increasing demands on old growth forests. However, it is a sustainable alternative to plastic, and furniture from Engineered Wood Products (EWPs) are more sustainable than those from solid lumber. Like cabinetry, sustainability also depends on materials used, manufacturing practices and transport, and length of use (Abbas, 2018). Another challenge, especially for small scale producers, is effective marketing that can compete with large-scale chain stores.

Opportunities: Premium products can sell for a very high price. Generally solid wood furniture sells for a higher price than alternatives.

Threats: One small furniture builder in Terrace is Bare Wood Furniture. There are also numerous large or chain stores selling furniture including the Brick, City Furniture, Totem, Flying Fish, Ashley's, Kondolas, and EasyHome. Other centers in Northwest BC have a similar variety of furniture stores. Tom's Furniture in Telkwa is another example.

Considerations for Northwest BC: Although there are a number of chain furniture stores throughout BC, only a few smaller local businesses were identified. Generally local furniture is considered more desirable, and this may suggest a market opening for a new furniture business in the region. There is a large amount of available feedstock lumber in the region from local saw mills.

Machine Stress-Rated Lumber

Info: Machine stress-rated (MSR) lumber is dimension lumber that has been graded via mechanical means in addition to visual (Southern Pine Inspection Bureau, n.d.). Machine lumber graders are installed as part of the assembly line of a lumber mill (Southern Pine Inspection Bureau, n.d.). Through communications with Metriguard in Washington, the following information was attained: there are two primary machines to choose from, the 7200 HCLT and the 2350 Sonic Lumber Grader. The 7200 is faster and more accurate, but requires more space, as it reads the lumber lengthwise and therefore requires approximately 13ft of space, compared to the 2350, which reads the lumber width wise and only requires a couple feet of the assembly line. The 7200 also requires much more maintenance due to the faster speeds which it runs at. The 7200 costs around $350,000 US ($470,000 CAD) and the 2350 costs around $150,000 USD ($200,000 CAD). There is also a 312 bending proof tester for lateral bending for $58,500 USD ($78,000 CAD), which may be required by a local grading agency to qualify as MSR lumber.

Strengths: The following paragraph is information retrieved from communications with Canfor Vancouver. MSR is becoming more standard at mills, because MSR lumber is highly preferred for structural wood components like trusses and joists. It is more expensive than visually graded; there is a premium for MSR, which varies by time of year and lumber dimensions. For example, currently (September, 2018) the pricing for Spruce 1650 [pressure point] 2 x 4s have a $100 premium, and spruce 2100 [pressure point] 2 x 4s have a $125 premium. Generally, premiums are highest around September, because roofing is going up last in new builds before winter comes, so demand increases. According to Canfor, MSR lumber is highly preferred for trusses and joists (structural wood components).

Weaknesses: Adding these machines to a mill's assembly line effectively can have a negative impact on employment rates if these machines are replacing trained human graders. Can also be used in addition to visual grading, which would not impact jobs.

Opportunities: Skeena Sawmills does not provide MSR rated lumber (communications with Frank Gratian from Skeena Sawmills). According to Metriguard, Skeena Sawmills rented some equipment last June from them and was looking into MSR production. Frank Gratian from Skeena explained that they tested the feasibility of having an MSR machine in their mill, but the high moisture content of their wood, which was chosen through agreement with their clients, appears to be too high to pass the typical pressure points. In addition, their clients generally don't require MSR certification, so it is not required for Skeena Sawmills.

Threats: MSR lumber does not appear to be commonly used in the region; the sales rep at Terrace Home Hardware (communications in October 2018) didn't even know what MSR lumber was. Skeena Sawmills did some preliminary testing on their lumber to see if producing MSR lumber was feasible for them. A very low amount of second growth showed required strength for typical ratings, and even old growth didn't show a high proportion of MSR approved lumber. It was therefore determined that MSR is not a feasible service in this region. Frank Gratian, who led the project, believes that it is likely because of the moisture content. Their lumber is usually dried to around 25% instead of the standard 19%, since that is all that their contracts to their clients require. He believes that it is likely that the lumber would have shown higher strength if dried to 19% or lower.

