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How Inflation Might Impact the Industrial Wood Pellet Industry¹

From raw feedstock to end user: a comprehensive analysis using simulation.

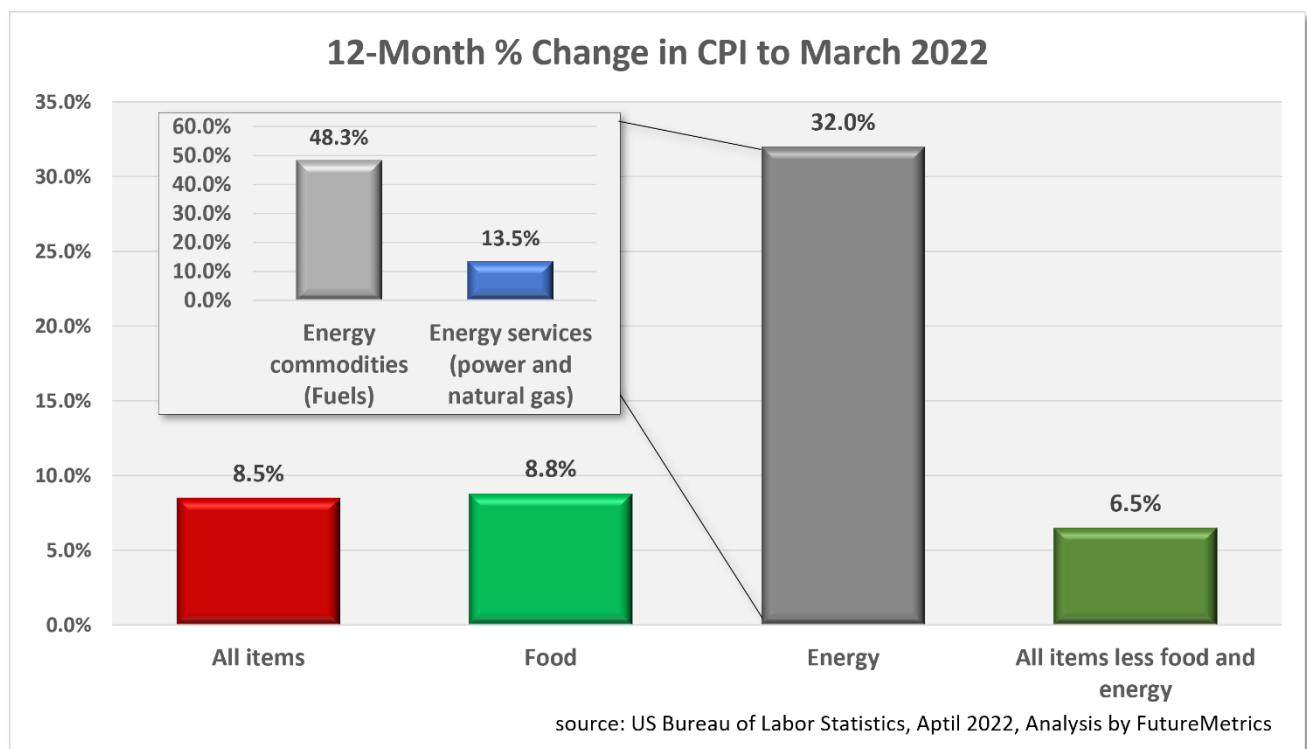
With some thoughts on mitigating the negative impacts of inflation.

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With assistance from Hannah Campbell, Logistics Specialist, FutureMetrics

April 21, 2022

The consumer price index in the US is increasing at nearly double-digit annualized rates. But energy costs have increased even more dramatically with an increase of 32% in the last 12 months. The fuels component of energy cost has increased by over 48%.



¹ So-called “industrial” wood pellets are pellet fuel that is produced for use in large power boilers as a substitute for coal. So-called “premium” or “heating” pellets are typically lower in ash content and are used as fuel for heating homes and businesses with relatively small scale pellet boilers and pellet stoves.



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Higher fuel costs across the world will trickle down into the prices of almost everything because the world depends on supply chains that are stitched together by a variety of transportation modalities. That dependence on transportation networks has increased over time. Much focus is on the cost of final delivered goods. However, the movement of materials from one value adding node to the next is the linkage that is not only essential but is most sensitive to changes in fossil fuel costs.

That sensitivity is front and center today.

This white paper discusses supply chain costs in the context of wood pellet fuel. It will look at the sensitivity of several of the key parts of the wood pellet supply chain. This paper will also discuss ways to mitigate the impacts of fuel price inflation.

This paper looks at four key steps in the industrial wood pellet supply chain:

1. Harvesting and moving raw materials from the forest to sawmills and/or pellet mills².
2. Conversion to pellets at the pellet mill.
3. Moving the pellets from the mills to the ports.
4. Transporting the pellets from the origin port to the foreign port (shipping).

The models used in this analysis are comprehensive. But as with any model, they simplify reality. Every situation in the real world will have unique and sometimes random characteristics and events. But while the actual costs in real-world operations may be different, the conclusions derived from this analysis are informative.

This analysis does not look at the impacts of inflation on the prices of sawmill residuals. However, the analysis in the first section below, “Forest to Mill”, is applicable to any mill that uses the forest resources as its feedstock. How the changes in costs for sawlogs flow through to changes in residual pricing is not a part of this analysis. This delivered wood costs analysis is based on roundwood delivered to the pellet factory.

Forest to Mill

FutureMetrics has analyzed data on delivered wood costs and, using multivariate regression analysis to understand how macroeconomic inputs influence wood costs, has shown that in some locations diesel fuel cost contributes to more than 65% of the predictive power of the regression equation for wood cost

² Many pellet factories receive the by-products from the so-called primary users; the sawmills. On average, about 50% of the roundwood delivered to a sawmill becomes lumber, furniture, flooring, etc. The rest often goes to secondary users including pellet mills. Some pellet factories also receive materials that are not suitable for the sawmills directly from the managed forests. Those materials may include roundwood that is too crooked for sawing or has a rotted center, small-diameter thinnings whose removals increase the productivity of the managed forest, and forest residuals such as the tops and limbs that are unsuitable for any other use.



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delivered to the mill³. This analysis is not based on regression modeling but is based on simulation analysis of operating cost models based on real-world conditions.

In the models used in this section most real-world operating inputs associated with logging and transport are considered. Diesel fuel is a major cost. Other cash flow inputs include labor, maintenance, the amortized costs of equipment, and a profit margin.

This section of the analysis is in two parts: logging operations, and then delivering the wood from the truck landing at the forest operations to the mill.

Harvest Operations

The forest logging operations are impacted by diesel fuel costs. The following modeled harvest scenario uses a feller-buncher, a grapple skidder, a delimeter, and a truck loader to harvest the trees and load the trucks that will transport the roundwood to the buyer. Four of the critical inputs to the model are defined using PERT distributions⁴: fuel cost per liter, cubic meters per tree, kilograms per cubic meter of the wood, and labor cost per hour. Volume per tree and density per m³ will vary by tree size and species.



³ Another strong predictor of delivered wood costs are housing starts. An active housing market increases sawmill activity and thus increases the supply of both forest and sawmill residuals. Thus, increased housing starts put downward pressure on delivered wood prices.

⁴ For a description of a PERT distribution see https://en.wikipedia.org/wiki/PERT_distribution. FutureMetrics uses [Palisade Corporation](#)'s DecisionTools Suite's @RISK module to perform the simulations.



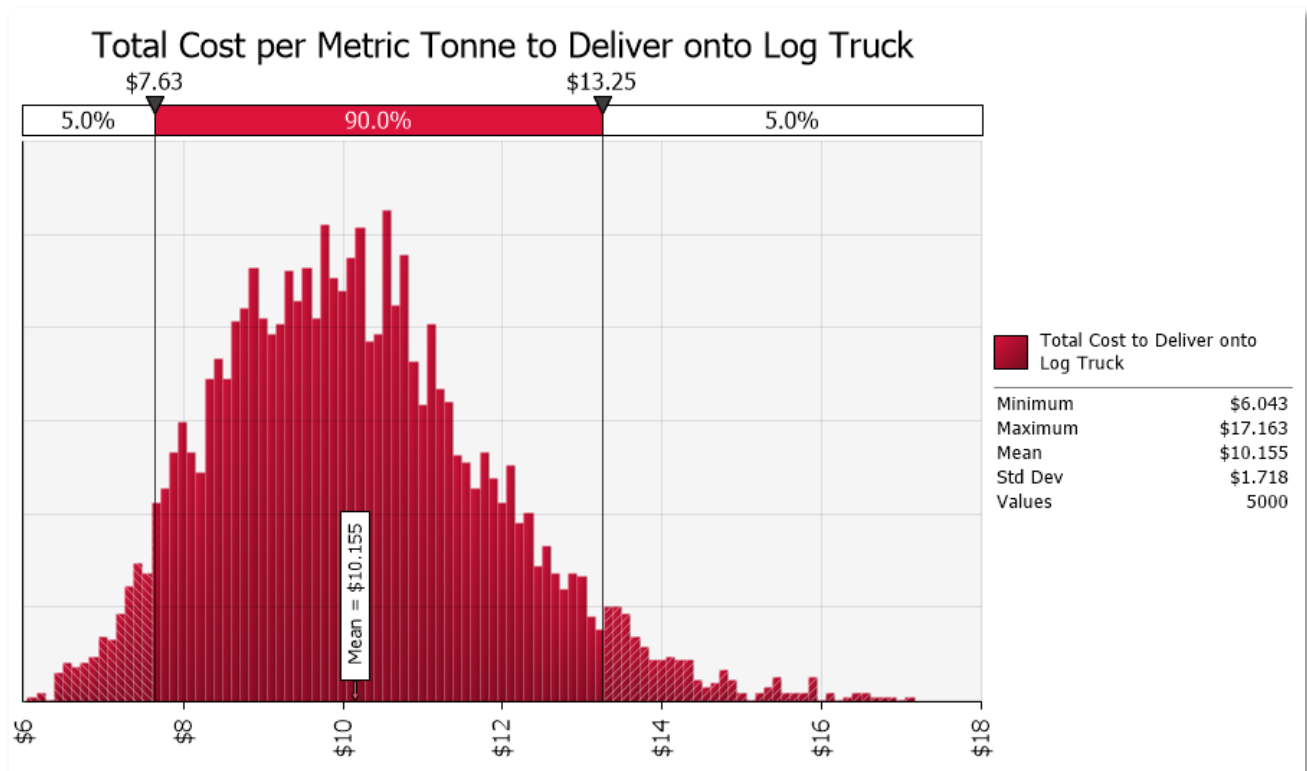
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Feller Buncher and Grapple Skidder

Other assumptions on fuel consumption per hour of operation, maintenance costs per hour, total hours operated in a year, the profit margin for the logging contractor, etc. are held constant at rates typical for the types of machinery and the industry⁵.

The results of allowing all four inputs to vary in a 5000 iteration Monte Carlo simulation⁶ are shown in the chart below.



Under the assumptions in the model, the average cost to harvest and deliver a tonne of roundwood to the truck landing is about \$10.15. But, as the simulation output shows, with variations in fuel cost, the efficiency of the machinery, the size of the trees, the density of the species, changes in labor costs, and other variables that are unique to the site, the cost per tonne could lower or higher.

⁵ Fuel consumption per working hour and other inputs for the logging equipment's operations are based on data from the Ontario Ministry of Natural Resources and Forestry. Different sized machines will consume different quantities of diesel fuel per hour but may also move more cubic meters (and tonnes) per hour.

⁶ https://www.palisade.com/risk/monte_carlo_simulation.asp



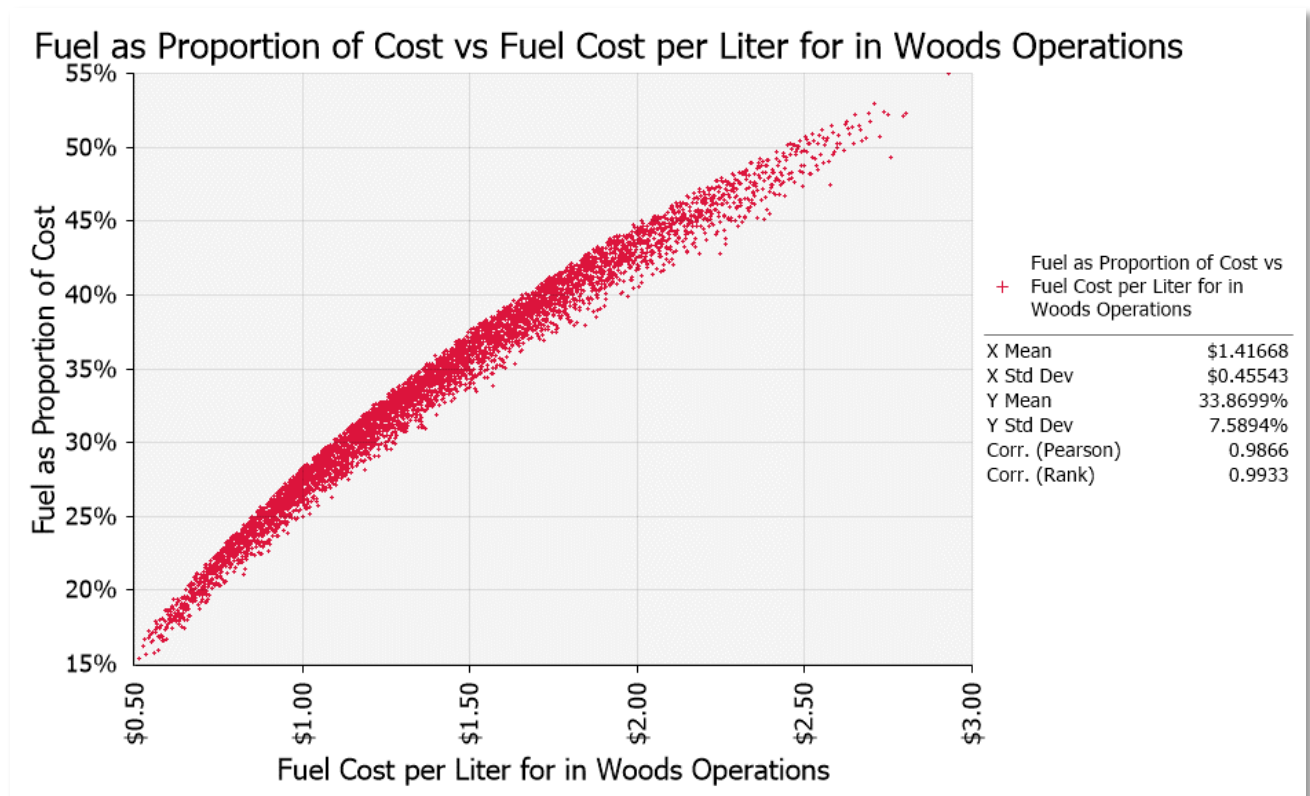
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The modeled PERT distribution for fuel cost has the cost per liter vary from \$0.50 to \$2.50 with the mean of the distribution at \$1.42 per liter (\$1.79 to \$9.50 with a mean of \$5.36 per gallon). Note that diesel fuel prices in Canada are currently US\$1.53/liter (US\$5.81/gallon)⁷.

