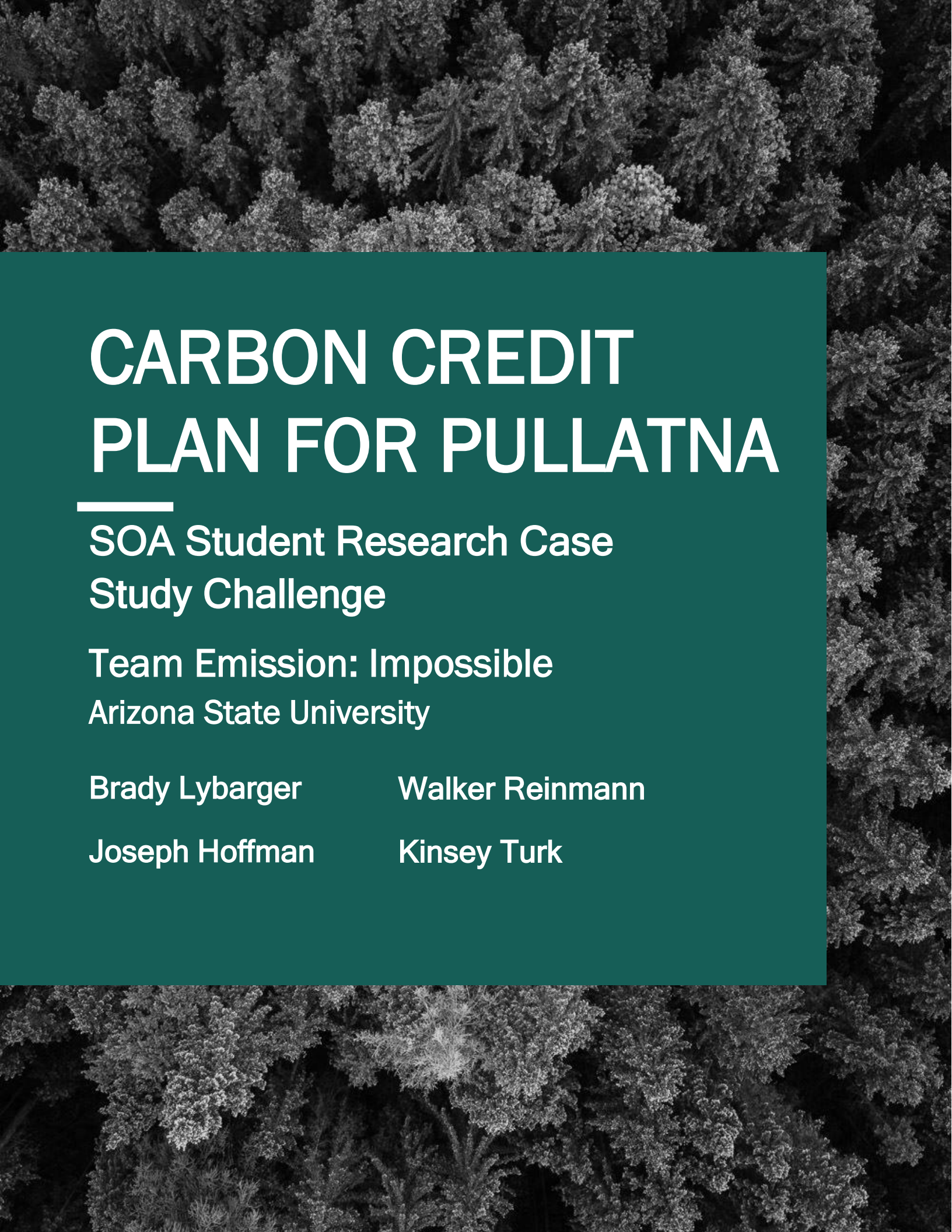

CARBON CREDIT PLAN FOR PULLATNA

SOA Student Research Case Study Challenge

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EXECUTIVE SUMMARY

Our company, Team Emission: Impossible, has been hired by Pullanta's Department of Environmental Concerns to help implement a carbon credit program that will reduce carbon emissions to 75% of the 2018 emission level by the end of 2030. The program involves the implementation of three carbon emission bonds (Bronze, Silver, and Gold) with yearly linearly decreasing carbon credits. Each credit allows a business to emit one metric ton of carbon. These bonds will be made available to all companies in Pullanta, with exception to the transportation sector, which will instead be offered a transportation emission bond. This bond offers businesses a floating number of carbon credits based on the level of overall emission reduction within the sector, to encourage a more active reduction in the rapidly growing transportation sector's emissions.

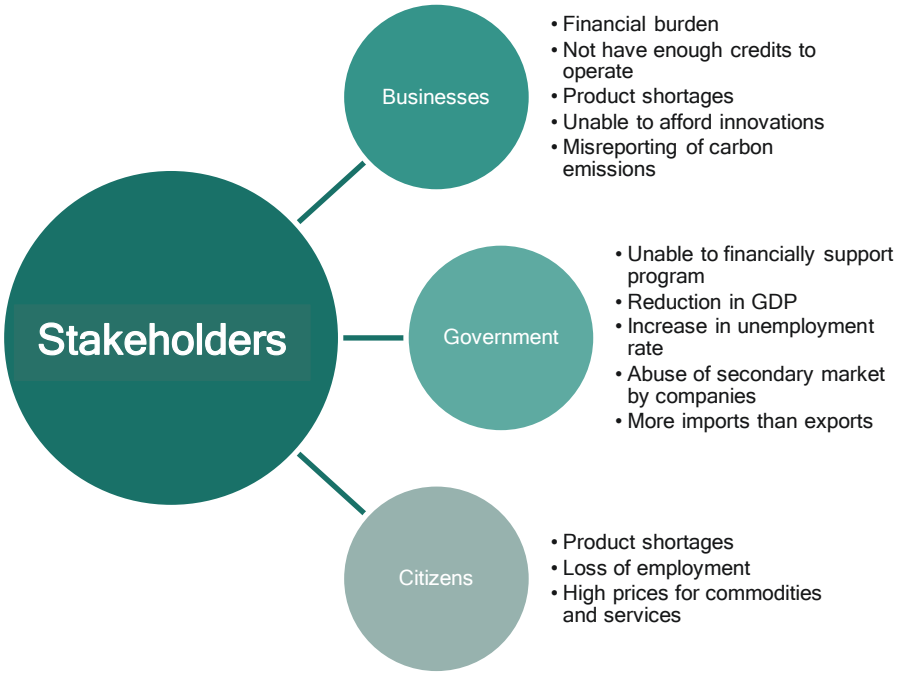
The existence of an open secondary market will not be permitted under this program. Instead, unused credits can be sold back to the government at a reduced price and later resold as a secondary emission supplement to companies who need more credits. In the case that no replacement credits are available, a carbon tax is utilized.

Under the program outlined above, we expect 2030 emission totals to equal 633,688,759 metric tonnes, which achieves the aggregate emission goal established by Pullanta. The program is also projected to generate revenue of ₱157.3 billion over the next decade.

ASSESSMENT OF RISKS

While developing the carbon credit program, we should analyze what risks could impact the three main stakeholders—businesses, government, and citizens—and ensure that our program addresses them. Figure 1 summarizes the risks outlined below.

Figure 1: Summary of Risk for Different Stakeholders



The main risk attributed to the creation of a carbon credit program is the improper pricing of the financial instruments. The price must be adequate for the government to run the program. If the price is too high it will place an inordinate burden upon companies causing them to forgo additional production and innovation and could even cause them to move production out of Pullanta. This will hinder GDP, cause product shortages, and potentially increase Pullanta's unemployment rate.

