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PIPELINE HYDRO - TRANSPORT of Wood Chips is an Environmentally Sound, Social Responsibility in the Transportation Industry, Supporting International Trade for Industrial, Paper, or Biomass Markets: ***Continuous flow increases export output, enhances workforce opportunities, while dramatically reducing carbon emission footprint and costly highway infrastructure expenditures by excluding truck transportation.***

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Introduction

Wood chip feedstock supply is heavily impacted by a level of transport efficiency or by its negative effect on environmental exigencies, when predominantly associated with heavy over the road, truck-based transportation. This paper examines an alternative transport process for the movement of wood chips from within Maine's temperate forests to a port facility, for subsequent loading to a vessel. Pipeline transport of wood chips (hydro-transport) is an "economically viable means of delivering large volumes" of [wood chips], and can replace conventional modes of transport – (e.g., truck transport, or rail transport)" [1] - to improve the economy of pulp and paper mills, fibreboard, plywood, as well as renewable energy, wood chip biomass facilities. This paper is a review of extant studies and publications produced by various segments within the forest products and transportation industries regarding traditional means and methods of transportation and onshore pipeline transport of wood chips in water mixed (slurries).

The aim is to: identify challenges and structural barriers to pipeline transport; apply appropriate recalibrated mechanical and construction related performance equations; facilitate a business environment built around the practical regulations and transparency necessary to ensure sustainable, ethical, and responsible business practices where applicable to transportation – through lenses of Corporate Social Responsibility (CSR): Concepts, Methodologies, Tools, and Applications are a vital reference source on the ways in which corporate entities can implement responsible strategies and create synergistic value for both businesses and society.

Beyond the expansive financial costs of truck transport, there are existential threats to our regional and global environment - intensified by transportation, not only by truck transport but, also by rail. Industrial and commercial transport is inextricably associated with high carbon emissions, CO_2 contamination of the atmosphere. Over the road truck transportation is viewed in comparison to other forms of on land bulk transport modes such as rail. Transportation in this review includes pipeline transport, and all such transport is hereinafter referred to as 'onshore' transportation.

This inspective assessment explores an alternative onshore pipeline transport option for the movement of wood chips. This is not a new concept however it is examined here as paradigm alternative to truck or rail transport from forest to port across Maine. We discuss two pipeline scenarios with varied distances, which support two distinct scenarios that require independent examination.

"The economic advantages of pipeline transportation are quite attractive:" [2]

A Proven Case Review of: Hydraulic transportation of wood chips by pipeline.

The Pulp and Paper Research Institute, of Canada, "pioneered in studies of the technical feasibility of sending wood in the form of chips in water slurry over long distances through pipelines from the forests to the mills."[3] Thiesmeyer wrote that "At first there was not much interest in this subject on the part of the pulp and paper industry. *The concept seemed too radical a departure from conventional practices* of sending the wood in the form of logs down the river systems or by truck or rail." This is likely the same type of sentiment one might expect in the current climate of rushed opinions and pushback. However, when a sustainable supply of processed wood chips became an overwhelming demand for paper mills; the focused turned to pipeline transportation of feedstock, and that supply was required to be delivered direct from the forests to the mill. The pipeline was constructed.

> *"Conventional chips supplied from a nearby mill were sent through this pipeline at varying velocities and in varying mixtures with the water. The velocities used ranged from 1.2 to 3 meters per second and the mixtures ranged up to 48 percent by volume of wood. At this high concentration of chips a 20-centimeter (7.87") diameter pipeline would be capable of carrying approximately 800 tons bone-dry of wood per day from forest to mill at a flow rate of 1.8 meters per second, and a pipeline 88 kilometers (54.68 miles) in length would empty itself in approximately 24 hours. Hence, there would be no strong requirement for a large pile of chips at the mill or at the feeder end of the pipeline. Thus year-round operations would be possible and it was estimated that 900,000 cubic meters of wood would be necessary to feed such a line on a continuous basis the year round. Moreover, it was established that the chip-water slurry could be passed through an ordinary centrifugal pump without damage and, indeed, that the damage to the wood for pulp or papermaking was really negligible after it had been given the equivalent of hundreds of kilometers of transportation in the pipeline."*[4]

Benefits of chip pipelines – Reported in the Above Pipeline Program[5] *and (Current Comments)*

1. Low unit transportation costs. (*Economies of Scale apply and will reduce transportation costs as the volume increases. The proposed pipeline in this paper can be engineered to transport 900,000 Metric Tonnes (990,000 US Tons) yearly. The capacity of the port infrastructure is capable of handling that increased volume.*

2. Low labor content of the system. There should therefore be only a minor increase in transportation costs over a conservatively estimated 20-year pipeline life. (*While the project would provide a significant job base for local workers, the need for a larger work force would only be driven by the increase in export volume but not due to increased tasks.*)

3. Low annual depreciation charges compared to new rail or road construction. Even a buried line would be less costly than a new road or railroad roadbed. (*During the initial construction phase, a second line could be lowered into the trenches for future flow to the port, or to allow for a return water line, or to provide a second line to transport a different type of wood chip at the same time the first line is pumping.*)

4. Drastic reduction in [facility – pump station], forest and in-transit inventories of pulpwood.

5. Suitability to continuous \ operations.

6. All usable wood species transported without sinkage losses. Reduced need for costly selective logging and handling.

7. Utilization of small-diameter wood (tree-tops and branches) which are now largely wasted. (*for biomass production and transport, the use of residual fiber from traditional forestry*

operations is extremely cost efficient, carbon neutral and the material would have been left in the forests to decay.)

8. Independence from many weather and terrain conditions. This is particularly important in northern latitudes. (*All lines would be buried at least 5' deep to avoid frost. Lines would be most easily and economically buried in right of ways and or road easement areas – thus reducing the cost of land and the acquisition of obtaining entitlements.)*

9. Elimination of log storage, handling and protection costs at the mill (*fire insurance, watering-down of blockpiles, large capital equipment for building blockpiles and processing logs to chips.*) No need for log ponds, booms, stackers, conveyors, rafts and tugs, jackladders, woodroom and barkers.