The chart below shows how the proportion of fuel cost to the total cost increases as fuel costs increase.

Note that as other inputs vary, for a given fuel cost, the proportion graphed on the y-axis varies slightly. Thus, the dispersion of dots from each of the 5000 iterations of the simulation.



While fuel cost has a strong influence on the costs, the model shows that larger trees and higher density wood (if the metric of interest is tonnes rather than cubic meters) has a stronger influence on the cost of the roundwood per tonne delivered to the truck landing.

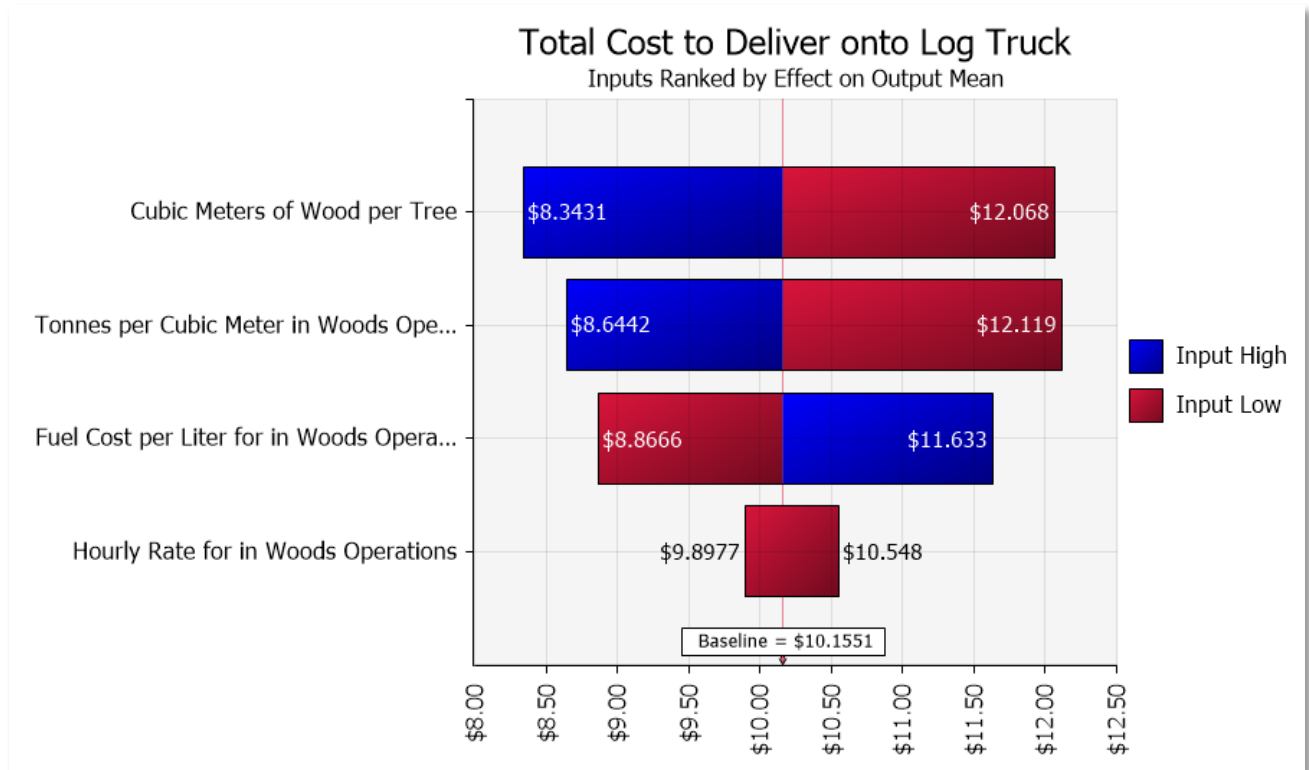
The “tornado” chart below illustrates that conclusion.

⁷ https://www.globalpetrolprices.com/Canada/diesel_prices/



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Although the forest operations are sensitive to diesel fuel costs, the change in the cost per tonne from just the fuel varying from \$0.50 to \$2.50 per liter are about \$3.27. Modeling labor costs to be from 90% to 150% of the baseline has a muted impact on the total cost.

The analysis shows that efficient machinery, well-trained operators, and a well-planned harvesting operation to maximize productivity are important.

However, the wood is not yet delivered to the mill. The other cost embedded in delivered wood is the cost of trucking from the forest truck landing to the mill.

From the Truck Landing to the Mill

The model used in this section of the analysis is based on a detailed model of trucking cost produced by the Ontario Ministry of Natural Resources and Forestry. It has been modified by FutureMetrics to allow simulation analysis. The model is for a round trip with the return trip empty.

There are many inputs to the model. For this analysis, PERT distributions are assigned to the following inputs.



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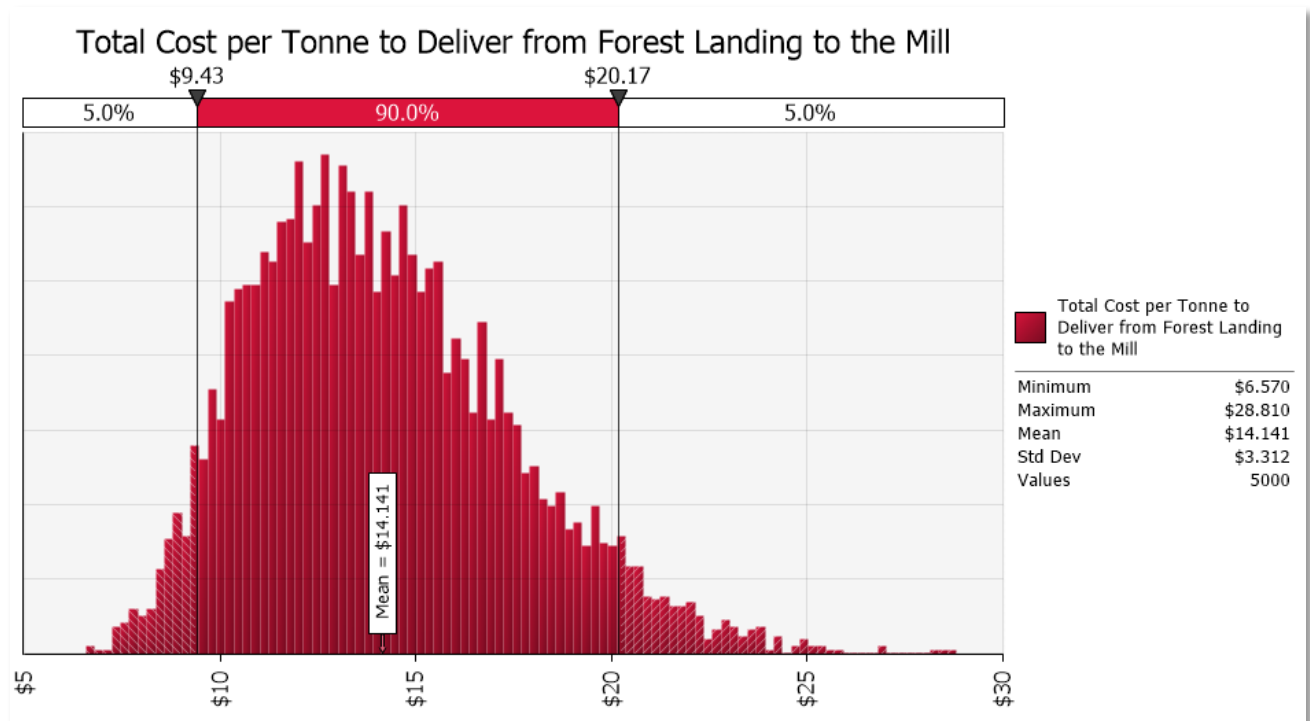
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- The distances that the truck has to travel on four classes of roads: Major highways, secondary roads, country roads, and forest roads built for the logging operations. The average speeds traveled on each are based on typical driving speeds on each class of road.
- Again, roundwood density is allowed to vary.
- Labor cost per hour.
- And most importantly, the cost per liter of diesel fuel is modeled to vary as in the previous section from \$0.50 to \$2.50 per liter.

The maximums and minimums and expected values that define the PERT distributions are subjectively chosen based on what could be a typical supply chain for roundwood from the forest. Every actual situation will be different. The one-way distance input assumptions are shown in the table below.

	Kilometers			Miles		
	minimum	expected	maximum	minimum	expected	maximum
Primary Highway	40	80	200	25	50	124
Secondary Highway	5	10	40	3	6	25
Country Road	4	6	20	2	4	12
Woods Road	1	5	12	1	3	7

Based on the inputs to the model, the cost per tonne to truck the roundwood to the mill is on average about \$14.15 per tonne.

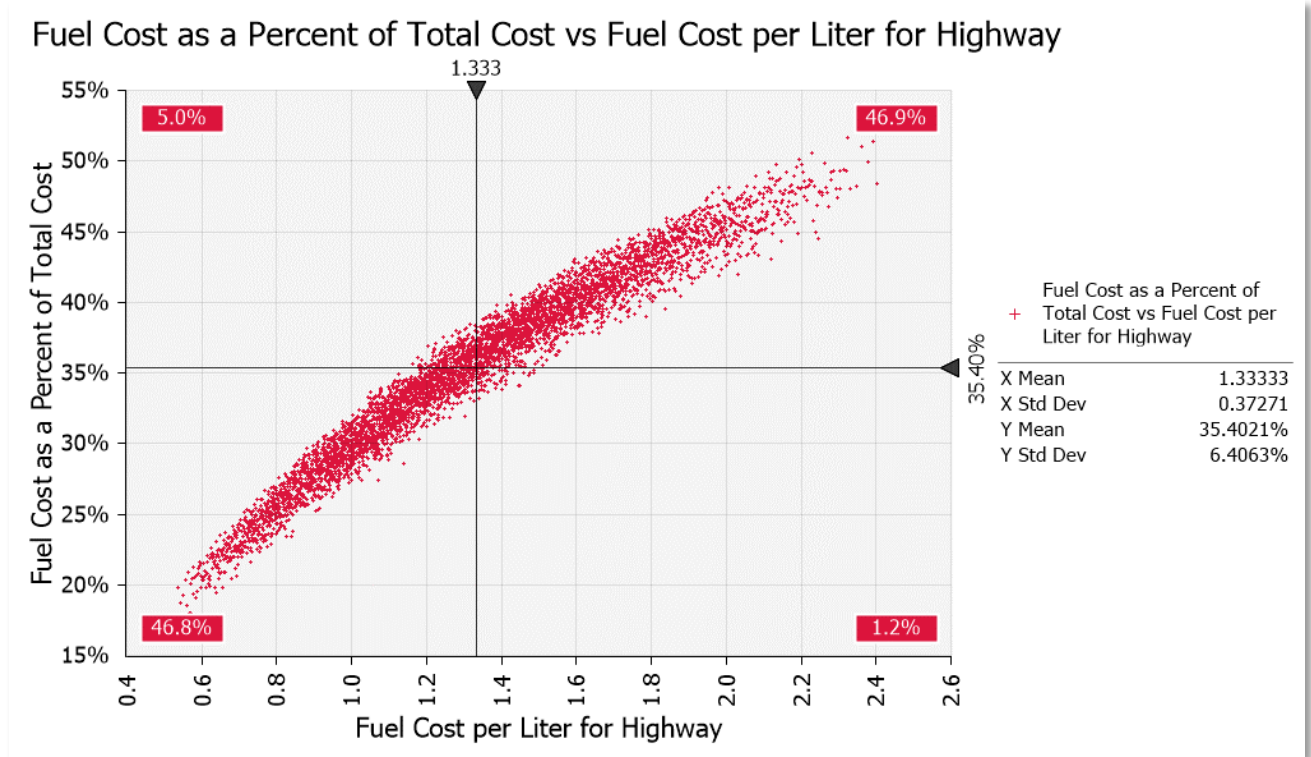




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As expected, as fuel costs rise, the proportion of fuel cost in the total cost of moving the wood from the forest landing to the mill also increases. Note that as other inputs vary, for a given fuel cost, the proportion graphed on the y-axis varies slightly. Thus, the dispersion of dots from each of the 5000 iterations of the simulation.