Considerations for Northwest BC: The high moisture content of the region's wood limits the economic feasibility of installing MSR equipment in a local mill. However, whereas Skeena Sawmills only dries their wood to 25% moisture content, some mills in the region may dry their wood to 19% or less for their contracts, in which case MSR ratings may be more achievable. More research is needed to determine if a) any mills in the region dry their lumber lower than 19%, and b) MSR is common or well-known to other lumber providers or builders in the region (or if Terrace's Home Hardware is representative of the region's familiarity with the product). If there are sawmills with the adequate moisture, and it is determined that MSR lumber is commonly used in the region, there should be further testing in the region on local lumber to determine if the lower moisture content is sufficient to improve the stress ratings. If so, an MSR addition to a local sawmill may be a smart upgrade, especially with the increasing construction and housing in the region as new industrial projects move in.

Wood-Cement Composites

Product Information: Wood-cement composites (WCCs) consist of small pieces of wood mixed with cement and cured under pressure (Natural Resources Canada, 2016). Products from WCCs can range from porous, low-density panels using wood-wool (which is created using what is essentially a giant, powered cheese grader for logs and lumber; Alice, 2016), to particleboards made from wood particles, shavings, and cement (Natural Resources Canada, 2016). Moulded products can also be made from sawdust and fibers (Natural Resources Canada, 2016). Some wood species are not suitable for WCC application because of their sugars and other chemicals which inhibit cement curing (Natural Resources Canada, 2016). Typical WCC products are primarily siding, because it outperforms vinyl in durability, maintenance, and ease of painting (Natural Resources Canada, 2016). WCCs as boards (wood-cement boards, or WCBs) also include roofing, flooring, and walls (Natural Resources Canada, 2016). Aspen is an apparently compatible wood species for WCC, as well as poplar and alder (Pasca et al., 2010). Larch appears to be less compatible (Pasca et al., 2010). Of 21 North American wood species, Lodgepole pine showed the highest suitability (Pasca et al., 2010). Next in line was western white pine and grand fir (Pasca et al., 2010). Engelman spruce, western redcedar, and ponderosa pine did not perform well in this study (Pasca et al., 2010). Another study shows that softwoods perform better than hardwoods (Defo, Cloutier, & Riedl, 2004). The particle moisture content is around 12% (Ronquim et al., 2014). Wood treatment is required prior to combination with cement to eliminate setting-inhibitory properties in the wood (Quiroga, Marzocchi, & Rintoul, 2016). Pre-treatment processes include water extraction, degradation by alkaline hydrolysis, and retention of inhibitory substances (Quiroga, Marzocchi, & Rintoul, 2016).

Strengths: WCCs have good moisture resistance, dimensional stability, acoustic and insulating properties (Natural Resources Canada, 2016). WCCs have higher durability, dimensional stability, acoustic and thermal insulation, and lower costs than organic resins (Soares Del Menezzi, Gomes de Castro, & Rabelo de Souza, 2007). WCC can also be made from mill waste (Falk, 1993).

Weaknesses: Wood cement composites, in the example of siding products, are costlier and more complicated to install (BuildDirect, 2015). In addition, wood cement composites produce a lot of fine dust when cut, and this can be a health concerns for those inhaling the dust (Allura, n.d.).