10. Possible re-use of carrier water at the mill for water reclamation.

11. Availability through the forests of a pressurized water supply for fire-fighting in an emergency. Eventually a permanent system of hydrants at important locations.

12. Possibility of sharing between two or more companies the costs and chip volume use of the pipeline system.

13. Possible multiple use of the line for alternate slugs of chips and other materials (minerals, ores, etc.) also available in the same forest areas. Technology for this exists already. (*Demand for multiple species from the same forests is already in existence*.)

14. Processing of slash and bark at the head of the trunk pipeline or its subsidiary feeder lines, flumes or conveyors. Hence, removal of the fire hazard represented by present practice of leaving slash scattered over the logged area.

15. Better yields and product quality because of continuous delivery of green wood to the mill. (*In this case, to the port facility*).

16. Possible transportation of bark, needles, stumps and roots for utilization. (*EU markets exist for other products including bark, saw dust, mulch materials, etc.*).

17. Wider choice for the location of new mills, even to urban centers closer to markets. (*Today we would look at additional forest locations that could be utilized as well. Shorter pipelines could be established to tie the added forest location to the primary pumping station. The hydraulic push could be accomplished by water flow from the main station and back thought the new location, in a looped system. This would eliminate the need to build a new pump at the new forest location*.)

18. Possible computerized transportation integrated with computerized mill pulping and papermaking. (*Today, we would implement a system of data collection points along the pipeline to monitor the myriad of events and circumstances in the flow. This would be third part inspection services, which would provide assurances and accountability measures for controlling or governing entities, and buyers alike.)*

19. Much faster wood delivery to the mills for much faster processing there on a continuous flow basis. (*A continuous flow would provide the following (365 days per year, at 24 hours per day would provide 8,760 hours X 85% efficiency probability = 7,446 productive hours per year)*.

20. Financing of such a project can be established through MaineDOT Grants, USDA Grants, Towns and Municipalities, Public Private Partnerships, Joint Ventures between major forestry professionals, equipment suppliers, End User/Buyers and by Port Authority recognition and support.

The economic advantages of pipeline transportation are quite attractive[6]
The below observations are cited from above mention:

Automation:
Pipelines have been automated for approximately twenty years. Once [material] has been injected into the pipeline it is left unattended until the next input or discharge point. Pumping stations are controlled automatically from a central master station.

Dependability:
Dependability of pipelines has been proven. A pipeline in Utah has been operating for seven years.[7] The Consolidated Coal Company (*evidence of solid flow of materials harsher than wood chips*) operated a 108-mile pipeline in Ohio without a shutdown for three years.

Operating Costs:
Operating costs are; low; other costs are mostly fixed and remain nearly constant over the life of the installation. Other transportation systems have higher operating costs and are more easily affected by the rising costs of labor and personnel.

Maintenance Costs:
Maintenance costs are low since pumping stations have few moving parts and the pipeline is buried and subject to little wear.

Unintended Attribute of Pipeline Transport of Wood Chips: Another benefit to a pipeline transportation system is that it would have major positive and unintended consequences on advancing the EU requirement that all wood fiber from North America must meet Phytosanitation Guidelines that demand wood chip be heated to a temperature of 56°C to the core of the chips, for a minimum of 30-minutes. This Phytosanitation process has been a stumbling block or barrier to wood chip exports since 2015. This author was the first person (entity) to achieve a full cycle, successful shipment of Heat Treated Kraft Quality Paper Wood Chips to the EU in September 2014. The shipment went to Mercer International Paper Company in Germany. The shipment originated from Searsport, Maine.

Feedstock Transport Locations
Maine forests are classified as 'Temperate' where they cycle through all four seasons and depending on the regions throughout Maine, "you can find coniferous forests full of evergreen trees that have leaves year-round; deciduous forests with trees that shed their leaves every year; and some forests with a mix of everything."[8] We explore pipeline distances, which support two distinct scenarios requiring independent examination. (Exhibit "A")

The first scenario would extend up to approximately 50-miles, from within the heavily wooded forests of the Native American 'Passamaquoddy Tribal Land Trust', and it would terminate at the deep-water Port of Eastport, Maine. This scenario provides a continuous supply source whereby the pipeline would move wood chips on a continuous 24/7/365 supply schedule, with very little truck movement required.

The alternative scenario would provide a pipeline system with an approximate distance of just under 20-miles from within the Meddybemps/Perry region, where a pipeline receiving station or facility could be constructed and the wood chip materials could be transported to the Port of Eastport, Maine.

We make no distinction between any particular species of wood-chip feedstock, whether its end-use is destined for paper production,[9] manufacture of medium density fiber (MDF),[10] oriented strand board (OSB),[11] or high energy densified biomass ($E=MC^3$).[12]

Barriers to Increased Utilization of Port Facility

Roads – Highway Constraints

State Route 190 (SR 190) is a 7.1-mile (11.4 km) state highway that travels from Water Street in Eastport to U.S. Route 1 (US 1) in Perry.[13] Route 190 serves as the connector route to Eastport from the mainland. (Exhibit "B") Route 190 continues as the primary transportation corridor serving the island city and the Port of Eastport. Route 190 traverses through Passamaquoddy territory and presents a naturally understandable barrier due to the necessity of, and reliance upon this small 7.1-mile path of State Road, to support an extraordinary use of heavy trucks loaded with wood chips for export. According to a study for transport of windmills, conducted by Sewall, the adjoining Route 1 at the intersection of Route 190 is typically a "50 mph route and slower toward Calais on Rt-1 and presumptively toward Eastport on Route 190. Pavement is roughly two-twelve foot lanes with 6-foot shoulder for a total of 36-feet."[14]

To support the "steady stream of shipments that averaged 300,000 [metric] tons a year and provided consistent work for about 70 direct and indirect workers"[15] there is a requirement for 11,000 truckloads annually, or a minimum requirement of 917 truckloads of wood chips to be delivered monthly – and a return traverse over the same road, by empty truck. For immediate clarity, export volume is measured in metric tonnage. The equivalent of 300,000 metric tonnes is 330,000 US tons. Legally authorized payloads of wood chips, per truck is 30-US tons. This volume would require 11,000 fully loaded trucks per year to traverse Route 190. This accounts for inbound traffic only and is doubled to 22,000 passages, to account for the return trip outbound from Eastport.