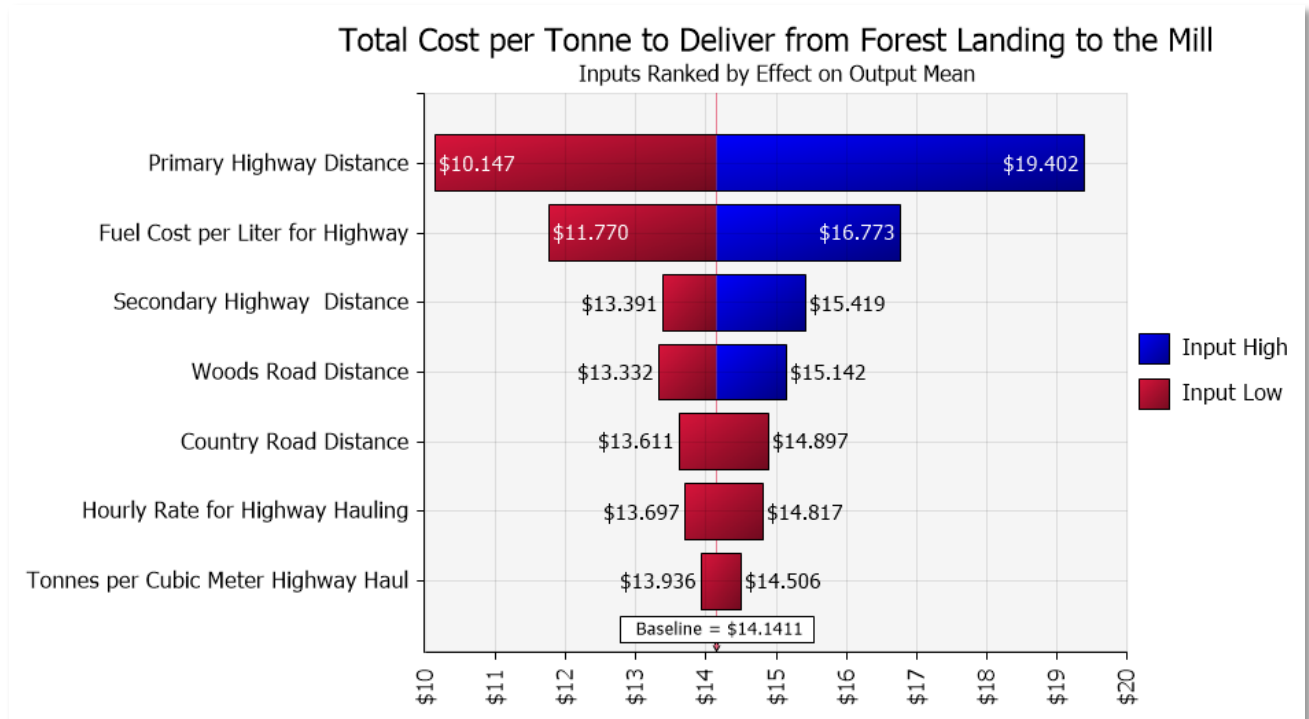
Looking more closely at what drives the result, it is clear that the distance that the wood has to travel via primary highway to the mill is a critical parameter.

The tornado chart below shows this.



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The shorter the haul distance, the lower the cost of delivered wood and the less sensitive the cost is to changes in diesel fuel cost.

For larger industrial pellet mills that have a larger draw basin and therefore bring some wood in from longer distances away, the exposure to diesel fuel risk is higher.

Based on these two models logging and transport, an estimate of the total delivered cost to the pellet factory can be derived.

Total Delivered Cost to the Mill (not including stumpage⁸)

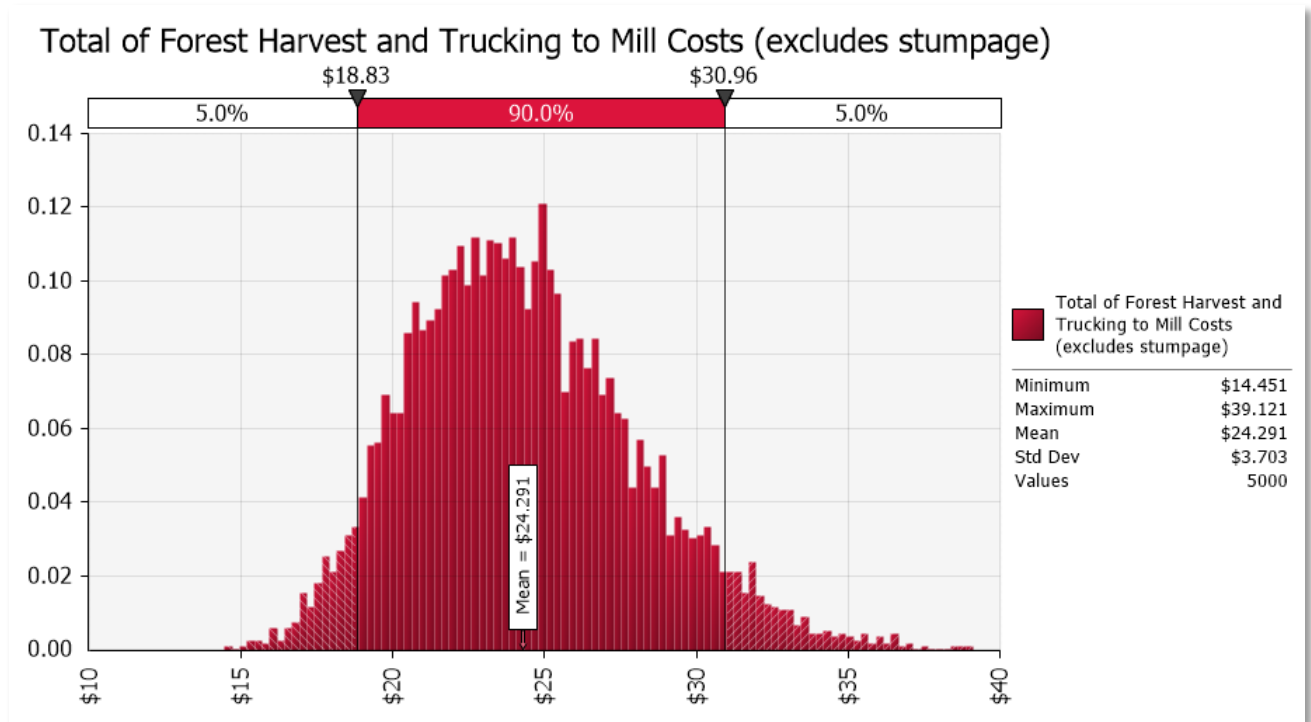
Running the simulation on both the harvest and transport models simultaneously yields the following.

⁸ Stumpage is the price a timber buyer pays the landowner. Since a tree will have portions that are of higher value (the sawlog portion) and lower value (pulp wood and pellet mill feedstock), the stumpage fees for a given tree may vary from higher for sawlogs or veneer quality, to lower for pulp chips and lower grades of biomass.



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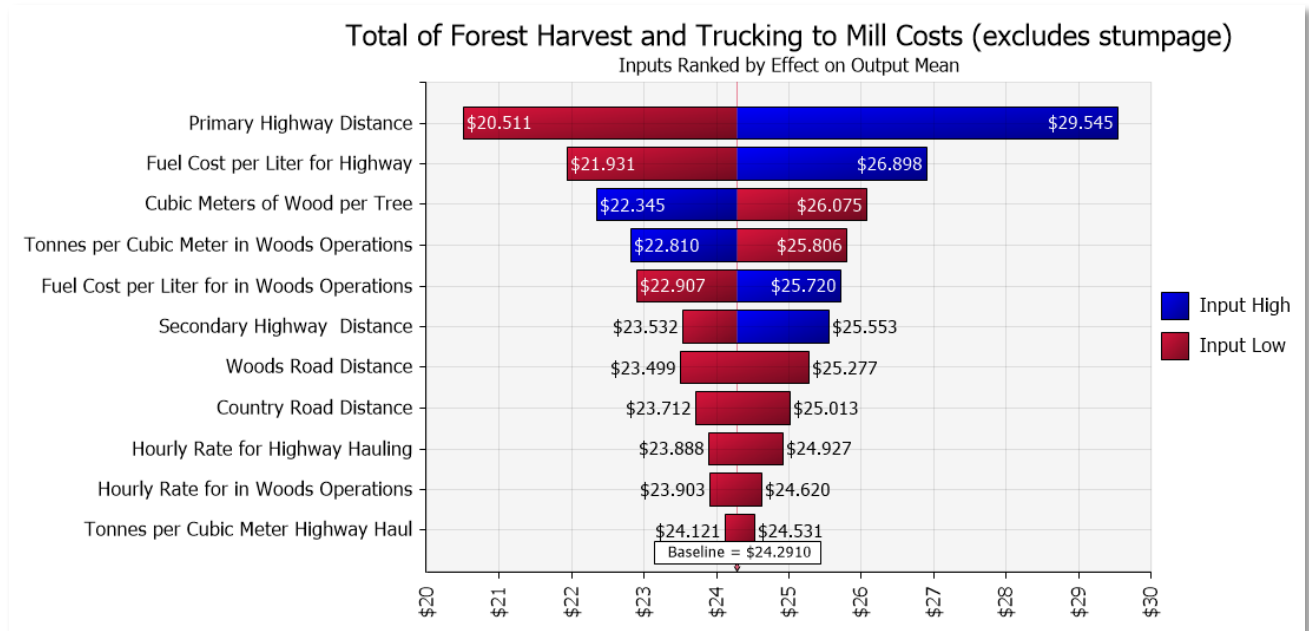
The expected cost per metric tonne delivered is about \$24.30 (not including any stumpage fee). Under some combinations of inputs, it can be greater than \$35/tonne.

The tornado chart below again highlights that the major contributor to delivered wood cost increases are increases in the distance traveled. The two strongest inputs that effect the output are related to highway travel.



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The increase in the cost of wood in a tonne of pellets from the mean of the simulation to the 95th percentile value shown on the probability distribution on the previous page is about \$6.65.

From the mean to the maximum value in the far-right tail of the distribution on the previous page results in a wood cost per tonne of pellets increase of about \$14.83. It is highly unlikely that diesel fuel will be over \$9/gallon and thus unlikely that the maximum value in the simulation will be seen in reality. But it is informative to see what the impact could be on delivered wood costs.

Fuel cost per liter is not in the control of the loggers and truckers. But haul distances can be managed by the pellet factory management. In general, the wood procurement plans should minimize the average haul distance. In times of high fuel costs, the mill may focus on closer sources if possible.

If input wood average 50% moisture content and the pellet are 6%, it takes about 1.8 tonnes of incoming wood to make a tonne of pellets⁹. For most pellet factories, additional woody biomass is used for fuel for the dryer heat. That biomass is often less costly than pellet feedstock.

Thus, at 50% incoming average moisture content, if wood costs go up by \$1.00, the cost of wood to make a tonne of pellets, not including dryer energy requirements, goes up by \$1.80.

⁹ See the FutureMetrics interactive dashboard to see how this value is obtained. [HERE](#).



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Stumpage costs are not included in the cost model. For this analysis, as discussed in the next section of this paper, a stumpage fee of \$8 per metric tonne is used. Actual stumpage costs applied to the lower grade wood that makes its way to a pellet mill will vary significantly depending on many variables.

There may be other inflation sensitive costs that contribute to the cost per tonne of pellets produced. The next section discusses the conversion of feedstock to pellets at the pellet factory.

Conversion from Wood to Wood Pellets

The operating costs per tonne of pellets produced varies at each pellet plant.

This section of this white paper uses FutureMetrics' comprehensive model of pellet plant capital and operating costs. There are many input assumptions. For this analysis, the inputs that are used are about the average values for a typical 500,000 metric tonne per year factory.

Wood cost for pellet feedstock is based on the value in the previous section plus an assumed stumpage fee of \$8 per tonne. The price of the lower grade wood that pellet mills accept typically does not carry a significant proportion of the actual stumpage fee for the whole tree if the lower portion of the tree is of sawlog quality. In reality, apportioning stumpage to the cost of delivered lower grade wood that is typical pellet feedstock is more complex than in this simplified model. But the purpose is to derive a total delivered cost that calibrates with actual real-world costs.

Wood costs plus the assumed stumpage fee at a specific pellet factory may be lower or higher than the value from wood supply model in the previous section.

The pellet plant operating model also assumes that 80% of the incoming wood has to be debarked and chipped on site. That influences power consumption, labor costs, and maintenance costs. But it also produces bark which supplements the need to purchase biomass to fuel the dryer energy plant. That ratio will also vary significantly at each unique operation.

High inflation will impact almost every line item in the factory's operating budget. However, as the table below shows, all other costs are dwarfed by wood costs.

Based on the expected wood costs from above, the table below shows the estimated major operating costs for a pellet factory with a nameplate production¹⁰ of 500,000 metric tonnes per year.

¹⁰ Nameplate herein is defined as the output that could be achieved if the factory ran at a full output rate for every hour of the year. The assumption in this model is that the plant runs at a 92% capacity factory or the equivalent of 8,059 hours out of the possible 8,760 hours in a year.