If priced too low, more credits than expected will be sold, and the program's primary objective of reducing emissions will fail. An additional underpricing risk is that companies will purchase more credits than they need – whether it be to hurt competitors who do not have enough credits to operate, or to avoid making any emission reduction changes, negative impacts will be felt by Pullanta.

Even if the financial instruments are priced perfectly, there is still risk associated with competing countries. Companies in Pullanta could look to move production to countries

where carbon emissions are not so heavily regulated. This will also negatively impact GDP and unemployment, which hurts both the government and the citizens of Pullanta.

PROGRAM DESIGN

Aggregate Emission Yearly Goals

Since implementation of the carbon credit program would roll out in 2020, Pullanta needs an estimate as to what 2020 carbon emissions will look like. An ARIMA model was applied to forecast the emission estimates (Appendix A1). The estimates were divided by sector in order to accurately measure the characteristics of emission history.

In order to set allowable aggregate carbon emissions each year, a varied linear trend was applied to each sector. It was decided to vary the number of carbon credits by industry sector instead of a uniform 25% decrease due to the different natures of the six sectors. Larger carbon contributors should be made to decrease at a higher rate than low polluters. As shown in Table 1, varied linear decreases in carbon emissions were set for sectors such that their weighted averages approximated 25%.

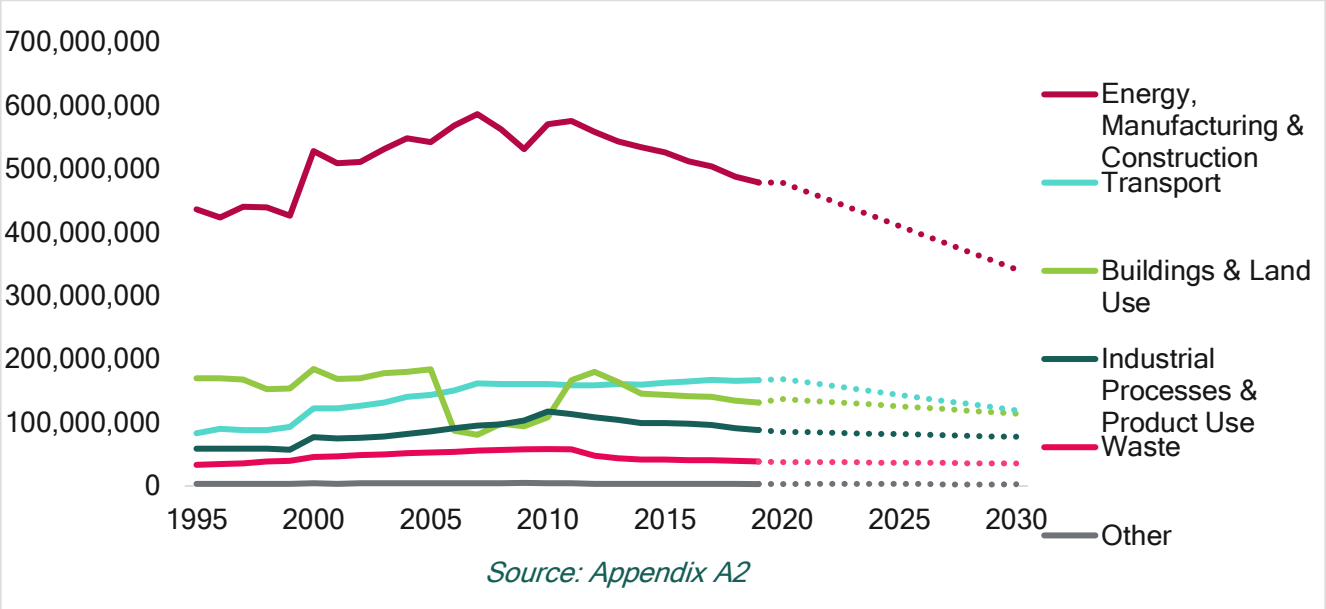
Table 1: Set Percentage Decrease by Sector

Sector	% of 2018 Emissions	% Decrease
Building and Land Use (B)	14.57%	15%
Energy, Manufacturing, and Construction (E)	52.94%	30%
Industrial Processes and Product Use (I)	9.92%	15%
Other (O)	0.33%	10%
Transport (T)	17.96%	28%
Waste (W)	4.29%	10%
Total	100%	25.04%

Target 2030 levels can be found by applying set percentage decrease to each sector's 2018 emission level.