Opportunities: One study shows that poplar and alder result in improved properties of wood-cement particleboards compared to standard wood particleboard (Nazerian, Ghalehno, & Gozali, 2011). Most WCC products currently come from rainforest species or some Middle East species. One study from the University of British Columbia indicated that lodgepole pine beetle affected trees were suitable for wood-concrete composites, and suitability continues to improve as Time Since Death increases, until decay sets in (Pasca et al., 2010). Specifically, if a pine beetle tree will begin to decay ten years after dying from pine beetle infestation, then the suitability of that tree for wood cement composites will continue to increase until 10 years after death, when decay starts (Pasca et al., 2010). This is believed to be because the sugars and other compounds in the wood that inhibit the setting of cement break down earlier than the fibrous material in the wood, which is the sought-after portion of the wood for WCCs.

Threats: Some of Northwest BC's local species, like western red cedar and Engelmann spruce, do not perform well with WCCs because of their inhibiting effects on cement curing (Quiroga, Marzocchi, & Rintoul, 2016). Low cost alternatives, such as vinyl in the case of siding, are currently dominating the market despite inferior performance to WCC.

Considerations for Northwest BC: WCC's have a steady, stable position in the construction markets, and are only expected to increase due to their reduced cost and improved durability and strength properties compared to traditional lumber (Chang, 2006). As construction steadily increases in Northwest BC, there may be an opportunity for local WCC production. The primary fallback for WCC in this region is the species selection. Many local species like cedar and spruce are not suitable for WCC production. Species like western hemlock and balsam fir have little coverage on their suitability, and should be further research on their potential for use in WCCs. Pine, alder and poplar are present in the region in moderate amounts, and may be used for WCC production.

Energy-Production Flooring

Info: Preliminary research has shown that a simplistic twist on the typical design of wooden flooring can result in turning the energy of footsteps into usable electricity (Cushman, 2016). Generally, this flooring requires a lot of traffic to produce a significant amount of energy, and therefore would be best in places like grocery stores or malls (Cushman, 2016).

Strengths: Energy-production flooring can be made at a low-cost using wood wastes and provides a renewable energy source (Cushman, 2016).

Weaknesses: Relatively new idea with very little supporting documentation (Yao et al., 2016). Appears to still be in the novelty stages.

Opportunities: The market for this product is in its very early stages, which can potentially be capitalized on with a primary producer of energy-production flooring present in the region.

Threats: No case studies to date to support the feasibility of this product.

Considerations for Northwest BC: Northwest BC does not have a large number of facilities where high foot traffic exists to the extent that could utilize energy production flooring. However, there are some facilities, such as the local colleges and university branches, and some medium-sized malls. These locations could potentially benefit from this product. However, it is expected that a large amount of the product would be exported out of the region. Because the product is still so new, it would likely need to be sold at competitive prices to traditional flooring in order to gain momentum in the market.

Log Homes

Info: Log home building enterprises typically employ around 4-10 people, but can employ up to 20 or more people depending on size (Westcoast CED Consulting Ltd., 2012). Log home businesses can range from small home-based operations to large scale enterprises like Pioneer Log Homes of Williams Lake. A profit margin for new construction is around 20% (BiggerPockets, 2014). Log home buildings may replace some unsustainable materials when compared to alternative construction options, but log homes often also require logs from old growth forests.

Strengths: Log homes are superior to standard wood-framed houses in that they require less alternative materials that may have reduced strength, visual, and environmental characteristics. These materials may include drywall, insulation, siding, framing, etc. Log homes are considered a high value home.

Weaknesses: Log homes can only utilize high-quality solid logs of significant size, which typically puts demand on old growth forests. The logs required for log homes must have a very low moisture content (Westcoast CED Consulting Ltd., 2012). Unlike standard wood-framed houses, log homes require relatively more maintenance. The exterior surfaces need to be re-varnished regularly, and shifting logs require caulking or other treatment to new cracks.

Opportunities: Many softwood species can be utilized for log homes, and there is an increasing demand for housing in the region as new industrial projects develop. If second growth logs can be sufficient for log home building, this may be a marketing opportunity to increase demand.

Threats: Two log home builders in the region are Lussier Log Homes in Terrace (Naturally:wood, n.d.) and Driftwood Creek Log Homes in Smithers (Driftwood Creek Log Homes, n.d.).