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Breakdown of Operating Costs for a 500,000 tpy Plant - Expected Case

	\$/tonne of pellets		
Pellet Fiber at \$32.30 per green metric tonne	\$60.76	\$30,910,000	55.3%
Dryer Energy Biomass Fuel at \$20.00 per metric tonne	\$5.87	\$2,990,000	5.3%
Labor	\$7.30	\$3,710,000	6.6%
Electricity at \$0.08/kWh	\$13.28	\$6,750,000	12.1%
Maintenance, consumables, and fuel costs	\$14.32	\$7,280,000	13.0%
SG&A	\$4.77	\$2,430,000	4.3%
Other Costs	\$3.50	\$1,780,000	3.2%
Operating Expenses	\$109.79	\$55,850,000	100.0%

Given all of the assumptions of the model, wood costs are about 55% of operating costs of this hypothetical pellet factory. Before debt service, taxes, and a some other fixed costs, the cost to produce a tonne of pellets is about \$110.

To see what a potential worst-case scenario would look like, based on the 95th percentile wood cost from the simulation analysis in the previous section above, the cost to produce a tonne of pellets is about \$142.

Breakdown of Operating Costs for a 500,000 tpy Plant - High Inflation Case

	\$/tonne of pellets		
Pellet Fiber at \$39.16 per green metric tonne	\$73.66	\$37,470,000	52.0%
Dryer Energy Biomass Fuel at \$30.00 per metric tonne	\$8.80	\$4,480,000	6.2%
Labor	\$10.95	\$5,570,000	7.7%
Electricity at \$0.12/kWh	\$19.91	\$10,130,000	14.1%
Maintenance, consumables, and fuel costs	\$18.32	\$9,320,000	12.9%
SG&A	\$6.20	\$3,160,000	4.4%
Other Costs	\$3.70	\$1,880,000	2.6%
Operating Expenses	\$141.54	\$72,010,000	100.0%

It is unlikely that this high inflation case scenario will occur. But it is eye-opening. As will be shown in the next section, the high inflation case scenario would be extremely challenging for producers if the price paid for the pellet fuel did not adjust significantly.

Assuming that the high wood cost is unavoidable, the pellet producer may have a few options for mitigating the impact of inflation on the other line items. Power cost may not increase by 50% (as the model assumes for the high inflation case) and the pellet factory can perhaps better optimize motor starts to minimize maximum demand. Furthermore, a pellet plant should be designed to optimize running power demand in terms of kWh per tonne of pellets produced. Labor costs may be optimized also with elimination of overtime and potentially by consolidating jobs as long as that does not negatively impact reliability, safety, and the quality of the pellet fuel.



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Once the pellets are produced, they have to be moved to the port.

Pellet Mill to Port Cost plus Port Storage and Ship Loading Costs

Rail

A number of industrial pellet factories are far enough from the port that raiing rather than trucking the pellets to the port is the optimal logistical solution. If rail is an option and the offer from the railroad is reasonable, rail is the lower cost solution and rail transport is less sensitive to fuel cost increases than truck transport.

Note that every railroad hauling deal is different. The numbers for any specific project will vary from the numbers below based on a number of characteristics that define each solution for transporting pellets from the mill to the port. The key inputs are distance, fuel consumption, and fuel cost; but many other factors are weighed by the rail operator in determining a quote for a hauling agreement.

Long-term hauling agreements insulate the producers from short-term price fluctuations caused by supply chain disruptions such as those created by the pandemic. But fuel surcharge adjustors are common.

The table below is based on a quote from a major rail operator. Since the quote was offered a few years ago, fuel surcharges have increased¹¹. Based on the quote from a few years ago for 300 kilometers (186 mile) rail haul, the cost per tonne was about \$13.31.

Tonnes per Year	460,000
% Days of Year Plant Runs	92%
Tonnes per Railcar	88
Railcars per Year	5,227
Average Railcars per Day	14
Average Railcars per Week	101
Tonnes per Day	1,260
Turnaround of Railcars (wks)	1.0
Total Railcars to Lease	101
Yearly Cost to Lease	\$638,129
Lease Cost per Tonne	\$1.39
Pull Rate plus Lease per Car	\$1,171.36
Cost per Tonne	\$13.31

¹¹ See [HERE](#) for a list of current US fuel surcharges per mile.



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With current fuel surcharges, and with all other inputs held the same, the cost goes from \$13.31 to \$13.97 per metric tonne.

Tonnes per Year	460,000
% Days of Year Plant Runs	92%
Tonnes per Railcar	88
Railcars per Year	5,227
Average Railcars per Day	14
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Yearly Cost to Lease	\$638,129
Lease Cost per Tonne	\$1.39
Pull Rate plus Lease per Car	\$1,229.41
Cost per Tonne	\$13.97

Clearly, rail provides a strong protection against diesel fuel price increases when compared to trucking (see the next section on trucking costs).

But rail only works if certain criteria are met. For example, the pellet factory has to have rail access at the site and the project will have to invest in infrastructure to manage empty and full rail cars, the rail line from the factory to the port has to be efficient with little or no need to switch rail lines, and the port has to have the ability to receive and efficiently unload the rail cars filled with pellets.

Truck

This section of this white paper uses the same model as was used for estimating the cost of trucking from the forest landing to the mill. However, in this analysis, the bulk density of the cargo is based on pellets not green roundwood. There are also no country or woods roads to transit.

The PERT distributions are defined as follows.

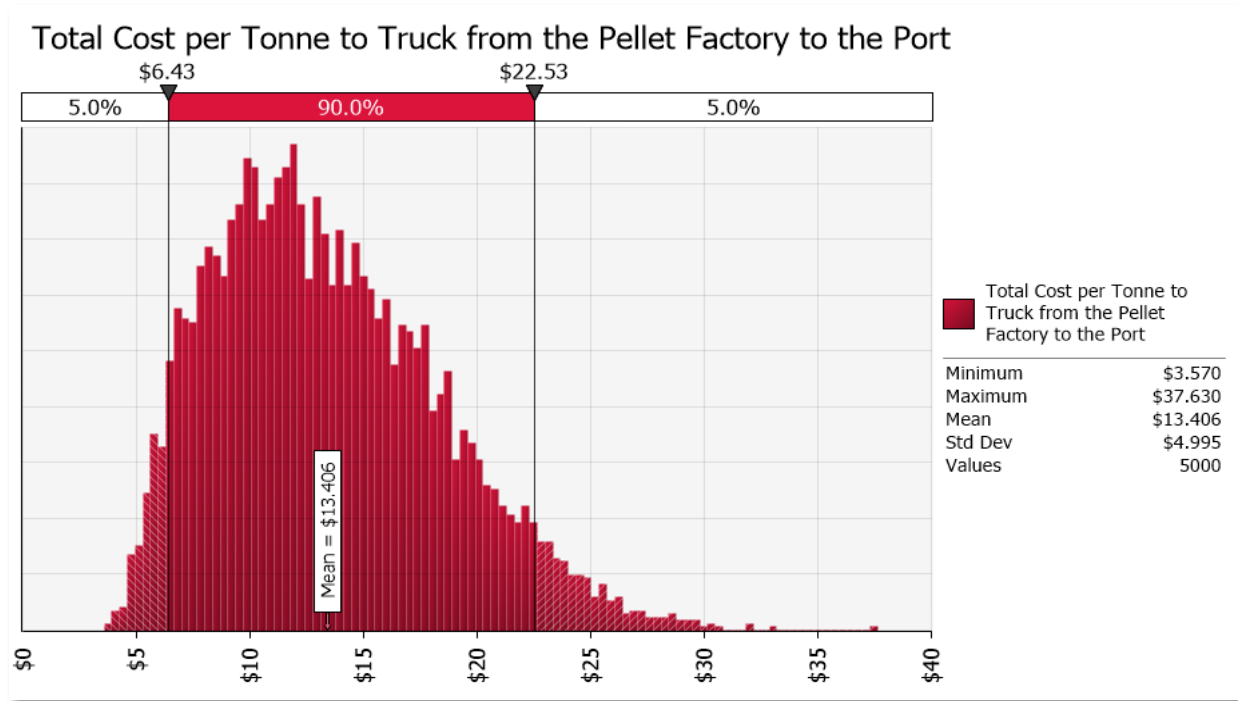
	Kilometers			Miles		
	min	expected	max	min	expected	max
Primary Highway	30	100	300	18.6	62.1	186.4
Secondary Highway	0	5	15	0.0	3.1	9.3

The results of the 5000-iteration simulation are illustrated in the following chart.

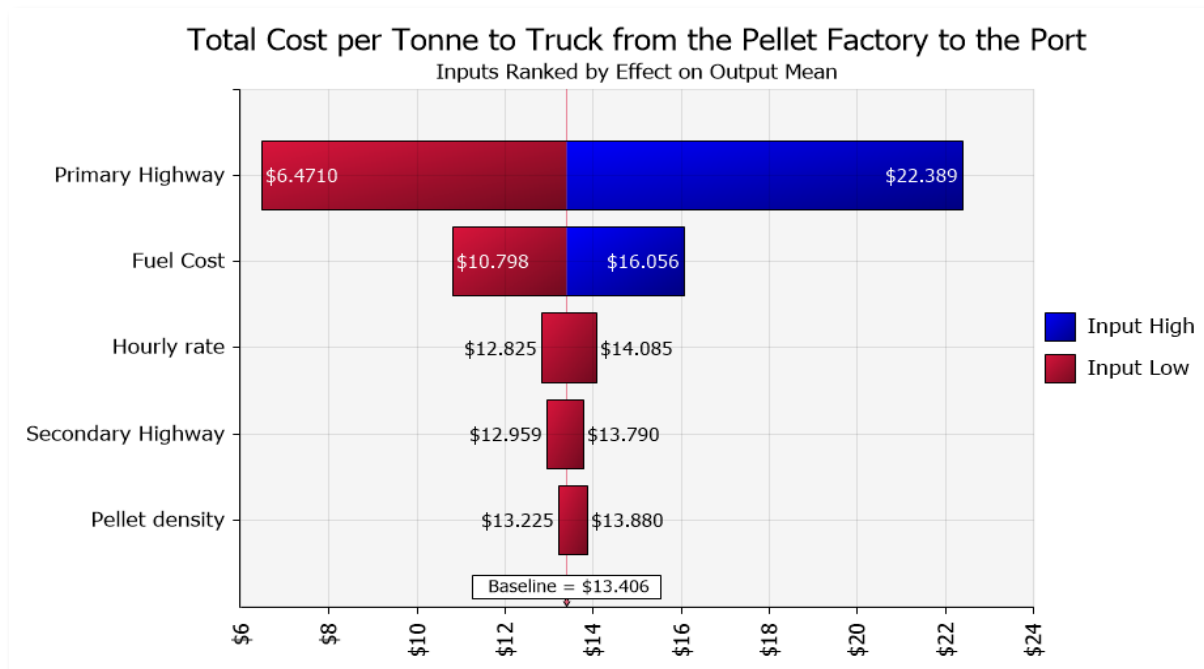


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The mean distance from the simulation output from the mill to the port is 122 kilometers (32 miles). But as the tornado chart below shows, the cost is very sensitive to distance.

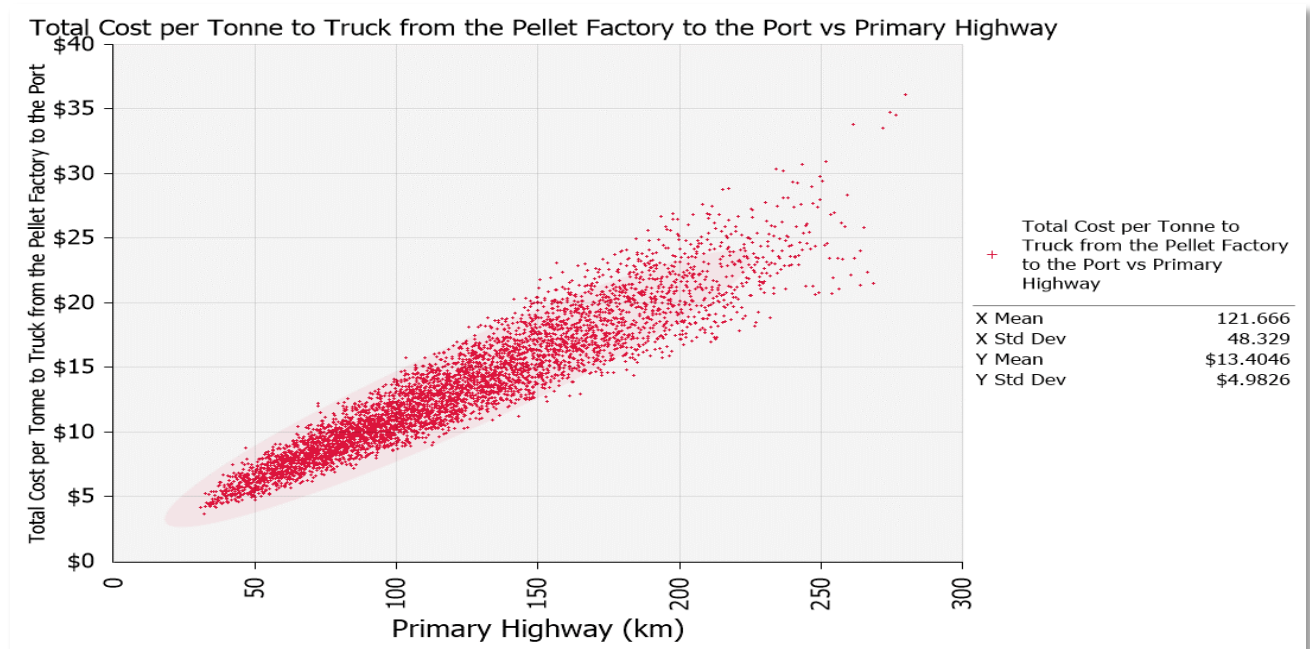




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The chart below shows the relationship between distance and per tonne cost. Note that as the distance increases, the dispersion of simulation outcomes widens. This indicates higher uncertainty. Higher uncertainty means that the risk of unexpected (and sometimes unfavorable) outcomes is increased.