Route 190 - Heavy Truck Traffic Calculations

Annual Volume: Wood Chips	Metric Tonnes -	US Tons - USt
	300,000	330,000
Average Legal Truck GVW (pounds)	72,000	80,000
Average Legal Truck GVW (tonnes/tons)	36	40
Truck/Trailer	9	10
Payload	27	30
Annual Inbound Volume of Truck Traffic	11,000	11,000
Monthly Inbound Truck Traffic	916.67	916.67
Estimated Weekly Inbound Truck Traffic	229.17	229.17
Estimated Weekly Hours of Truck Traffic		75
Hourly Inbound Truck Traffic - to Port		3.06
Hourly Outbound Truck Traffic - from Port		3.06
Total Hourly Truck Traffic Count		6.11
Annual GVW Inbound (Truck/Trailer/Cargo)		330,000
Annual GVW Outbound (Truck/Trailer/Empty)		110,000
		440,000

Maine truck weights allow for a fully loaded rig to be 80,000 pounds (40-US Tons) gross vehicle weight GVW comprised of tractor/trailer and payload. On Interstate Systems, there can be exceptions granted to increase the GVW up to 100,000 pounds. Not accounting for overweight loading permits, the standard GVW inbound to the port will be 80,000 pounds (40-US Tons), and the outbound GVW will approximate 20,000 pounds (10-US Tons).

Considering reasonable hours for heavy truck traverse across Route 190 may be between 6 AM and 7 PM (13-hours per day), Monday through Friday plus partial day on Saturday (75-hours per week); the monthly inbound traverse of 917 trucks would roughly equal 229 trucks per week traffic, to require three (3) trucks per hour – each way or six (6) trucks per hour – hour after hour. Annual US Tonnage over the 7.1-mile stretch of Route 190 will be 440,000 US Tons per year to be moved by heavy truck transport.

The above numerical estimates reflect truck traffic required only for wood chip movement, there is no observance for additional truck traffic required to support any other port-related services, no accounting for trucking needs to serve downtown business operations or any other service, and there is no accounting for traditional private or personal vehicular traffic to support work related transportation for remote employment. Route 190 cannot sustain truck transport to support the lowest prediction of 330,000 US Tons per year, much less support an increase in wear and tear on Route 190 should the export volume of wood chips meet desired expansion volumes per year.

Rail Service – Lack of Existence – Consideration of Restoring Rail Line
One does not need to be an economic development professional to have an appreciation of the effect various transportation modes have on the economic vitality of a city. Eastport lost its rail connection in 1978 when Maine Central Railroad abandoned the 15.5-mile line out of financial necessity. In 1980 the track and its infrastructure were removed. "Eastport is just about the only port without a rail connection in the country."[16] Assuming there were available land for a restoration of the line, and adequate funding for the project was obtainable; the rail would not go directly to the port, but it would likely terminate in Perry.

Terminating in Perry would create the need for transshipping facility to offload rail cars, and load wood chip hauler trucks, in a similar manner as was performed in South LaGrange, during the height of the paper mill production days. The 60-acre rail-siding in South LaGrange afforded a 40-railcar spur, on approximately a ½ mile rail siding, holding approximately 75-tons of wood chips each (*estimated but slightly higher than an average of 70-US tons*). One rail movement per week to Perry would provide 3,000 US tons per week – two rail movements would provide 6,000 US tons per week. We base this action on the two rail movement statistics.

The maximum weeks that an active delivery schedule could produce is 52-weeks per year. This is unrealistic due to circumstances out of the control of any major rail service. Weather plays a major part in delivery, breakdowns or routine maintenance cuts into the schedule, and rail operation and management is not perfect. A probability of continuous service can reasonably be set at an 85% productivity rate, which provides for 44-weeks of productive rail capacity. This schedule can produce 265,200 US tons per year, and a short fall of 64,800 US tons per year through the facility. Using the 30-US ton per truck capacity, we require 8,840 trucks per year to traverse Route 190 to and from the port and the rail facility. The remaining 64,800 US tons will come by 2,160 trucks, over Route 190 to and from the port. Combined truck requirement is 11,000 truckloads per year.

> *"The end result is that not one single truck is removed from Route 190 in this scenario"*

Cost of Rail Construction
A rule of thumb for new track construction is between $1 Million - $2 Million per mile,[17] depending on who is constructing the track. For a track with an additional rail siding for a 40-car pull, the cost would be closer to the $2 million and as such that number is relied upon for this review. Some rail clients need a lot of track space to handle the movement, housing, and operations of a rail system. The basic planning budget for rail and track only, for the 15.5 miles to be rebuilt equals upwards of $31 million before rail cars and engines are acquired and before a transloading system is purchased and set in place.

For a 40-car pull, each car is estimated to cost on average, "between $100,000 and $200,000".[18] For 40-rail cars, we use the lower end of the scale, and estimate the cost of $4 million. An efficient use of the rail siding and its 40-cars would be to have 40-cars sitting in Perry, with 40-cars in the originating yard (such as Millinocket), and another 40-cars in transit at all times. This would provide for the two trips per week schedule. A 120-rail car purchase is estimated to be $12 million.