To get the yearly breakdown, a linear trend was applied from 2020's predicted values to the 2030 carbon goal using the set percentage decrease in Table 1. Figure 2 shows the historical and yearly projected emission goals by sector.

Figure 2: Historical and Projected Emissions by Sector (metric tonnes)



Source: Appendix A2

Credit Limits

Credits distributed to companies will come from purchasing the carbon financial instruments. The specified number of credits for a given year will be issued to the companies at the beginning of the year. These credits cannot be rolled over to next years. Based on analysis of emission data (Appendix C1), we allow companies to emit 1,000 tonnes of carbon per year without any credits. This number allows the lowest 20% of companies in terms of yearly emissions to maintain their emission amounts without buying any emission bonds. Companies are encouraged to buy up-front, but this rewards low emission companies by not requiring them to pay for credits and allows high emission companies to account for uncertainty in deciding how many bonds to purchase.

There is no limit as to the number of credits a single entity can purchase. With the exclusion of an open secondary market and decreasing nature of the financial instruments, companies are incentivized to only buy what is necessary.

Social Cost of Carbon

The social cost of carbon developed is used as the price of a carbon credit. To estimate it, we used Equation 1, a nearest neighbor's approach paired with an inland discount factor.

Equation 1: Pullanta Social Cost of Carbon

$$= \left[\frac{1}{3} * \text{Saudi Arabia Social Cost} + \frac{1}{3} * \text{Australia Social Cost} + \frac{1}{3} * \text{UAE Social Cost}\right] * \text{Inland Discount Factor}$$

We first identified the nearest neighbor that had similar attributes to Pullanta, by considering emissions, GDP, and population. Assigning equal weight to neighboring values, we calculated the social cost of carbon to be $25.33, or ₱42.22.

The final step was including the inland discount factor. Through research, we found that the portion of a country bordering an ocean significantly affects the social cost of carbon. By comparing the costs in the U.S., China, and India (see Appendix A3), as well as geography, we arrived upon a 50% discount for countries that lack major coastlines.

Given the area and percentage of the population in Pullanta, we assumed it is mostly inland and applied the 50% discount factor for a final social cost of carbon of ₱21.12. This value is set as the value of one carbon credit and keeps constant up to inflation adjustment.

