Forest Products Association of Canada
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Association des produits forestiers du Canada
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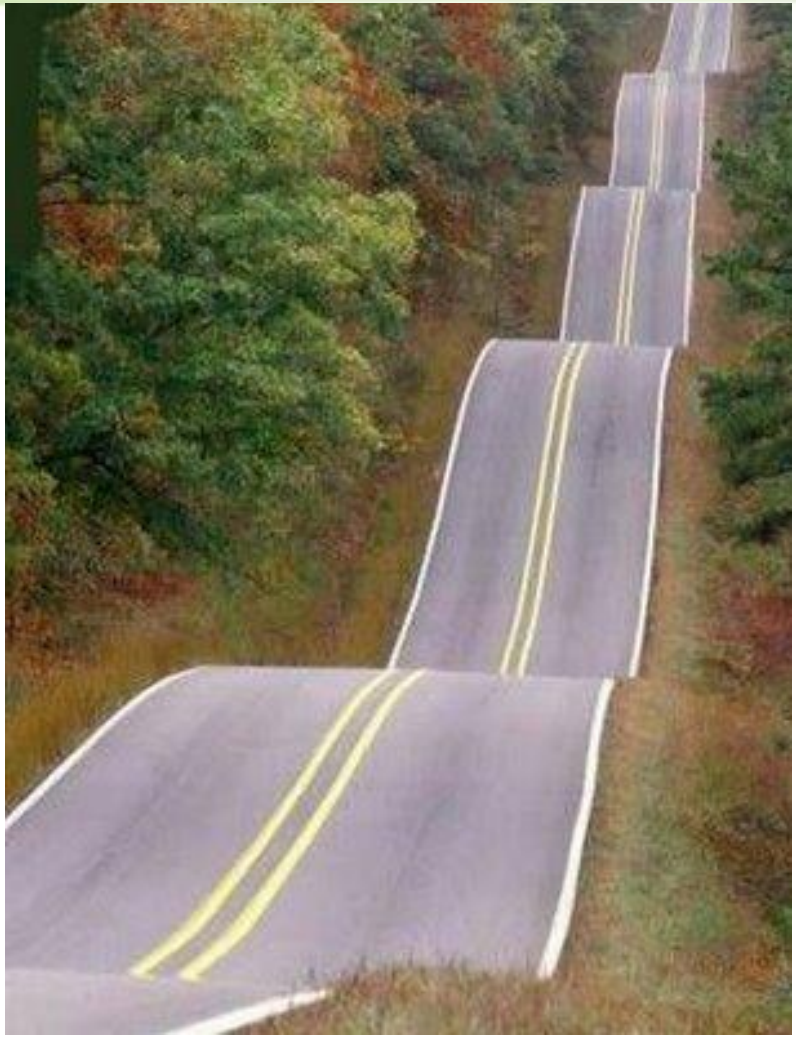
FPInnovations

Creating forest sector solutions

THE WAY FORWARD

Biopathways Phase II

The Way Forward



Source: myamazingfact.blogspot.com

Objectives of Bio-pathways Project

- Support the industry in identifying possible transformational strategies
- Create ‘sunrise’ industry vision
- Encourage federal and provincial policy makers to support transformation
- Provide analytics to investors and partners of potential opportunities

What Did We Learn In Phase I?

- Economics of different bio-product technologies vary widely depending on site conditions and mill configurations, location, scale.

- Some of the bio-product technologies have much better returns than conventional production
  - ROCE of 20%+
- The ‘best’ approach integrates conventional and new technologies (for economics and jobs)

- The most promising future involves sawmills and engineered wood products together with bio-refineries for production of pulp/bio-energy/bio-chemicals

PHASE II: OVERVIEW

Phase II: What Was Done

- Core teams of researchers assigned to:
  - Synthesize available information for biomaterials; biochemicals and bioenergy markets
  - Consider business model modifications
  - Validate Phase I results with scenarios
  - Grow the analysis to cover more technologies and carbon footprint
  - Develop bio-pathways roadmaps for chemical, mechanical pulps and lumber
- Engaged broad range of stakeholders through three workshops to road test results along the way

Phase II Findings: General

- The Canadian forest sector is already producing a range of green and low carbon products
- There are great opportunities to increase this contribution to increase the value for the sector
- This will not replace the traditional forest industry, but will be an important supplement. Integrating production is crucial.
- There are many viable options for converting forest biomass to energy and chemicals
- Phase I results were validated and expanded

See Appendix for summary of bioenergy; biochemical and biomaterial findings

The Big Picture

GLOBAL MARKET POTENTIALS FOR DIFFERENT BIO-PRODUCTS FROM FOREST BIOMASS (Billion US$)

	2015	2020	2030
Bio-energy, bio-chemicals, fiber composites	505	776	1309
Conventional forest industrial products	495	512	545

References:

Heat, power, bio-fuels, bio-gas: FAO, 2010 and IIASA, 2010

Green chemical products: NRCAN and Industry Canada, 2010, and Consulting Reports, 2008-2010

Building with wood and living with wood: FPInnovations 2010, and Nilsson & Goodison, 2010

Conventional forest products: FAO, 2008, and Nilsson & Goodison, 2010

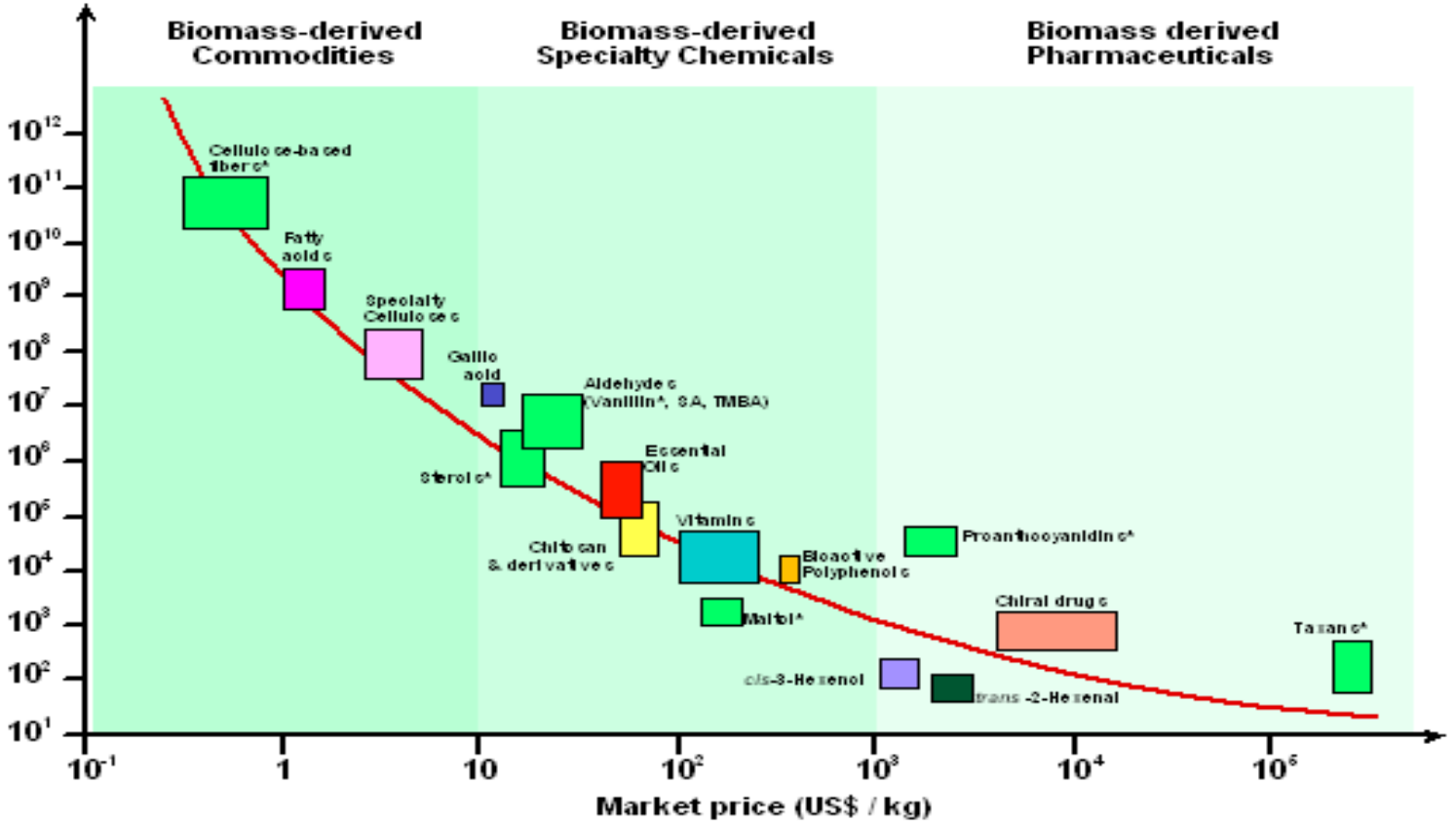
Gross Market Opportunities

PRODUCTS	GLOBAL MARKET POTENTIAL, 2015 (US$ billion)	CAGR (%), 2009-2015 (approximate)
Green chemicals	**62.3**	**5.3**
Alcohols	**62.0**	**5.3**
Bio-plastic and plastic resins	**3.6**	**23.7**
Platform chemicals	**4.0**	**12.6**
Wood fibre composites	**35.0**	**10.0**
Glass fibre market	**8.4**	**6.3***
Carbon fibre	**18.6**	**9.5**
Revenues, Canadian forests product industry	**50.0**	**Neg. or 0-2**

References:
Markets and Markets. 2009. Global Renewable Chemicals Market.
The Freedonia Group. 2009. World Bioplastics. Industry Study 2548.
Lucintel. 2009. Global Glass fibre Market 2010-2015: Supply, Demand and Opportunity Analysis.
Acmite Market Intelligence. 2010. World Carbon fibre Composite Market.
* CAGR for 2010-2015

MARKET CHARACTERISTICS

Market Size / Price For Co-Products



- Big volumes – low values
- Low volumes – high values

adapted from Estaban Chornet, November 2005

Markets: Additional Findings

Overall: We can not afford to wait – opportunity may pass us by through aggressive actions of others

Bio-Fuels

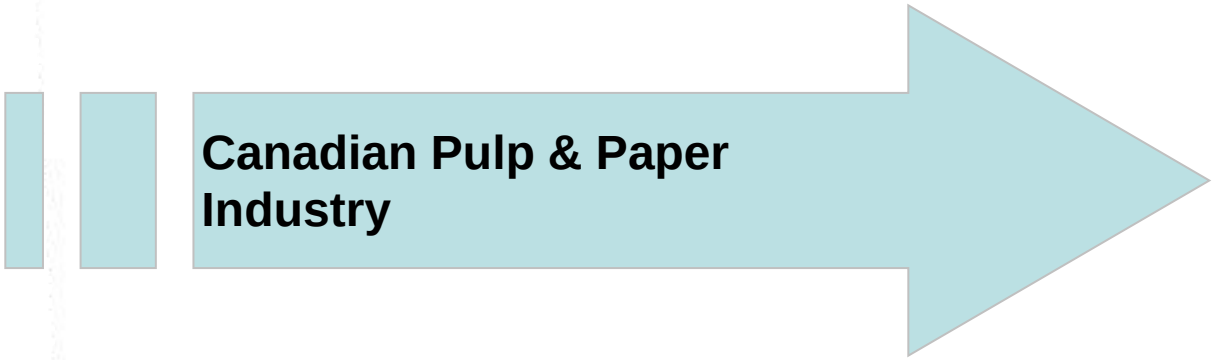
- The large-scale deployment of bio-fuels is expected to happen 2020-2030
- Political policies will play a key role in the size of the deployment

Bio-Chemicals

- Degree of hazard in petrochemicals is driving market toward green chemicals

Pulp and Paper Roadmaps

There are three primary paths forward for the Canadian Pulp and Paper Industry.



Advanced Textiles, Composites

Power / Heat

Refinery: Transportation Fuels, Chemicals

Wood Roadmaps

There are three primary paths forward for the Canadian Wood Products Industry.