Acquisition or relocation of South LaGrange transloading system would cost approximately $1 million new and $500,000 used with transport to Perry. Finally, we need to purchase a locomotive engine. That acquisition could mirror a recent purchase by Union Pacific where they bought "ten more all-electric locomotives…from Caterpillar Inc.'s Progress Rail, investing over $100 million in total."[19] That would average a $10 million purchase for the locomotive alone.

Rail Infrastructure and Equipment to Restore Eastport Rail Service

	Per Unit $	***Unist***	***Budget***
Track construction with additional rail siding for 40-rail cars:	$ 2,000,000	15.5	$ 31,000,000
Acquisition of wood chip rail cars:	$ 100,000	120	$ 12,000,000
Acquisition ofelectric locomotive engine	$ 10,000,000	1	$ 10,000,000
Relocation of LaGrange transload system	$ 500,000	1	$ 500,000
			$ 53,500,000

Wood chip Transportation Costs by Truck – Current Estimated

Average costs of truck transport of wood chips, per short ton, within a range of 20-miles to the port, is currently estimated to be $8.50 per US Ton, and alternatively if delivered from within a 50-mile range, the delivery cost per US Ton is currently estimated to be $15.00 per US Ton. To accommodate an export volume of 330,000 US Tons (300,000 MT) from the 20-mile distanced facility, the annual approximate delivery cost is $2,805,000. Alternatively, if delivered from the 50-mile distanced facility, the delivery cost is approximated to be $4,950,000 annually.

This paper's primary goal is not to examine ways to reduce the cost of transport of raw materials to the port but, rather it seeks to substitute and potentially eliminate the transportation of wood chips to the port by truck. End user procurement prices are set by market conditions so are not discussed. The focus is to examine the best method of delivery to the port to make an export contract possible. Thus, even if transport costs to the port via pipeline, is equivalent to the cost of trucking, the global initiatives, and corporate social responsibility challenges are met. Where the end user cost may not be appreciably affected the utilization of a pipeline for wood chip transportation is justified.

Tangential Matters

Another ominous transportation cost for trucking of wood chips may be significantly impacted by a move following electric vehicle trends in Maine over the next several years. EV purchases in Maine are roughly 2% of total vehicle sales but are expected to surpass 30% of sales within ten years. The average increase in individual EV weight is 35% and there is a push to replace current tractor and cab equipment with electric trucks and cabs. Legal weight of a fully loaded tractor and trailer on State Roads is 80,000 gross vehicle weight GVW. That is roughly 40-tons total, with 30-tons of cargo and 10 tons of equipment. If the weight is increased by even 30% then the weight of the equipment will be weigh 13 tons. A three ton increase in equipment reduces the cargo load to 27-US Tons and that translates into more truck trips required, with lighter payloads, a higher per US Ton cost, and more wear and tear on the roads.

Road repair or reconstruction to support 22,000 truck passes over Route 190 will be a constant obligation. Currently Maine DOT is scheduled to seek pricing proposals, in a planned advertisement on 4/5/2023, for Project WHITING-EASTPORT, ROUTE1/ROUTE 190 #026630.04, which entails 'Highway Preservation Paving' of Route 1: Beginning at the Pleasant Point town line and extending south 3.97 miles. [Route 190: Beginning 0.02 of a mile west of Gardner Lake Road and extending east 3.77 miles. FHWA INFRA Grant recipient.][20] With heavy truck traffic required to support the port operations, the next MaineDOT project might include 'Highway Construction/Rehabilitation' at about $450,000 per mile or roughly $3.3 million for the 7.1-mile stretch. This would be a recurring cost brought on by heavy traffic and wear and tear.

Environmental – Carbon Emission Concerns Related to Heavy Trucks

According to the Natural Resources Council of Maine, "Trucks have an outsized impact on climate change in Maine. The transportation sector is responsible for 54% of Maine's carbon pollution, and 27% of those emissions are from medium- and heavy-duty trucks. Reducing emissions from these heavier vehicles is a key part of Maine's Climate Action Plan, which is why the Natural Resources Council of Maine is supporting the Maine Department of Environmental Protection's (DEP) proposed Advanced Clean Trucks (ACT) rule."[21]

The growing bandwagon of clean-truck states also marks progress toward a goal of making 100% of bus and truck sales electric by 2050, as pledged by 15 governors and the mayor of Washington, D.C., in a memorandum of understanding from 2020. Maine has already taken steps to adopt the ACT rule in 2022.[22] At stake here is that trucks will move toward electric power, increasing the cost of trucks exponentially, reducing effective payloads to offset increased weights associated with batteries, the availability of trucks will become scarce, and drivers are already in demand due to the shortage of driver availability – which can only be countered by increased wages for drivers.

Onshore Hydro-Transport Wood Chip Pipeline

Pipeline Hydraulic Transport

Pipeline transportation of solids in a slurry mixture is not a new concept. Early research on solid mixture flow is traced back to a 1906 systematic experimentation incorporated the testing of solid liquid mixtures through a horizontal pipeline using centrifugal pump design.[23] During and following the 1960s, significant research was performed on "solid-liquid mixture flow pipelines constructed to hydraulically transport a variety of solids."[24] Both the "technical and economic advantages of pipeline hydro-transport have encouraged various sectors to consider replacing conventional modes of transport, (e.g., road and rail), with pipelines for long-distance transport purposes."[25]

Among the advantages included are: economies of scale in the construction of the pipeline and associated equipment; capacity to transport, in a continual flow, large volumes of solids in slurry; excellent safety record (fewer than two incidents per 10,000 km (6213.7 miles) of pipeline reported per year)[26]; the certainty of - (24/7/365) - continuous operation; substantial reduction of production inventories; consolidated and streamlined labor participation; and, avoidance of interference or interruptions due to seasonal inclement weather, or restraint of the use of roads and highways, or terrain conditions such as are analogous to the temperate forests of Maine.

'A fully operational pipeline, with direct transport from a wood chip pumping station, and terminating at to the port of Eastport, will enable the port operators to substantially increase export volume, reduce incremental costs associated with port operations, increase the Town of Eastport's revenue base, enhance the size of its workforce and promote increased wage rates.'