Financial Instruments

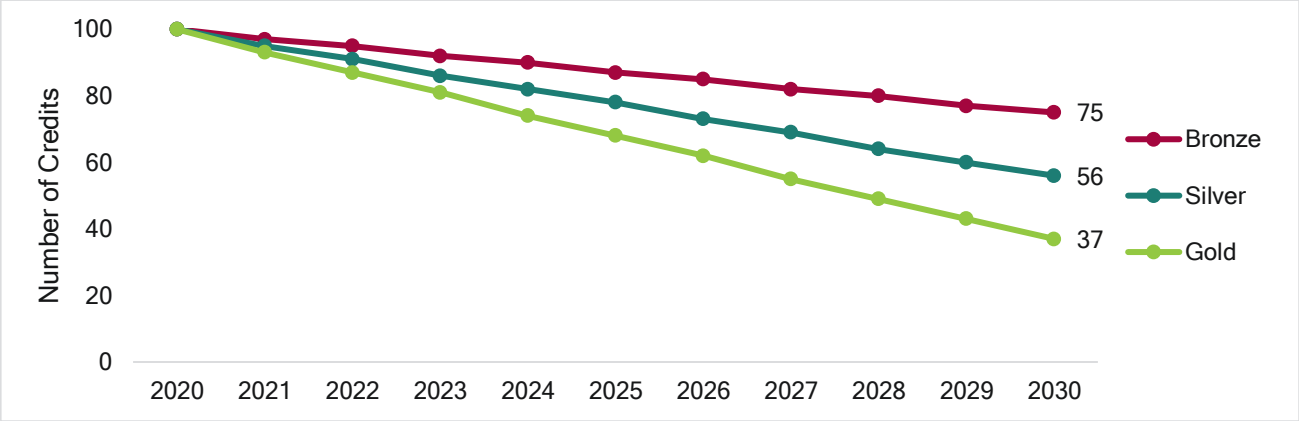
Metal Emission Bonds	• Bond with linearly decreasing credits • Time period: 10 years (or time until 2030) • Bronze: most expensive, yearly decrease of 2.5% • Silver: price between Bronze and Gold, yearly decrease of 4.4% • Gold: least expensive, yearly decrease of 6.3%
Transportation Emission Bond	• Companies in transportation sector must purchase this bond • Floating bond • Time period: 10 years (or time until 2030) • Cost comparable to that of bronze bond
Secondary Emission Supplement	• Redistributes carbon credits sold back to governement • Applied at end of the year to address excess carbon emissions • Costs 15% above social cost of carbon • Intended for companies that run out of credits

Metal Emission Bonds

Three different metal emission bonds – labeled Gold, Silver, and Bronze – will be made available to non-transport sectors. The rate of decrease will be linear. Companies will be motivated to cut their emissions gradually.

Each bond will yield 100 carbon credits in the first year. The linear rate of decline will increase going from the Bronze to Silver to Gold, such that the three bonds ends with 75, 56, and 37 credits, respectively. The yearly credits of the three bonds are visualized in Figure 3.

Figure 3: Yearly Carbon Credits Awarded by Bonds



Since the Bronze bond provides the most carbon credits, it will be the most expensive at a price of ₱18,137.92. However, companies will be incentivized to purchase the Silver bond, with fewer credits, for a price of ₱15,431.66, which includes a 5% discount. The Gold bond, with the least amount of credits, has a discount of 10% for an upfront price of ₱12,931.69. See Appendix A5 for pricing formulas. This encourages companies with the ability to rapidly decrease emissions to purchase the more progressive Silver and Gold Bonds, while still allowing companies with less room to reduce emissions to have a base-level reduction plan under the Bronze bond.

If a company enters the market in the middle of the program, they will receive the same amount as every other bondholder would receive for that year, and for the years going forward. For detailed justification see Appendix A4.

Transportation Emission Bond

The transportation sector of Pullanta was identified as having a significant increase in emissions over the last 25 years, so we designed a separate transportation emissions bond.

Table 2: Transportation Average Yearly Increase in Emissions

Sector	Average Increase in Yearly Emissions
Buildings & Land Use	0.62105%
Energy, Manufacturing & Construction	0.53958%
Industrial Processes & Product Use	1.97541%
Other	-0.20819%
Transport	3.12891%
Waste	0.75882%

Companies in the transportation sector will not be allowed to buy metal emission bonds. Instead, the transportation emission bond is designed to promote a more rapid rate of carbon emissions reduction while providing a steeper reward for doing so. The bond delivers credits yearly just like the metal emission bonds; however, the number of carbon credits dispersed are floating – meaning they depend on the previous year's reduction amount. If the previous year's reduction in emissions was greater than the index, a level reduction of 4,930,304 tonnes, the bond would allow for more credits the following year. If a year's reductions did not exceed the index, the bond would grant fewer credits.