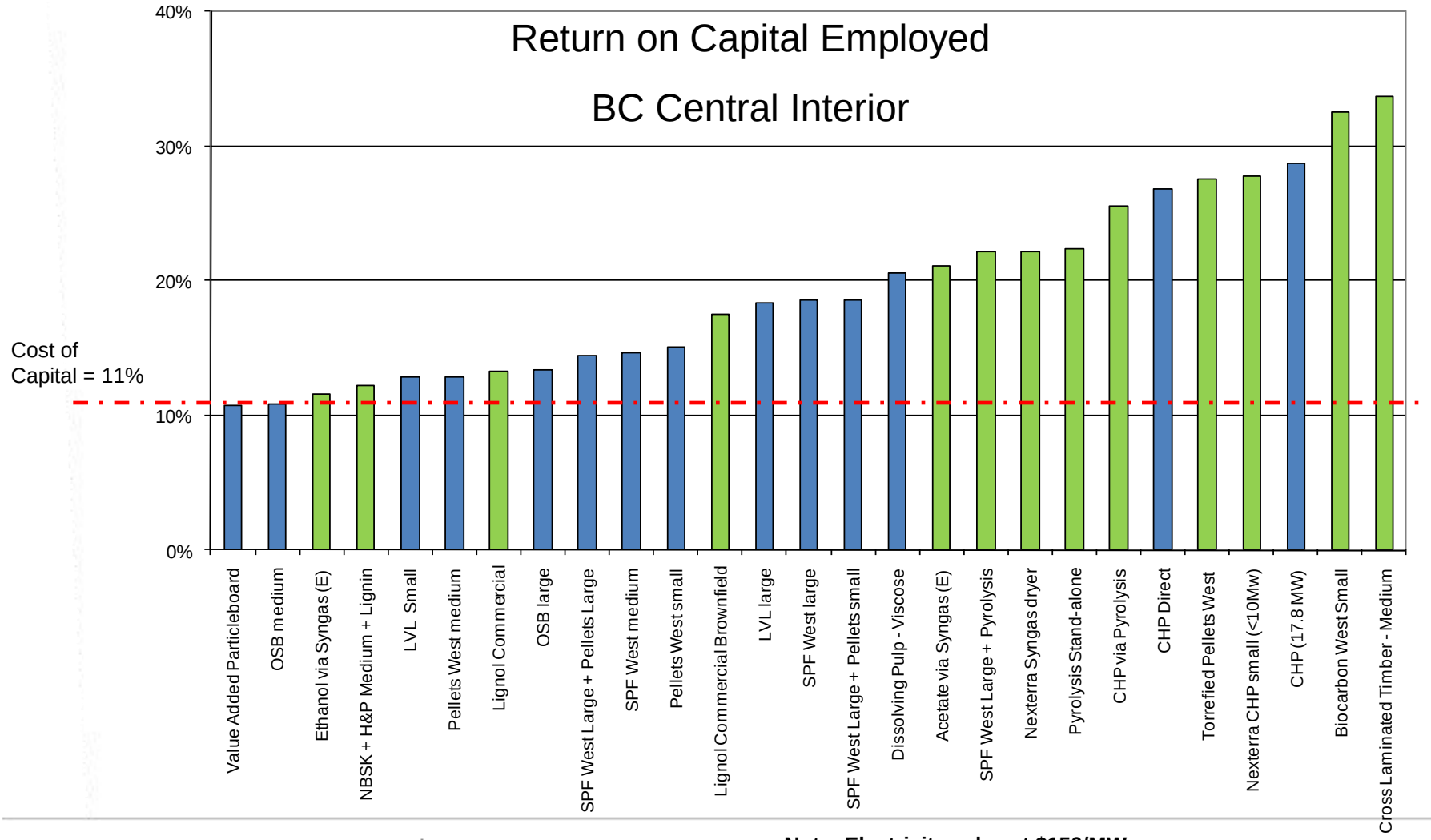
Building with Wood

Living with Wood

Transportation Fuels, Chemicals

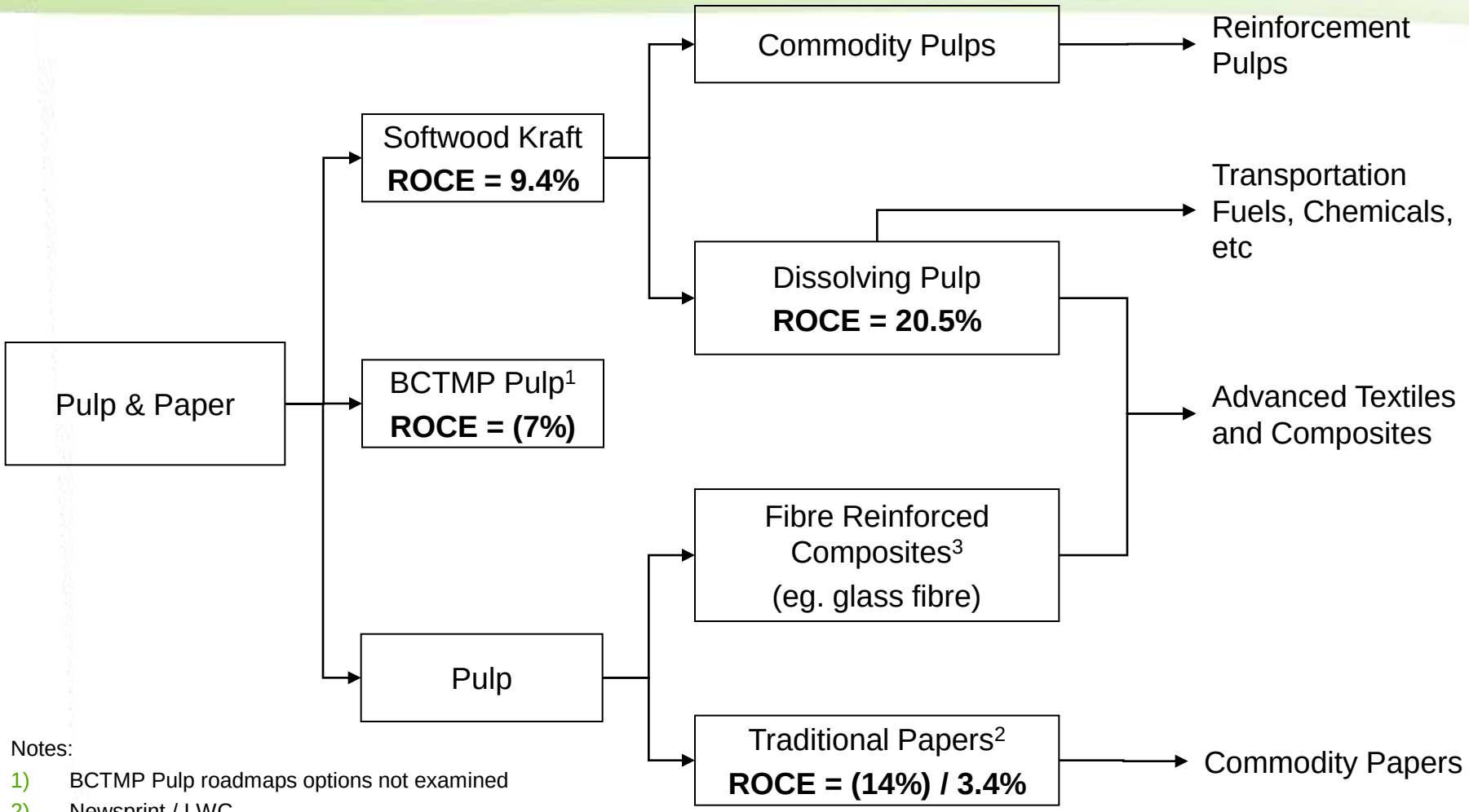
BIOPATHWAYS ROADMAPS
BC INTERIOR

Top Performing Technologies



Note: Electricity sales at $150/MW

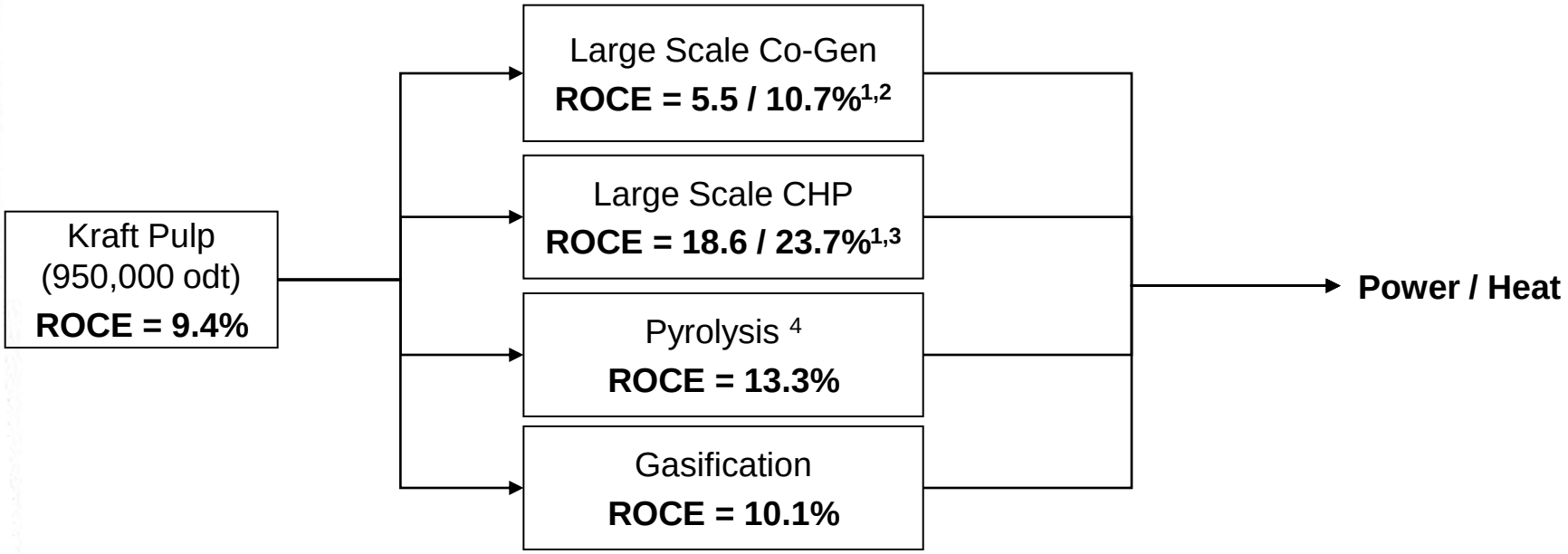
Pulp and Paper Roadmap – Option 1 Advanced Textiles / Composites BC Central Interior



Notes:

1) BCTMP Pulp roadmaps options not examined
2) Newsprint / LWC
3) Not examined by Bio Pathways

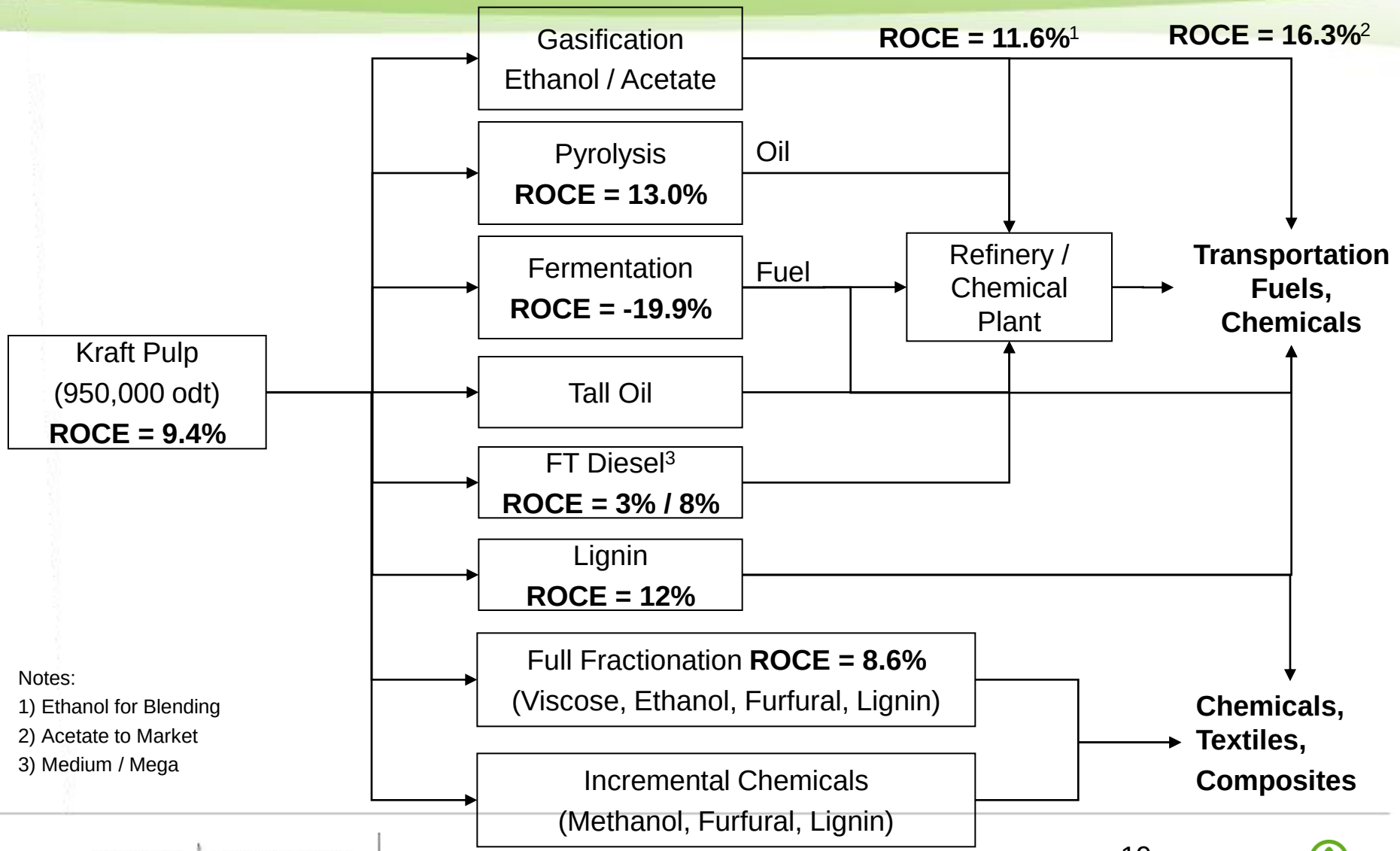
Pulp and Paper Roadmap – Option 2 Power / Heat Pathways BC Central Interior



Notes:

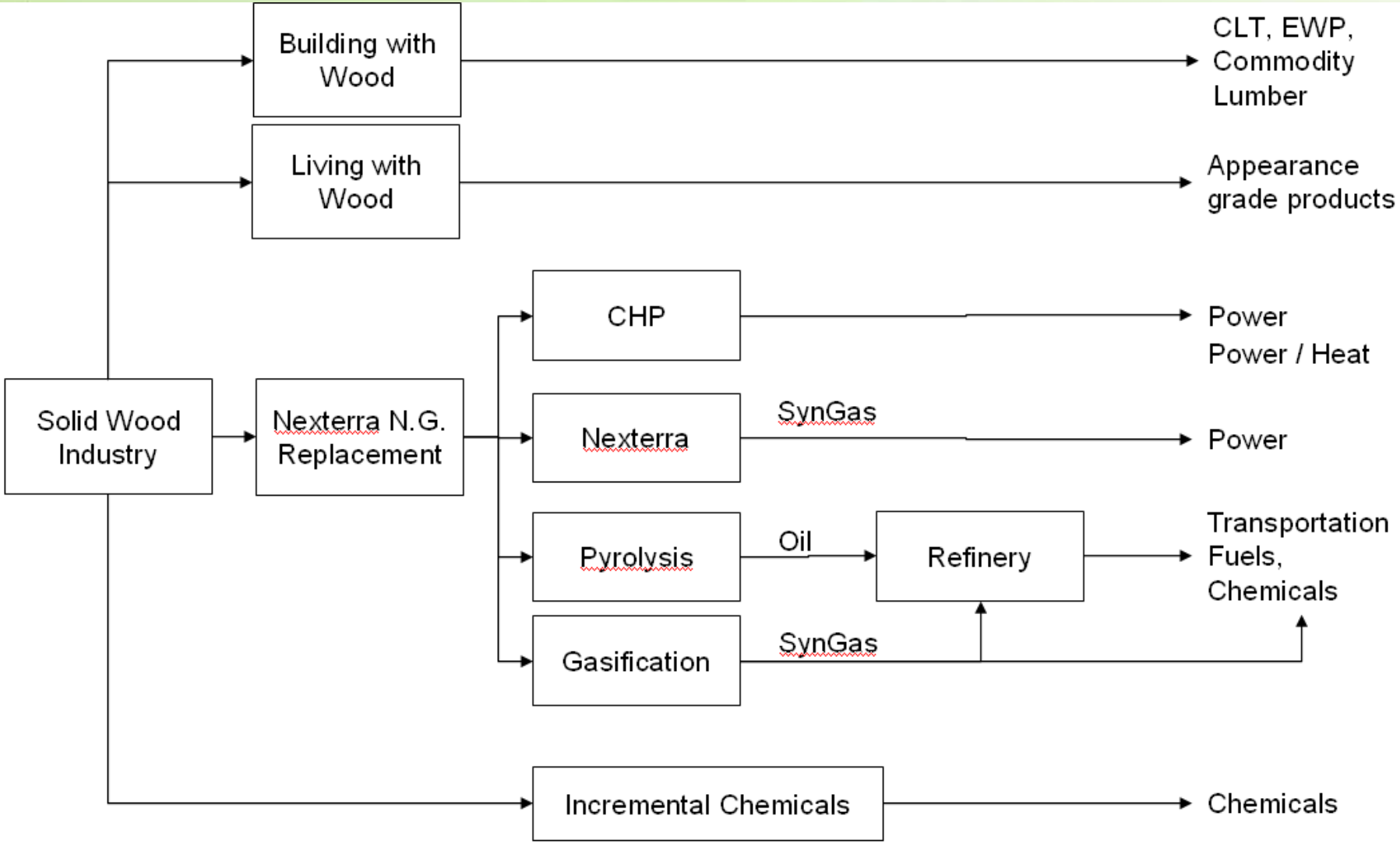
1) First ROCE is based on Forest Residues / Second is based on Hog Fuel
2) At $150/MW then ROCE = 12.4%
3) At $150/MW then ROCE = 22.8%
4) Draft

Pulp and Paper Roadmap – Option 3 Refinery Pathways BC Central Interior



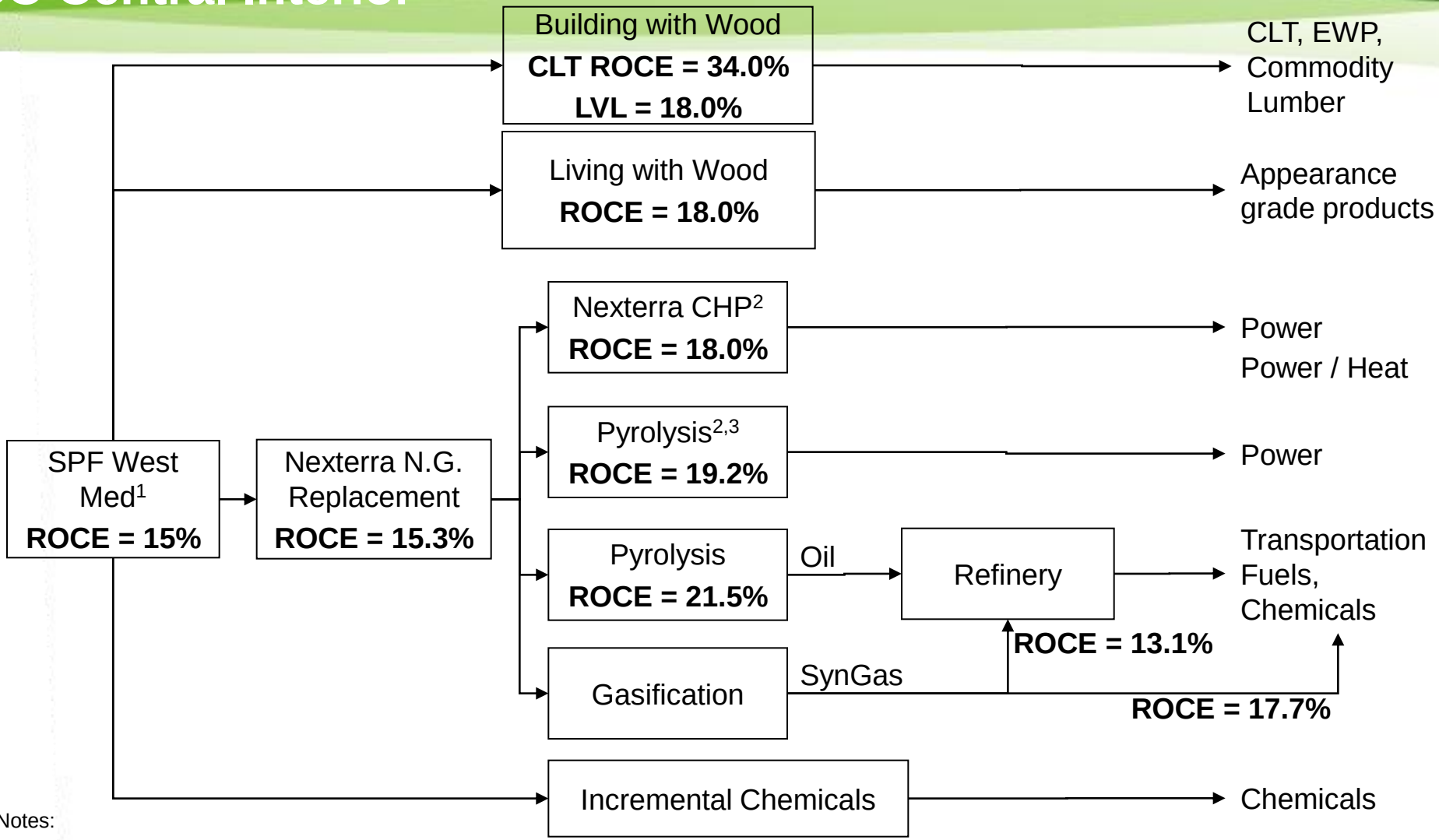
Notes:
1) Ethanol for Blending
2) Acetate to Market
3) Medium / Mega

Building Materials - Wood Roadmap



Fermentation not included due to scale needed.

Building Materials - Wood Roadmap with ROCE Results
BC Central Interior



Notes:

1) Based on 250 mmfbm facility, hog fuel imported to match scales.