Hydraulic Operation Principles of Wood Chip Pipeline

Experimental investigations on slurry pipelines for transportation of wood chips has produced a wide range of variables from pipeline materials, diameters, lengths, wood chip dimensions and density characteristics, types of slurry mixtures, and optimal velocities of transport. This paper examines the following physical and hydrological properties. The proposed pipeline is a single line, without a return line for water reclamation, with an 8" diameter (~200 mm) steel pipe, with test experimental lengths of 50-miles, and 20-miles respectively. Wood chips are both coniferous (35-lbs/cf) and deciduous (40-lbs/cf) with dimensions of thickness: 3-10mm 85% Min. Width: Size 48 mm up < 5% Size 9.5 – 45.0 mm > 80% Size 4.8 -9.5 mm < 12%.

The optimum slurry of solids mixture is between 30% to 45% (conservative use of 30%) wood chips to water content in the slurry mix. Wood chip transport velocities have been studied from .5-meters to 5-meters per second, however there is wide consensus that the actual range of velocity should be between 1.5-meters and 2-meters per second. To predict conservatively, and under estimate pipe-flow performance, we use the 1 meter per second velocity flow rate.

Wood chips, dry weights are 0.38 gram per cubic centimeter or 380 kilogram per cubic meter, i.e. density of wood chips, dry is equal to 380 kg/m^3.[27] In Imperial or US customary measurement system, the density is equal to 23.72 pound per cubic foot or 0.22 ounce per cubic inch. These weights are calculated at bone dry moisture content (MC) however, the wood chips would enter the system at closer to 45% to 50% MC – which provides for an approximate weight of 35-pounds per cubic foot.

Utilizing the volumetric formula for a sphere (pipeline) we calculate that $V = \pi r^2 h$ and we conclude there is a volume of 1.39626 cubic feet per 1-foot of pipe – or, (35 lbs X 1.39626 cf = 48.869 lbs per linear foot of pipe). There are 3.28084 linear feet per meter or 160.33 pounds of wood chips per meter. We opt to calculate productivity on a 1-meter per second flow velocity of a rounded volume of 160 lbs/s

Next we assign the conservative 30% wood/slurry mixture ratio. In a 1-meter section, we will move ~ 48.1 pounds of wood chips per second. Carry this to its full potential to obtain 2,886 lbs/min or 1.44 US tons p/min; per hour we can achieve 173,160 pounds or 86.58 US tons per hour; 63,293 US tons per month; and 748,449 US tons per year. Factor in a productive capacity rate of 85% and we have a maximum capacity flow of 644,674 US tons of wood chips to the port by pipeline. While export contracts are not in place for 644,674 US tons of wood chips, the pipeline is capable of supporting that volume if ever needed.

Pounds	***US Tons***	
48.10	0.02	second
2,886.00	1.44	minute
173,160.00	86.58	per hour
4,155,840.00	2,077.92	per day
29,170,800.00	14,585.40	per week
126,406,800.00	63,203.40	per month
1,516,881,600.00	758,440.80	per year
85%	644,674.68	Productivity

"Not one tractor trailer or wood chip hauling truck is required."

Capital Costs for Pump Station 20-Mile Distance (One Way Movement) with Booster Stations as Required

Estimated for a 104 km distance (~ 65 miles)

Item	Cost ($ in 2004)	Cost ($ in 2022)	20-Mile	50-Mile
Pump Station Facilities - Equipment - Infrastructure				
Land (estimated)	19,700.00	30,535.00	30,535.00	30,535.00
Access roads	39,900.00	61,845.00	61,845.00	61,845.00
Conveyor systems	245,300.00	380,215.00	380,215.00	380,215.00
Mixing tank (water and chips)	61,300.00	95,015.00	95,015.00	95,015.00
Piping	405,100.00	627,905.00	627,905.00	627,905.00
Foundations for pumping area	100,000.00	155,000.00	155,000.00	155,000.00
Storage tank for water	769,300.00	1,192,415.00	1,192,415.00	1,192,415.00
Auxiliary Pump (with one redundancy pump)	137,100.00	212,505.00	212,505.00	212,505.00
Power Supply and substation	400,000.00	620,000.00	620,000.00	620,000.00
Communications Lines	40,000.00	62,000.00	62,000.00	62,000.00
Buildings	236,800.00	367,040.00	367,040.00	367,040.00
Road along pipeline	266,000.00	412,300.00	412,300.00	412,300.00
Fire suppression system	65,800.00	101,990.00	101,990.00	101,990.00
Mobile stacker for dead storage	100,000.00	155,000.00	155,000.00	155,000.00
Main Pump for transport (pressure for transport of slurry)	2,678,800.00	4,152,140.00	4,152,140.00	4,152,140.00
Pipeline for transport (furnish and install)	58,863,900.00	91,239,045.00	28,073,552.31	70,183,880.77
Total capital cost Pump Station - Origination	**64,429,000.00**	**99,864,950.00**	**36,699,457.31**	**78,809,785.77**
Booster Station Facilities				
Substation	400,000.00	620,000.00	620,000.00	620,000.00
Booster Pump for mixture	1,283,000.00	1,988,650.00	1,988,650.00	1,988,650.00
Booster pump for water	1,017,500.00	1,577,125.00	1,577,125.00	1,577,125.00
Building	19,700.00	30,535.00	30,535.00	30,535.00
Access roads	4,000.00	6,200.00	6,200.00	6,200.00
Land	700.00	1,085.00	1,085.00	1,085.00
Foundation for pump area	100,000.00	155,000.00	155,000.00	155,000.00
Total capital cost Booster Pump Station - Origination	**2,824,900.00**	**4,378,595.00**	**4,378,595.00**	**4,378,595.00**
Total Project	**67,253,900.00**	**104,243,545.00**	**41,078,052.31**	**83,188,380.77**
	Per mile Cost	***) & 50 Respective***	**2,053,902.62**	**1,663,767.62**

