2015 RESOURCE OPTIONS INVENTORY

WOOD BASED BIOMASS

DRAFT FOR COMMENTS

BC hydro

FOR GENERATIONS

March 31, 2015

BACKGROUND & OBJECTIVES

BCH is updating its Resource Options Inventory for use in long term planning

Objective for today: seek inputs from industry experts to inform the characterization of BioEnergy resource option

- Potential (fiber) : do the high potential areas align with your expectation?
- Locations : are they reasonable assumptions?
- Costs ($/MWh): project development, fiber delivery etc: right ballpark?
- Technology advancements : anything we should be aware of?

General approach same as last Resource Options Update in 2013

AGENDA

Industrial Forestry Service

- Overview of approach & Results (including key changes from 2013)
  - Fiber availability
  - Delivered Fiber Cost
  - Energy Project Cost (BioEnergy Project Economics & Technologies)
- Next steps

FIBER AVAILABILITY

BC Fiber Model (proprietary):

- Annual Allowable Cuts (AAC)
- Harvest level: Dead pine shelf life & harvest partition
- 13 regions
- Remove existing and proposed new industry demand:
  - Sawmill, pulp mills, pellet plants, board plants, BioEnergy (with existing Electricity Purchase Agreements and existing Load Displacement Agreements)
  - Lumber, pulp, paper selling prices; US/CAN exchange rate (1CAN:0.9USD); US & Japanese Housing Starts
- What's left is the fiber potentially for new BioEnergy in each region, 4 fiber categories

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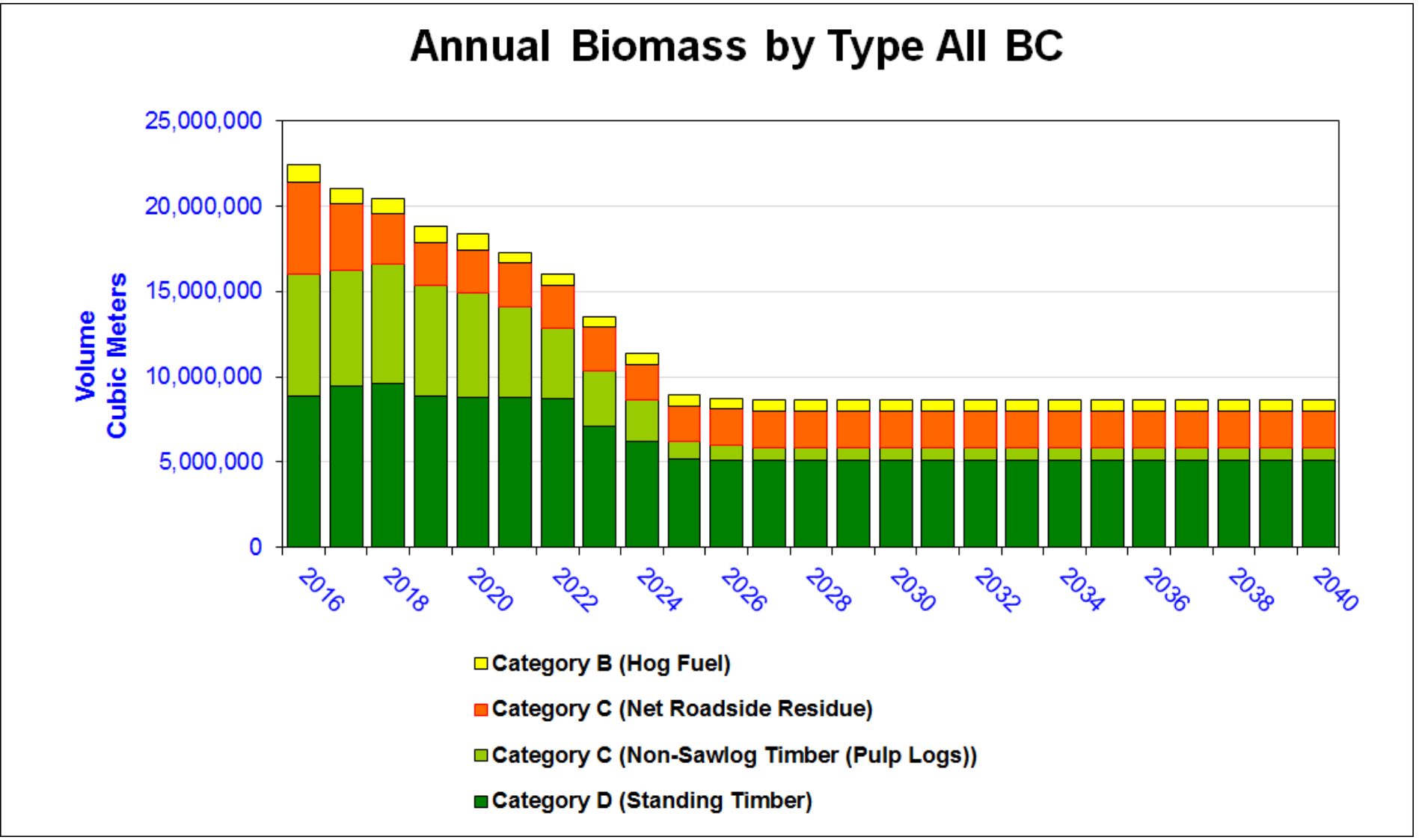
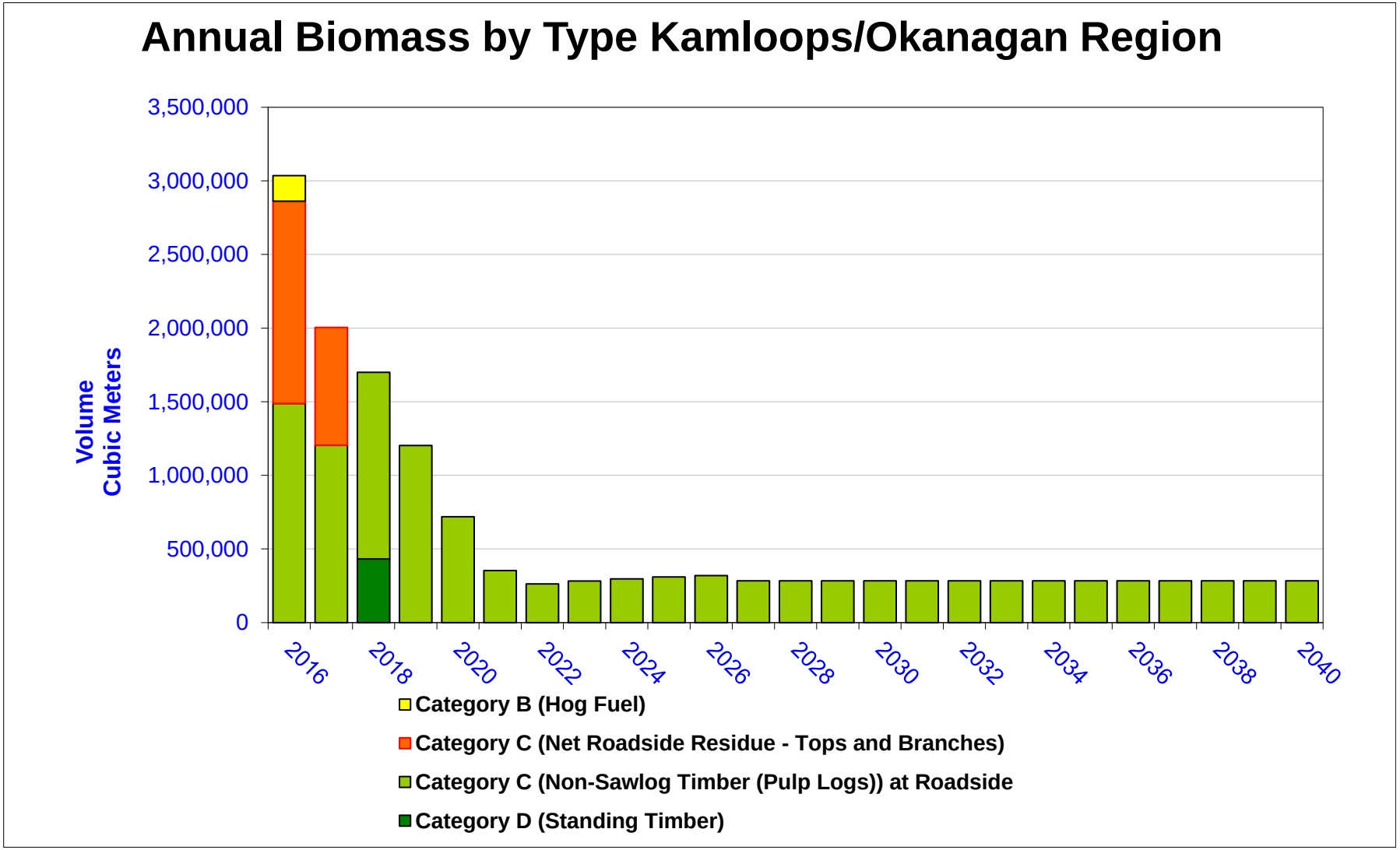
FOR GENERATIONS