The longer the distance between the pellet mill and the port, the more sensitive is the cost per tonne to changes in diesel fuel costs.

Compare Rail and Truck

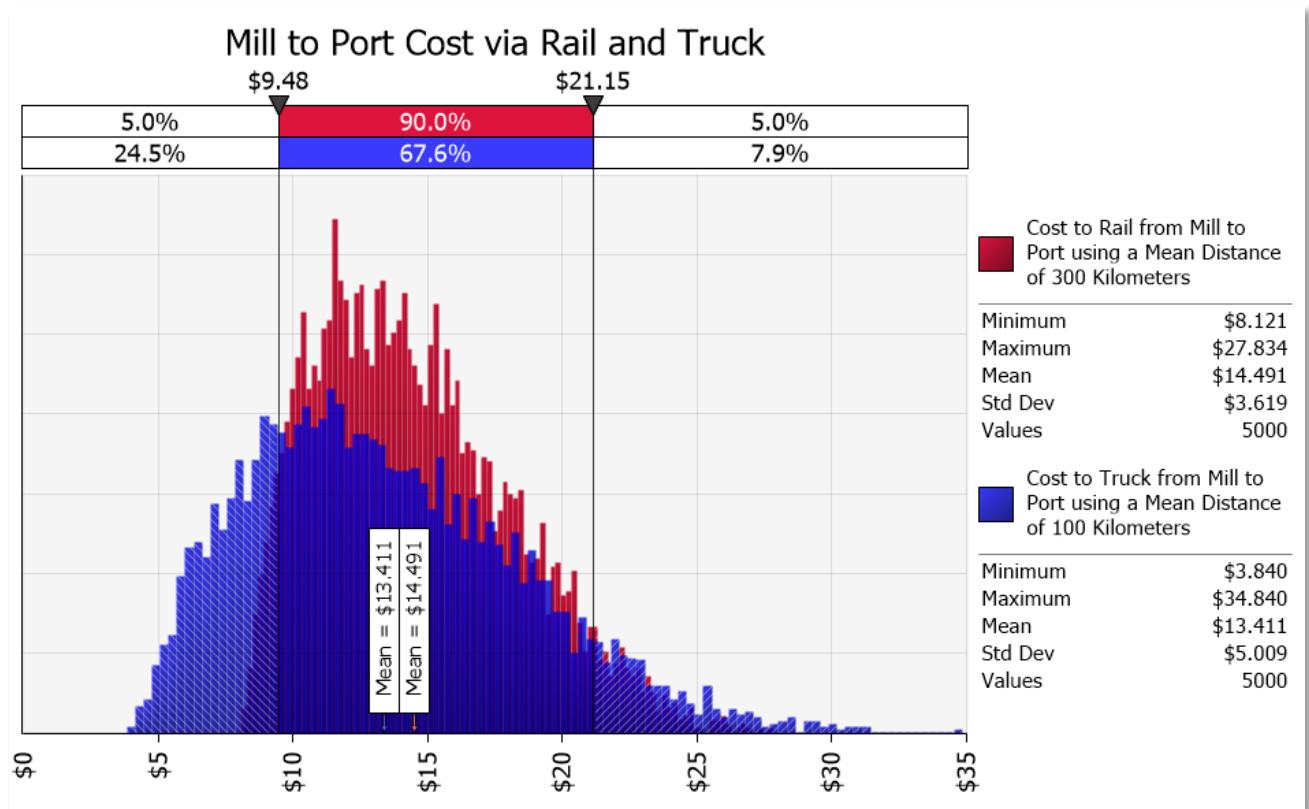
Each solution has strengths and weaknesses. A rail solution typically requires some capital investment for rail tracks and switched to store and manage empty and full cars as well and a locomotive to move them. In general, the longer the distance, the better is rail as a solution.

The chart below compares the models above (with all of their built in assumptions) for a one-way 100-kilometer truck haul a 300-kilometer train haul.



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The simulation means for scenarios are nearly the same. However, note that the standard deviation of the truck solution is larger. There is more uncertainty with changes in distance and fuel costs with truck than with rail. But also note that for shorter distances with lower fuel costs, trucking is better (the left tail of the blue distribution).

The Final Cost to Get the Pellets onto a Ship

The last cost in the supply chain before shipping is the cost of storing the pellets at the port and the cost of loading them onto a ship.

There are many pellet storage solutions. Domes, silos, and warehouses are common. They all share the need to be able to hold a shipload of pellets.

The amortized cost of the storage solution plus maintenance and a profit margin guides the cost per tonne to store the pellets. The same is true for the ship loading infrastructure. The discount rate and the number of years used in the discounted cash flow models used by the owners of the terminal infrastructure will vary. The total throughput of the terminal will also influence the cost per tonne (higher throughput dilutes the fixed costs per tonne).



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When loading the ship, there are also stevedoring costs that vary by location.



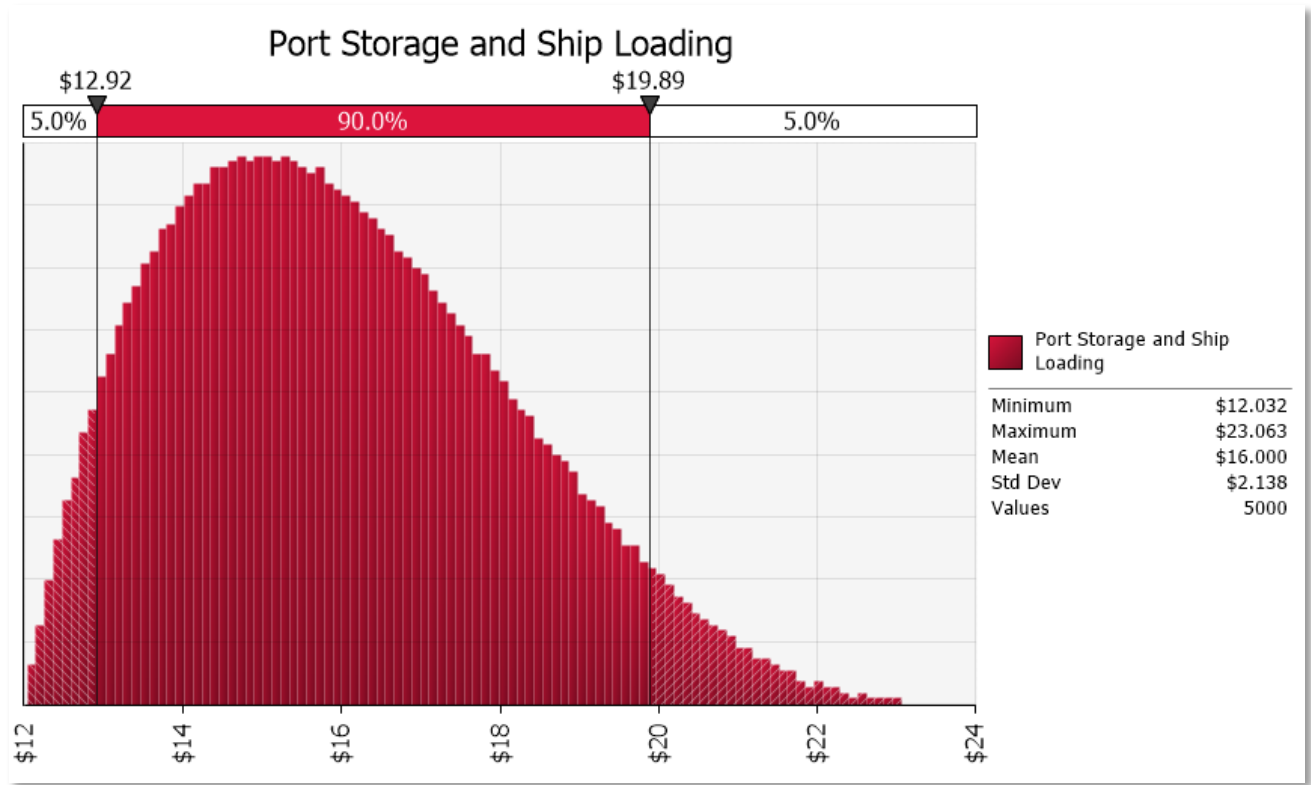
The Drax/Pinnacle Westview BC Terminal with Panamax Vessel (~65,000 tonnes pellet capacity on the ship)

The values used in this analysis are subjectively chosen but are based on typical costs. For this analysis, the mean expected cost from the simulation for the total of both storage and ship loading costs is \$16.00 per metric tonne. The 95th percentile cost is \$19.89 per tonne.



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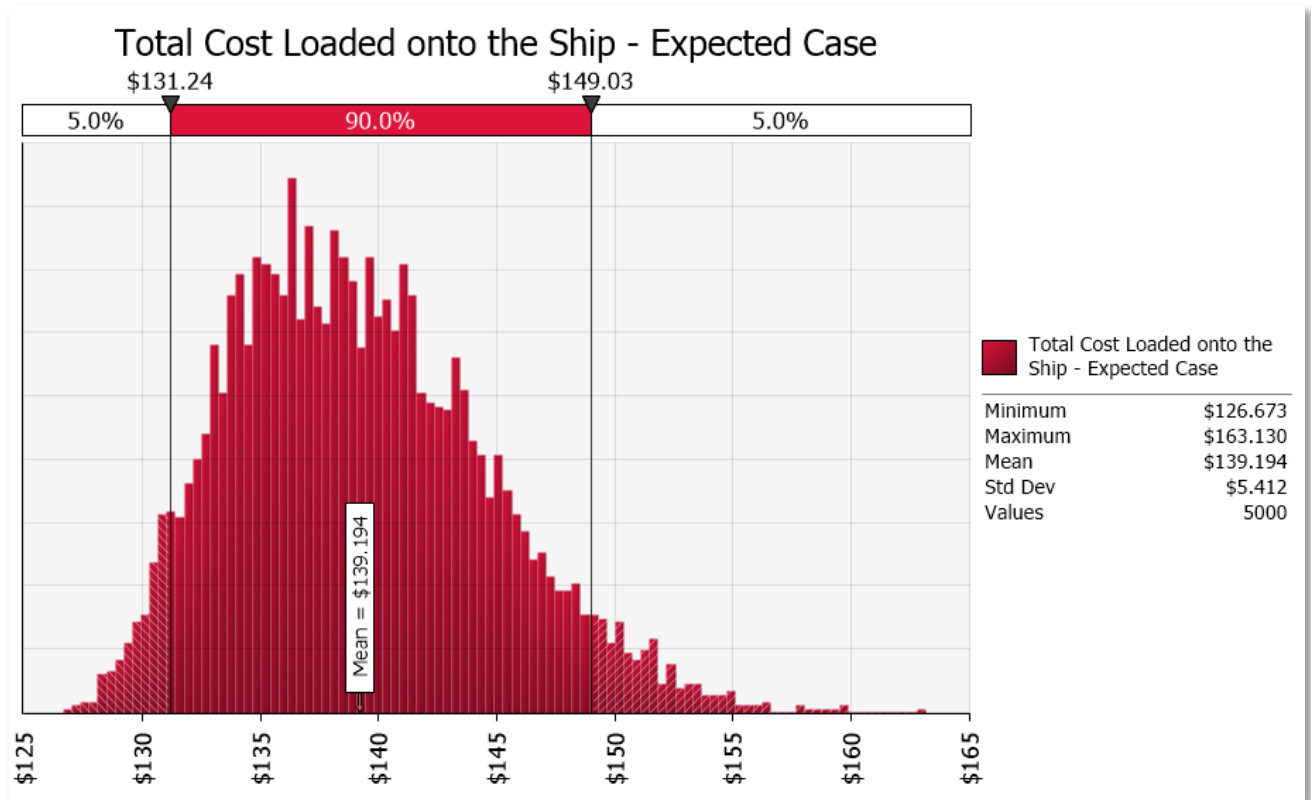
Inflation may influence the cost ship loading and maintenance, but the amortized costs of the infrastructure are fixed. In this simplified model, under the high inflation scenario, the curve is shifted right by 20%.

When all the costs in the models are summed, using the trucking solution for mill to port transportation, the mean of the simulation output is about \$139.20 per metric tonne. The chart below illustrates this.