A critical design in this bond is that payments match the yearly cost of the Bronze emission bond. Therefore, more substantial decreases in given years result in more carbon credits at a better price the next year. There is also a built-in reduction of carbon credits to ensure the overall target reductions are met by 2030.

Secondary Emission Supplement

The secondary emission supplement is designed to redistribute carbon credits that were sold back to the government. A company can purchase as many of these recycled credits as needed, which will be packaged as a secondary emission supplement priced at a 15% increase in the price per credit. These credits will be added to their portfolio at the end of the

year. The 15% price increase serves to discourage companies from waiting to buy credits until the last minute, while not being overly inhibitive.

Bond Payment

Expecting revenue from financial instruments sales to be fully earned in a single upfront payment could put significant financial stress on some companies. Therefore, revenues from the Bronze, Silver, and Gold bonds can also be collected yearly, where payments are based on the proportion of that year's credits to total credits granted by the bond (Appendix A5). The Transportation bond revenue works on a similar structure to the Bronze bond. In all cases, the yearly payment must be made before the bond's credits are dispersed. According to this structure, the yearly payment slightly understates the value of carbon credits in the first few years and compensates later. This allows for slight leniency for companies in the early years. See Appendix A6 for an example of how this works.

IMPLEMENTATION PLAN

Primary Market

In order to allow businesses to participate actively in this program, the government must establish an online marketplace where companies can register to establish a portfolio of carbon credits. The marketplace will allow companies to buy and sell credits at appropriate times, as well as check on the number of outstanding credits available to purchase through bonds or secondary emission supplements. The online marketplace will also store each company's portfolio data, allowing government regulators to check if companies are meeting all regulations regarding carbon emissions.

Secondary Market

Under the carbon credit program, companies will not be allowed to trade credits directly to other companies. If a company wishes to relinquish some of the credits in their portfolio, the government market, which sells the bonds, will offer a guaranteed buyback of all credits at 80% of the base price. These credits will be made available to other companies exclusively through the secondary emission supplement.

The purpose of this design is to remove companies' incentives to buy and hoard more credits than they need, as unused credits will now enforce a minor loss for companies. However, credits will still maintain a known value due to the guaranteed buyback from the government, allowing companies to more accurately predict their expenses per credit.

Regulations

In case companies' emissions exceed purchased credits, and no secondary emission supplements are available, a penalty would be in place. The European Union's Emissions Trading System uses an excess emissions penalty of €100 per metric ton beyond the allowed limit. Our program will impose the equivalent penalty of ₱181.81 per ton, 8.61 times greater than the social cost of carbon; thus, it will serve as an effective deterrent to exceeding limits.

Additionally, companies must be required to submit their carbon emissions quarterly to ensure completeness of data and must be monitored to ensure that their numbers are accurate.

Effectiveness of Program

This program's effectiveness will be evaluated by:

1. Successful reduction of overall emissions to 75% of the 2018 level by 2030.
2. Ability to keep resulting carbon emissions within 90% of the ultimate goal with 90% certainty.
3. Generate revenue for the government to fund green programs.