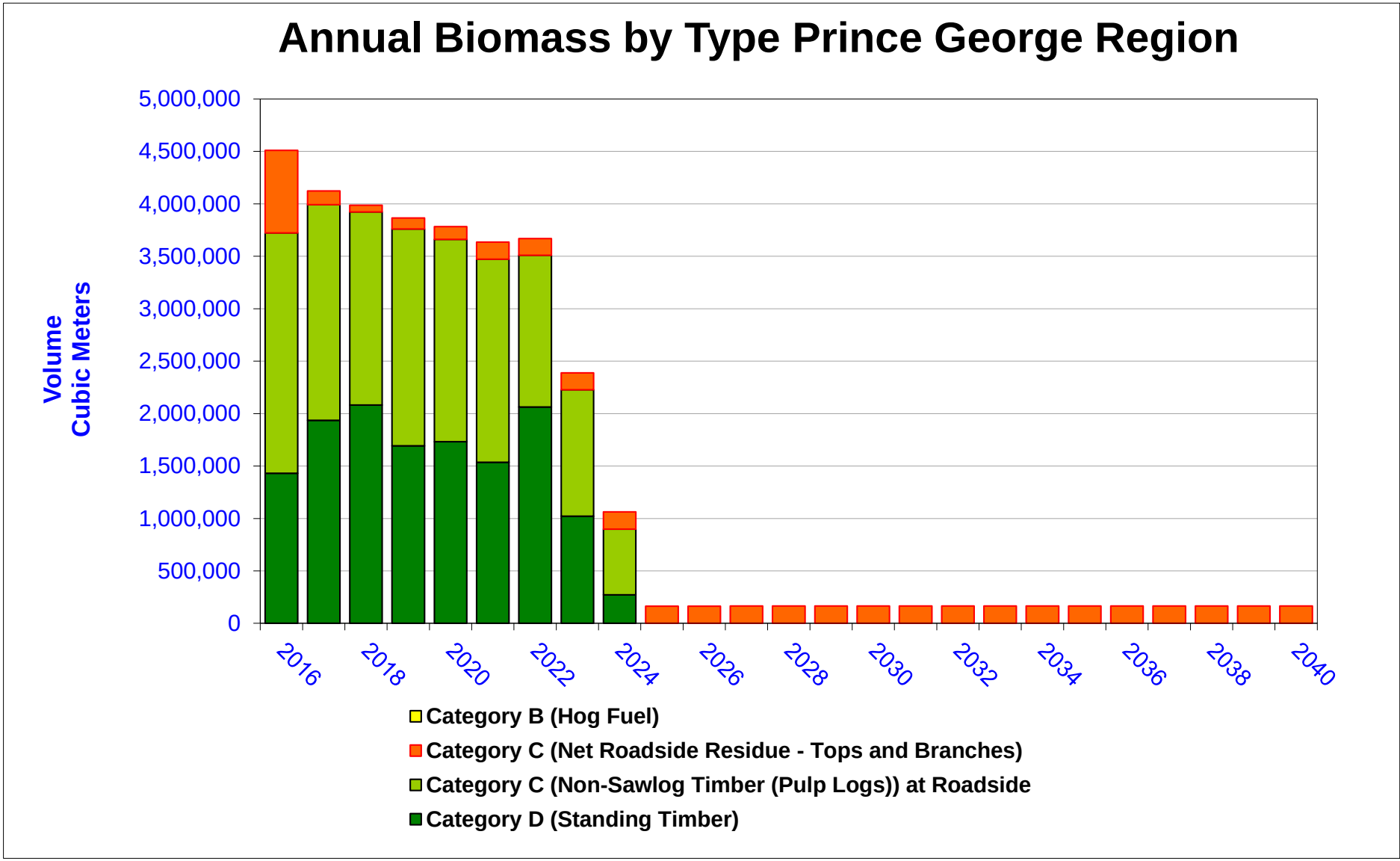
RESULTS - BC


Annual Biomass by Type All BC
Volume Cubic Meters
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Category B (Hog Fuel)
Category C (Net Roadside Residue)
Category C (Non-Sawlog Timber (Pulp Logs))
Category D (Standing Timber)