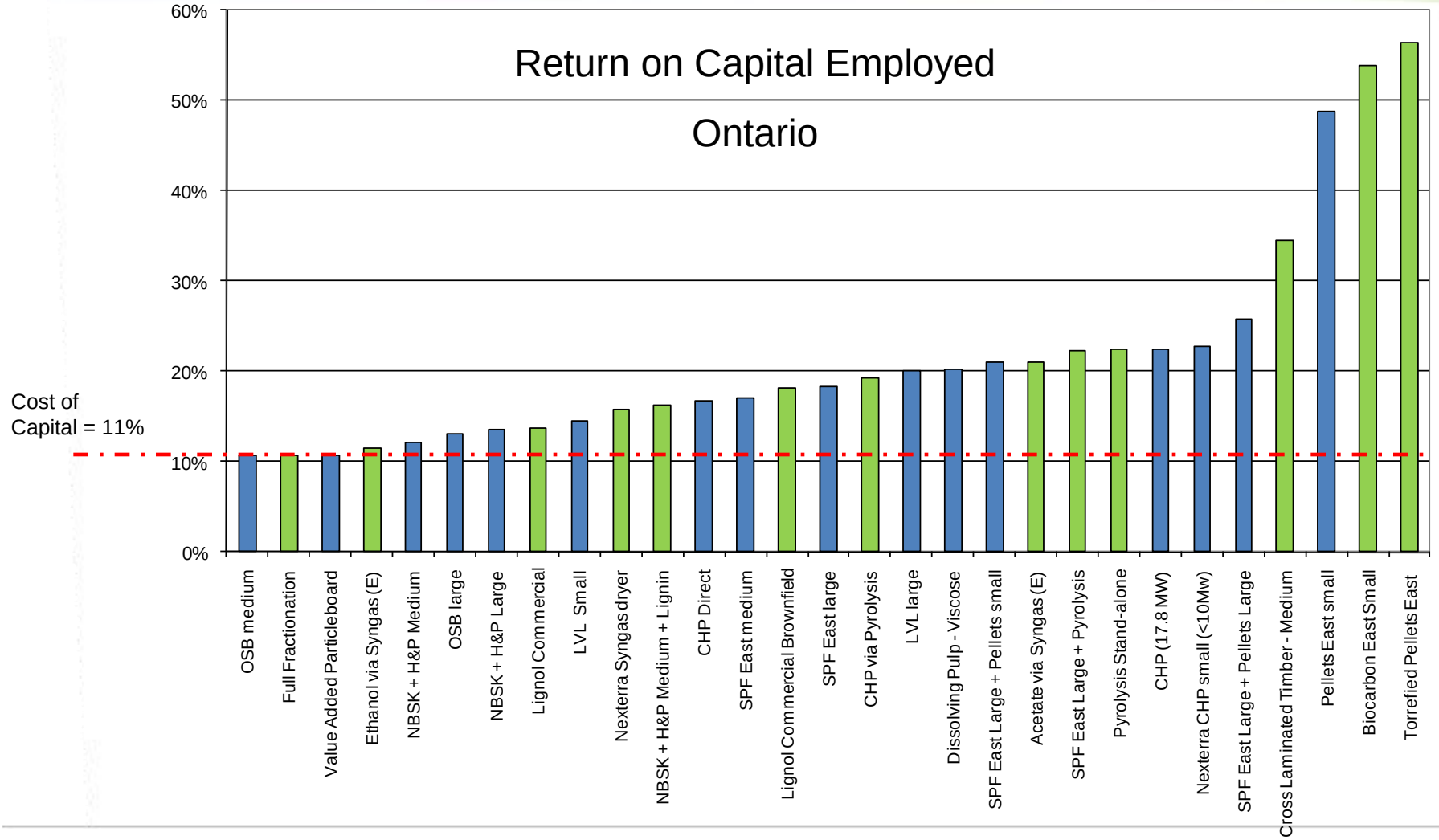
2) Based on $150/MW

3) Draft Results

Bio Pathways Roadmaps

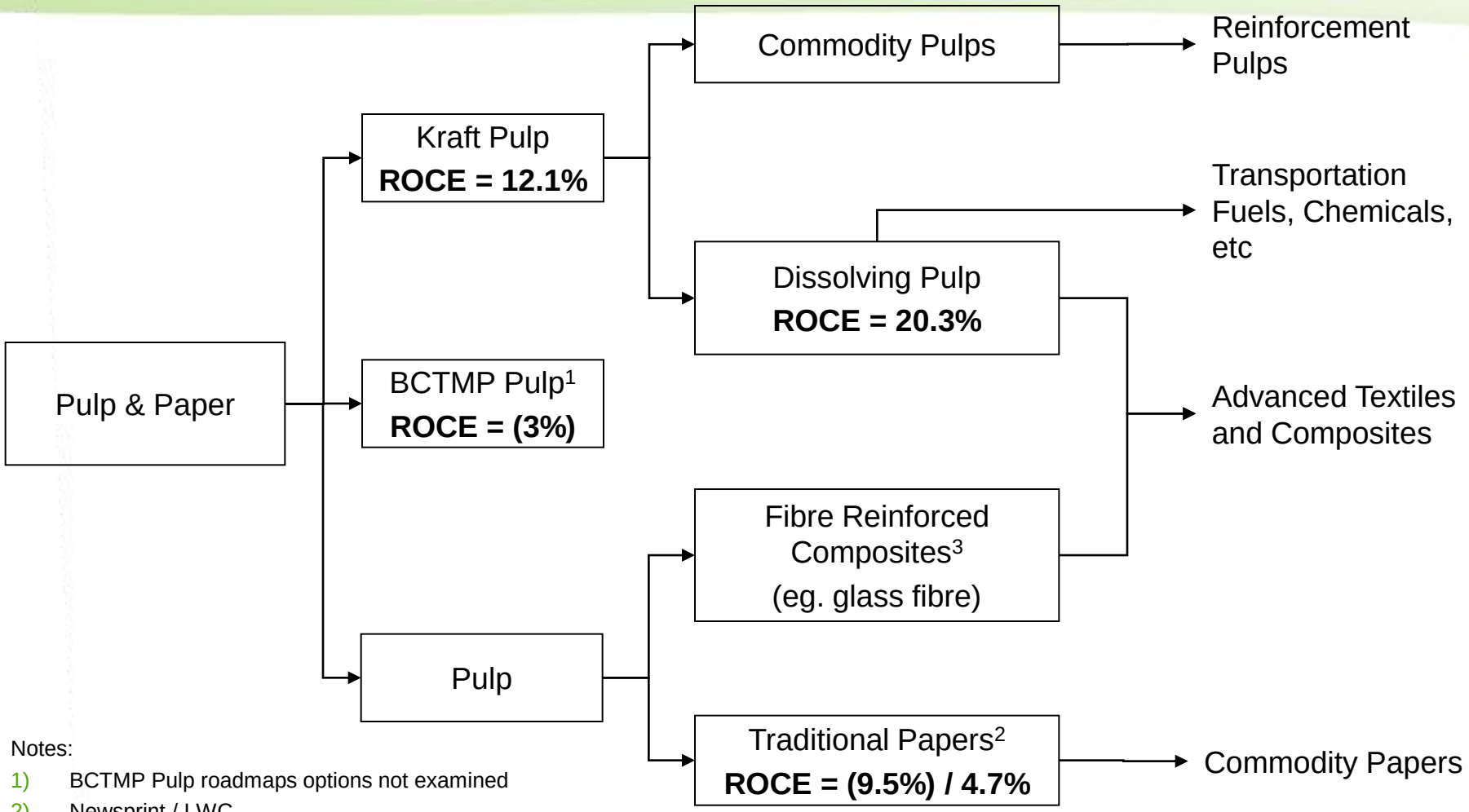
Results for Ontario

Top Performing Technologies



Note: Contains Feed-In-Tariff estimate for pellets.

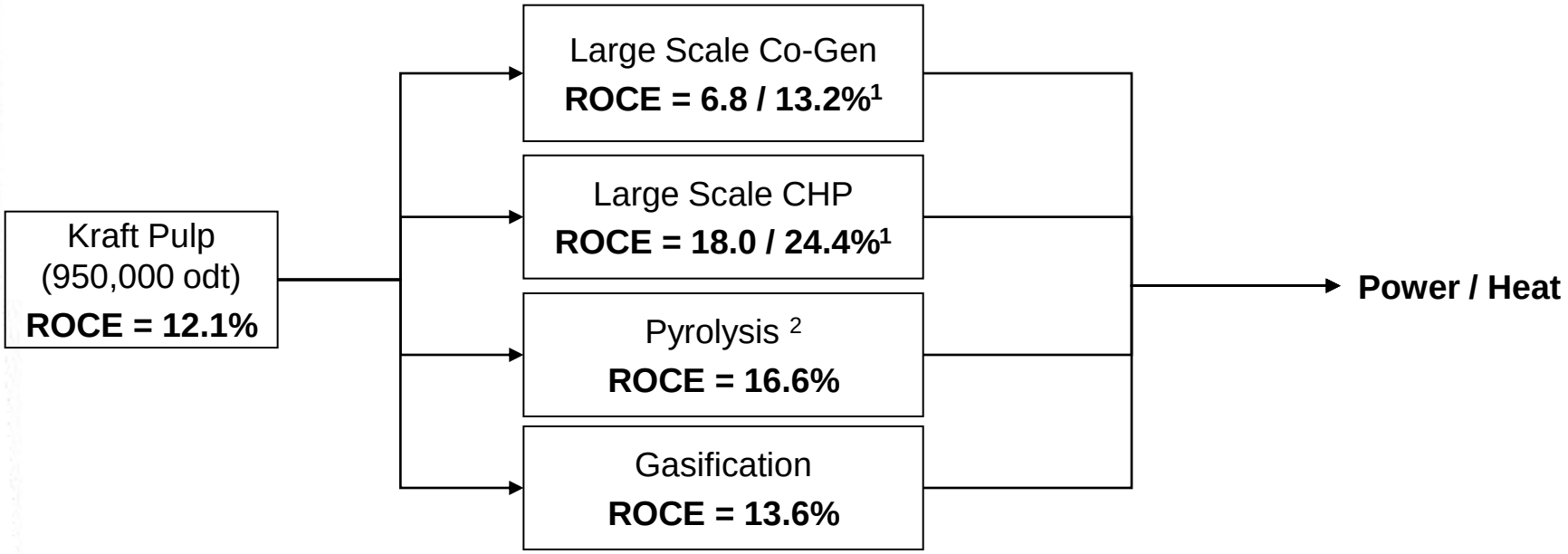
Pulp and Paper Roadmap – Option 1 Advanced Textiles / Composites Ontario



Notes:

1) BCTMP Pulp roadmaps options not examined
2) Newsprint / LWC
3) Not examined by Bio Pathways

Pulp and Paper Roadmap – Option 2 Power / Heat Pathways Ontario

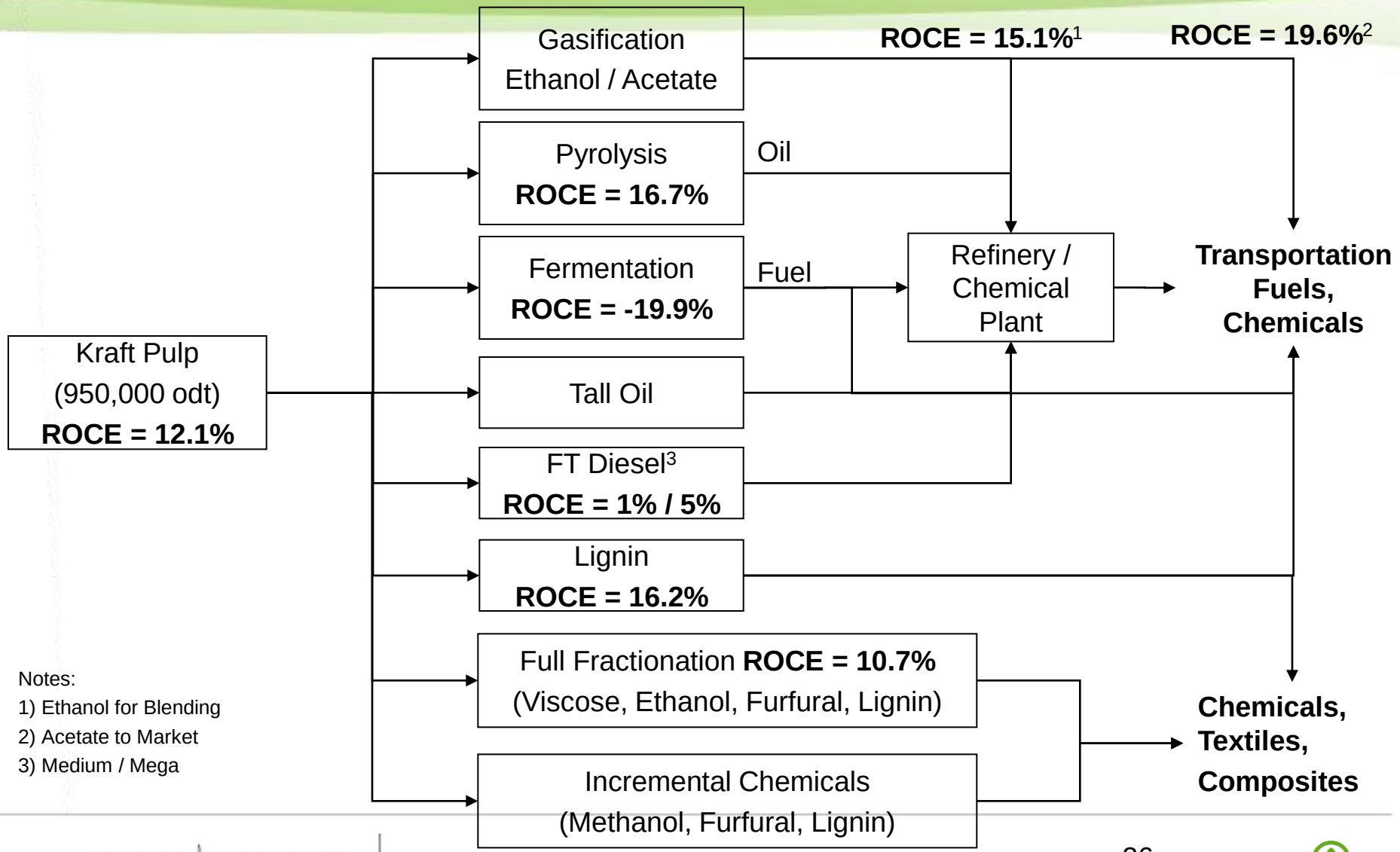


Notes:

1) First ROCE is based on Forest Residues / Second is based on Hog Fuel

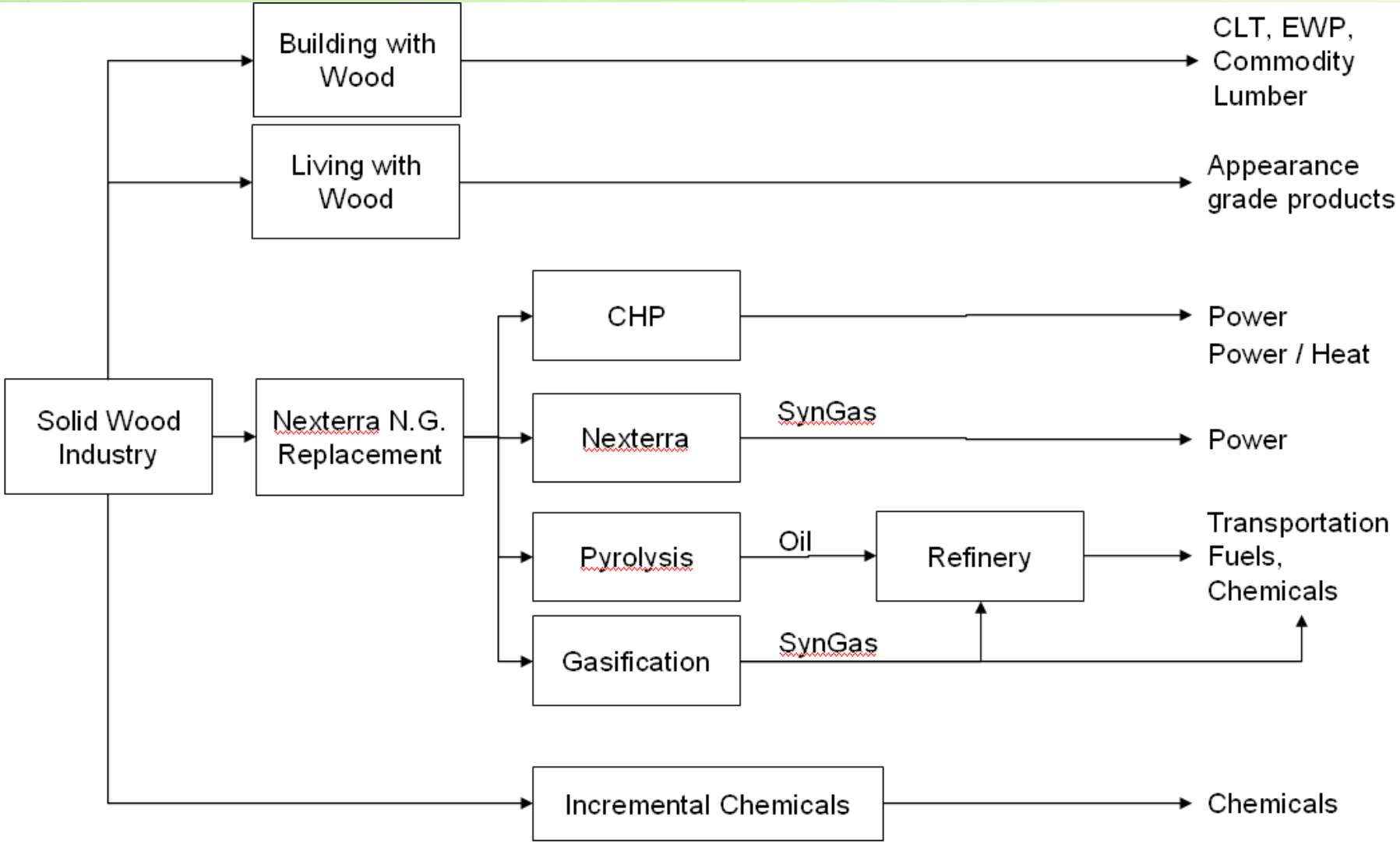
2) Draft

Pulp and Paper Roadmap – Option 3 Refinery Pathways Ontario



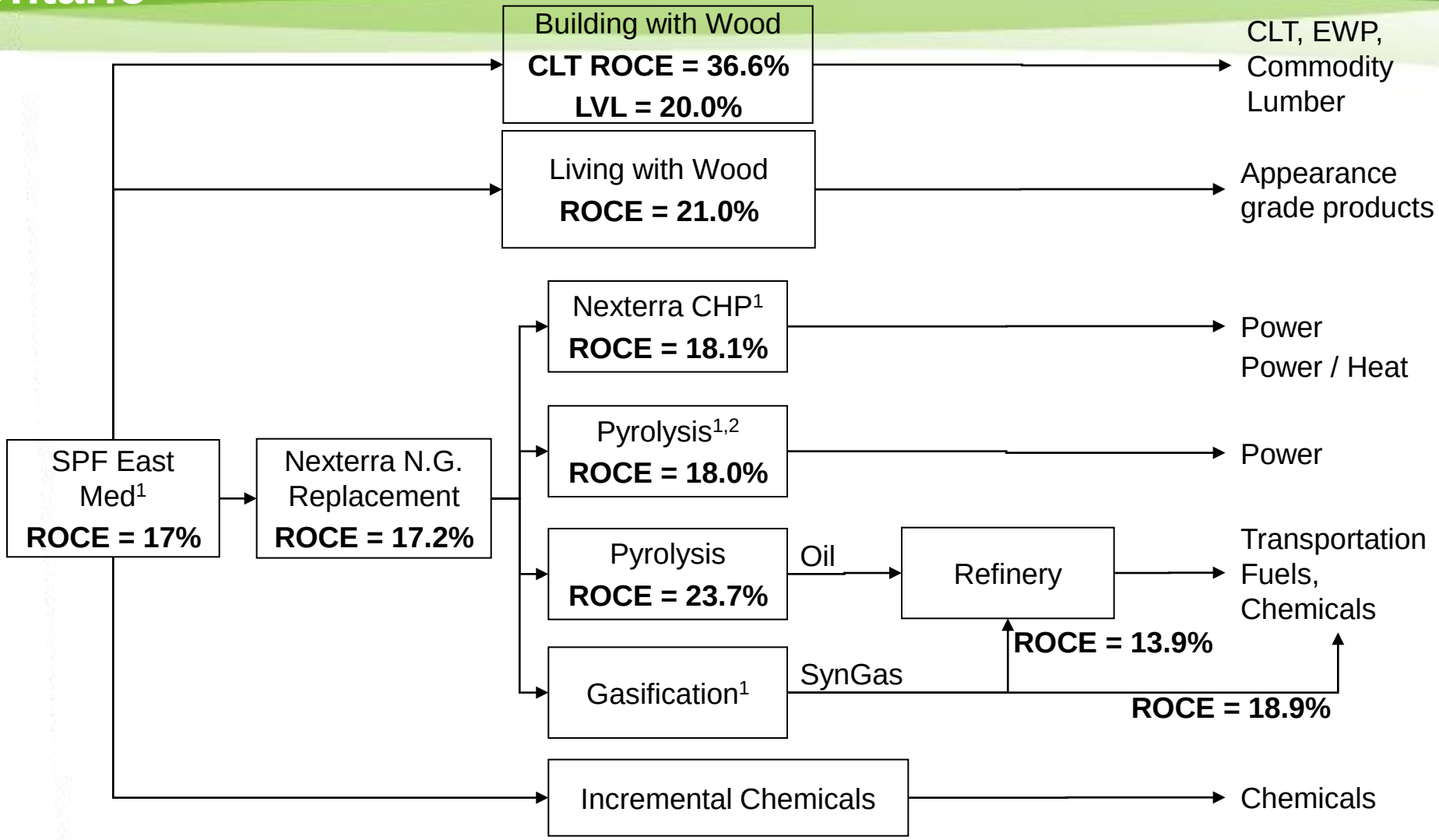
Notes:
1) Ethanol for Blending
2) Acetate to Market
3) Medium / Mega

Building Materials - Wood Roadmap



Fermentation not included due to scale needed.