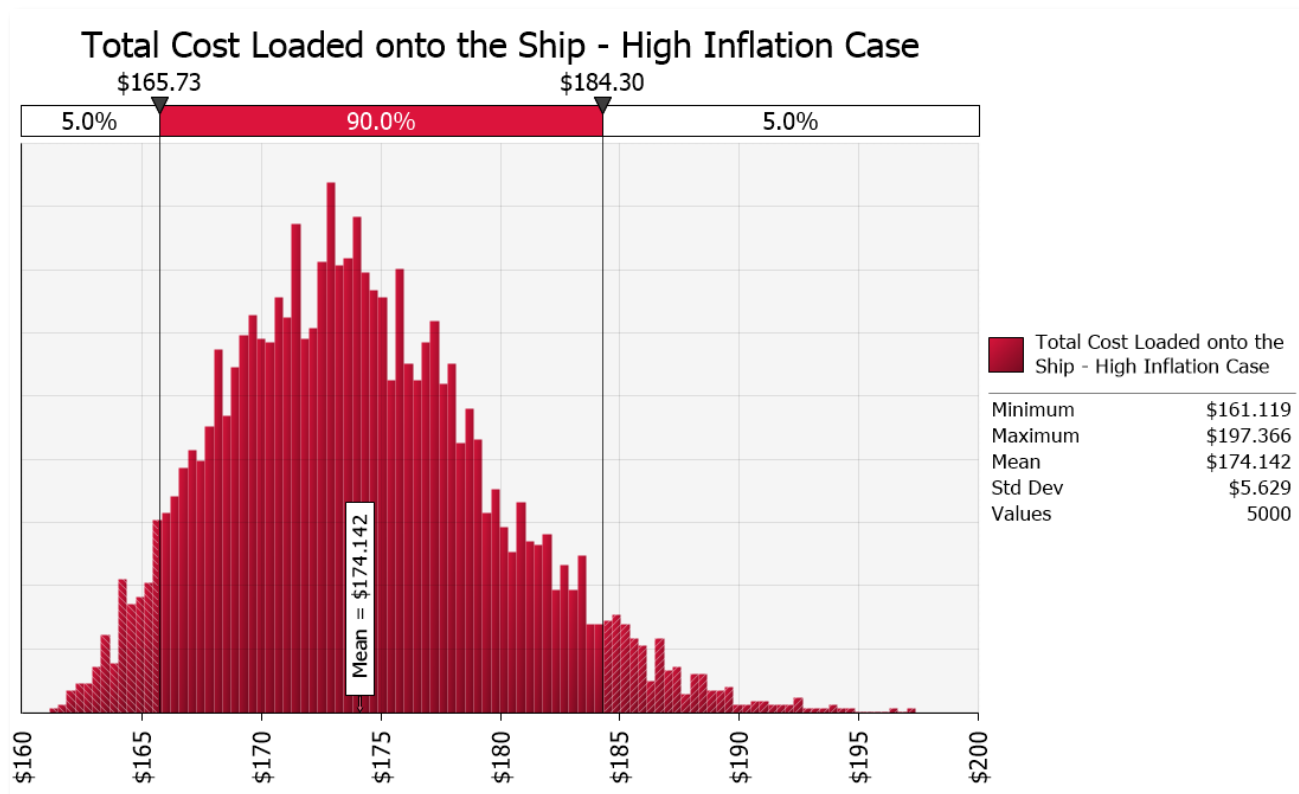


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With the high inflation scenario impacting all points as discussed in the sections above, the cost per tonne embedded in the pellets as they sit in the ship's holds rise to a simulation mean of about \$174.15. The chart below shows this result.



This higher costs outcome, the mean of which is some \$35/tonne higher than the base case, is challenging. The long-tail outcomes would be almost impossible to manage if the top line revenue is fixed.

Looking at operating cash flows shows why. There are only a few major pellet producers that share financial data publicly. Enviva is one and, before Pinnacle was acquired by Drax, they were another.

Using Enviva's annual financial statements¹², their tonnage sales weighted average EBITDA¹³ per metric tonne over the past four years is estimated to be a healthy \$37.73. Before Pinnacle was acquired by Drax in 2020, it published its financial statement in Canada. Their tonnage sales weighted average EBITDA per tonne over three years was CA\$29.23. At current exchange rates that is a more modest \$23.20/tonne.

Assuming that the major producers are more or less in this range, and assuming that the top line revenue from pellet sales is more or less fixed by long-term offtake agreements, the simulation outcomes suggest that EBITDA/tonne could be negative under a combination of unfavorable forces.

There are possible pathways to partially mitigate these challenges.

¹² Enviva is a publicly traded company. Its quarterly and annual reports are [HERE](#).

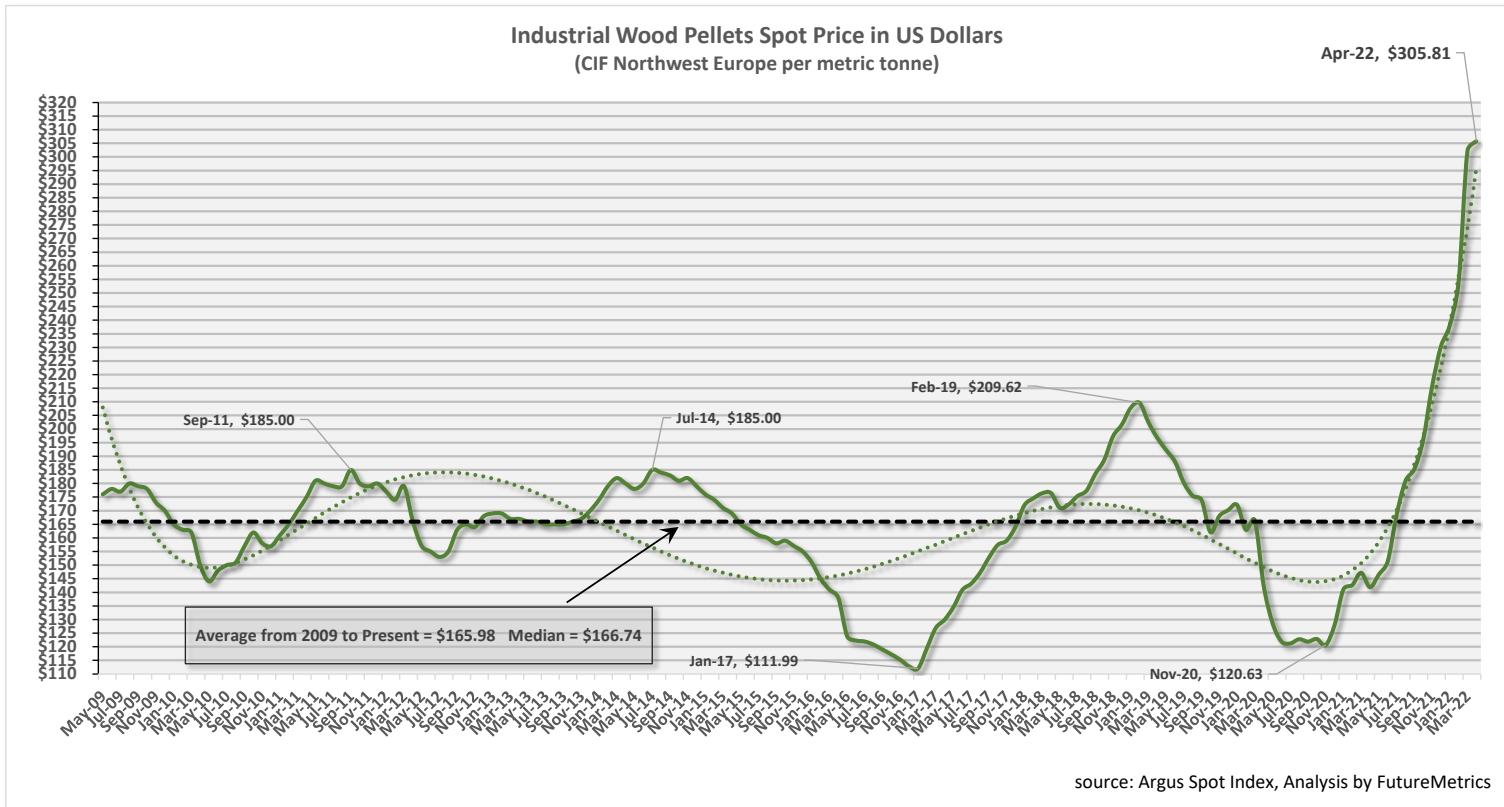
¹³ Earnings before interest, taxes, depreciation, and amortizations is a common measure of operating cash flows.



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Most producers are not entirely dependent on the contracted sales prices. A proportion of the annual production will be sold on the spot market if production exceeds the minimum offtake commitment, and the spot market can be favorable. In fact, the spot market has been very favorable recently (see chart below).



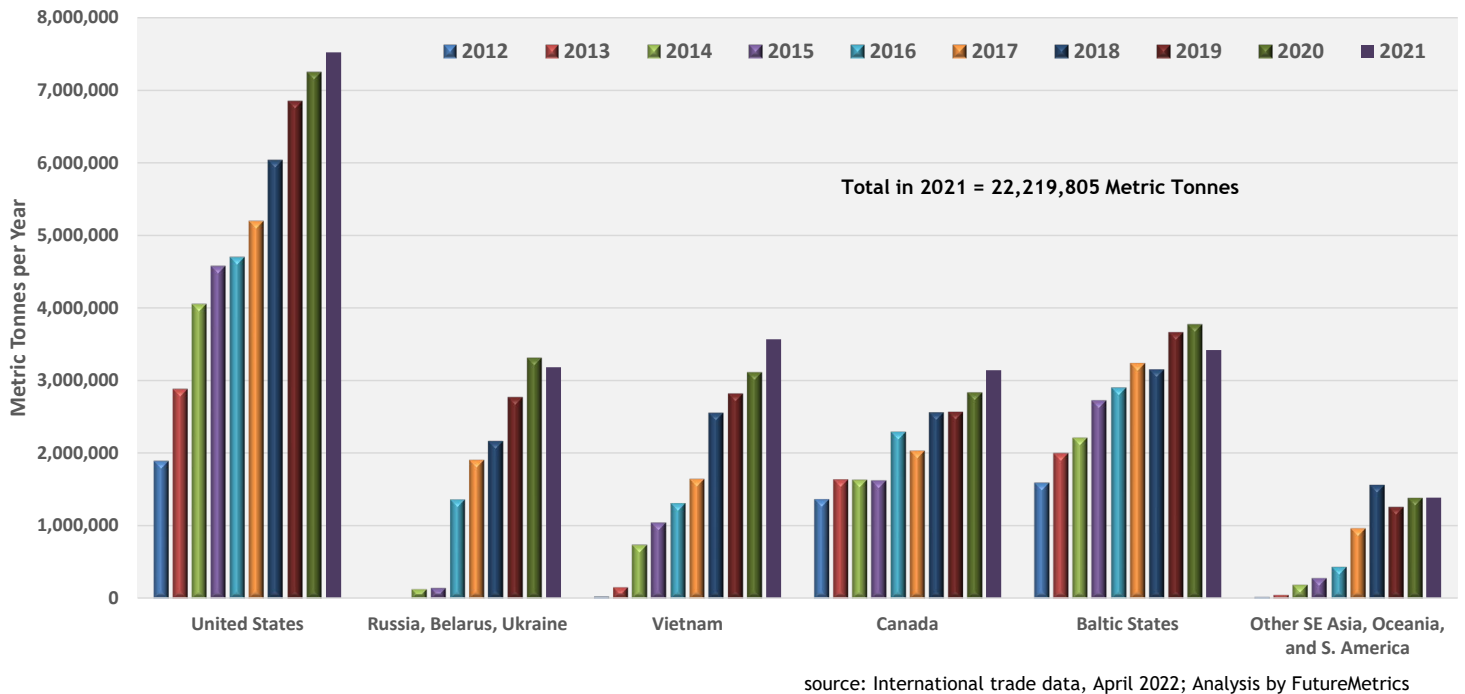
The same market forces that create inflation in costs are creating hyperinflation in pellet prices. This is likely to persist given the indefinite loss of supply from Russia, Belarus, and Ukraine. The chart below shows that those three countries exported over 3 million tonnes per year in 2020 and 2021. In 2021 that was 14.3% of the total global trade in wood pellets.



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Major Pellet Exporting Regions



Thus, for those producers that have slack capacity, the higher revenue from spot sales can at least partially mitigate the increase in costs if inflation is high and persistent.

Shipping – The last Leg in the Supply Chain

Shipping costs per tonne are a function of many inputs. Each transit deal from one port to another will have unique characteristics that contribute to the per tonne rate.

But there are macroeconomic inputs that do a pretty good job of predicting what the shipping rates would be minus the shorter-term price excursions due to supply and demand imbalances and external shocks (most recently, the pandemic and the war in Europe). FutureMetrics has built a macro-model that, among other independent parameters, uses the price of Brent crude oil.