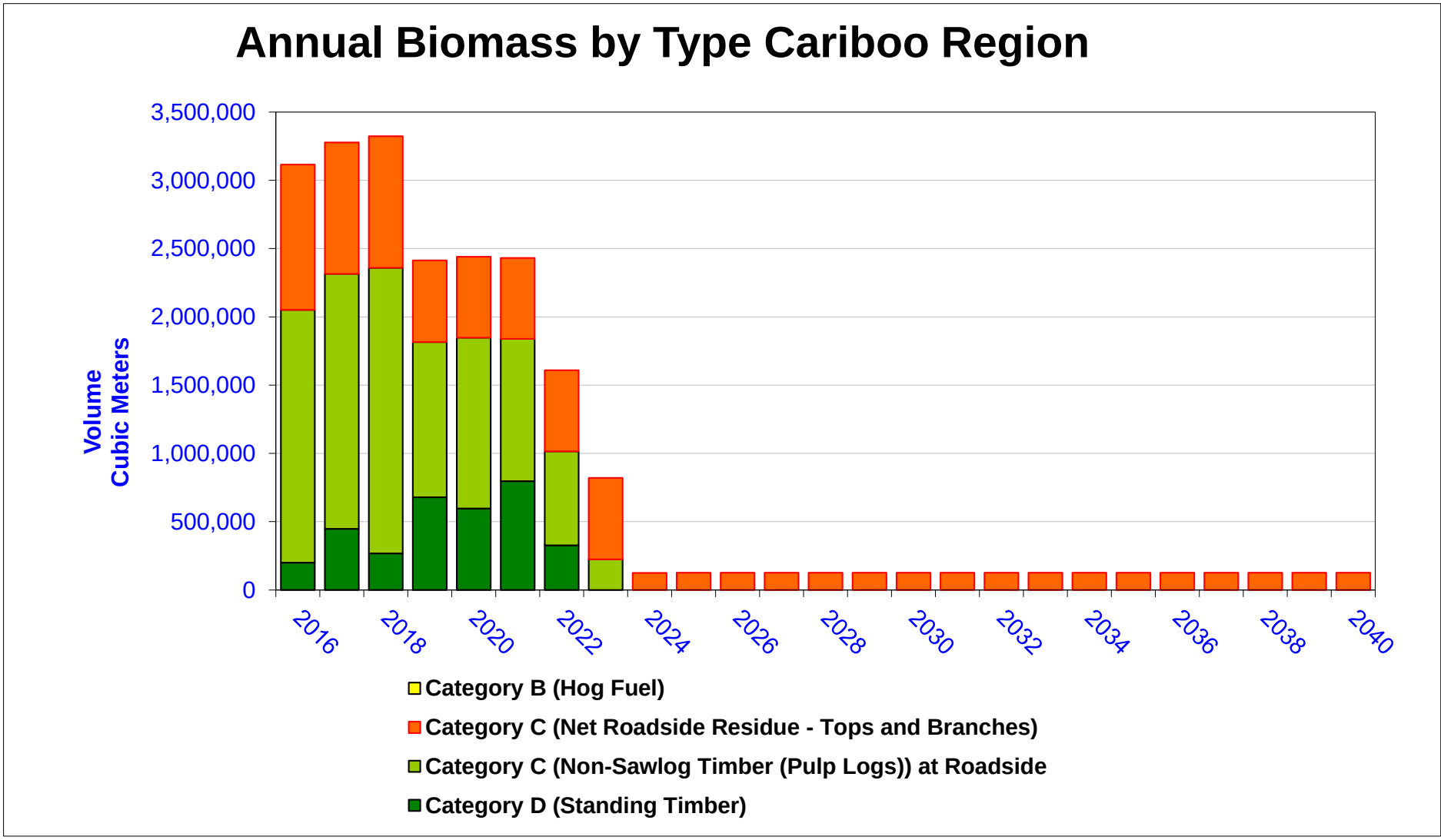
RESULTS – KAMLOOPS/OKANAGAN REGION



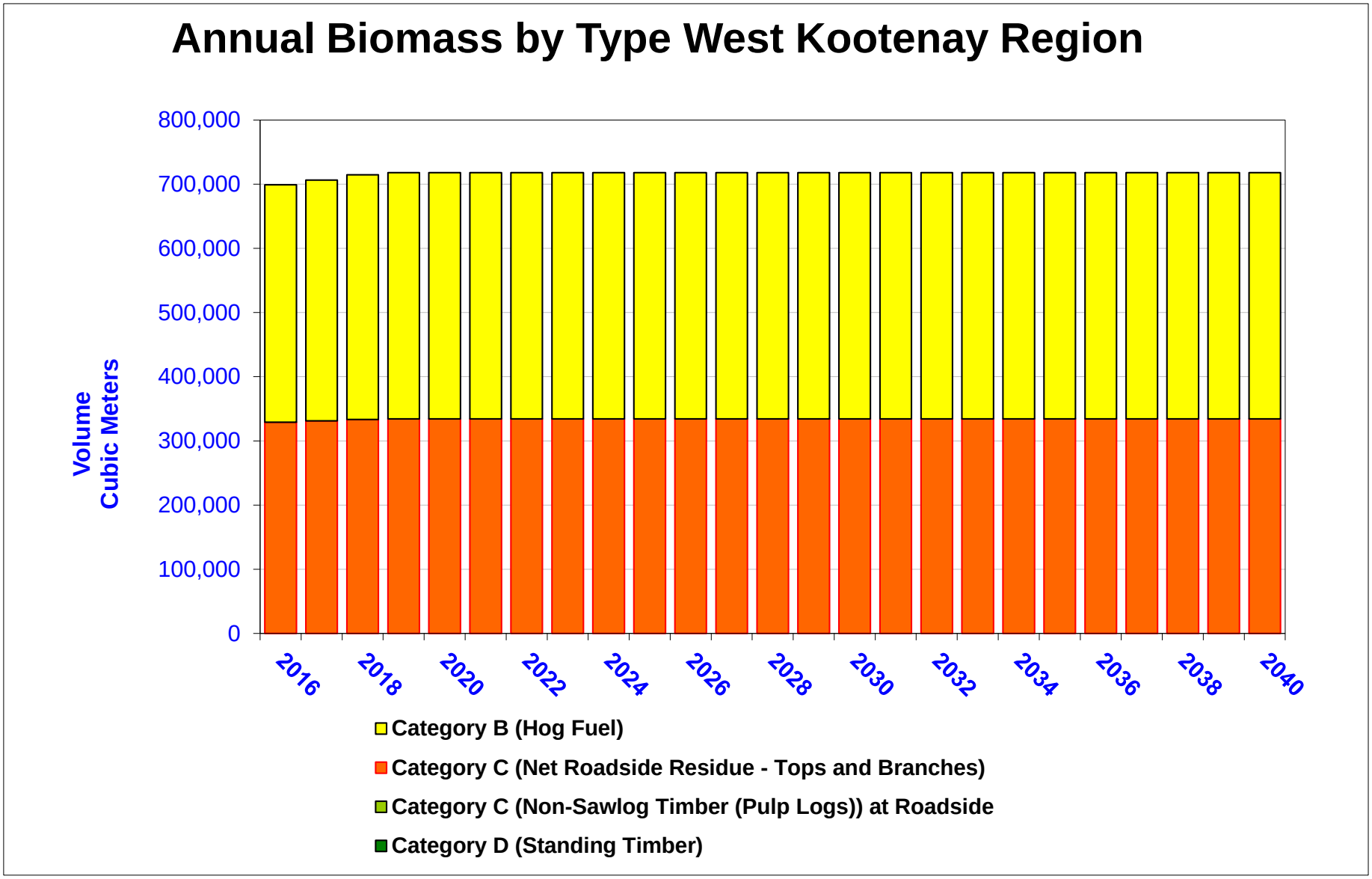
RESULTS – PRINCE GEORGE REGION



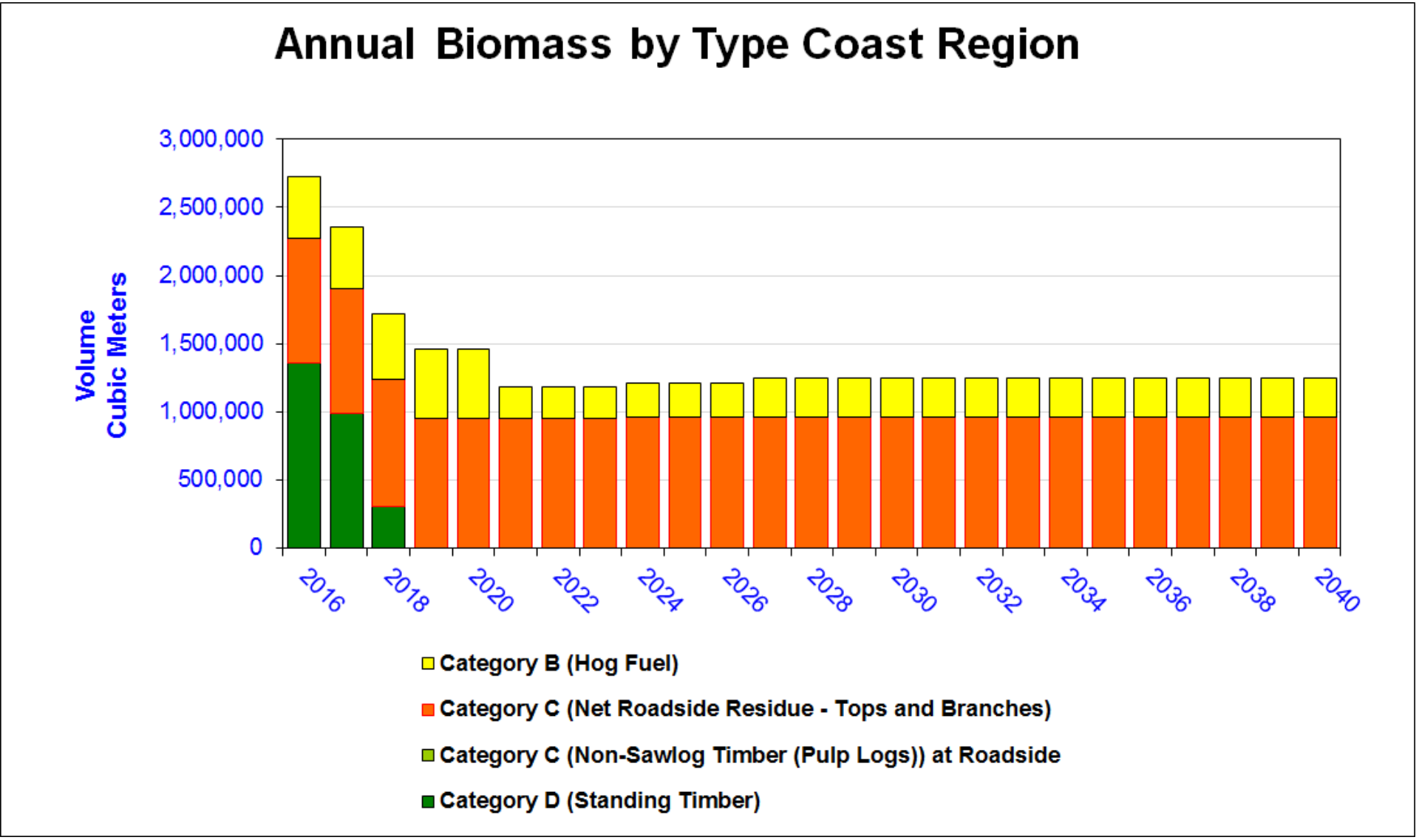
RESULTS – CARIBOO REGION



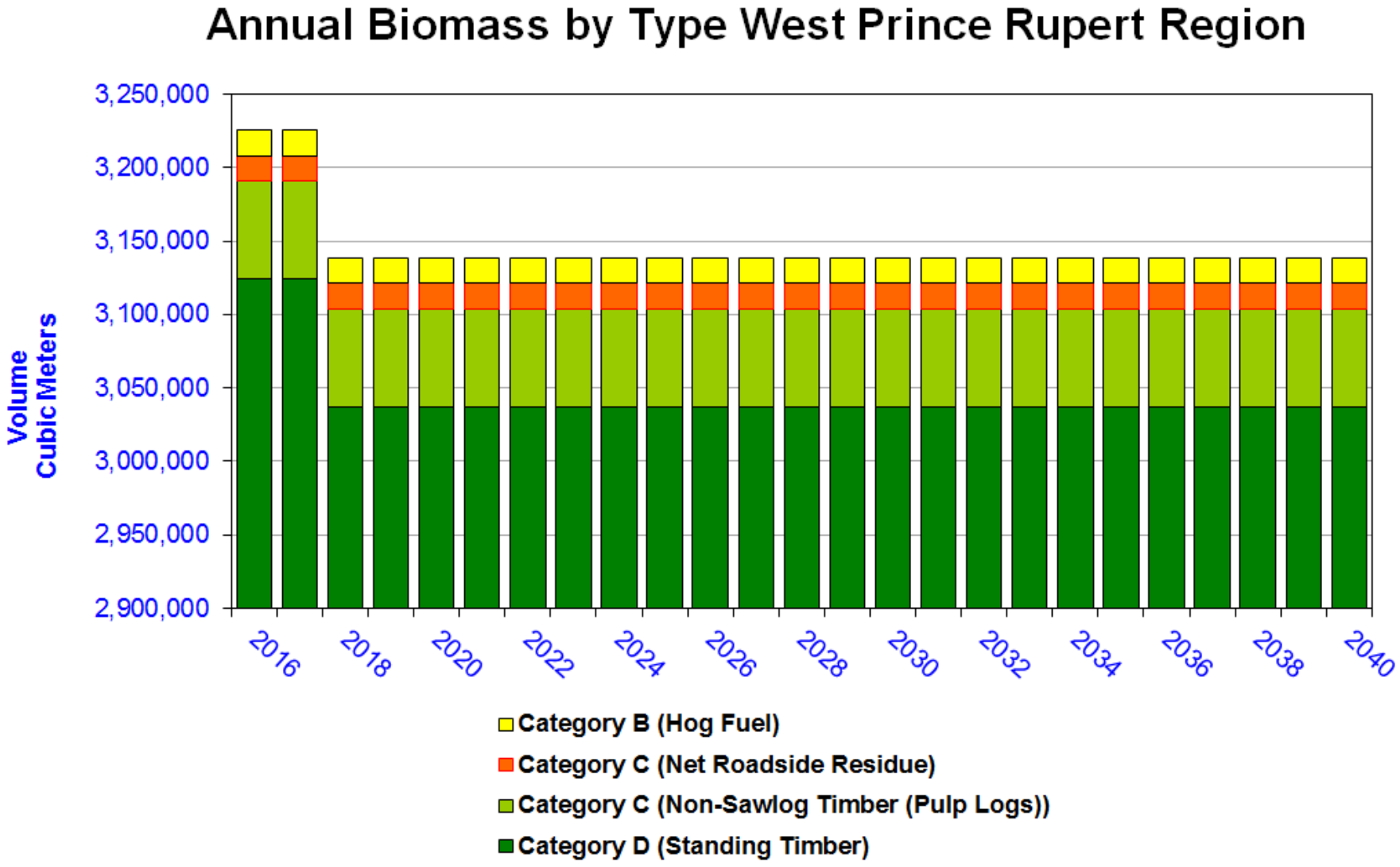
RESULTS – WEST KOOTENAY REGION



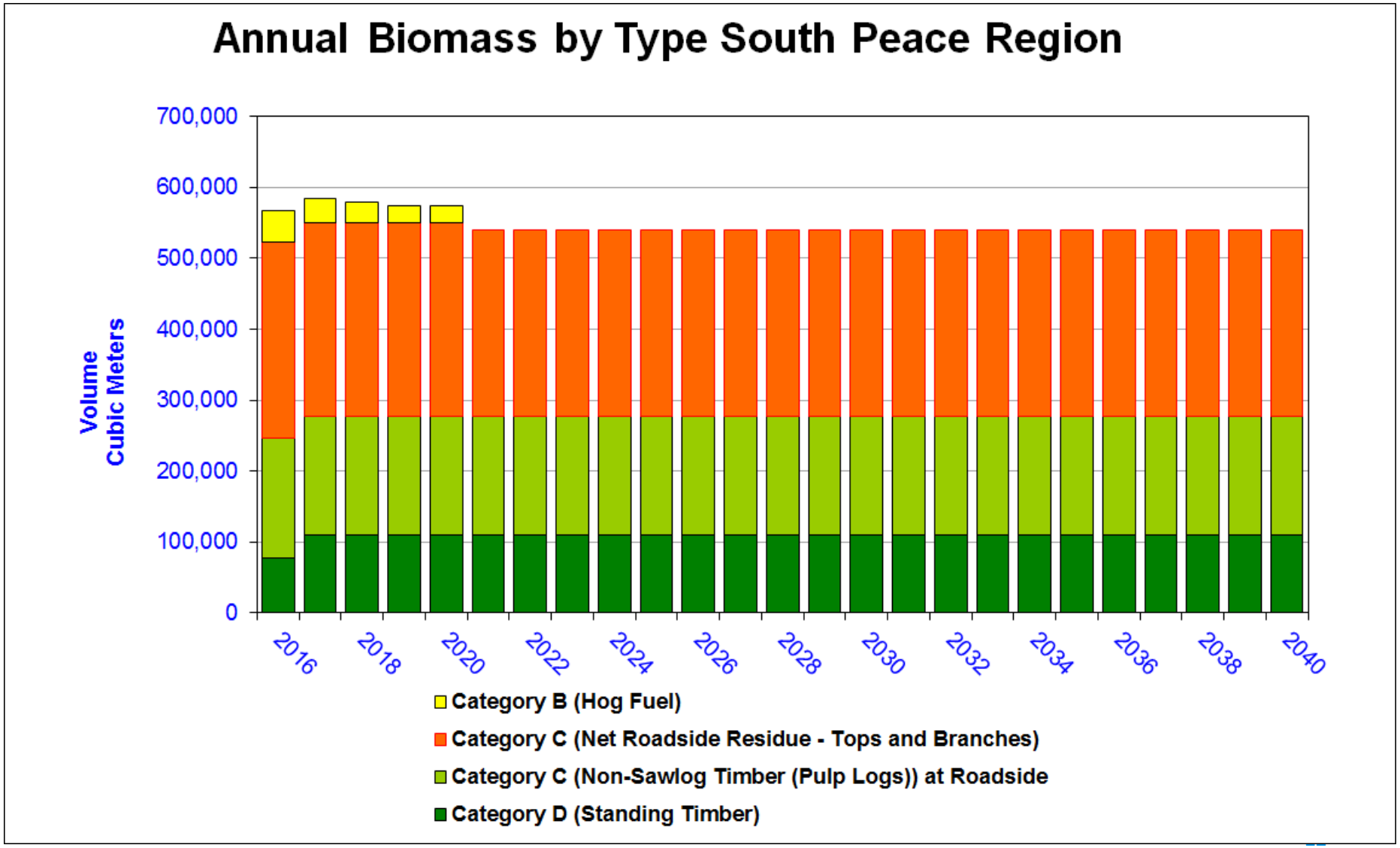
RESULTS - COAST REGION



RESULTS – PRINCE RUPERT REGION



RESULTS – SOUTH PEACE REGION



FIBER AVAILABILITY

- 2 periods: 2016 to 2025 (to match AAC fall down), 2026 to 2040 (to coincide with mid-term timber supply)
- 4 fiber categories:
  - Sawmill woodwaste/hog fuel: avg over the 9 year and subsequent 15 year period
  - Roadside woodwaste waste from normal harvesting operation: lowest 3 year running avg for the 9 year and subsequent 15 year period
  - Standing pulp logs waste from Mountain Pine Beetle epidemic: lowest 3 year running avg for the 9 year and subsequent 15 year period
  - Standing timber: avg over the next 9 year and subsequent 15 year period