Building Materials - Wood Roadmap with ROCE Results Ontario



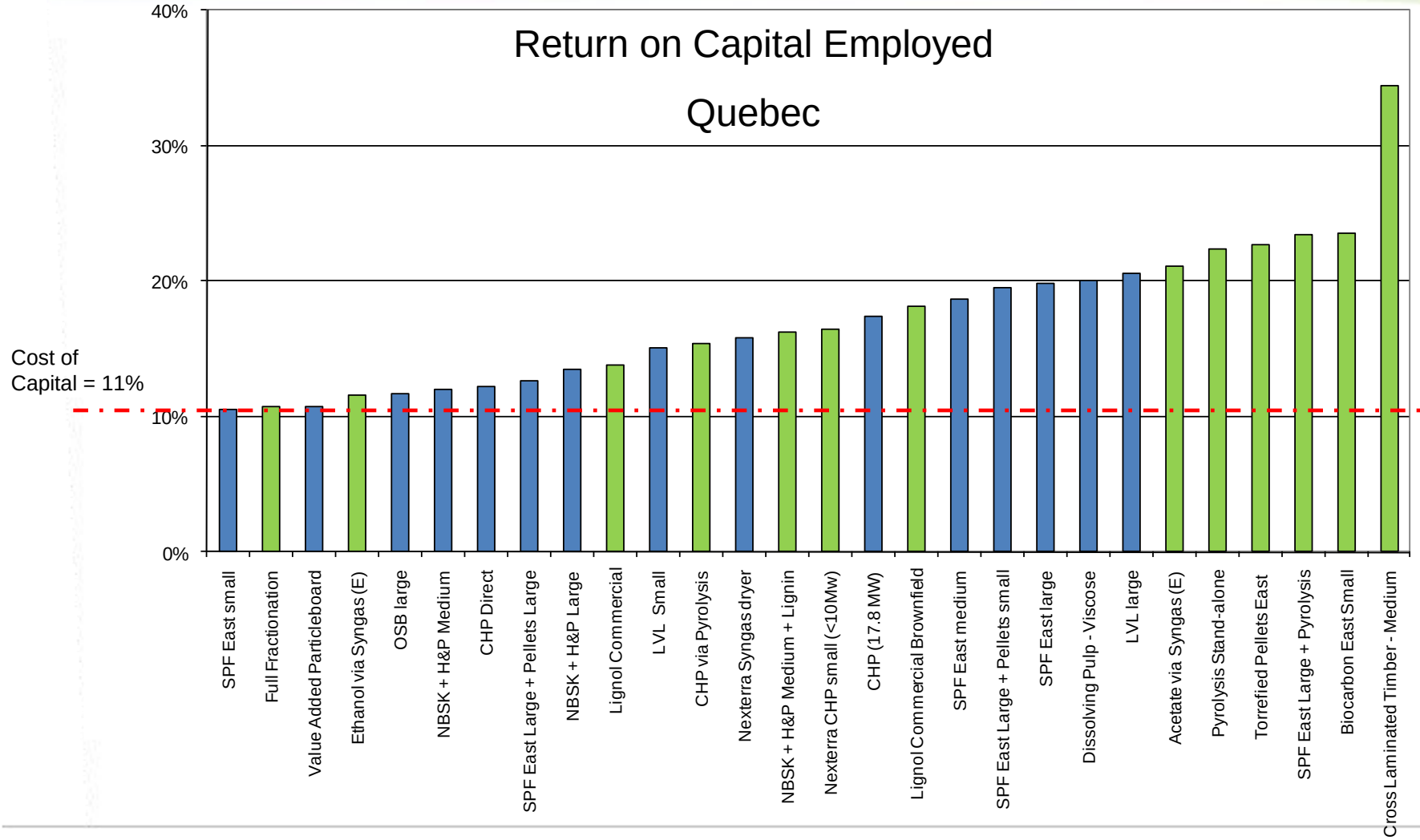
Notes:

1) Based on 250 mmfbm facility, hog fuel imported to match scales.
2) Draft Results

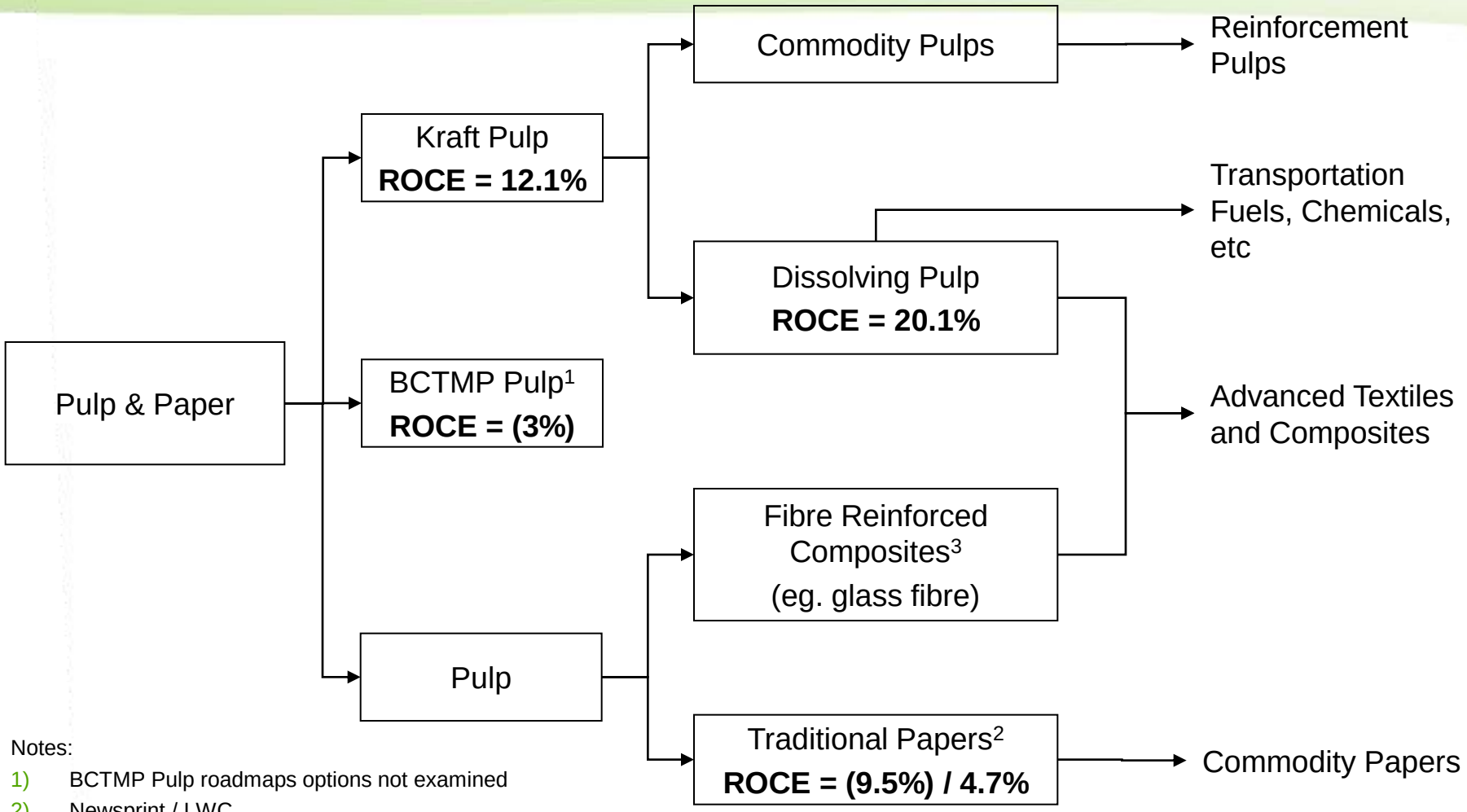
Bio Pathways Roadmaps

Results for Quebec

Top Performing Technologies



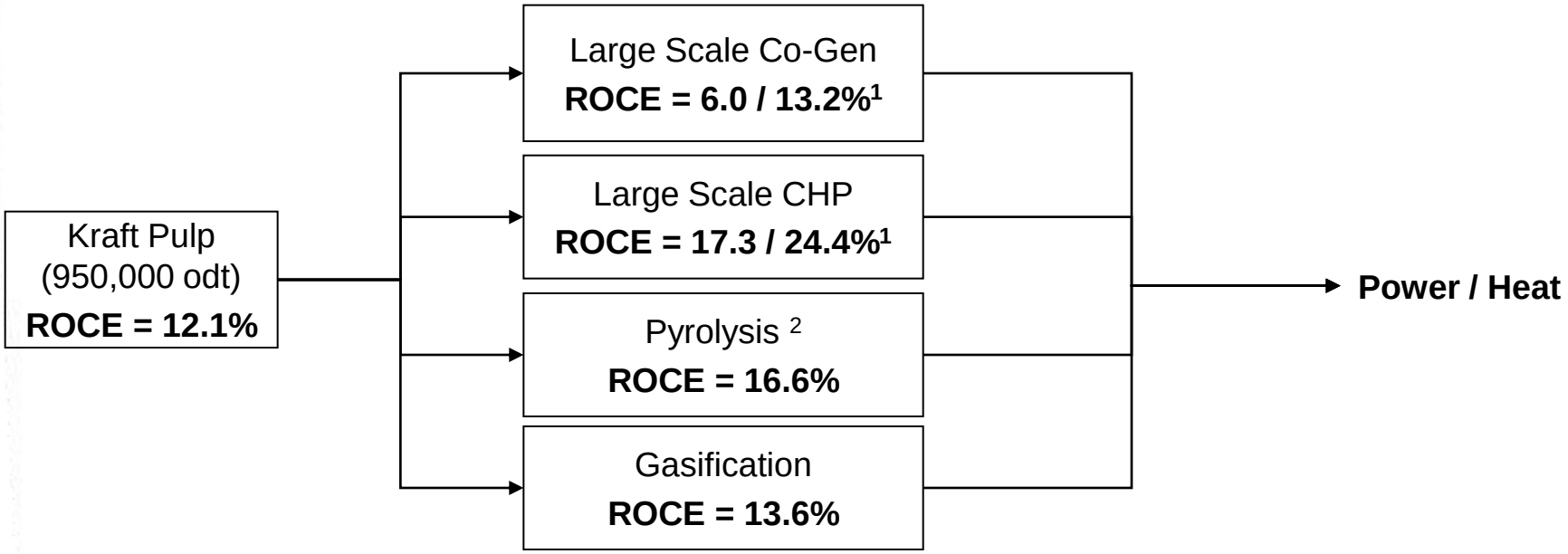
Pulp and Paper Roadmap – Option 1 Advanced Textiles / Composites Quebec



Notes:

1) BCTMP Pulp roadmaps options not examined
2) Newsprint / LWC
3) Not examined by Bio Pathways

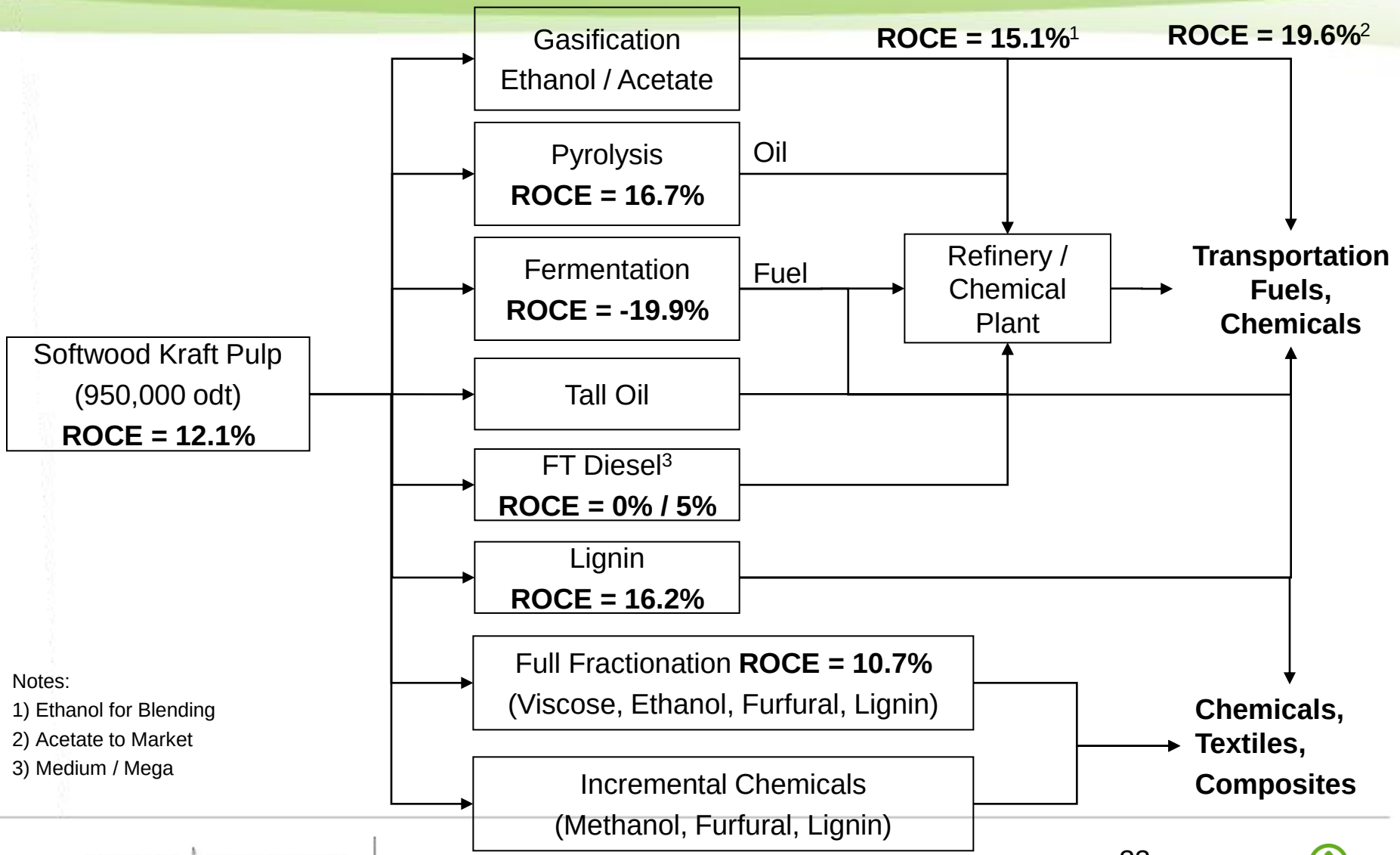
Pulp and Paper Roadmap – Option 2 Power / Heat Pathways Quebec



Notes:

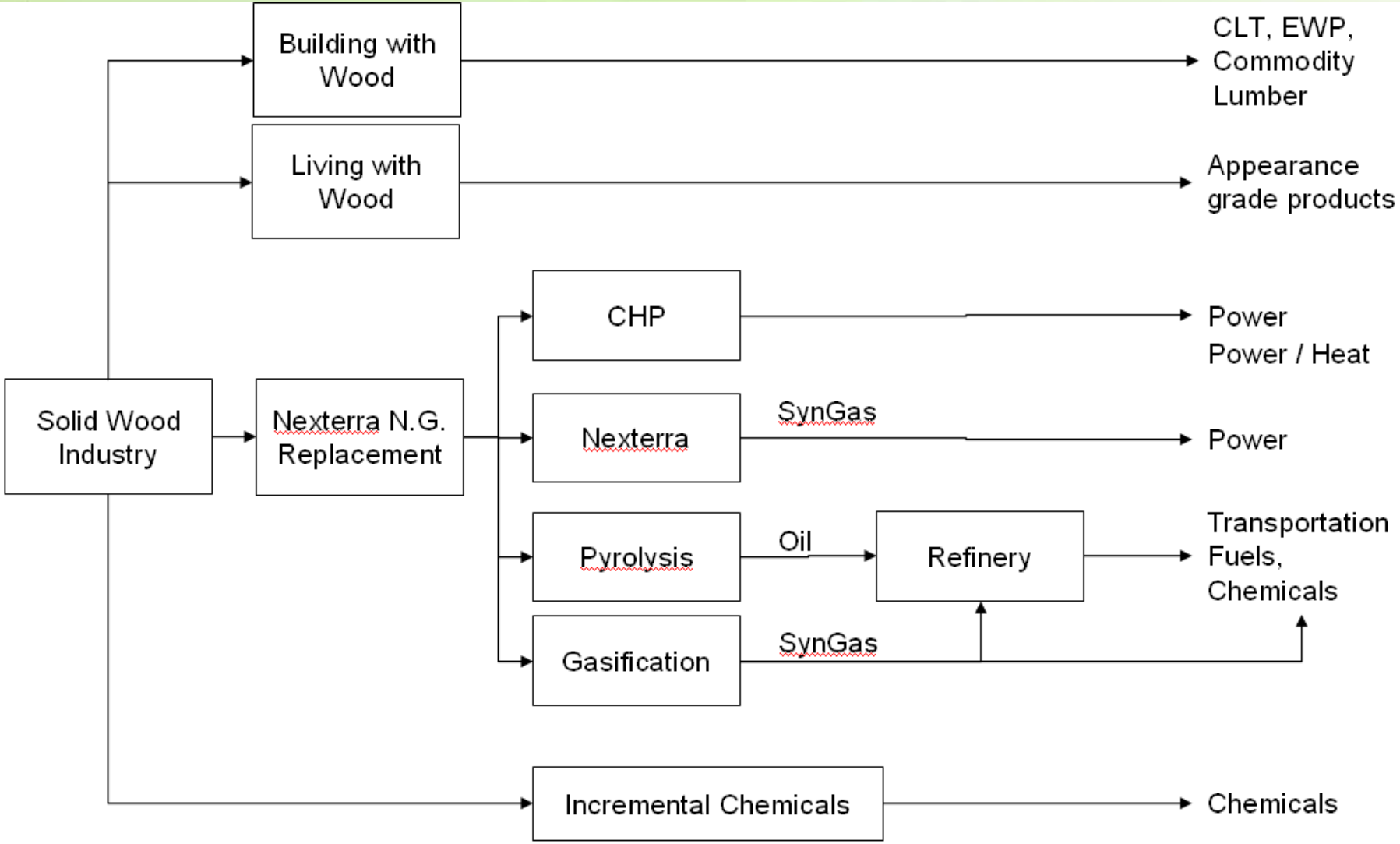
1) First ROCE is based on Forest Residues / Second is based on Hog Fuel
2) Draft

Pulp and Paper Roadmap – Option 3 Refinery Pathways Quebec



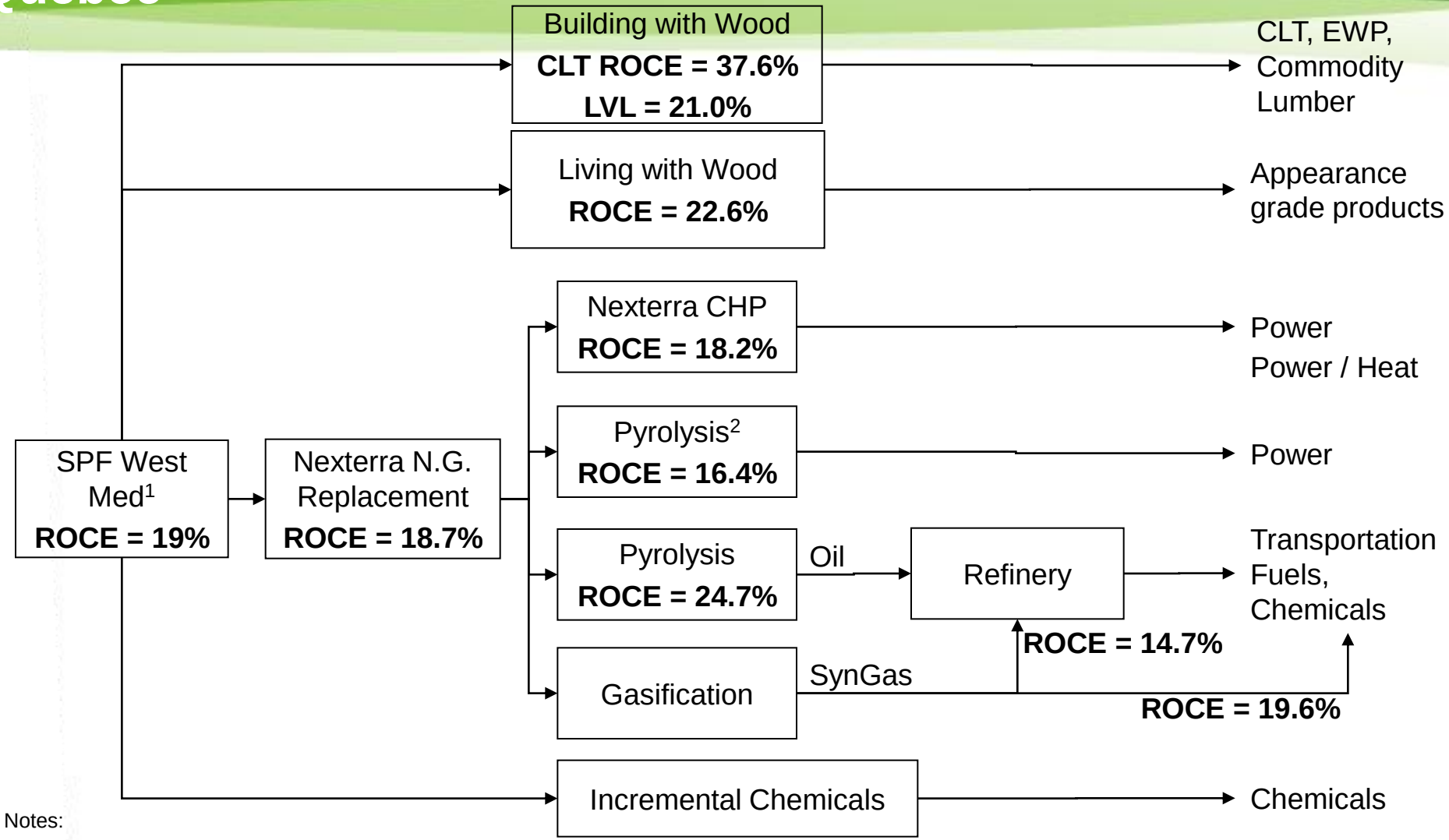
Notes:
1) Ethanol for Blending
2) Acetate to Market
3) Medium / Mega

Building Materials - Wood Roadmap



Fermentation not included due to scale needed.