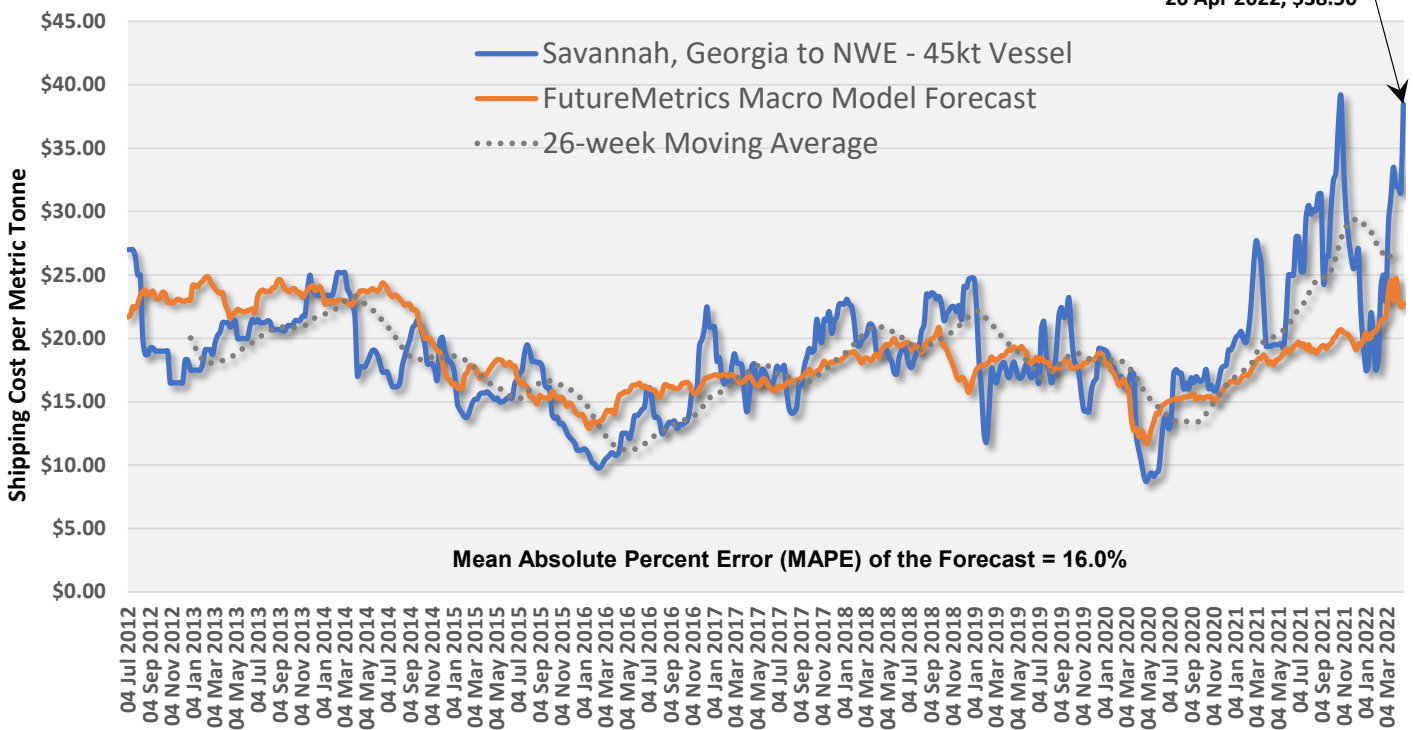
The chart below shows the actual versus the predicted cost per tonne for a 45,000-tonne load from Savannah, Georgia (USA) to Rotterdam.



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Savannah, Georgia to NWE - 45kt Vessel



NWE = Northwest Europe - i.e., Rotterdam

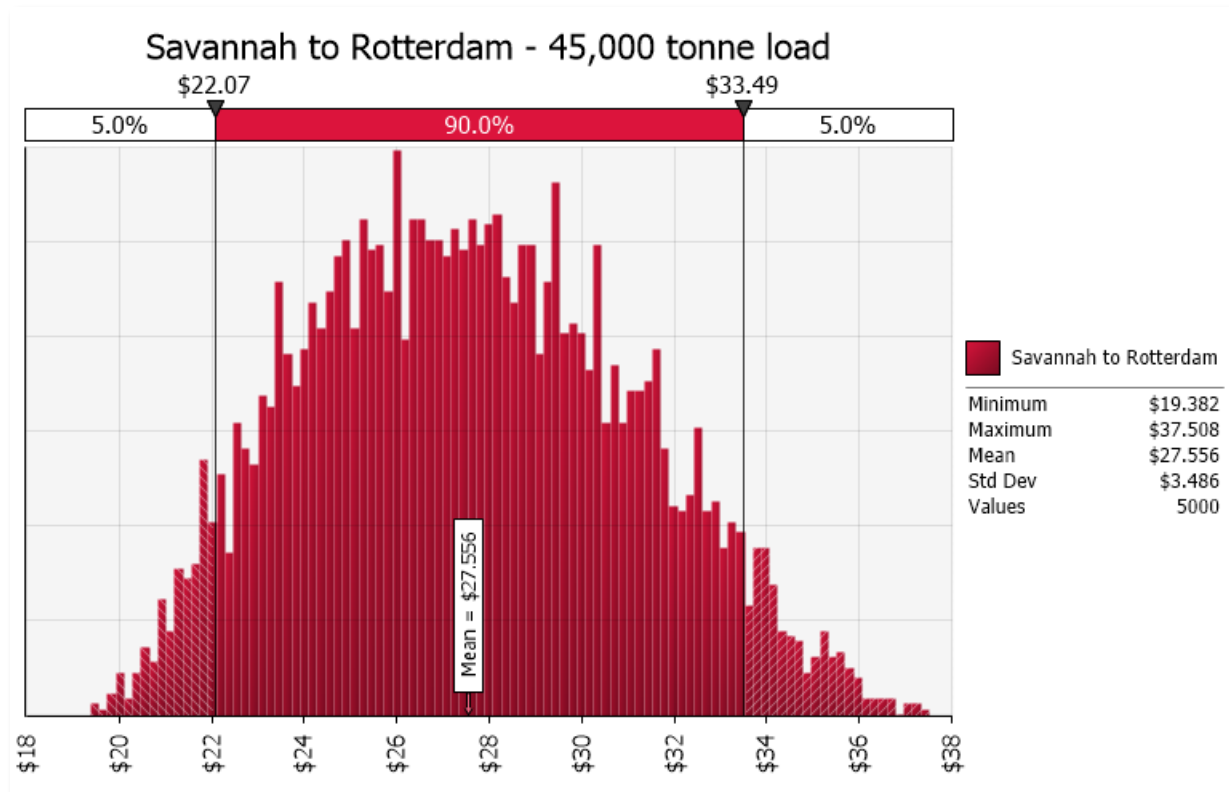
Forecast modeling by FutureMetrics; underlying data from Argus - Apr-2022

Applying PERT distributions to the independent variables yields the results illustrated in the chart on the next page.



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Note that on the date of the writing of this white paper Brent was at about \$112 per barrel and the Argus rate from Savannah to northwest Europe was \$38.50 (almost a record high over the ten years of data used in this analysis). The simulation model's mean price for Brent is \$115 and the mean of the simulation estimate for the shipping rate is \$27.56.

The simulation model includes an estimate of the cost of the time the ship spends at the port being loaded and unloaded (about 2.3 days for each in the model). The actual time ships spend at the port may be shorter or longer. Recently, it has been longer. The covid-induced supply chain disruptions that have caused queues at ports are part of the reason for the shipping cost spikes.

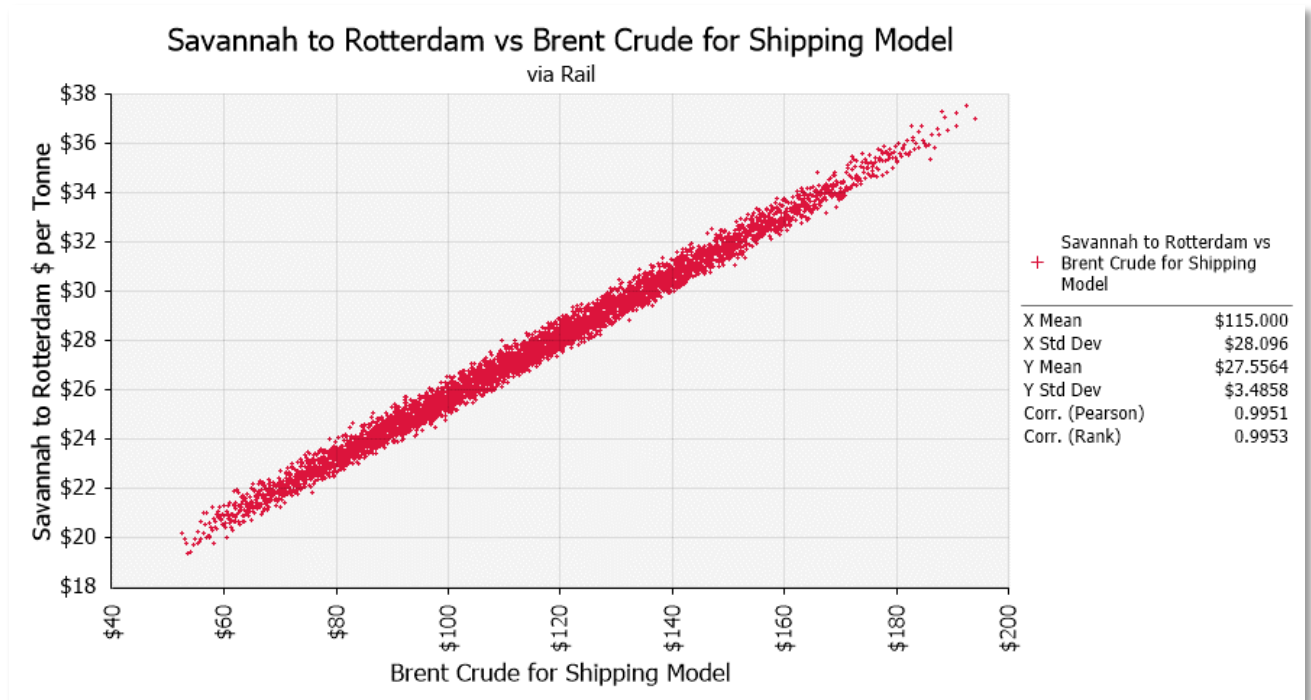
As the chart above illustrates, actual rates will fluctuate around the long-term equilibrium rate. External unexpected shocks will carry the rates much farther from the expected rates. The very high rates in late 2021 and the recent spike after the invasion of Ukraine and the associated curtailment of imports from Russian, Belarus, and Ukraine are examples of that.

Distance, transit time, size of vessel, vessel loading and unloading rates, etc., and several macroeconomic variables drive the model. The chart below shows how the price of Brent crude influences the model's prediction.



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As Brent varies from \$50 to \$200 per barrel, the variation in the model's forecast for shipping rates on this route for a 45,000-tonne load increase by about \$18/tonne.

As with other transport means that use fossil fuel, the longer the distance and the smaller the ship, the steeper the curve.

Many other short-term "microeconomic" forces influence shipping rates. This analysis of shipping provides insight into how fossil fuel prices impact rates and suggests what the rates should be when the markets are in balance.

Pellet producers selling CIF or pellet buyers buying FOB can engage in contracts with the shipping companies to transfer, at least for the short to medium terms, the price uncertainty risk.



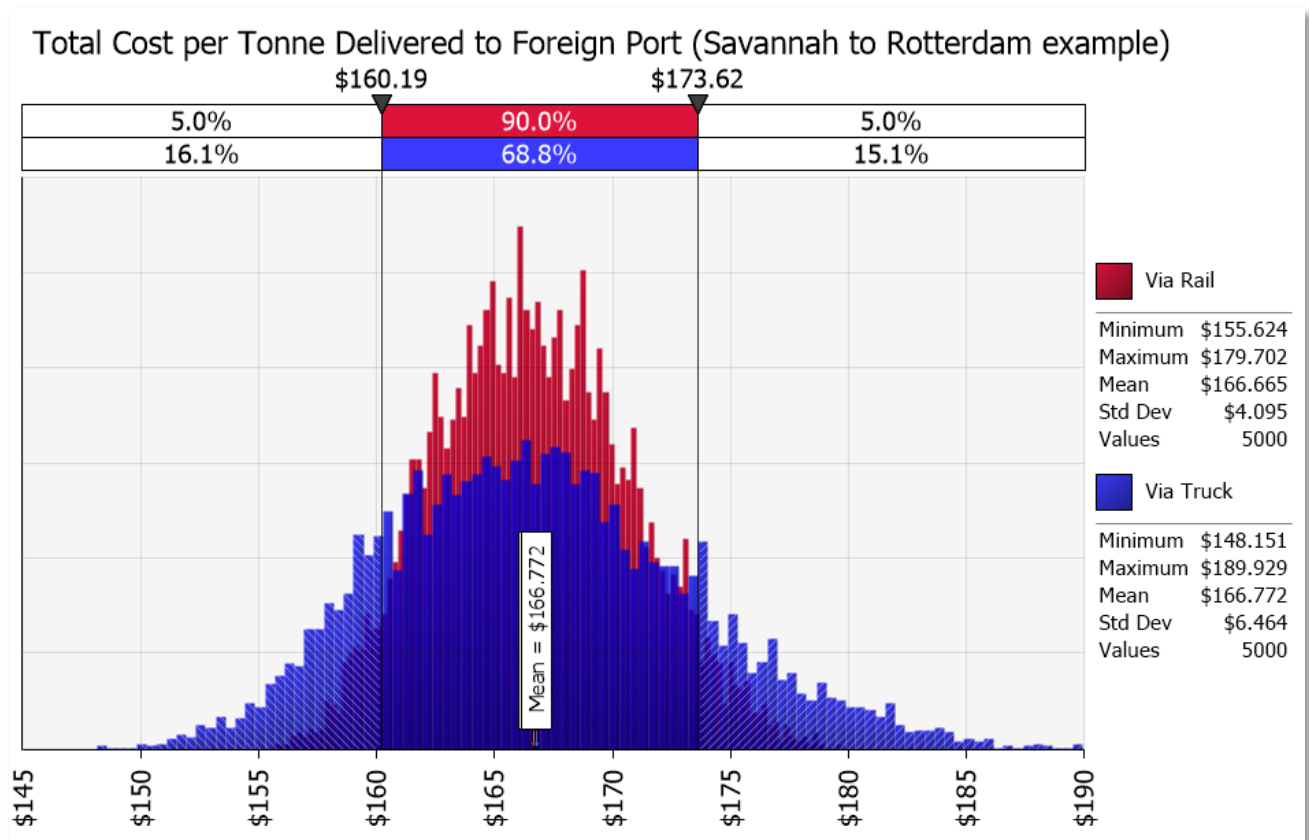
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Summary of Costs – Estimate of Total Cost to Deliver Industrial Pellets

Adding shipping cost to the cost of production yields the total cost to deliver a tonne of pellets to the foreign port.