FIBER AVAILABILITY

Region	Estimated Biomass Available Annually (cubic metres/year) by Period and Region							
	2016 - 2025				2026 - 2040			
	Sawmill hog fuel	Roadside logging residues	Pulp logs	Standing timber	Sawmill hog fuel	Roadside logging residues	Pulp logs	Standing timber
Coast	231,000	904,000		265,000	290,000	959,000		
East Kootenay		171,000				171,000		
West Kootenay	370,000	330,000			384,000	334,000		
Kamloops/Okanagan			281,000	43,000			283,000	
Cariboo		126,000		331,000		126,000		
Prince George		97,000	209,000	1,376,000		164,000		
Mackenzie		67,000	75,000	504,000		65,000		
South Peace		264,000	168,000	106,000		264,000	168,000	109,000
North-east				1,625,000				1,625,000
East Prince Rupert			458,000	550,000			254,000	11,000
West Prince Rupert	17,000	17,000	67,000	3,054,000	17,000	17,000	67,000	3,037,000
North-west				305,000				305,000

DELIVERED FIBER COST

- Fiber delivery points:
  - Locations assumed for the purpose of estimating transportation and delivery costs
  - Rationale for locations predicated on FLNRO indications of surplus biomass, based on historic availability of surplus
  - Several of these locations now have large projects forecast to commence operations (consider eliminating Prince George, Cariboo and Mackenzie?)
- Transportation cost & competition are key factors in the varying delivered fibre costs by region

DELIVERED FIBER COST

- Average log haul distance: relative to location of the working forest to the existing sawmills (for conversion to sawmill residues) or to the assumed fiber delivery points
- Average roadside waste haul distance : existing pellet plant experiences to working forest
- Average sawmill hog fuel distance and cost based on availability of surplus and distance to assumed fiber delivery points

DELIVERED FIBER COST

$/OVEN DRY TONNE (INCLUDING AVERAGE TRANSPORTATION COST)

Region Name	Standing Green Timber	Standing Pulplogs	Roadside Wood Waste	Sawmill Hog Fuel
West Prince Rupert	$174	$134	$65	$25
East Prince Rupert	$150	$116	$67	$23
North-West	$187	$144	$75	$25
Prince George	$162	$125	$67	$29
South Peace	$150	$116	$75	$40
North East	$187	$144	$67	$5
Cariboo	$162	$125	$62	$27
E. Kootenay	$162	$125	$70	$25
W. Kootenay	$174	$134	$80	$35
Kamloops/Okanagan	$162	$125	$73	$37
Mackenzie	$150	$116	$67	$10
Coast - Island	$199	$134	$67	$23
Coast - Mainland	$199	$134	$67	$30

- Standing Green Timber: cost excludes stumpage but includes $15/ODT conversion
- Standing Pulp logs: cost includes stumpage of $0.25/cubic metres + $15/ODT conversion
- Sawmill: market value

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FOR GENERATIONS

SUMMARY OF KEY CHANGES AND RESULTS

- Fewer sawmills, more pellet mills and bioenergy plants
- Less standing dead biomass as a result of harvesting, fires and trees falling down
- Reductions in regional Annual Allowable Cuts (AAC)
- Inclusion of deciduous into the AAC
- Allowance for pulp log shortages to come from standing green timber (Coastal BC impact)
- Higher pulp log costs
- Areas of highest potential:
  - South Peace (Chetwynd, Dawson Creek, Fort St John)
  - West Kootenay
  - Coastal (subject to salt issue)

BIOENERGY PROJECT ECONOMICS

- Common assumptions used by BCH for IPP projects
  - Cost of capital & interest during construction: 7% real
- Capital cost: $ 4.5 M/ MW
- Project lead time (construction and major capital spending): 2 years
- Project life: 15 years
- Typical plant size: 35 MW
- Capacity factor: 91% (~280 GWh/a)
- Annual cost: 3.5% of capital (OMA, taxes and misc expenses)
- Resulting Unit Energy Cost excluding delivered fiber cost: $ 84/MWh

BIOENERGY PROJECT ECONOMICS

- 2.45 cubic metres of wood = 1 oven dry tonnes at 0% moisture
- 0.72 oven dry tonnes to 1 MWh of electricity
- Fuel mix: assumes weighted average delivery of all available Sawmill woodwaste and Roadside debris, separately for standing pulp log, separately for standing timber (other suggestions? Some regions might have enough low cost fiber for smaller plant)

Period	2016 - 2025								2026 - 2040							
Biomass Type	Sawmill Waste		Roadside Residues		Pulplogs		Standing Timber		Sawmill Waste		Roadside Residues		Pulplogs		Standing Timber	
Region	GWh/ Year	Delivered Fiber Cost ($/MWh)	GWh/ Year	Delivered Fiber Cost ($/MWh)	GWh/ Year	Delivered Fiber Cost ($/MWh)	GWh/ Year	Delivered Fiber Cost ($/MWh)	GWh/ Year	Delivered Fiber Cost ($/MWh)	GWh/ Year	Delivered Fiber Cost ($/MWh)	GWh/ Year	Delivered Fiber Cost ($/MWh)	GWh/ Year	Delivered Fiber Cost ($/MWh)
Coast - Mainland	131	$22	512	$48			150	$143	164	$22	544	$48				
East Kootenay			97	$50							97	$50				
West Kootenay	210	$25	187	$58					217	$25	190	$58				
Kamloops/Okanagan					159	$90	24	$117					161	$90		
Cariboo			71	$45			188	$117			72	$45				
Prince George			55	$48	118	$90	780	$117			93	$48				
Mackenzie			38	$48	42	$84	286	$108			37	$48				
South Peace			149	$54	95	$84	60	$108			149	$54	95	$84	62	$108
North-east							921	$134							921	$134
East Prince Rupert					259	$84	312	$108					144	$84	6	$108
West Prince Rupert	10	$18	10	$47	38	$97	1731	$125	10	$18	10	$47	38	$97	1721	$125
North-west							173	$134							173	$134

BIOENERGY TECHNOLOGIES

Technologies	Capital Cost range ($/kW) Excluding interconnection cost	Project life (yrs)	ODT/MWh	Lead time (construction and major project spending) months	Fiber required (ODT/a) Assuming 91% capacity factor	Typical size (MW)	Additional considerations
Conventional Boiler	$4500	15	0.72	24	200 k	~35	
Organic Rankine Cycle	$6000	15	1.48?	24	10 k to 50 k?	2 to 10	Ideal for strategic location to match woodwaste availability
Fluidized Bed • Bubbling • Circulating	$4500	15	?	?		50+	Require large and steady state fiber supply

Other technologies? Further cost breakdown e.g: fixed OMA/variable OMA excluding fiber cost
Environmental attributes
CHP: Combined Heat & Power
Greenfield Versus Add-on

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NEXT STEPS / HOW TO CONNECT

Next Steps

- Submit written comments to BC Hydro by April 7, 2015
- Comments will be considered and incorporated as appropriate
- Final study results expected by end of April

Contact information

- Kathy Lee Kathy.Lee@bchydro.com
- IRP inbox integrated.resource.planning@bchydro.com