Building Materials - Wood Roadmap with ROCE Results Quebec



Notes:

1) Based on 250 mmfbm facility, hog fuel imported to match scales.

2) Draft Results

Provincial Comparisons

Pulp and Paper Pathways

Pathway	BC Central Interior	Ontario	Quebec
Softwood Kraft	9.4	12.1	12.1
BC TMP	(7)	(3)	(3)
Dissolving Pulp	20.5	20.3	20.1
LWC	3.4	4.7	4.7
Newsprint	(14)	(9.5)	(9.5)
Large Scale Co-Gen[1]	5.5 / 10.7	6.8 / 13.2	6.0 / 13.2
Large Scale CHP[1]	18.6 / 23.7	18 / 24.4	17.3 / 24.4
Pyrolysis to Power	13.3	16.6	16.6
Gasification to Power	10.1	13.6	13.6
Pyrolysis Oil	13	16.7	16.7
Fermentation	(19.9)	(19.9)	(19.9)
FT Diesel[2]	3 / 8	1 / 5	0 / 5
Lignin	12	16.2	16.2
Full Fractionation	8.6	10.7	10.7
Gasification to Ethanol	11.6	15.1	15.1
Gasification to Acetate	16.3	19.6	19.6

The overall impact on ROCE on pulp and paper pathways is generally less than on sawmill as sawmills save on residual transportation costs (as they are the source of residuals in most cases)

Larger scale pathways have the biggest impacts on the integrated facility. Regionally there are small differences between pathways with the exception of power applications where pricing policy impacts the results.

Note:
1) Forest Residuals / Hog Fuel
2) FT Diesel Medium / Mega

Building Materials Pathways

Pathway	BC Central Interior	Ontario	Quebec
SPF Medium (West / East / East)	15	17	19
Gasification for Dry Kilns	15.3	17.2	18.7
Cross Laminated Timber	34	36.6	37.6
Laminated Veneer Lumber	18	20	21
Living with Wood	18	21	22.6
Gasification CHP	18	18.1	18.2
Pyrolysis to Power	19.2	18	16.4
Pyrolysis to Oil	21.5	23.7	24.7
Gasification to Ethanol	13.1	13.9	14.7
Gasification to Acetate	17.7	18.9	19.6

The major swing within the roadmaps between the regions is the relative ranking of Pyrolysis to Power in BC, vis-à-vis the ranking of Living to Wood in Ontario and Quebec. Without the energy policies in BC (Carbon Tax, Carbon Credits, and Electricity Pricing) the relative ranking in the technologies would be the same with Living to Wood moving higher in the rankings.

Provincial Best Bets

BC Central Interior

Pulp and Paper

1. Large Scale CHP
2. Dissolving Pulp
3. Gasification to Acetate

Building Materials

1. CLT
2. Pyrolysis to Oil
3. Pyrolysis to Power

Ontario

Pulp and Paper

1. Large Scale CHP
2. Dissolving Pulp
3. Gasification to Acetate

Building Materials

1. CLT
2. Pyrolysis to Oil
3. Living with Wood

Quebec

Pulp and Paper

1. Large Scale CHP
2. Dissolving Pulp
3. Gasification to Acetate

Building Materials

1. CLT
2. Pyrolysis to Oil
3. Living with Wood

•For Pulp and Paper pathways as long as the residuals are available for hog fuel prices Combined Heat and Power applications seem to lead followed by higher value chemical production like dissolving pulp and acetate.
•For Building Materials the pathway starts with CLT and Pyrolysis to Oil and then depending on the power policy is either Pyrolysis to Power or moving more production to a Living with Wood focus.

Partial Picture

- The vision presented is partial and based on knowledge we have today

- Many other avenues must be explored
  - the development of industrial bio-technology for production of green specialty chemicals
  - the enzyme sector (highly profitable), a sub-sector of the chemical sector, using modern bio-technologies in production
  - pro-biotic bacteria (instead of antibiotics) in hygiene fiber products
  - nano-cellulose – from salad dressing to bullet-proof jackets

How To Implement

- Increase engagement by industry and governments
- Communicate results and potential
- Explore partnerships
  - Different industry sectors
  - Governments and agencies
  - Academia and research organizations
- Mobilize finances
  - partnerships with financial industry and governments
  - Investing in Forest Industry Transformation (IFIT) generated overwhelming interest in the industry
- Transfer technologies
- Review institutional responsibilities

Overall Conclusions

- Great opportunities exist for the forest industry in Bio-pathways
- Business as usual will not work; hard work required by industry, governments, and affiliated sectors
- Its hard to draw clear borders between Bio-pathways products and value added conventional forest products
- Therefore, the next step should be a general and broad value-added concept for the complete forest sector

APPENDIX 1

Phase II Findings: Bio-Energy

- Integrated CHP production in existing mills is a good first bioenergy step
- Production of heat and power and transportation fuels is economically viable in bio-refineries where high-value byproducts are also made, or feedstock is inexpensive
- Synthetic hydro-carbons are economically viable for production of bio-energy
- The scale of bio-energy deployment depends on bio-mass availability.
- The domestic market for bio-energy use is not well-developed
- There is lack of consistent policy framework for large-scale bio-energy demand and supply

Findings: Bio-Chemicals and Bio-Products

- Opportunities exist for developing new cellulose products
- Older, smaller scale pulp-mills can convert to production for bio-chemicals niche markets
- High-value bio-chemicals will start with multiple, small-niche markets and the old mill conversion can be an interim solution until markets have developed and big efficient mills can be established
- Integrated lignin extraction and NBSK pulp-mills is already an available alternative for adding revenues to pulp-mills
- Hemi-cellulose streams in the pulp-mills can now produce new chemicals for niche markets with high prices
- There are many small market applications of bio-products, e.g., replacement of glass or other fibers in fiber-reinforced composites
- Integration of bio-refineries with pulp- and saw-mills is essential to ensure high revenues from small streams

Phase II Findings: Bio-Materials (Wood)

- Analysis confirmed integration of traditional lumber and panel productions with new bio-products is key for success of both traditional and new products
- A strong future economic outlook exists for lumber through innovation, agility, and customer alignment
- Wood products industries have great opportunities with new building and prefabricated systems
- The non-residential construction market is a large-scale opportunity with the right products and systems
- The repair renovation market is huge with right products and systems
- Ultra-low density insulation and packaging are good possibilities

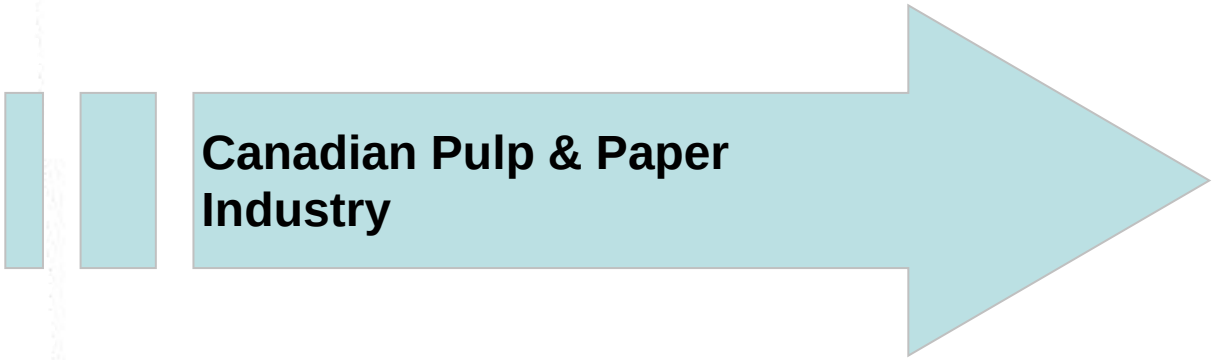
Markets: A Chemical Example

- The world's largest chemical industry is SABIC – Saudi Basic Industries Corporation
  - Expanding in specialty chemicals
  - Buying companies in the field of poly-carbonate, poly-methane, polyamid, synthetic rubber, foams, spandex-fibers, etc.
  - Targeting products for cars, aeroplanes, boats, textiles, etc.
  - Aiming at 20-25% of the world market of poly-carbonate, ethanol, propylen, and methanol

- During 2009-2011 some US $ 70 billion will be invested in chemical production in Saudi Arabia alone
- Doesn't leave much room for investments in other places – risk of over-capacities

Pulp and Paper Roadmaps

There are three primary paths forward for the Canadian Pulp and Paper Industry.

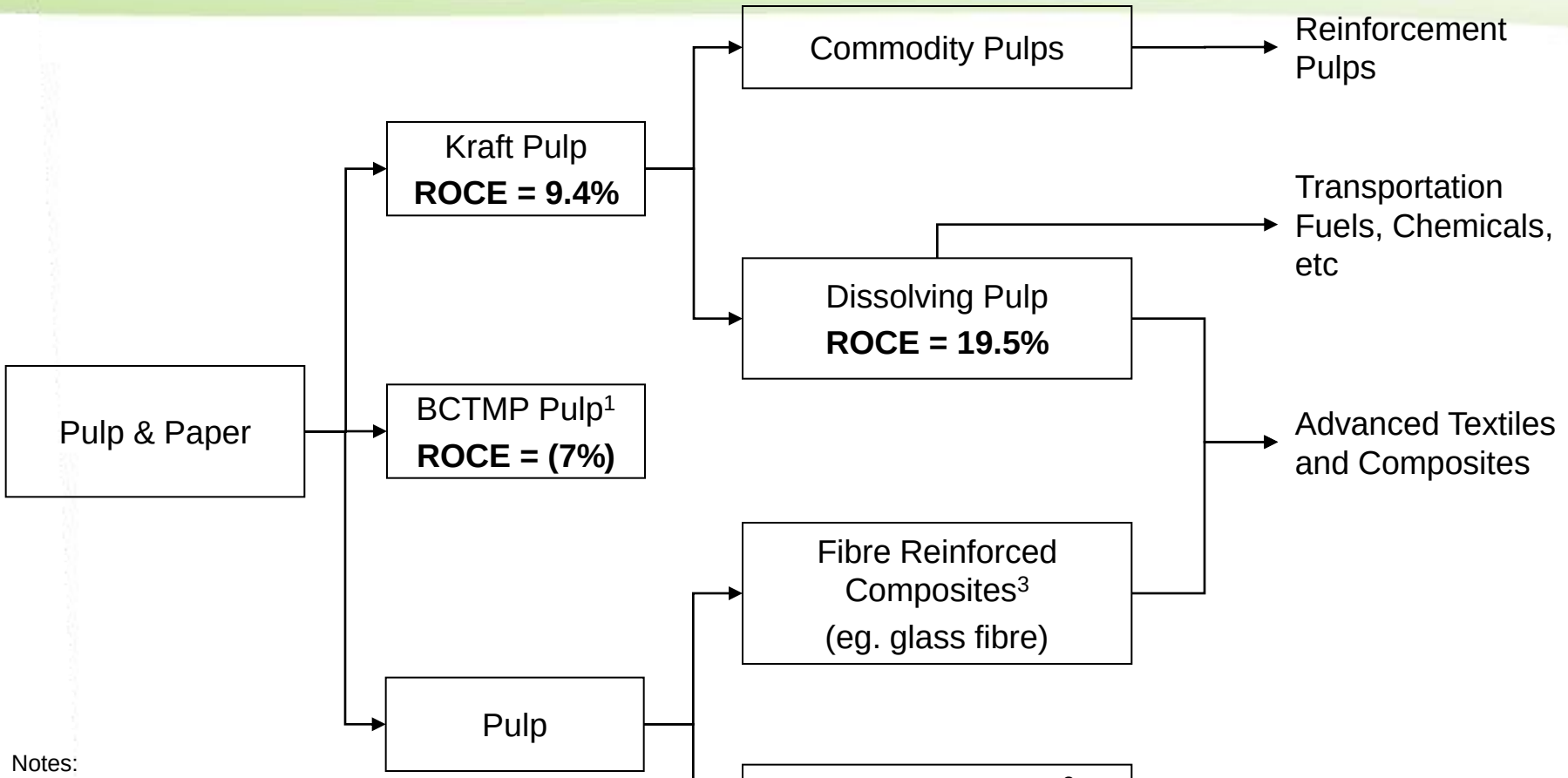


Advanced Textiles, Composites

Power / Heat

Transportation Fuels, Chemicals

Pulp and Paper Roadmap – Option 1
Advanced Textiles / Composites

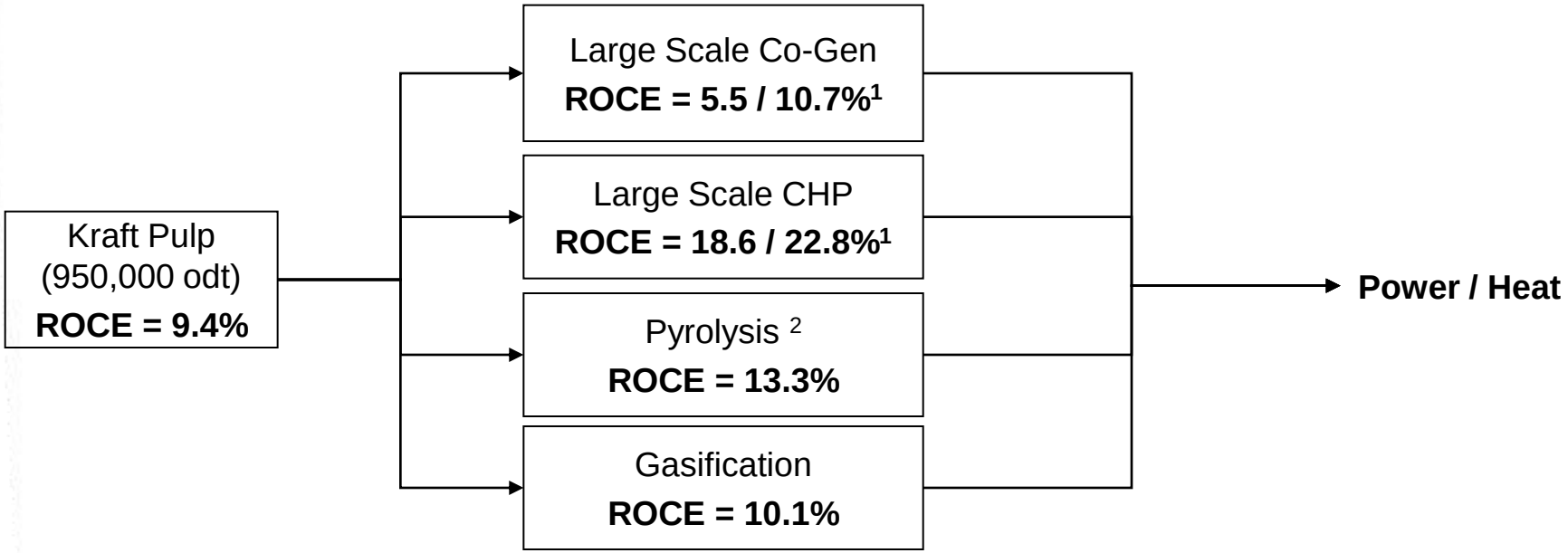


Notes:

1) BCTMP Pulp roadmaps options not examined
2) Newsprint / LWC
3) Not examined by Bio Pathways

All Data BC Normalized with Power at $150/MWh

Pulp and Paper Roadmap – Option 2
Power / Heat Pathways



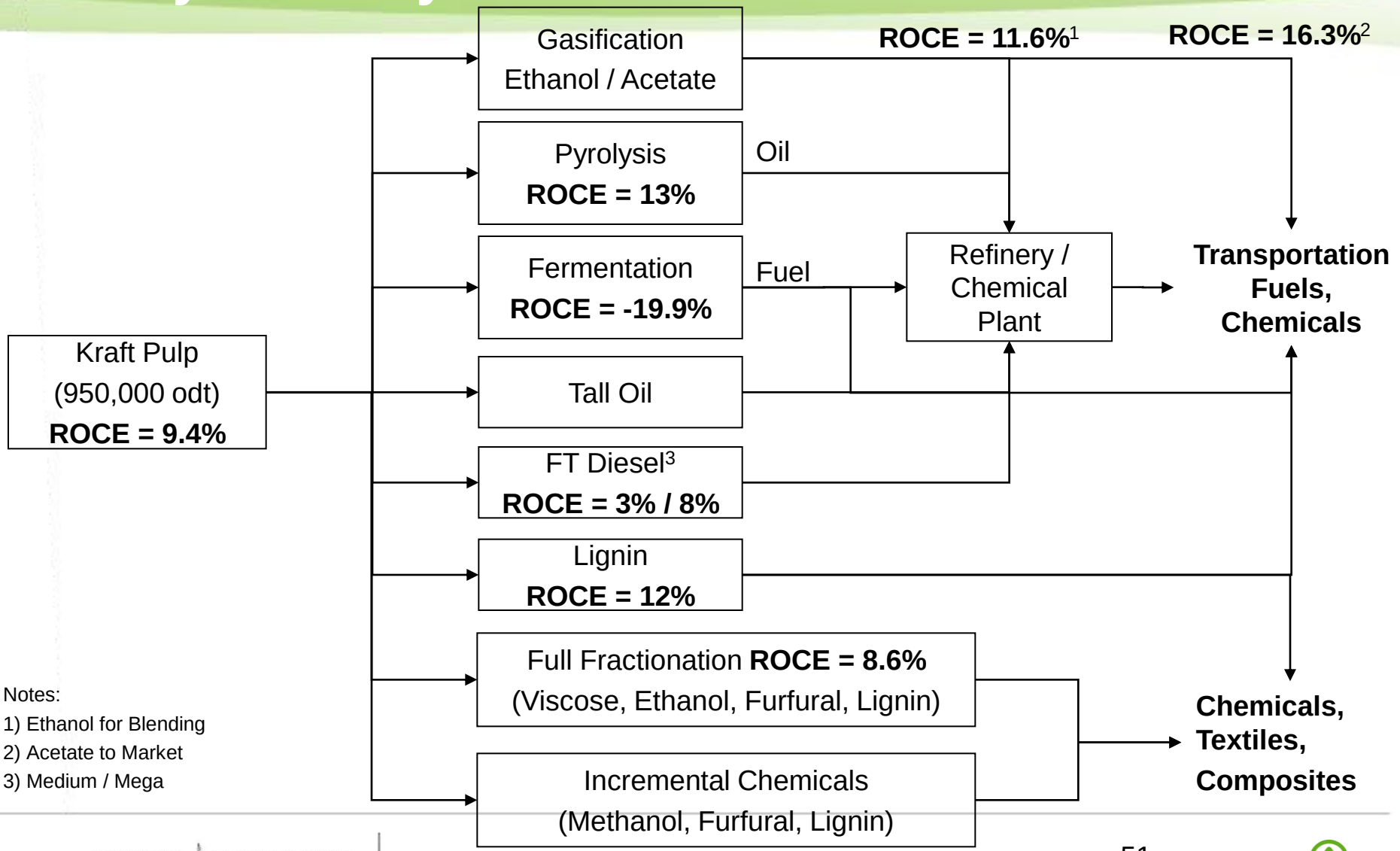
Notes:

1) First ROCE is based on Forest Residues / Second is based on Hog Fuel

2) Draft

All Data BC Normalized with Power at $150/MWh

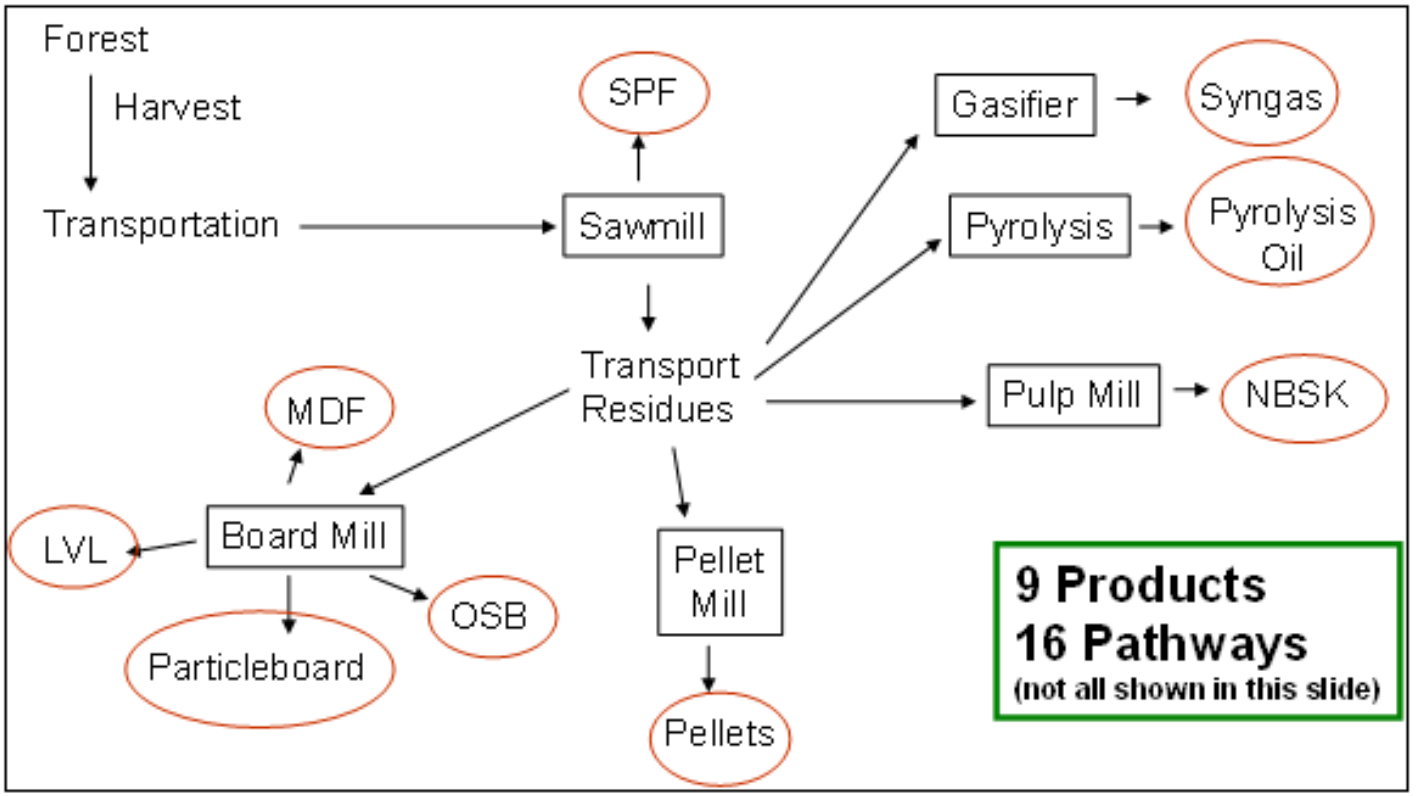
Pulp and Paper Roadmap – Option 3
Refinery Pathways



Notes:
1) Ethanol for Blending
2) Acetate to Market
3) Medium / Mega

All Data BC Normalized with Power at $150/MWh

Carbon Footprint Analysis



Source: Carbon Footprint Report, 2010

Combined Metrics of Pulp and Paper Pathways

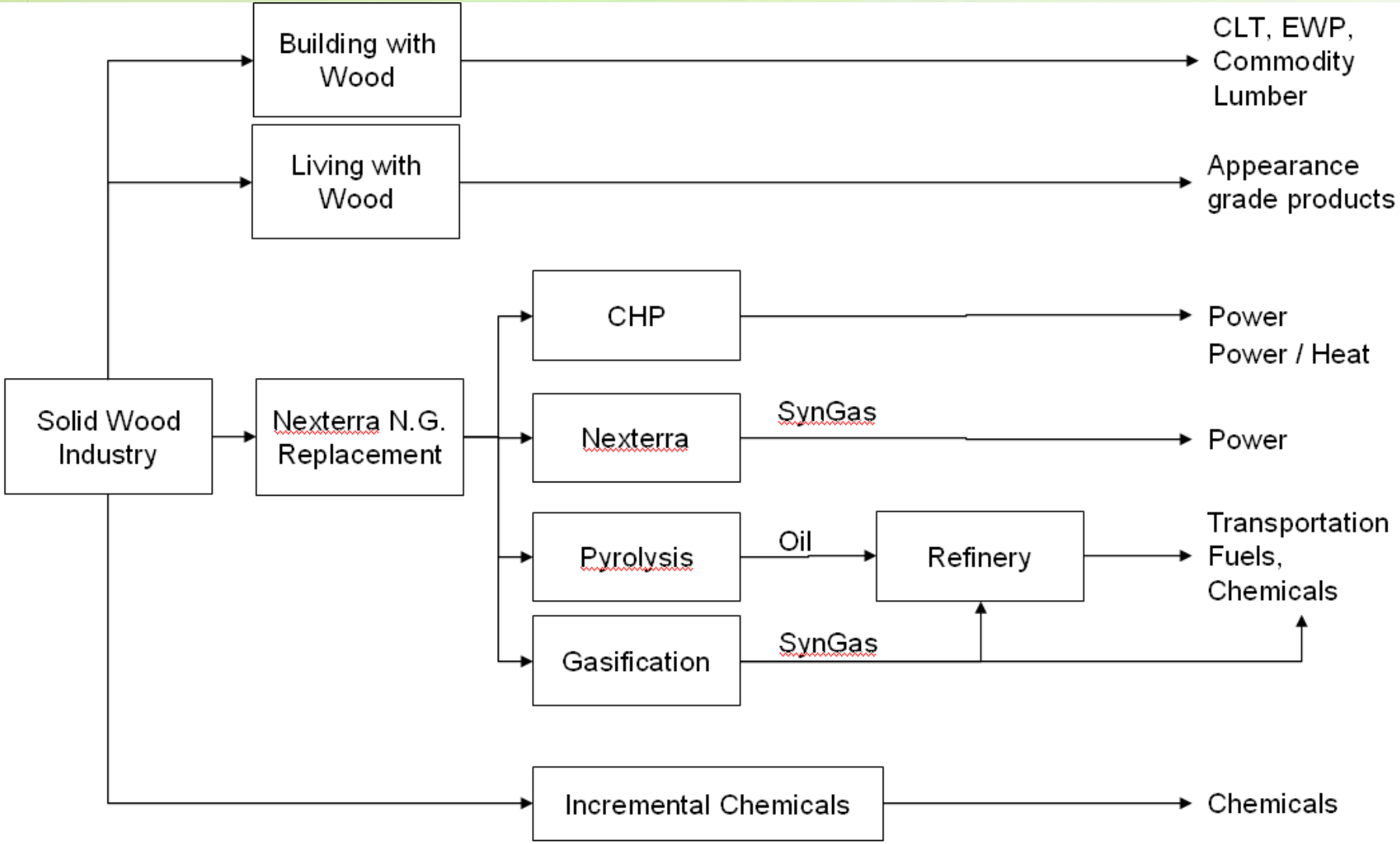
Pathway			ROCE	GDP ($M) / 100,000 ODT	Employment (FTE) / 100,000 ODT	Direct CO2e (kt) / 100,000 ODT
Advanced Textiles and Composites	Kraft	Commodity Pulp	9.4%	20	163	13.8
		Dissolving Pulp	19.5%	36	226	23.7
	BCTMP		(7.4%)	34	284	N/A
	Paper	Newsprint	(14%)	36	347	12.3
		LWC	3%	35	253	13.1
Power / Heat	Kraft	Large Co-Gen[1]	10.7%	24	193	0
		Large CHP[1]	22.8%	30	193	7.954
		Pyrolysis	13.3%	23	166	0
		Gasification	10.1%	22	165	0
Refinery	Kraft	Gasification - Ethanol	11.6%	22	165	0
		Gasification - Acetate	16.3%	25	170	0
		Pyrolysis	13.0%	22	165	0
		Fermentation	(19.9%)	12	180	4.5
		FT Diesel (Medium)	3%	20	144	N/A
		Lignin	12%	22	165	17.5
		Full Fractionation	8.6%	23	130	6.993

Notes:

1) ROCE based on hog fuel input.

All Data BC Normalized with Power at $150/MWh

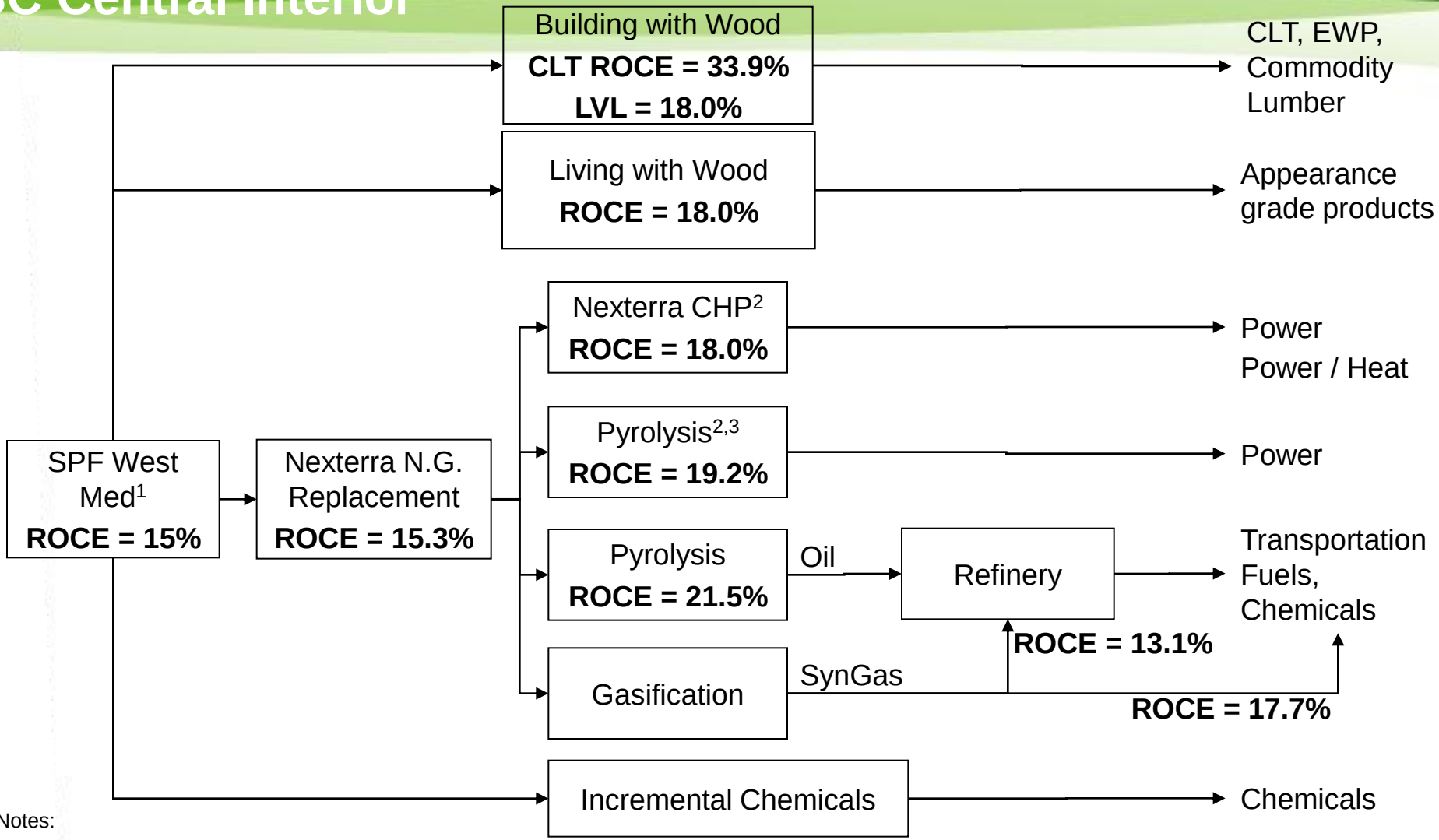
Building Materials - Wood Roadmap



Fermentation not included due to scale needed.

Building Materials – Example Roadmap

BC Central Interior



Notes:

1) Based on 250 mmfbm facility, hog fuel imported to match scales.

2) Based on $150/MW

3) Draft Results

All Data BC Normalized with Power at $150/MWh

Combined Metrics of Building Materials Pathways

Pathway			ROCE	GDP ($M) / 100,000 ODT	Employment (FTE) / 100,000 ODT	Direct CO2e (kt) / 100,000 ODT
Building With Wood	SPF West Med	SPF West Med	15%	25	196	9.5
		CLT	34%	N/A	N/A	5.3
		LVL Large	18%	48.5	362	6.8
Living with Wood[1]	SPF West Med		18%	26	199	9.5
Fuels and Chemicals	SPF West Med	N.G Replacement	15.3%	25.1	194	0
		Gasification to CHP	18%	28.5	202	0
		Pyrolysis to Power	19.2%	31.7	186	0
		Pyrolysis to Oil	21.5%	30.4	203	0
		Gasification to Ethanol	13.1%	31.7	221	0
		Gasification to Acetate	17.7%	33.9	221	0

Note:

1) Living Direct CO2 emissions per 100,000 odt are assumed to be the same as SPF West Med

All Data BC Normalized with Power at $150/MWh

Metrics Summary

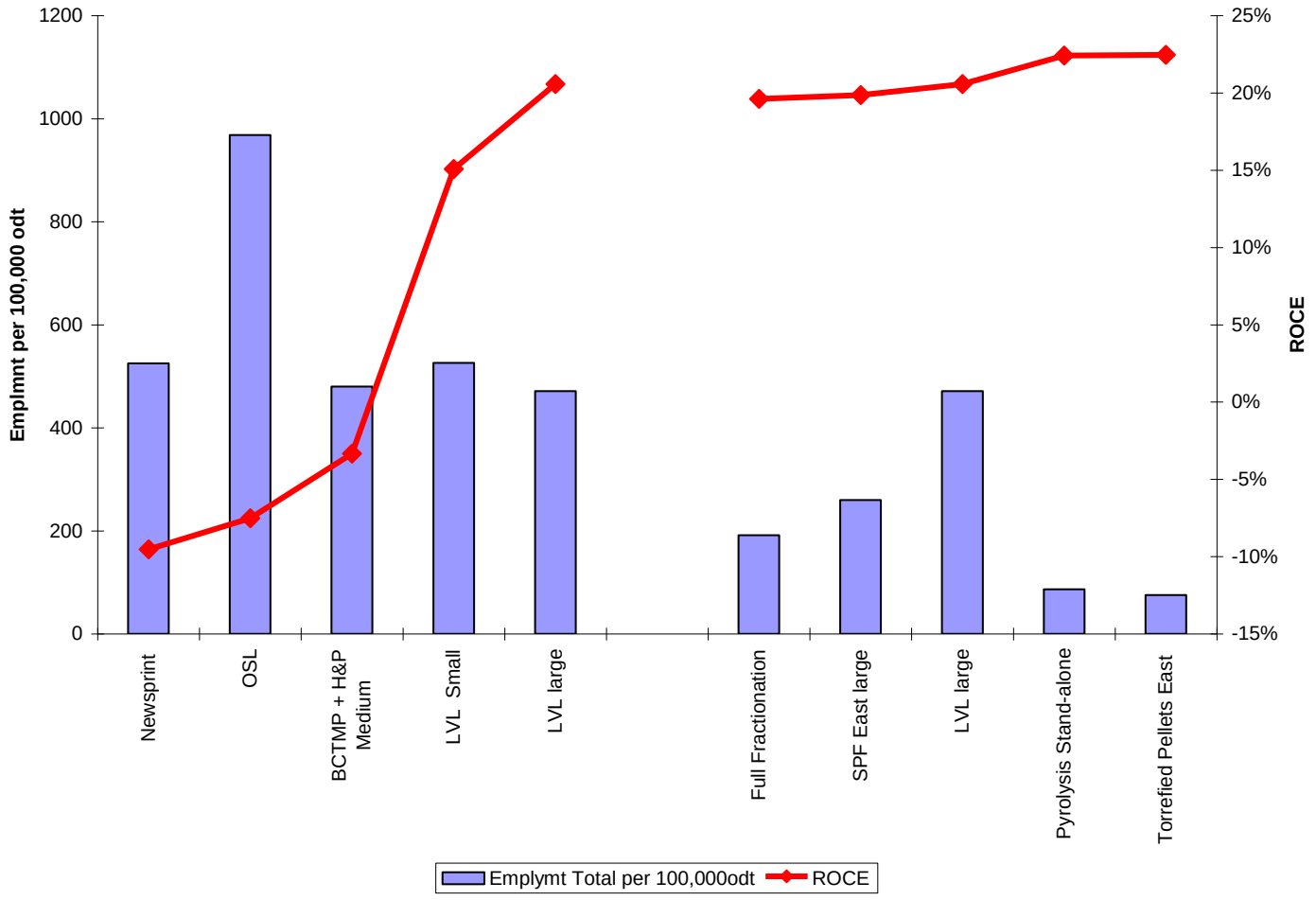
Pulp and Paper Pathways (clusters built on Pulp Mill sites):

- On average when a new technology is added to an existing pulp mill site we see an improvement in ROCE (average 3.7%), and improvement in contribution to GDP (10-25%) and employment (1-4%). The Heat and Power options often have stronger social metrics as the scale of the plants are larger than some of the more profitable Fuel and Chemical pathways.