Using the base case for inflation, the expected total cost to deliver pellets from Savannah to Rotterdam is shown below¹⁴. The chart has both the rail and truck mill-to-port scenarios overlaid.



Under the current prices for transportation fossil fuels, the model estimates an expected cost of about \$167 per tonne for both scenarios. However, for the mill-to-port cost models, the rail one-way simulation mean distance to the port is 350 km and the truck one-way simulation mean is 121 km.

¹⁴ FutureMetrics' shipping cost model can take inputs for any origin port, any destination port. and for any ship size.



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Note that this final cost does not include the profits to the producer. The actual final delivered price, discussed in the conclusion below, needs to have a margin between the inherent cost to produce and deliver and the pellets and the purchase price.

Conclusion

This analysis has been about the cost to produce and transport pellets. In fact, most of the uncertainty in costs is associated with transportation. From the forest to the mill to the final destination, logistics more or less define the final cost.

This analysis has not considered the non-operating cash outflows such as debt service, taxes, and annual capital investments. Nor has it considered the margins that the producer expects in order to make a profit.

Using the results in the chart above, the gap between the expected cost of about \$167/tonne and the price paid at the foreign port indicates a basis for a gap between the cost of produce and deliver and the price paid for imported pellets..

Based on FutureMetrics research, the trade flow weighted average CIF price for pellets imported into the UK¹⁵ at the end of February 2022 is about \$198 per metric tonne (see chart on the next page). Note that a relatively small proportion of imported pellets are bought on the spot market. Most are traded under long-term offtake agreements with the buyers. Thus, the actual contract prices for long-term agreements are probably slightly lower than the values in the chart that are derived from trade data which does not differentiate between spot deals (at very high prices now as the chart on page 23 shows) and trades under existing contracts.

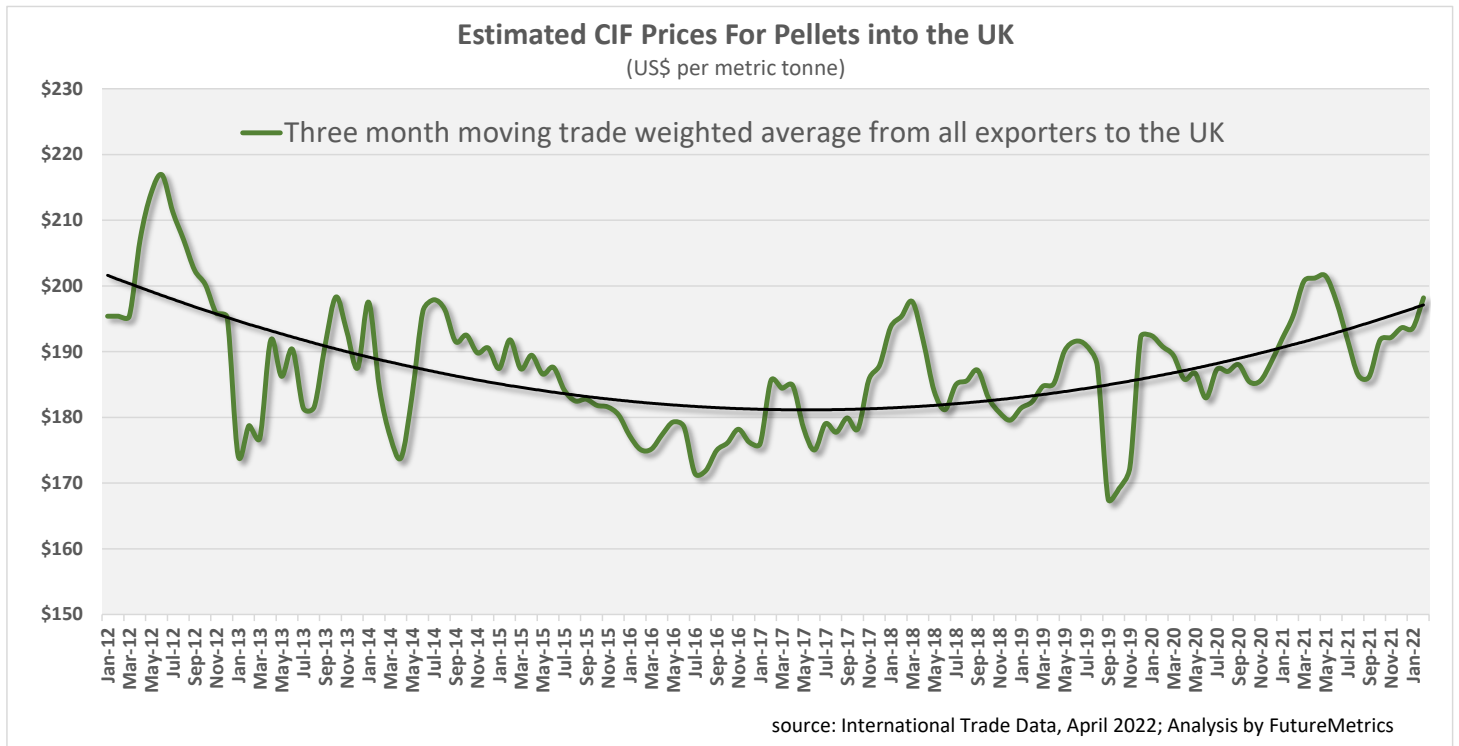
Furthermore, the trade weighted average price is based on a number of exporting countries. The US as of January 2022 had about a 60% market share of UK imports. The prices paid from each country vary around the value shown in the chart on the next page. Over the 10 years of data used, the US has usually been slightly above the average. The recent trend of the delivered price of US imports to the UK has been around \$205/tonne.

¹⁵ The FutureMetrics' modeled shipping cost to Immingham. UK is about the same as the shipping cost to Rotterdam.



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The outcome of the model suggests that there is a sufficient gap between the mean cost of the simulation and current actual delivered prices to the UK for pellet producer's EBITDA/tonne to be in the ranges between \$20 and \$40 per tonne as discussed earlier in this paper. Higher costs, all else held constant, will shrink the margins.

The right side long-tail outcomes in the chart on the previous page would be challenging but are highly unlikely.

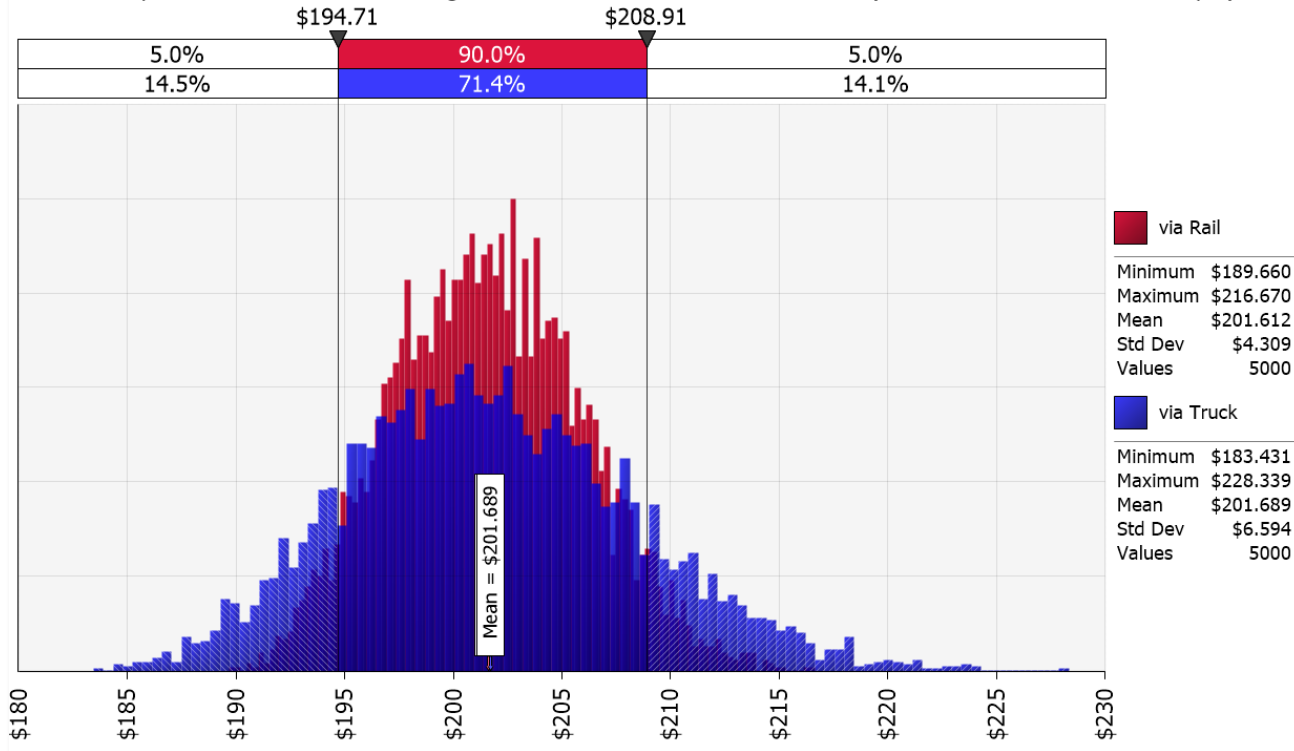
However, running the simulation with the assumptions of persistent and high inflation yields a result that illustrates the potential challenges that the industry could face.



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Total Cost per Tonne Delivered to Foreign Port PERSISTANT HIGH INFLATION (Savannah to Rotterdam example)



At the current average prices paid for pellets imported into the UK, this outcome would cause significant financial stress.

Given that the cost of everything, including baseload and load-following electricity from coal and natural gas, will be higher under this dire scenario, it is possible that the the offtake contract pricing could be adjusted. And it is very likely that the spot market would provide some relief for any slack capacity.

Because the industrial wood pellet markets have become integral to the decarbonization efforts of many nations by supplying baseload highly carbon beneficial power, and if those nations continue to support decarbonization policies, it is improbable that demand for sustainably produced pellet fuel will decline. Supply may be an issue in the short-term but demand and expected growth in demand should remain more or less as expected.

Of the approximately 44 million metric tonnes of pellets produced in 2021¹⁶, about 22.2 million of those pellets were traded across international borders. The international supply chains for wood pellets, the

¹⁶ Based on data from the Food and Agriculture Organization of the United Nations (FAO) through 2020 with 2021 forecast by FutureMetrics. <https://www.fao.org/faostat/en/#data/FO>



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majority of which is for pellets used to replace coal in utility power stations, has grown at a compounded annual growth rate (CAGR) of about 16.3% between 2012 and 2021.

Major Exporting Regions Annual Exports (metric tonnes)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	CAGR
United States	1,898,126	2,882,521	4,055,732	4,575,473	4,709,746	5,197,589	6,039,432	6,858,419	7,256,858	7,522,518	14.8%
Russia, Belarus, Ukraine			132,279	150,108	1,369,778	1,912,071	2,171,271	2,778,774	3,321,437	3,183,363	37.4%
Vietnam	33,829	160,123	744,773	1,050,249	1,317,396	1,648,861	2,560,183	2,828,444	3,121,143	3,567,910	59.3%
Canada	1,369,143	1,640,175	1,637,347	1,627,784	2,299,906	2,039,490	2,565,776	2,576,579	2,843,408	3,140,845	8.7%
Baltic States	1,597,382	2,000,585	2,215,645	2,728,558	2,910,392	3,242,741	3,158,615	3,672,837	3,782,184	3,419,618	7.9%
Other SE Asia, Oceania, and S. America	27,008	55,992	194,458	286,726	438,970	970,768	1,566,868	1,267,235	1,391,926	1,385,552	48.3%
	4,925,488	6,739,396	8,980,234	10,418,897	13,046,189	15,011,519	18,062,145	19,982,288	21,716,957	22,219,805	16.3%

source: International trade data, April 2022; Analysis by FutureMetrics

Shorter term fluctuations in transportation costs, such as those created by the bottlenecks resulting from the covid pandemic, those created by cyclical supply and demand imbalances in transport infrastructure (trucks, rail, ships), and those created by black swan external shocks, typically fade as costs return to a longer-term market clearing cost equilibrium.

The variable inputs that most strongly define the expected costs in all of the models described in this white paper are a function of fuel cost and then the distance that the products have to travel. In general, the smaller the cargo capacity moved by the prime mover (truck, locomotive, ship), the more sensitive is the cost of transport to changes in fuel costs and distance.

While it is tonnes that are measured in trade, it is energy that is actually being sold. The end user is buying concentrated energy that they convert to electricity and heat.

Lowering the cost per delivered gigajoule (GJ) of energy should be part of every producer’s strategic planning.

Improving productivity rates across the supply chain is an obvious prescription.

But the supply side of the industry needs to continue to support the development of viable technologies for competitively producing so-called advanced pellets that have higher energy and bulk densities. Some advanced pellet technologies allow for almost 40% more energy per cubic meter. All transport costs, from the pellet mill to the end user, in terms of cost per GJ delivered, would be significantly improved.

The water-resistant, low dust, and brittle characteristics of some version 2.0 pellets opens the doors to several benefits that would lower the net cost of using pellet fuel in place of coal.

The demand side is investing significant funds in improving generation economics with biomass carbon capture and sequestration (BECCS). The supply side’s R&D for moving past version 1.0 of pellet fuel should accelerate like the rate of increase in the cost of energy commodities shown on the first page of this paper.

This period of high inflation and an extremely short pellet market is probably transitory. But it does motivate serious thinking about the future