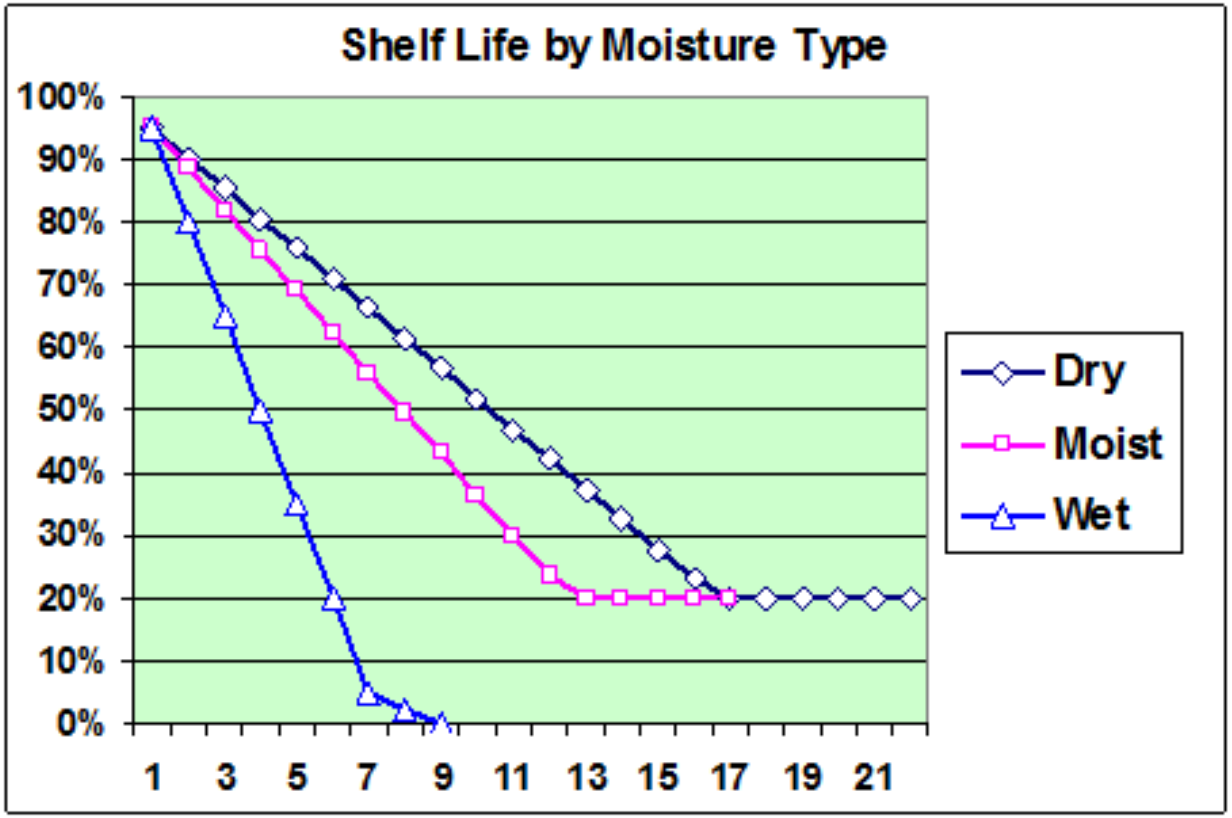
General information and engagement materials