Considerations for Northwest BC: The market for log homes usually depends on the volume of rural housing in the region, since log homes are most often built outside of urban centers. Northwest BC has a large proportion of residents living rurally or sub-rurally (rural subdivisions), which suggests a high proportion of log home owners. Visual assessment confirms the favorability and high proportion of log homes in the region. New builds are increasing in frequency in the region as new industrial projects develop, and as a result there may be increased demand for log homes in the region. One potential challenge for a log building company in the region may be the competition for local logs with Asian markets, to which most saw logs are currently exported.

Shakes and Shingles

Info: Shakes and shingles are slabs of solid wood used in roofing and siding (BC Shake and Shingle Association, 2013). Shakes are typically thicker and more assorted in shape than shingles (BC Shake and Shingle Association, 2013). Capital investment is around $80,000 (converted to 2019 CAD), and profit margin was 4% in 1986 but has been improving (United States International Trade Commission, 1986). Further research is required to find a more current estimate of profit margins. Shakes and Shingles can be used as a replacement for petroleum roofing materials, but puts increased demand on old growth stands (BC Shake and Shingle Association, 2013).

Strengths: Cedar shakes and shingles are highly durable, withstanding impacts and high winds far better than asphalt roofing (BC Shake and Shingle Association, 2013). Cedar shakes can last over 30 years, whereas the lifespan on asphalt roofing usually averages around 15 years (BC Shake and Shingle Association, 2013). The shake and shingle industry has been around for a long time, and production techniques remain fairly consistent (BC Shake and Shingle Association, 2013).

Weaknesses: Wood shakes and shingles are more expensive than asphalt roofing (BC Shake and Shingle Association, 2013). Wood roofing is more prone to algae growth in humid environments (BC Shake and Shingle Association, 2013). Wood roofing requires higher maintenance than asphalt roofing: leaves, debris and other litter must be regularly cleared to allow the wood to breathe (BC Shake and Shingle Association, 2013). The use of asphalt roofing has far surpassed wood shingles in the last two decades because of its lower cost and (in some cases) better performance (BC Shake and Shingle Association, 2013). In addition, there is relatively little cedar supply in Northwest BC.

Opportunities: Cedar is a highly valued wood in construction for its durability and visual appeal.

Threats: US tariffs have caused serious cut backs to cedar shakes and shingles producers in BC and across Canada (Yang, 2018). Demand for shakes and shingles declined after 2009 and has not recovered (Gregory, McBeath, & Filipescu, 2018).

Considerations for Northwest BC: Copper Mountain Cedar Products Ltd, and Lake Drive Lumber in Terrace BC are two shakes and shingles producers in the northwest. The high demand for cedar for other products in Northwest BC, in addition to the current shakes and shingles operations in the region, may make it difficult to maintain an adequate supply of cedar for a new shakes and shingles operation.

Tonewood

Info: Tonewood are sheets of wood, usually spruce, that hold excellent sound qualities and are used for making instruments such as guitars (Andrews, n.d.). Spruce is the ideal species because of its high stiffness-to-weight ratio (Andrews, n.d.). In particular, Sitka spruce is highly sought after because of its availability and tone (Bourgeois, 1994). Cedar is also a top species for tonewood (Bourgeois, 1994). A tonewood business can employ up to 22 people, and may use chainsaw, axe, trailer, bandsaw, and kiln. Capital expenses are therefore relatively low, but profit margins have the potential to be quite high (Ecotrust, 2002). Tonewoods use only the highest quality wood, which can be worth up to $113,000 per mbf (Ecotrust, 2002). A tonewood business can produce up to 2,000 units per day, or 40,000 guitar tops per month, depending on facility capacity (Ecotrust, 2002).

Strengths: BC's Sitka Spruce is highly sought after as tonewood (Dispa, 2018).