Source: Kumar, A., Cameron, J., and Flynn, P., *Pipeline Transport of Biomass* , Department of Mechanical Engineering, University of Alberta, Edmonton, Canada 2004
https://www.researchgate.net/publication/8647398_Pipeline_Transport_of_Biomass
Costs are reported in USD 2004 Exchange and modified to 2022 by CPI Inflation Calculator, Accessed at:
https://www.bls.gov/data/inflation_calculator.htm

The two scenario processes simplified:

The proposal is to transport up to a minimum of 330,000 US Tons of wood chips to meet the size standards of either MDF or Biomass, through an 8" steel pipeline, in a slurry of 70% water to 30% wood chip, and to pump these wood chips a distance of either 20-miles or 50-miles from a pumping station to the laydown yard at the port of Eastport, without the need for any trucking of wood chips between the points of origination and the port destination.

Pipeline Construction and Per Ton Transport Cost Estimates[28]

Preliminary cost analysis of pipeline construction in 2022 dollars is adjusted from a 2004 detailed cost analysis of a 65-mile single pipe system. We used a CPI Inflation Calculator, as found at: https://www.bls.gov/data/inflation_calculator.htm. The one line item that is most costly in any scenario is the furnishing and installation of the actual pipeline. Here we adjusted the pipeline cost only from 65-miles to an adjusted 20-mile and 50-mile distance accordingly. The 20-mile distanced facility has an estimated cost of $41,078,052 or roughly $2 million per mile. Alternatively, the 50-mile distanced facility has an estimated cost of $83,188,330 or roughly $1.67 million per mile. In the peer reviewed publication[29] we also utilize the cost of transport for the 20-mile system and the 50-mile system respectively. In reliance upon the above mentioned publication, by Kumar, et al, and the CPI adjustments, the cost of transport of wood chips along the 20-mile system is $21.54 per US ton and for the 50-mile system the cost is $18.48 per US ton respectively.

Corporate social responsibility: environmental impact

Corporate social responsibility (CSR) can refer to a wide range of actions that businesses may take. One primary focus of CSR is the environment. *Environmental CSR* aims to reduce any damaging effects on the environment from business processes. Activities in this paper focus primarily on: Reduction of Carbon Emissions. The unmistakable aim in this transition of wood chip transportation by pipeline is to remove as many heavy trucks from the roadways in Maine as possible.

Typical wood chip trailers will haul 30 US ton of wood chips in a single load. As discussed in this paper the minimum volume of wood chips that would require truck transportation is 330,000 US tons or roughly 11,000 fully loaded wood chip hauler trailers.

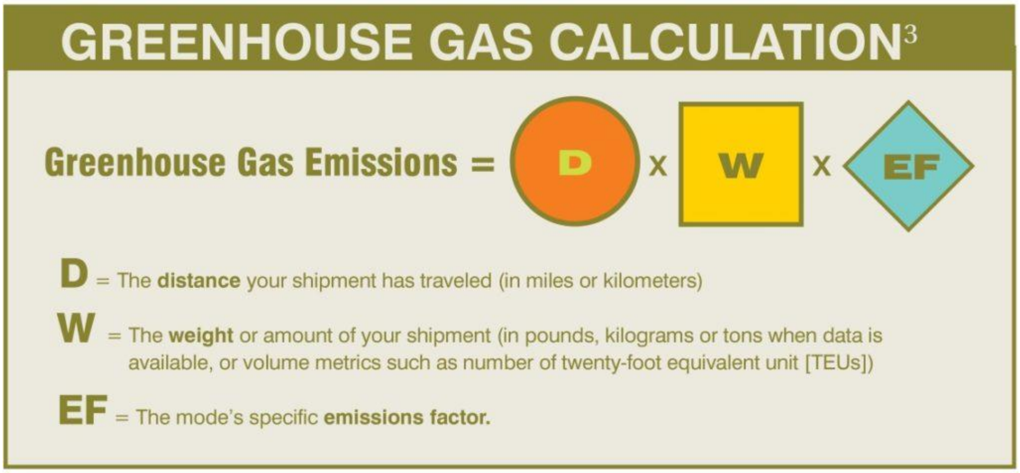
Considering the two pipeline scenarios studied in this review; the first of which would originate in the Meddybemps/Perry pipeline site is 20-miles from the port facility. This round trip process would require 440,000 miles per year with a combination truck/trailer rig of 80,000 GVW.

Alternatively, if driving from the Passamaquoddy Tribal Land Trust yard, the same number of trucks would be required however, the round trip per truck is 100-miles. To accomplish the transport to the port from this origination point is 1,100,000 miles per year.

Along with buses and passenger vehicles, trucks are responsible for excessive transportation carbon emissions in the US.[30] A truck CO2 emission per km calculator reveals that an average truck, covering a distance of around 120,000 miles every year, emits 223 tons of CO2 per annum. This is based on an estimated calculation of 400 miles every day over six days per week, and a total of 50 weeks every year. The calculation is also based on 6.5 miles (10.46km) per gallon of fuel (diesel).[31]

In 2020, diesel fuel consumption in the transport sector of the US produced 432 million metric tons of carbon dioxide, which equaled just over a quarter of the total CO2 emissions of the transport sector. To estimate diesel truck CO2 emissions per km, a simple calculation can be used. Firstly, 1 liter of diesel equals 835g and consists of 86.2% carbon, which equals 720g of CO2 per single liter of diesel. Combustion of the carbon to CO2 requires 1920g of oxygen. The calculation then looks like this: 720 + 1920 = 2640g of CO2 per single liter of diesel. Consumption of 5 liters per 100 km will then be 5l x 2640 g/l / 100 (per km) = 132g CO2 per kilometer.[32]

A formula for calculating greenhouse gas emissions from a truck move:



Using the formula from above, we can arrive at a simple emissions calculation example for a truck that travels 1,000 miles with 30 short tons of cargo (a short ton is 2,000 lbs). One truck load of wood chips would weigh 30-US tons or 60,000 pounds (cargo only).