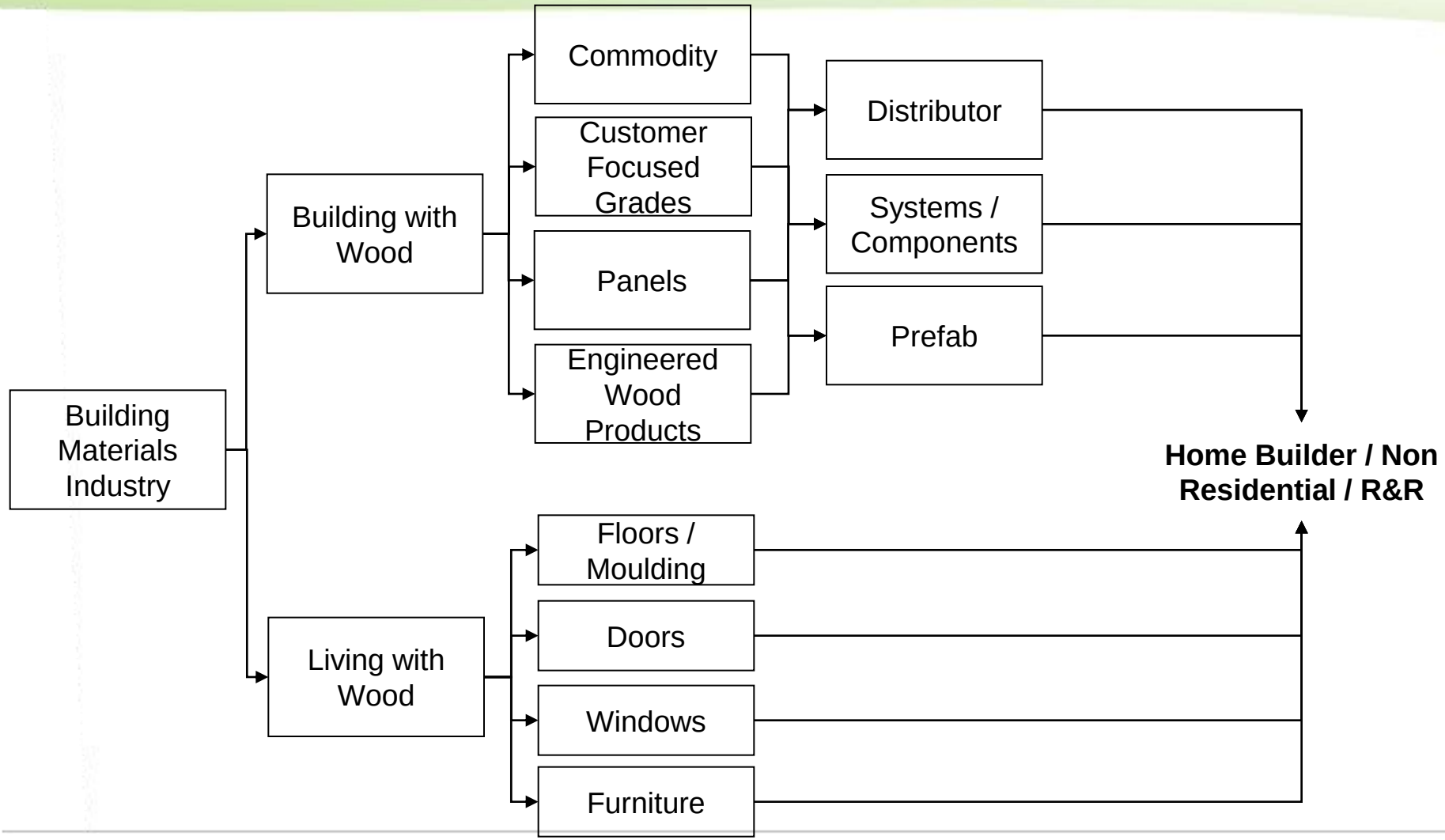
Building Material Pathways (clusters built on Sawmill site):

- New technology options for sawmill improve all the social metrics with the largest impacts coming from transforming the Building with Wood section. CLT specifically has a very large impact and the Fuels and Chemicals option also have strong performance and have the added benefit of drawing down the carbon footprint for the facility.
- There are trade offs in the metrics by shifting from conventional to bio-pathways production

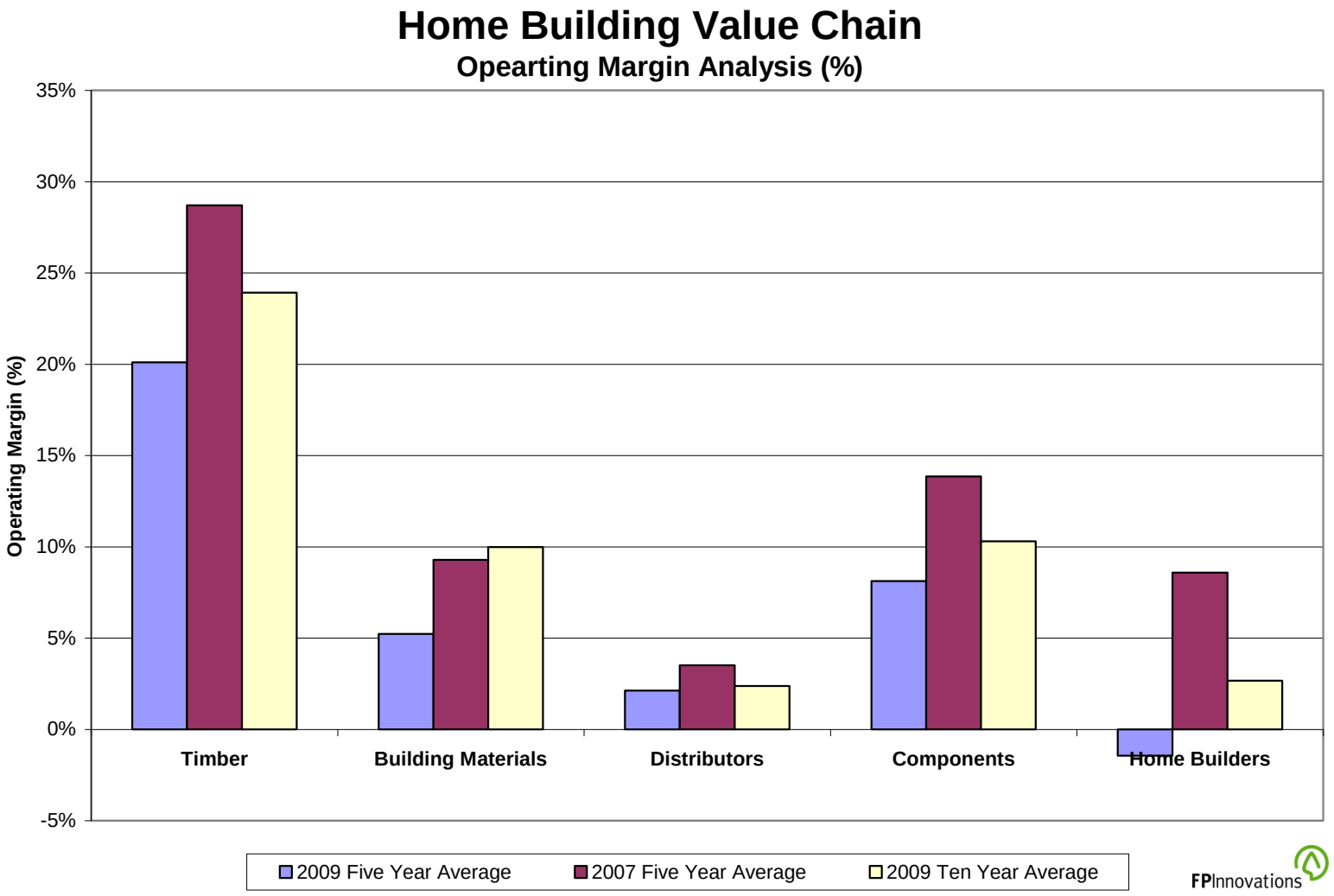
Trade-Offs


1200
1000
800
600
400
200
0
Emplmnt per 100,000 odt
25%
20%
15%
10%
5%
0%
-5%
-10%
-15%
ROCE
Newsprint
OSL
BCTMP + H&P Medium
LVL Small
LVL large
Full Fractionation
SPF East large
LVL large
Pyrolysis Stand-alone
Torrefied Pellets East
Emplymt Total per 100,000odt
ROCE

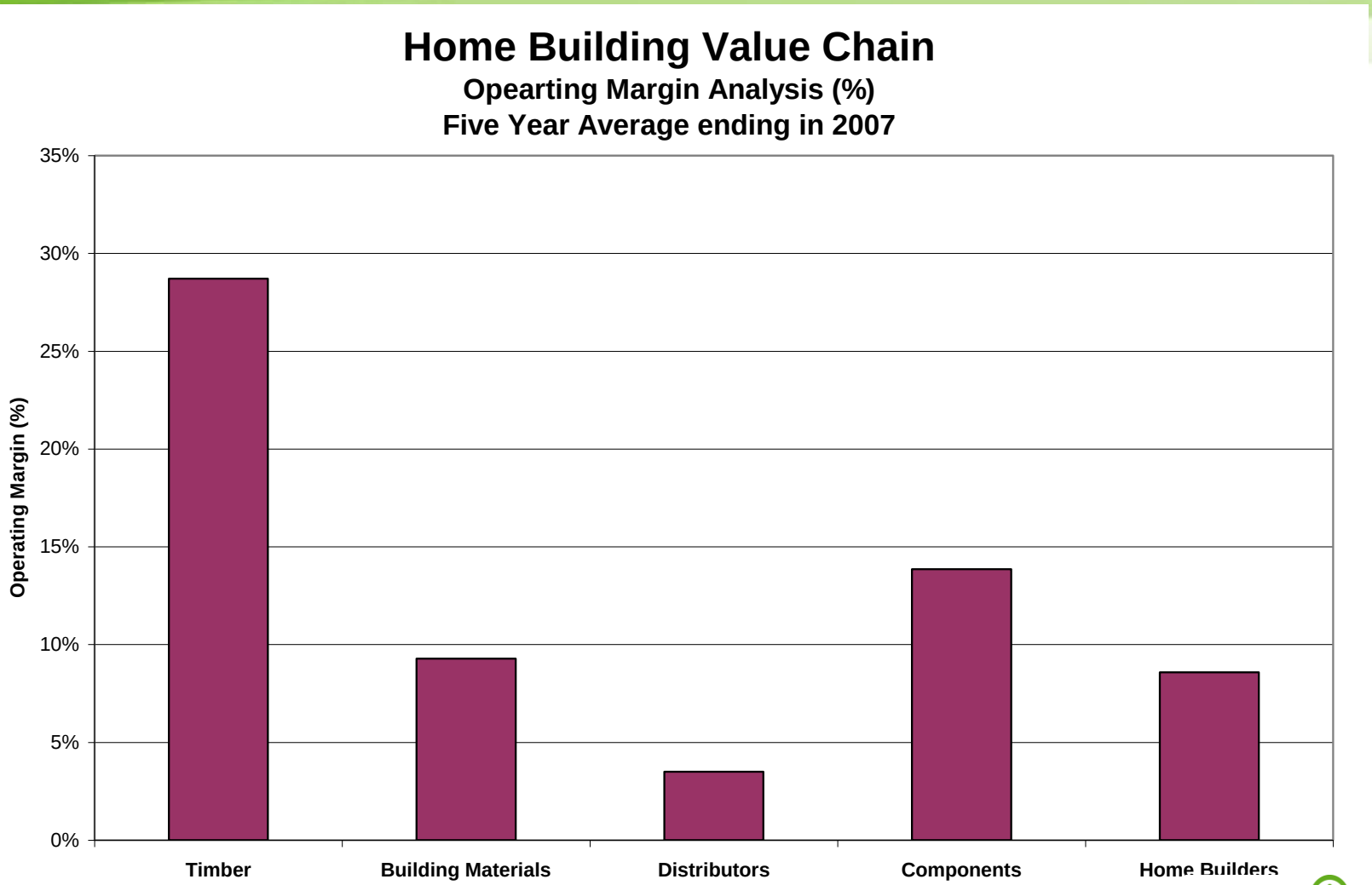
Building Materials - Wood Roadmap
Building with Wood / Living with Wood



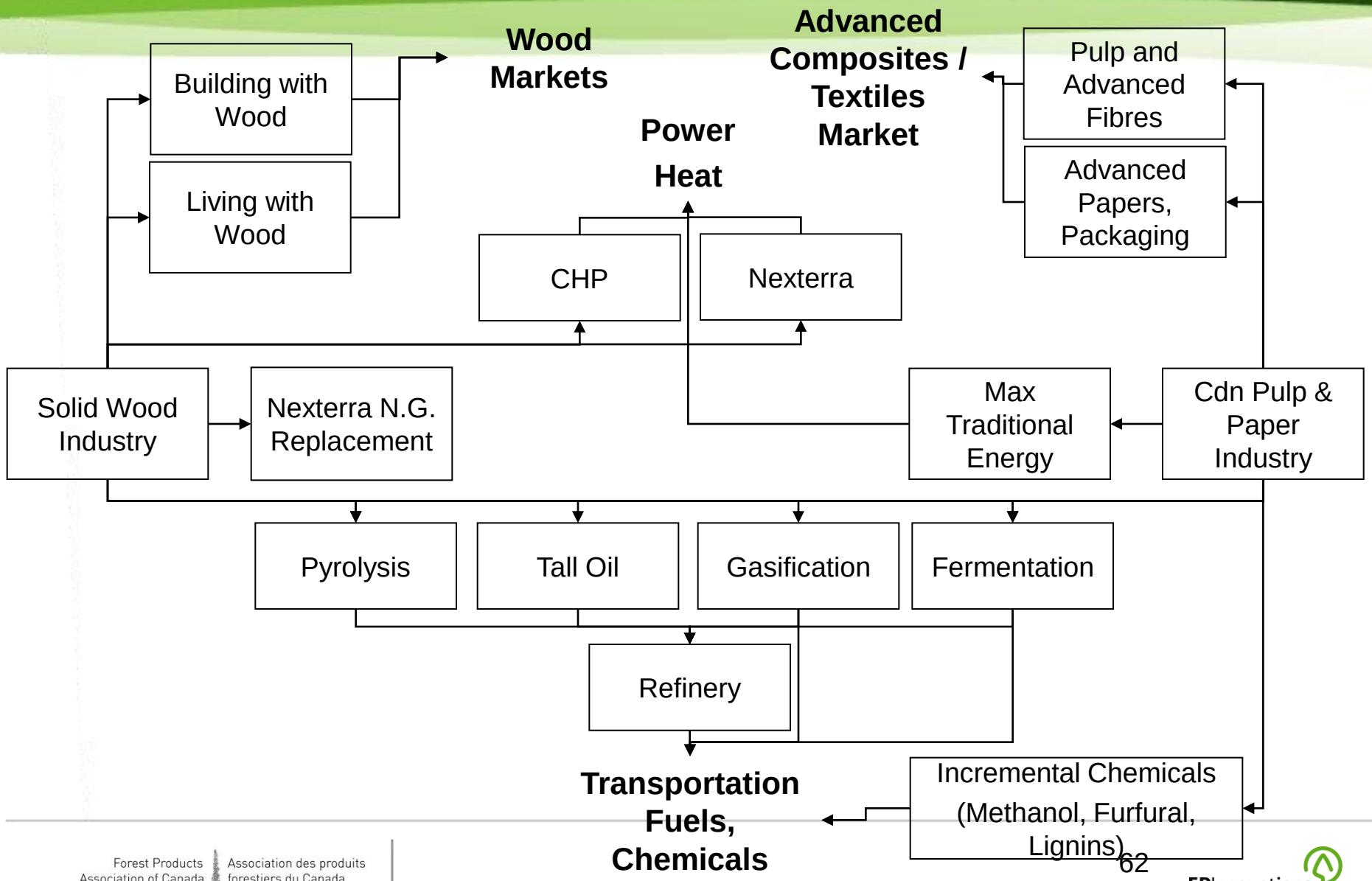
Home Building Value Chain



Home Building Value Chain



Reviewing Cluster Options



Build Economics for each Step

Refinery Capacity

Gasification

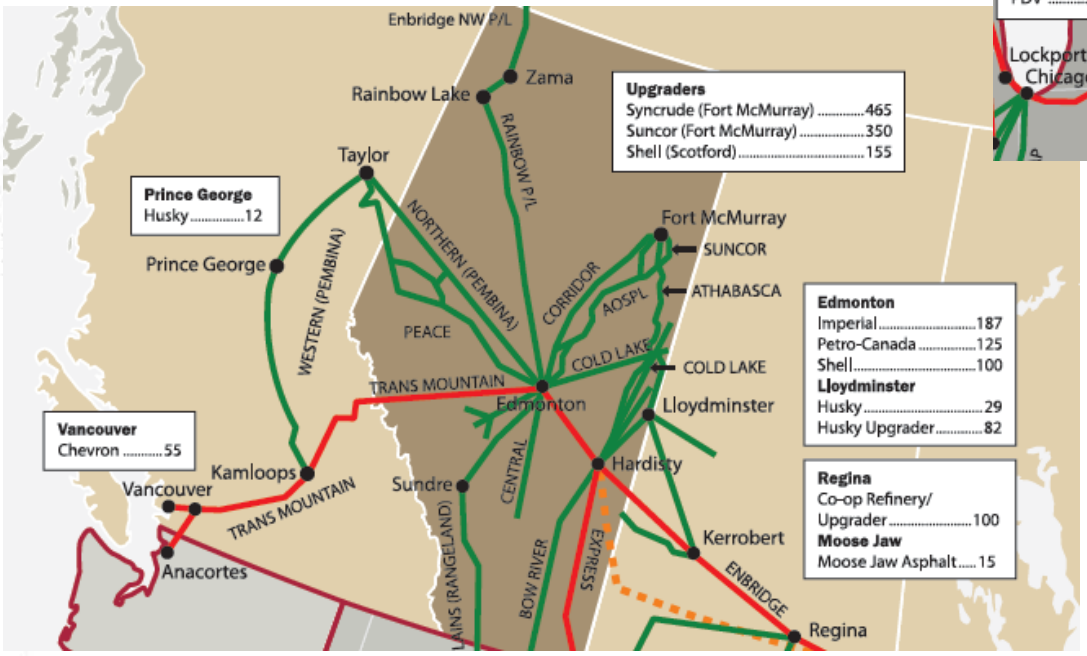
Ethanol = 42,000,000 litres or 264,172 barrels or

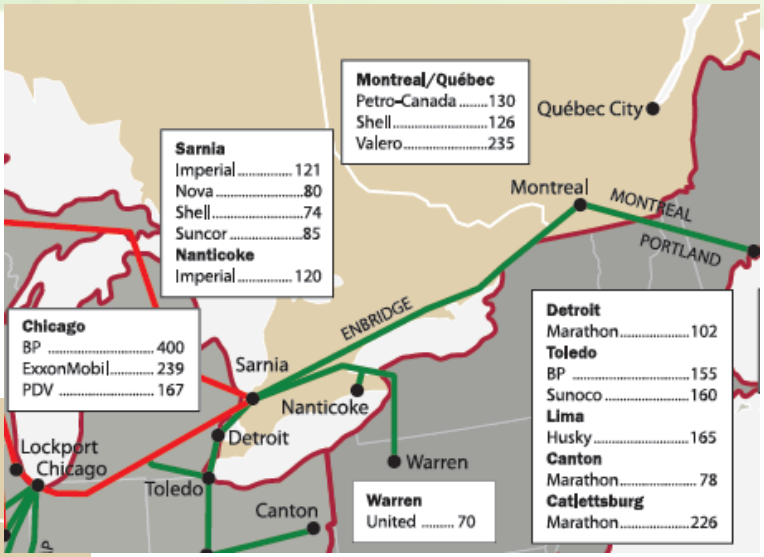
Refinery Capacity needed: 0.75

Pyrolysis

Fuel Oil = 83,000,000 litres or 523,941 barrels

Refinery Capacity needed: 1.5





The capacity of existing refineries would not be significantly challenged by additional production of ethanol from gasification or oil from Pyrolysis.