- www.bchydro.com/generationoptions

THANK YOU FOR YOUR INPUT

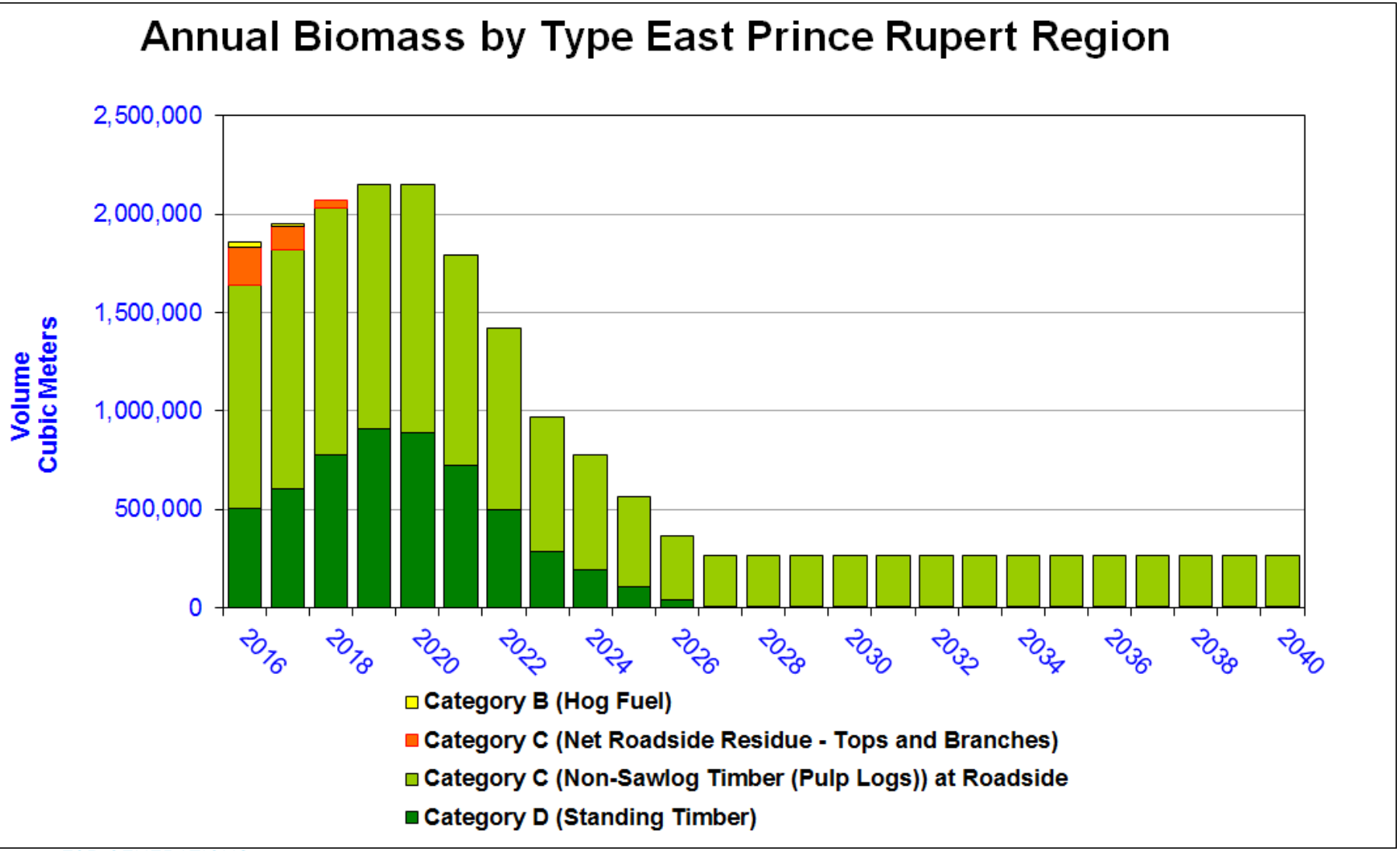
BACKUP SLIDES

SHELF LIFE

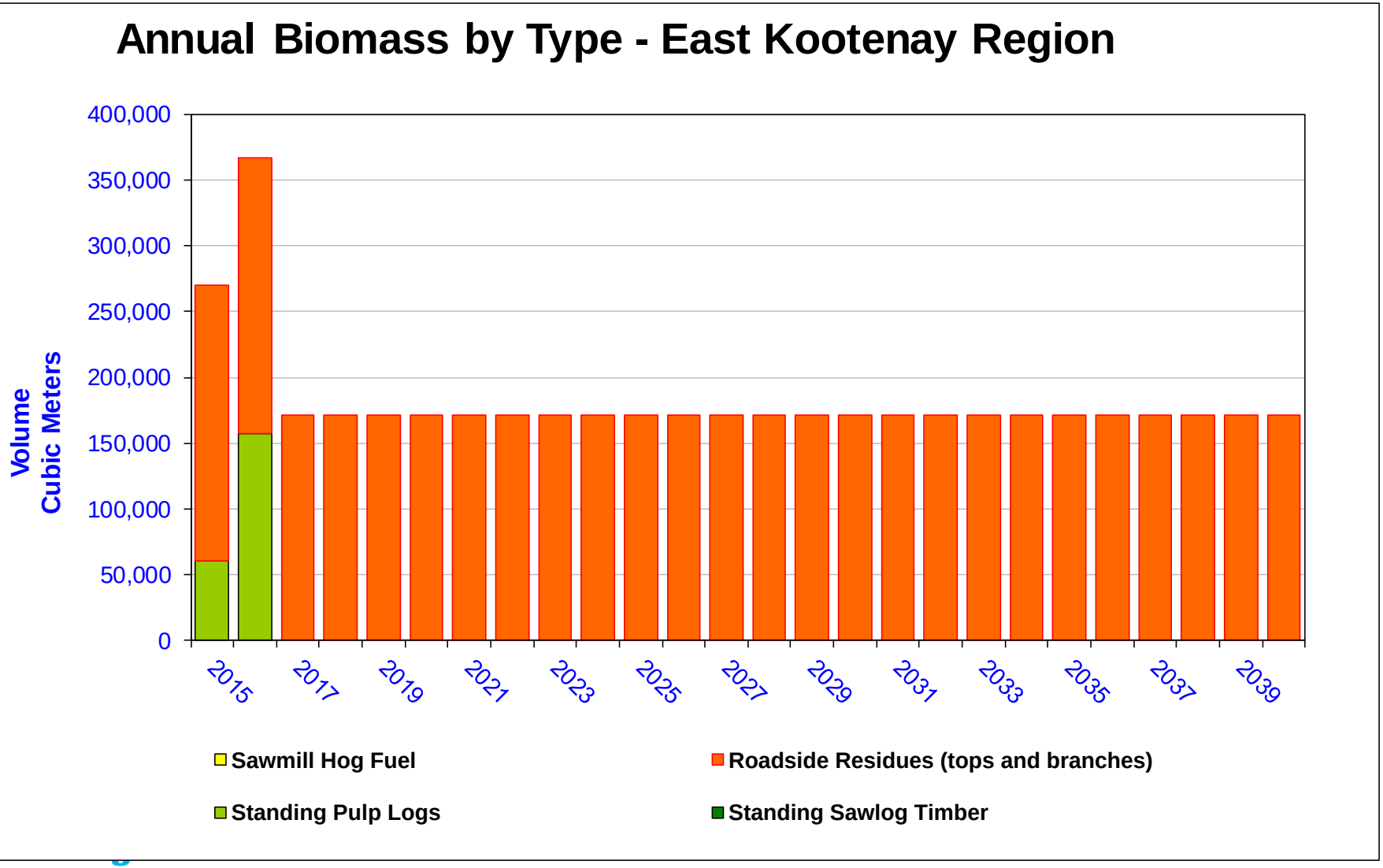


This table was applied to all stands assumed harvested as part of the AAC that contributes to the MPB partition *starting in the year in which 90% of the pine within the Forest Management Unit (FMU) was killed*. Prior to that point, it is assumed that all stands (dead or not) contain 95% sawlogs. However, once the MPB "shelf-life clock" starts, there are diminishing percentages of sawlogs, based upon the proportion of pine within each FMU and the length of time that passes after the pine has died.

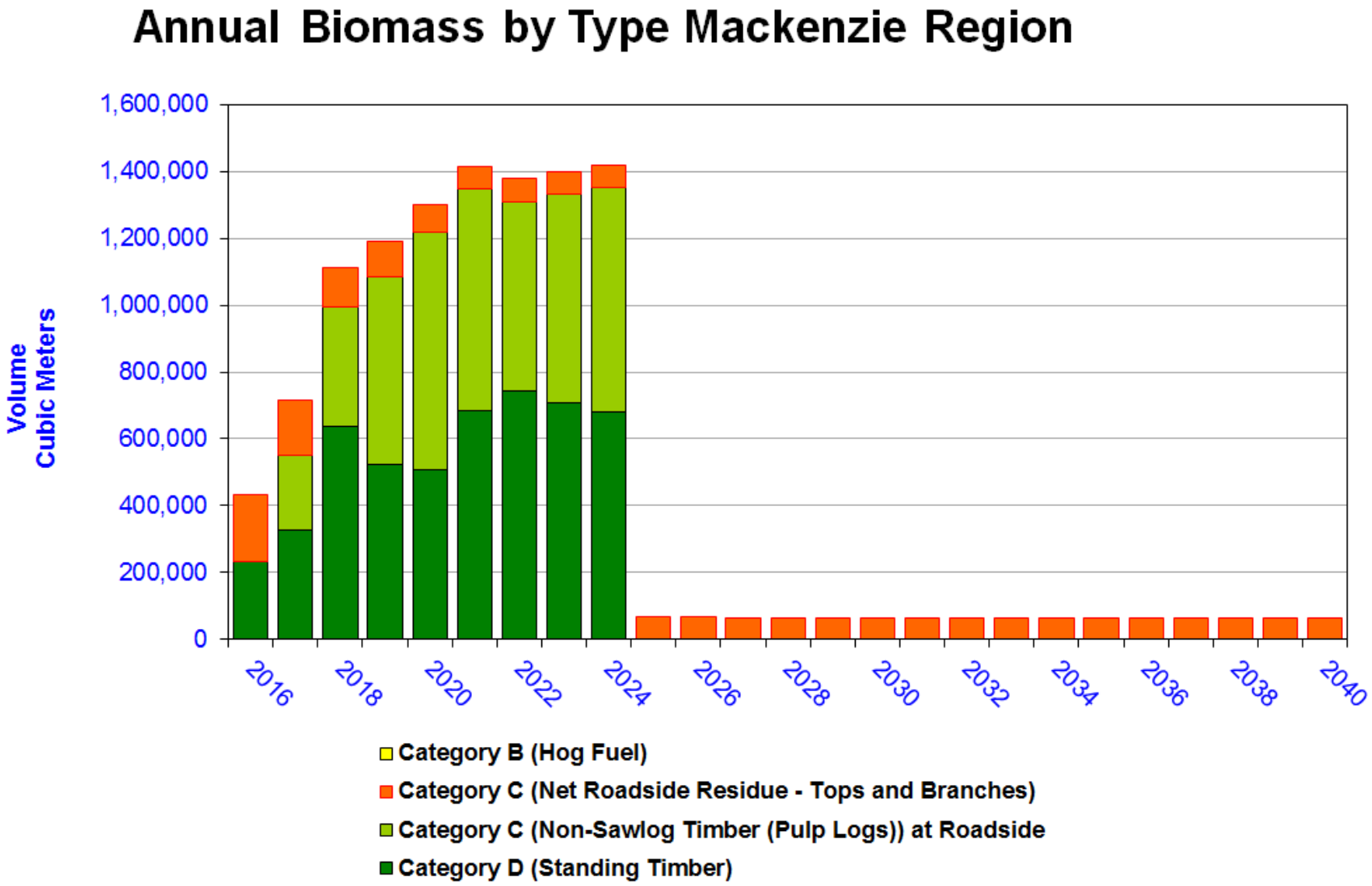
RESULTS


Annual Biomass by Type East Prince Rupert Region
Volume Cubic Meters
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Category B (Hog Fuel)
Category C (Net Roadside Residue - Tops and Branches)
Category C (Non-Sawlog Timber (Pulp Logs)) at Roadside
Category D (Standing Timber)