Weaknesses: Spruce is present here but the quality of log needed for tonewood is very specific, therefore finding adequate material for a tonewood facility can be a challenge.

Opportunities: Although there is not a large amount of old growth spruce in the region, a tonewood company needs only a small amount of lumber for a large number of products. In addition, marketing of local artisans and promotion of the unique forests of Northwest BC can be used as a selling point. Historically, the region's Sitka spruce was used to produce a patented style of tonewood that was highly sought-after.

Threats: There is one tonewood producer in Terrace, High Mountain Tonewoods (Andrews, n.d.). There is a concern for old growth Sitka forests (Clowes, Kaldjian, & Barber, 2016). There are a number of other producers worldwide. There is not a lot of accessible information to be found online for the feasibility or techno-economic details of a tonewood venture, and more research should be done to confirm the statements here.

Considerations for Northwest BC: Generally, one business can provide enough tonewood for a large number of consumers. Since there is already a well-established tonewood company in Terrace, BC, there is reduced feasibility of a second tonewood company in the region being successful. However, High Mountain Tonewoods appears to be considerably successful, and this is a good indicator that a tonewood venture, barring no other competitors, is a suitable business for Northwest BC.

High Density Fiberboard (Hardboard)

Info: Hardboard, or high-density fiberboard is a non-structural engineered wood product that is produced from exploded wood fibers that have been highly compressed under high temperature and pressure. Unlike other fiberboards, the temperature and pressure are much higher and are sufficient to bond the fibers without resin or adhesives, although resins are sometimes added depending on the production process (U.S. Environmental Protection Agency, 2002*a*). Hardboards can be tempered using linseed oil or alternatives to increase the hardboard waterproofing, impact resistance, hardness, and rigidity (U.S. Environmental Protection Agency, 2002*a*). For a 200 million ft^2 capacity plant, capital investment is estimated to be around $232 million (converted to 2019 CAD), with profit margin between 5% and 25%, and average employment rates between 100 and 300 people (U.S. Environmental Protection Agency, 1979). Pine, fir, spruce, aspen, birch, poplar, and alder are commonly used species (U.S. Environmental Protection Agency, 2002*a*).

Strengths: Hardboards can be resin free, eliminating the worry of formaldehyde emissions (Ampersand, n.d.). Hardboard production can also utilize sawmill chips and sawdust waste (U.S. Environmental Protection Agency, 2002*a*).

Weaknesses: Hardboard is very susceptible to water degradation, although this can be minimized through tempering (Ampersand, n.d.). Hardboards have a final moisture content between 2% and 9% (González-García, 2009). CO_2 and formaldehyde emissions (when using resins) are considered health and environmental concerns (González-García, 2009).

Opportunities: No hardboard manufacturers could be identified in western Canada.

Threats: Since the expiry of the latest softwood lumber agreement, Canadian softwood exporters have been facing high countervailing and anti-dumping duties, on an average of 20% (Global Affairs Canada, 2019).

Considerations for Northwest BC: There is a limited availability of appropriate species for hardboard in Northwest BC. There appear to be no producers of hardboard in the region, which may be an opportunity for a business startup with limited competition. Hardboard demand in Canada has been steadily increasing, although it has not recovered to its high in 2012. Hardboard production in Canada also indicates a “skyrocketing growth” (Indexbox, 2015). Exports of hardboard from Canada appear to be decreasing (Indexbox, 2015). US is the primary receiver of Canada exports, but exports to the US have been steadily declining since 2007 (Indexbox, 2015). It could be expected that exports to the US will further decrease with the latest duties imposed on Canada softwood exports to the US. As in the past, BC has generally suffered the greatest from the US duties, and this trend is likely to continue. Locally, housing and construction rates have been increasing since new industrial projects have been developing in Northwest BC, and this increase may correlate with an increase in hardboard demand. Further research should be done to confirm if there are other suppliers in Northwest BC.

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