Refinery Capacity vis-à-vis Lumber and Paper Capacity

- Six key regions overlap the Petroleum industry including
  - BC Vancouver (55,000 barrels / day)
  - BC Prince George (12,000 barrels / day)
  - AB Edmonton (412,000 barrels / day)
  - SK Lloydminster (111,000 barrels / day)
  - ON Thunder Bay / Sarnia (360,000 barrels / day) – barged from Thunder Bay
  - QC Montreal (491,000 barrels / day)
- Key players identified in the Petroleum industry with overlapping capacity include;

	Capacity
Imperial	308
Shell	300
Petro-Canada	255
Valero	235
Husky	123
Suncor	85
Nova	80
Chevron	55

* 1,000 barrels / day

Sawmilling	# of Facilities	Capacity
BC Vancouver	30	1,483,000 mfbm
BC Prince George	11	2,330,000 mfbm
AB Edmonton	14	1,780,000 mfbm
SK Lloydminster	3	127,000 mfbm
ON Thunder Bay	3 (closed 2009)	
ON Sarnia	0	

Pulp & Paper	# of Facilities	Capacity
BC Vancouver	12	3,500,000 admt
BC Prince George	15	4,800,000 admt
AB Edmonton	5	1,900,000 admt
SK Lloydminster	1(1)	385,000 admt
ON Thunder Bay	3	1,100,000 admt
ON Sarnia	8	1,000,000 admt

Refinery Integration – Furthering The Pyrolysis Pathway (1)

- The Pyrolysis Pathway has been a strong option for providing fuels and chemicals. There are technical challenges to overcome but there may be further synergistic options for the Forest and Paper Industry.
- The primary issue with using pyrolysis oil in a further refinery pathway is the high oxygen content in the oil. This problem is being addressed by hydro-cracking / hydro-processing the pyrolysis oil. This means hydrogen is added to the oil to make it compatible with heavy oil being fed into existing refinery operations, an approach being taken by UOP/Ensyn and the BioCoup program in Europe.
- As a result, Hydrogen capacity is a key to upgrading the pyrolysis oil. Hydrogen is available from several sources including production from refineries, electrolysis of water, and gasification. One of the critical uses of hydrogen is for upgrading non traditional oil such as oil from Canadian Tar Sands.
- If there is excess hydrogen at an existing refinery, there is a synergistic fit between upgrading pyrolysis oil at that refinery.

Refinery Integration – Furthering The Pyrolysis Pathway (2)

- In the case of no hydrogen availability then there are two options that provide synergistic fits with the forest industry.
  - Gasification of Biomass
  - Hydrogen capture from Sodium Chlorate production

Gasification of Biomass:

- Several research institutes including the US DOE are researching the production of hydrogen via gasification. One goal is to provide a distributed hydrogen production infrastructure to support future use of fuel cells. However technical challenges remain.
- As the challenges are addressed, there are opportunities for the existing industry to produce hydrogen

Hydrogen Sources – Sodium Chlorate

Hydrogen Capture from Sodium Chlorate:

- Another option that is currently technically available is capture of hydrogen from the production of sodium chlorate. This is now being done at the sodium chlorate plant in North Vancouver.
- Sodium Chlorate production is primary for the bleaching of wood fibre and is closely coupled in location to the pulp and paper industry.

PRODUCERS AND CAPACITIES - SODIUM CHLORATE - THOUSANDS OF SHORT TONS - 2006

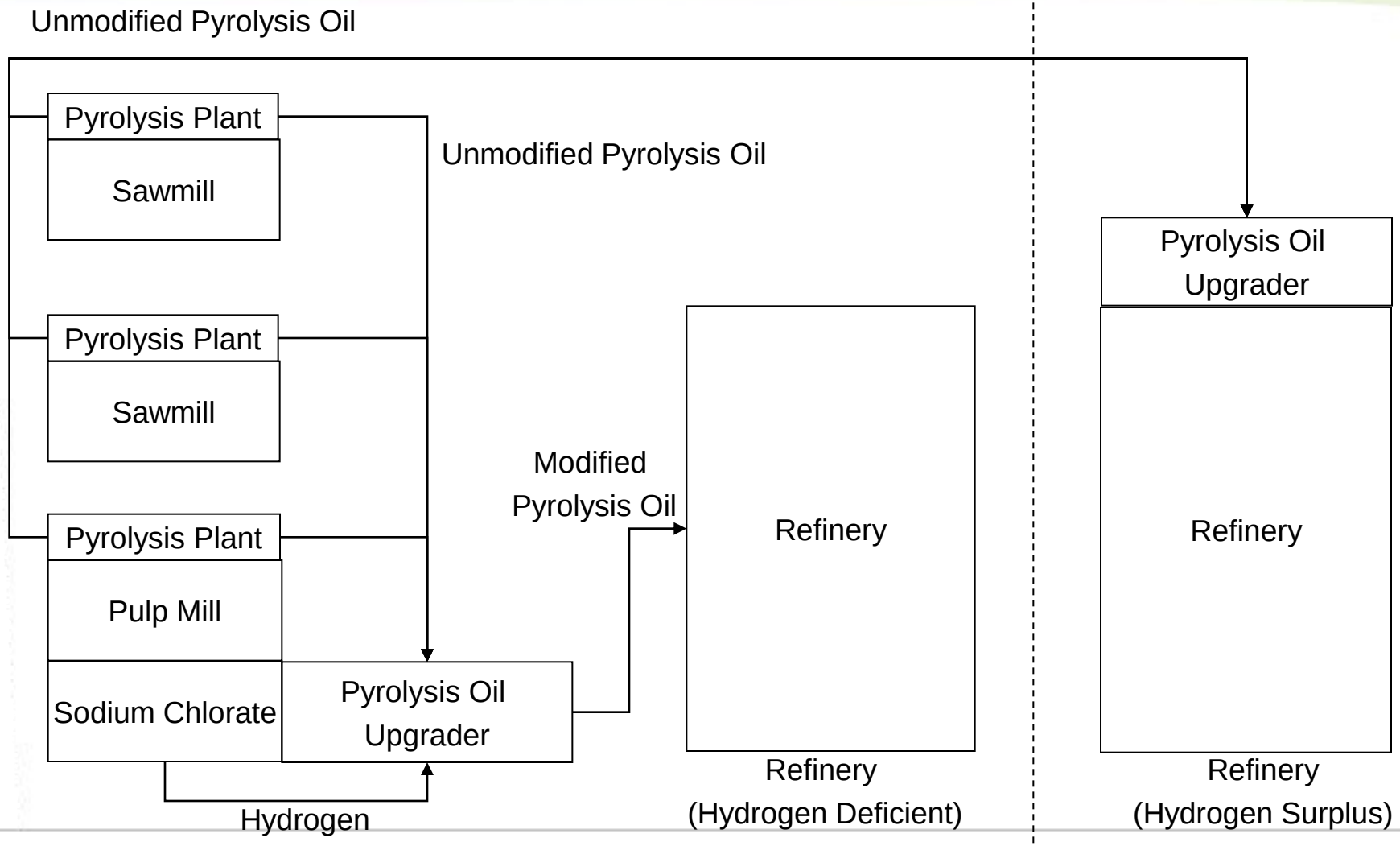
UNITED STATES:

PRODUCER	LOCATION	CAPACITY	PRODUCER	LOCATION	CAPACITY
Eka Chemicals	Columbus, MS	219	Kemira	Eastover, SC	90
Eka Chemicals	Moses Lake, WA	63	Kerr-McGee	Hamilton, MS	138
Erco Worldwide	Valdosta, GA	110	Other Integrated	Captive Producers	97
Kemira	Augusta, GA	145			
			TOTAL UNITED STATES		862

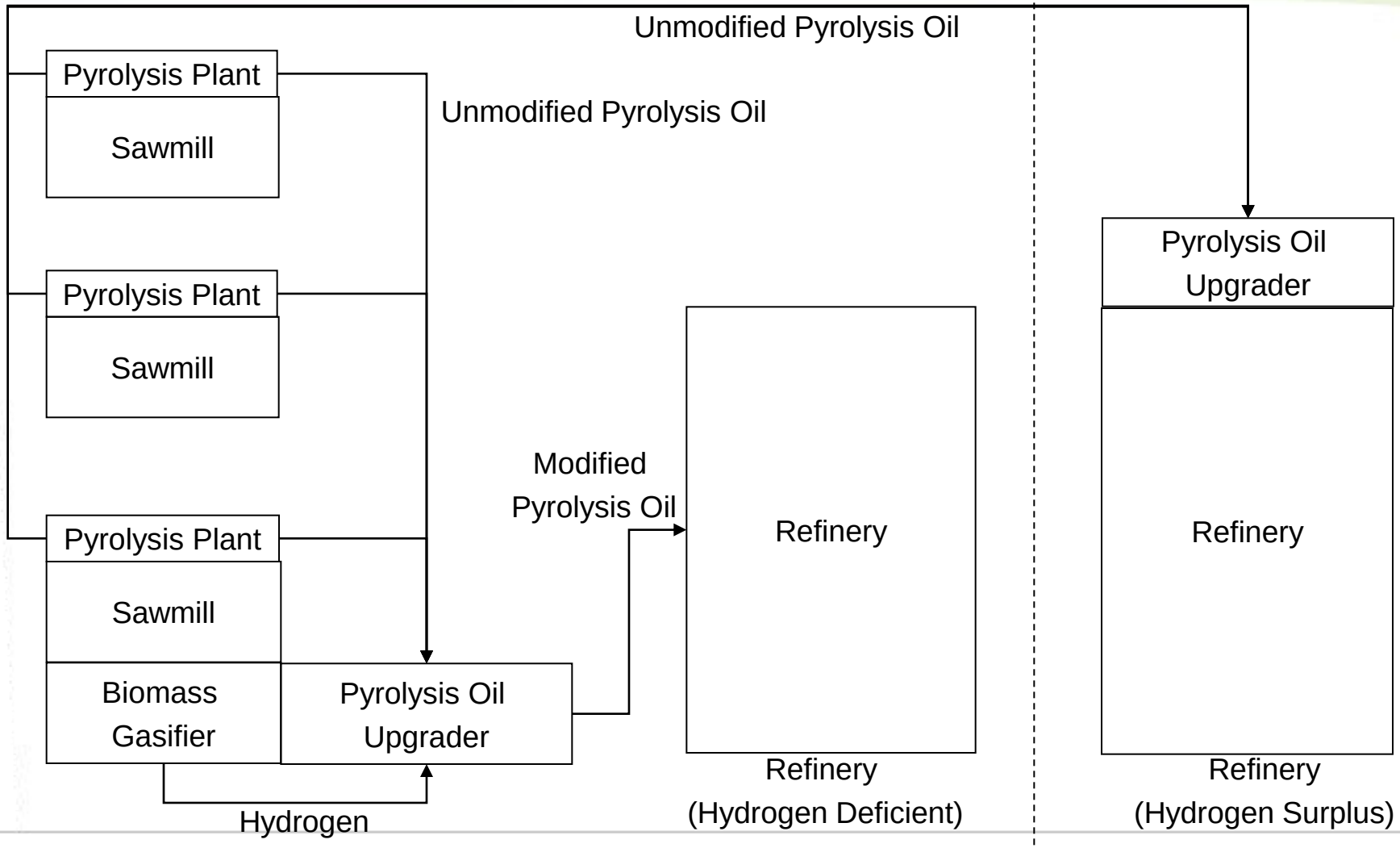
CANADA:

PRODUCER	LOCATION	CAPACITY	PRODUCER	LOCATION	CAPACITY
BC Chemical	Prince George, BC	70	Erco Worldwide	Bruderheim, Alb.	82
Canexus	Beauharnois, Que.	48	Erco Worldwide	Hargrave, Man.	44
Canexus	Brandon, Man.	260	Erco Worldwide	Saskatoon, Sask.	55
Canexus	Bruderheim, Alb.	77	Erco Worldwide	Buckingham, Que.	140
Canexus	Nanaimo, BC	18	Erco Worldwide	N. Vancouver, BC	100
Domtar	Lebel-Sur-Quevi, ON	25	Erco Worldwide	Grand Prairie, Alb.	55
Eka Chemicals	Magog, Que.	165	PCI Canada	Dalhousie, Que.	24
Eka Chemicals	Valleyfield, Que.	125	St. Anne Chem.	Nackawic, NB	11
TOTAL CANADA		1299			

Revised Refinery Cluster based on Sodium Chlorate - Upgrader at Pulp Mill Site



Revised Refinery Cluster based on Gassi-fied Biomass - Upgrader at Sawmill Site



Refinery Integration – Furthering The Pyrolysis Pathway (3)

- Even with technical hurdles for moving down the Fuels and Chemicals roadmap there are synergistic options with the existing industry;
  - in a pulp and paper facility through a hydrogen source such as sodium chlorate or biomass gasification,
  - or in a sawmill through a hydrogen source such as biomass gasification.
- The technical hurdles don't however rule out the pyrolysis pathway as heat and power options can still be exercised.
- Key to the long term success of this roadmap will be partnerships with the petroleum industry.

Calculations for Integrated Bio-pathways

- Pulp and Paper
  - Heat and Power (9.4% - 22.8%)
  - Refinery Paths (11.6% - 16.3%)
- Building Materials
  - Heat and Power (15.3% - 19.2%)
  - Refinery Paths (13.1%-21.5%)
  - Building Systems (18% - 34%)
- Most of the value is from upgrading the value of non chip residuals

Ideas for Innovation System

Support Program for Bio-pathways Production (1)

Market and strategic analyses of Bio-pathways products

Pulp & Paper

- Transform old mills into bio-refineries
- Develop pathways for chemicals, fuels and polymers from sugar and lignin
- Develop efficient separation technologies of wood into valuable components
- Develop new composites of cellulose materials and inorganic materials
- Develop nano-technologies for wood fibers
- Improve performance/weight ratio

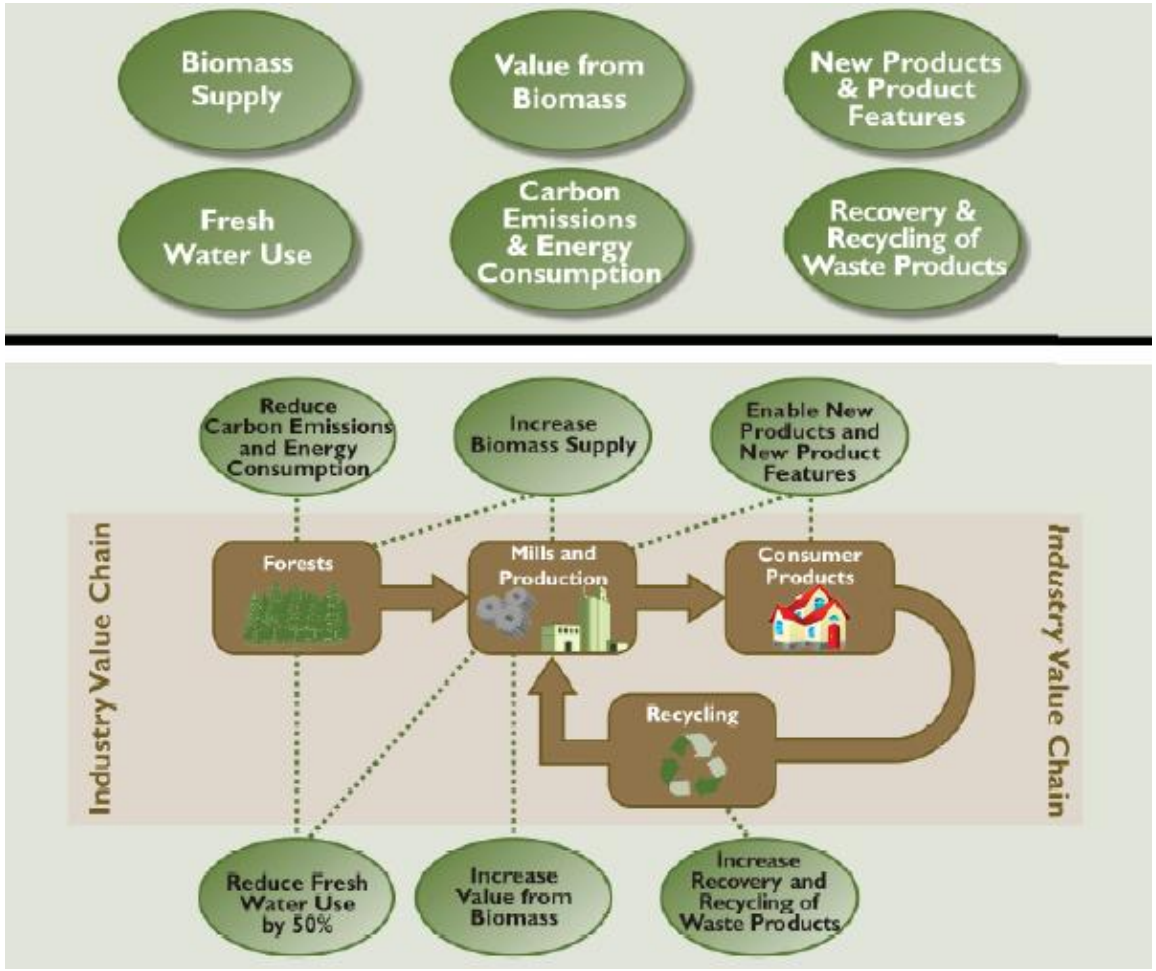
Support Program for Bio-pathways Production (2)

Market and strategic analyses of Bio-pathways products

Wood Products

- Investigate technologies from other sectors
- Develop building systems
- Investigate wood properties
- Develop composites
- Increase durability
- Improve performance/weight ratio

The Complete Industry Value Chain



Source: Agenda 2020 Technology Alliance, 2010