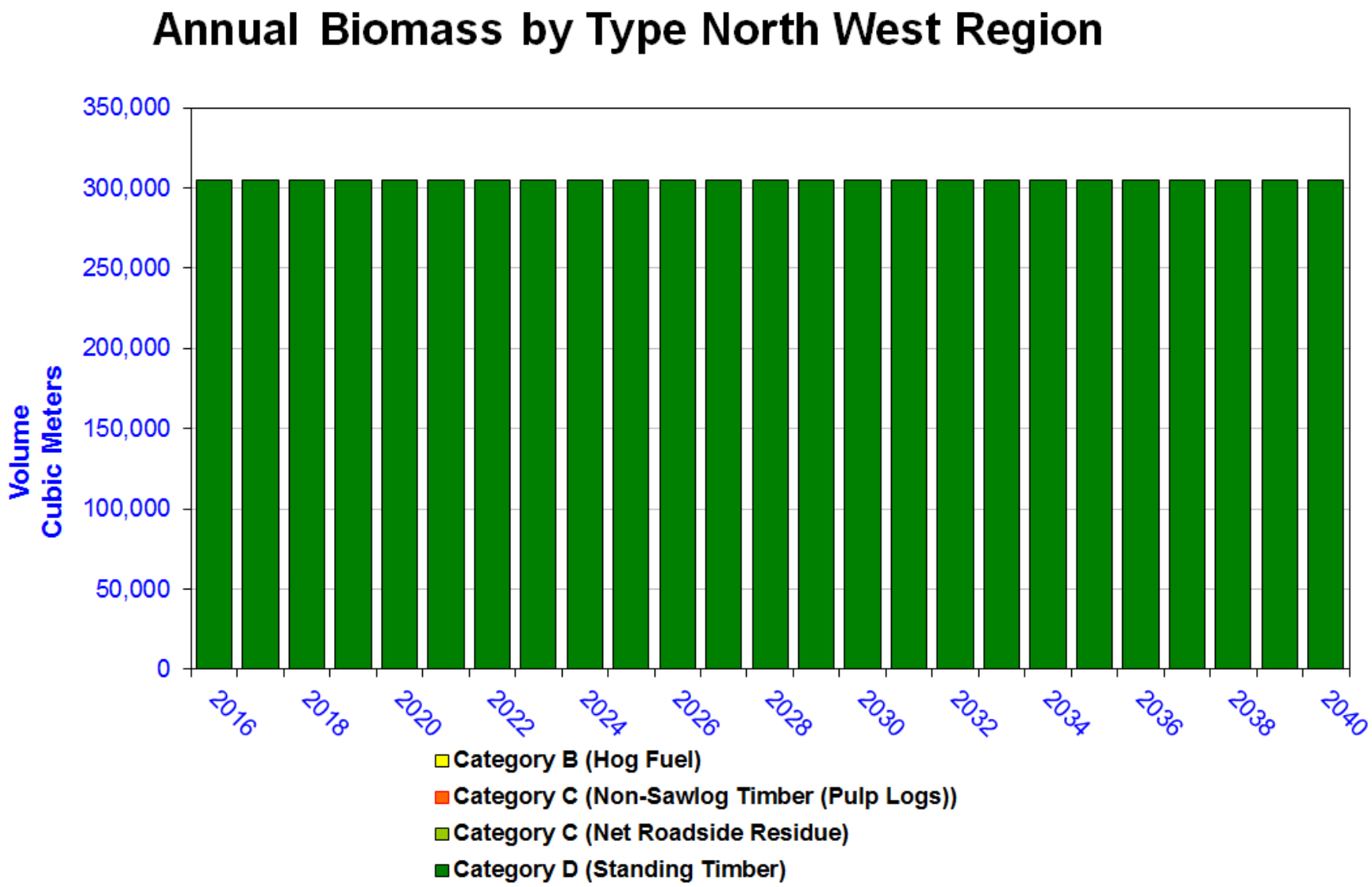
RESULTS


Annual Biomass by Type - East Kootenay Region
Volume Cubic Meters
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
Sawmill Hog Fuel
Roadside Residues (tops and branches)
Standing Pulp Logs
Standing Sawlog Timber

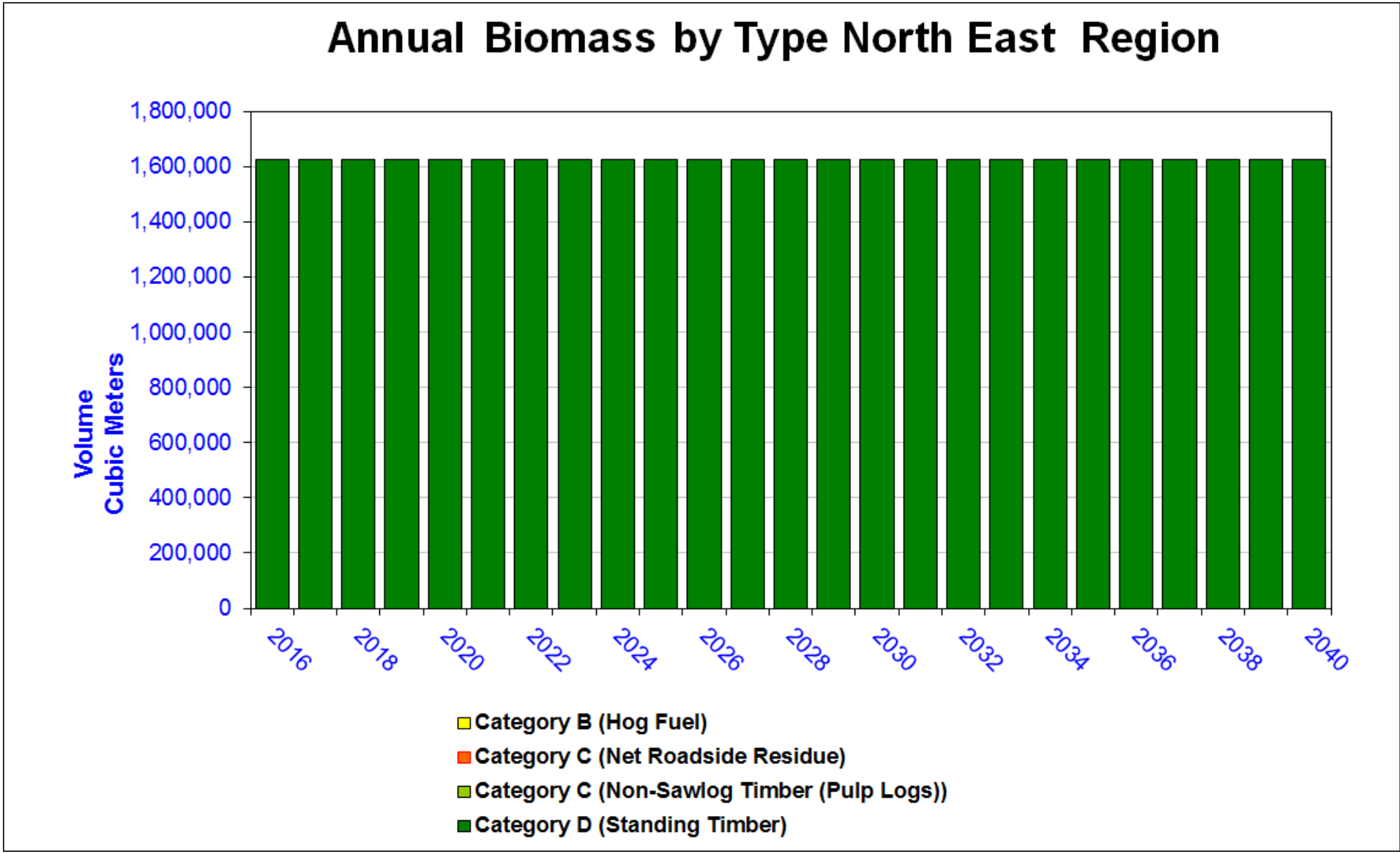
RESULTS


Annual Biomass by Type Mackenzie Region
Volume Cubic Meters
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Category B (Hog Fuel)
Category C (Net Roadside Residue - Tops and Branches)
Category C (Non-Sawlog Timber (Pulp Logs)) at Roadside
Category D (Standing Timber)

RESULTS


Annual Biomass by Type North West Region
Volume
Cubic Meters
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Category B (Hog Fuel)
Category C (Non-Sawlog Timber (Pulp Logs))
Category C (Net Roadside Residue)
Category D (Standing Timber)

RESULTS


Annual Biomass by Type North East Region
Volume
Cubic Meters
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Category B (Hog Fuel)
Category C (Net Roadside Residue)
Category C (Non-Sawlog Timber (Pulp Logs))
Category D (Standing Timber)