20-Mile Distance from Meddybemps/Perry to the Port Scenario:
Step 1: Determine the total amount of miles. Multiply 440,000 miles times 30 tons, which gives us a total of 13,200,000 transport miles.

Step 2: The average freight truck in the U.S. emits 161.8 grams of CO_2 per transport mile.

Step 3: Multiplying this emissions factor with the total transport miles {161.8 X 13,200,000), which gives us a total of 2,135,760,000 grams of CO_2.

Step 4: Convert the total grams into metric tons. Metric tons are the standard measurement unit for corporate emissions of greenhouse gases. There are 1,000,000 grams in a metric ton. To convert our answer from step three we divide it by 1,000,000. This gives us 2,135.76 metric tons of CO2.

Conclusion: The use of a pipeline for wood chip transport from Meddybemps/Perry will reduce the CO_2 footprint by 2,135.76 metric tons.

59-Mile Distance from Passamaquoddy Tribal Land Trust yard to the Port Scenario:
Step 1: Determine the total amount of miles. Multiply 1,100,000 miles times 30 tons, which gives us a total of 33,000,000 transport miles.

Step 2: The average freight truck in the U.S. emits 161.8 grams of CO_2 per transport mile.

Step 3: Multiplying this emissions factor with the total transport miles {161.8 X 33,000,000), which gives us a total of 5,339,400,000 grams of CO_2.

Step 4: Convert the total grams into metric tons. Metric tons are the standard measurement unit for corporate emissions of greenhouse gases. There are 1,000,000 grams in a metric ton. To convert our answer from step three we divide it by 1,000,000. This gives us 5,339,400 metric tons of CO2.

Conclusion: The use of a pipeline for wood chip transport from the Passamaquoddy Tribal Land Trust yard will reduce the CO_2 footprint by 5,339,400 metric tons.

Recommendations and Conclusion

Hydraulic transportation of wood chips by pipeline is a sound and reasonable alternative to truck transport of wood chips to the Port of Eastport.

Implementation of a pipeline for wood chip transport will provide the necessary delivery process for the port to reach its full potential regarding the export of wood chips.

The cost of pipeline transport is appreciably lower than that of truck transport. The environmental benefits of a pipeline over traditional truck transport are substantial in terms of significantly lowering the carbon footprint of transportation.

A pipeline installed along Route 190, within the easements and right of ways will eliminate the truck traffic along Route 190 and provide for unrestrained transport along a traditionally bottlenecked transport route.

Building of a pipeline at this time would also reduce the potential for ongoing road repairs and maintenance and also mitigate the future need for a total road reconstruction project along Route 190.

A pipeline that removes truck traffic associated with wood chips will also open the door to a lesser demanding transport of exportable logs to the port for either container loading or vessel loading.

Other Export Potentials

While biomass grade wood chips have been a primary focus for some time now; other end users of wood chips for MDF, OSB and Paper are interested in Maine. This writer has existing, current contacts that require in excess of 300,000 metric tonnes of fiber each, on an annual basis. A pipeline to the port can bring up to 600,000 metric tonnes of business. A typical client buyer of who have either executed contracts and agreements for wood chips via CMI, or are awaiting a reasonable path for supply includes: Koch Industries of Switzerland, Osman Barış ERDOĞAN (nephew to President Erdogan of Turkey), Yildiz Integre of the US and Turkey, Bord na Mona of Ireland, Bee Energy of Belgium (now defunct), Marubeni Canada Ltd., GNT Group of Companies of Canada, Mercer International of Germany, and others.

Log exports to the EU and beyond, can be exported from Eastport. While the relative proximity of ST. John, to Eastport will continue to be a viable export facility, Eastport may accommodate loggers who wish to haul logs to the port facility, in lieu of reduced traffic related to wood chips. Proven markets for log exports have been established. In excess of $23 million per year in containerized log exports has been established (however, due to trade war issues and COVID-19 these trade contracts have been temporarily halted). This writer had established an extremely cost effective shipment regime of logs from Searsport to either Boston of direct to Port Elizbeth, NJ. The required volume for the barge service was a minimum of 200-containers per month. The logistics of Searsport is perfect however the pushback by port situated entities stalled the project and then COVID hit then the opportunity stalled. This log export business however, is immediately accessible and can be actionable via Eastport.

Eastport can be designated the “Export Fiber Hub of Maine” as Portland is close to its maximum capacity, and Searsport has been and continues to be ill-equipped to handle wood chip export due to loading constraints. Pursuant to a recent spillage of baled waste materials from Ireland, intended for shipment to a local power plant, it is not likely that Searsport will venture into woodchips in the future.

A strategic alliance has been created with one of the world's leading shippers: Oldendorff. This Internationally Renowned company, has cooperated with CMI to bring vessels to Maine (and New Haven, CT) to move either wood chips in bulk and or in high density baled configuration that solved the long-standing stowage problem regarding wood chips. Typically wood chips would bulk out a vessel before weighing out. With the heat treated, $E=MC^3$ high density compacted product, the cubic foot stowage of wood chips has met and exceeded the stow value of wood pellets, thus eliminating the most important cost disadvantage previously known to wood chip export. A presentation was made to the International Biomass Conference in Nashville, TN.

For any further in-depth information or follow up questions; CMI can be reached at the below provided contacts.

Arthur House, EJD

Researchers and Consulting Companies

The above is a preliminary review and analysis in support of constructing a Hydraulic Pipeline transportation system for the transport of wood chips to the Port of Eastport. Substantive work on this proposed program is currently in progress in cooperation with Northern Illinois University.

Mahdi Vaezi, Ph.D., Assistant Professor in the Department of Engineering Technology, at the College of Engineering and Engineering Technology (CEET), Northern Illinois University located at 103B Still Hall | DeKalb, IL 60115 Email: mvaezi@niu.edu

Arthur House, EJD is a Forest Products Industry Consultant and Program Developer and Coordinator with an office in Belfast, Maine.

Mr. House is a Senior Resident Engineer with John Turner Consulting located in Dover, NH and serving the entire New England region and the State of New York. Mr. House's primary focus at JTC is on Maine-based, infrastructure projects as initiated by Municipalities, MaineDOT, and Maine Transit Authority.

Mr. House is President and Founder of Construction Management Institutes ("CMI"), of Maine and Florida – Established in 2001, as a consulting company, with 25-years of experience in biomass, biodiesel and renewable energy research and development. CMI and John Turner Consulting will provide consulting services on studying the techno-economy of large-scale and long-distance biomass pipelines, also assessing the viability of the proposed technology in the U.S. and its potential to be applied to other feedstock or commodity streams to enhance the outlook.

Collaborating with the Co-PIs and the consultants, coming from various sectors with expertise in pipeline flow, biomass processing, and bioenergy economy and logistics, helps link the project directly to biomass feedstock collection and preparation, transportation and biorefinery sectors.

A paper was recently published by the PI (Rheology of fiber suspension flows in pipeline hydro transport of biomass feedstock, Biosystems Engineering, vol. 200, 2020) and is listed in the proposal to address the concern about the continuum of the PI research studies.

Mr. House envisions working with MaineDOT, the Town of Eastport, regional municipalities, and Maine-based Universities or Colleges to seek support and funding for these education facilities to undertake their work.

Arthur House, EJD may be reached at his JTC Email: ahouse@consultjtc.com, his CMI Email: art@arthurhouse.com, or at ahouse@snhu.edu and ahouse1@rochesteru.edu, where he teaches Construction - Contract Law and Business Law, as an Adjunct Professor. Or he can be reached at Telephone: 207-930-5168

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Exhibit "A"

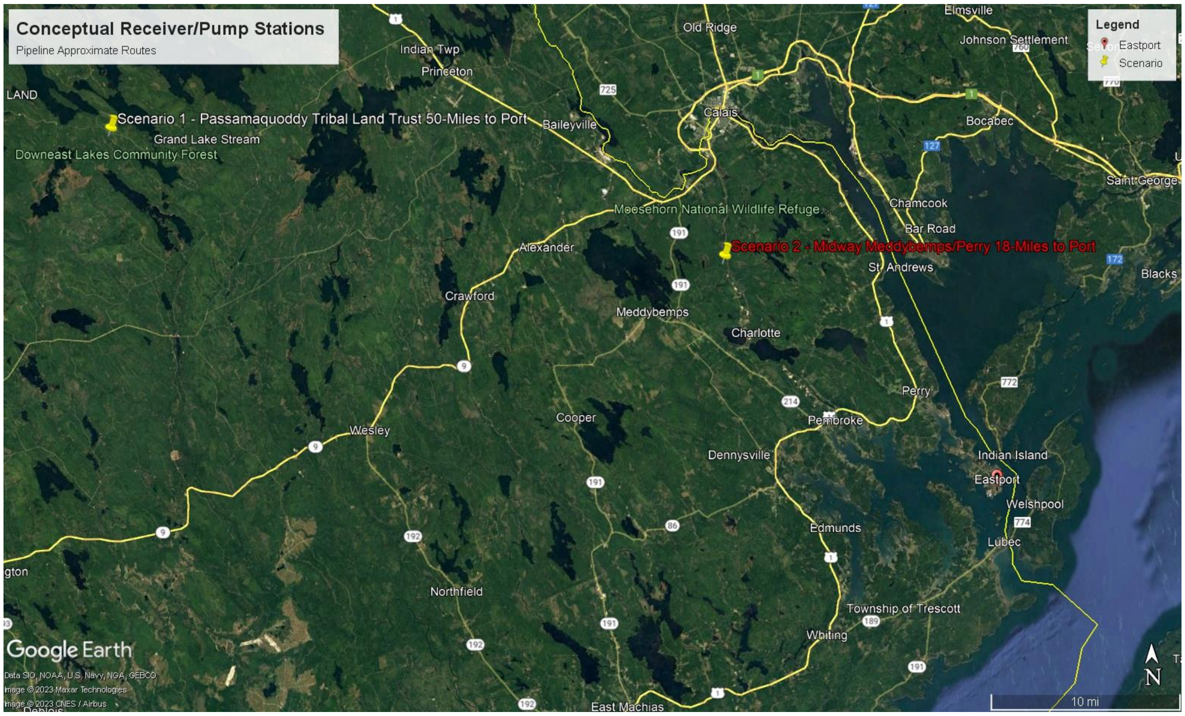
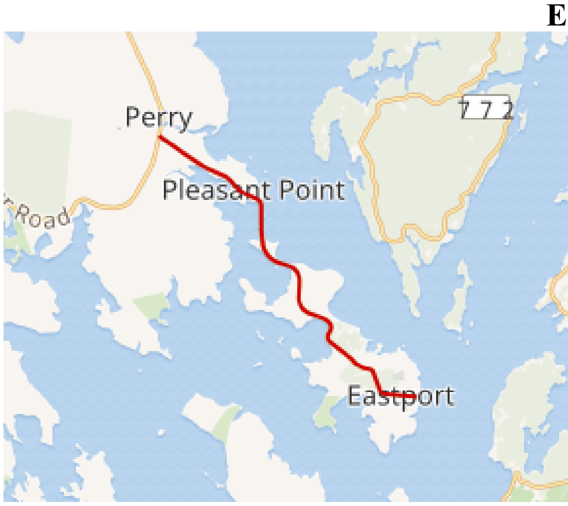


Exhibit "B"



Location	mi[1]	km	Destinations
Eastport	0.00	0.00	Water Street
Perry	7.10	11.43	US 1 (South River Road)

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