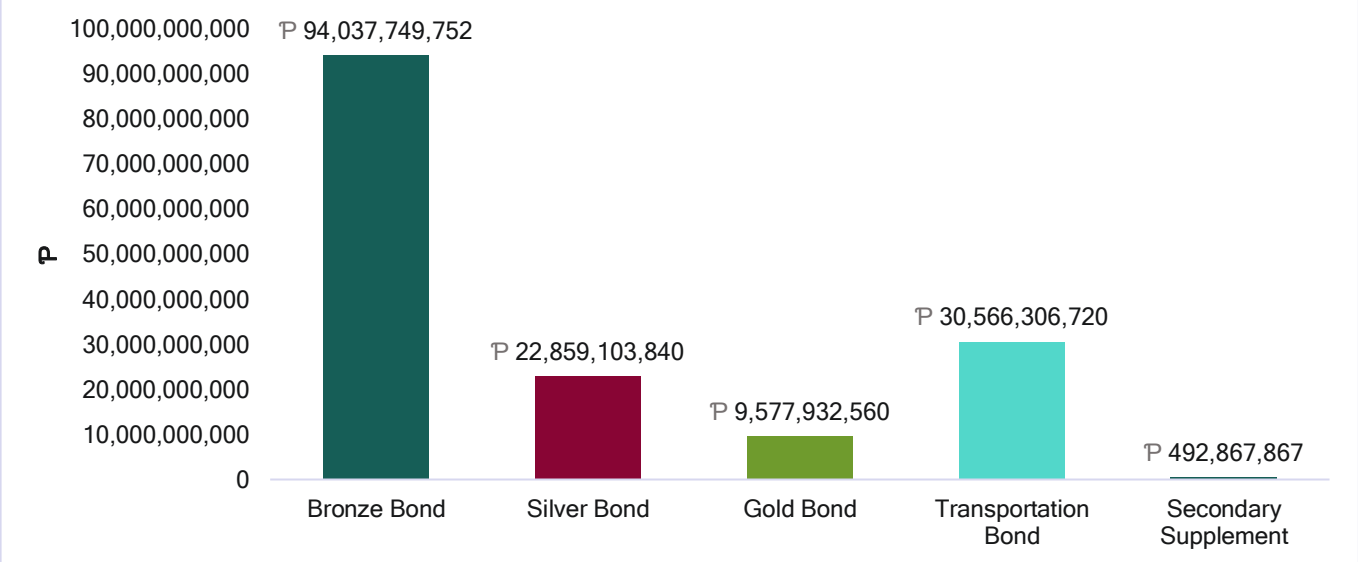
In the next section, we will evaluate our program based on these criteria.

REVENUE ANALYSIS

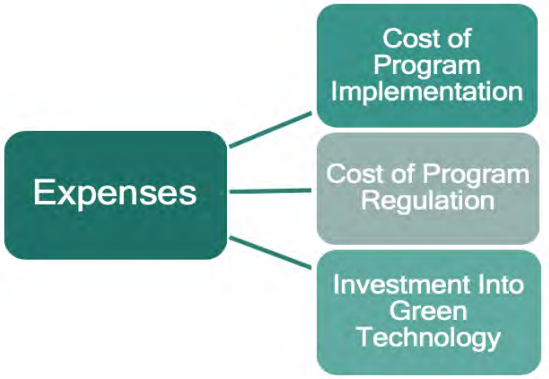
Revenue Projection

Our program, under the assumptions made (found on pages 16-17), generates a total revenue of approximately ₱157.3 billion over the next decade.

Figure 4: Revenues Generated by Financial Instruments: 59.7% of total revenue is generated from the Bronze emissions bond. The Silver and Gold emissions bond account for 14.51% and 6.08% respectively. The Transportation emissions bond accounts19.4% while the secondary emission supplement accounts for the last .31%.



Usage of Revenue



Appropriate use of revenue can benefit the society and reduce companies' costs and risks.

- Pay for the government costs associated with the implementation and management of the program. Revenue must be used to pay for the marketplace and server costs first.
- To ensure the success of the program, Pullanta can use revenue to fund high technology programs to monitor companies' carbon levels. This would decrease the operational risk of companies misreporting their emissions to avoid the purchasing of the secondary emission supplement or paying the penalty tax.
- Fund social programs to engage citizens in the carbon reduction effort. We can adopt the practice of Quebec, using carbon revenue to decrease taxes, indirectly funneling the costs of carbon back to the citizens, and decrease public debt, allowing cities more freedom to address the wants of their citizens.
- The revenue can be used for implementing environmentally friendly technology, like sustainable transportation and buildings, as well as renewable energy sources.

For detailed investment estimates see Appendix B1

DATA LIMITATIONS, ASSUMPTIONS & SENSITIVTY ANALYSIS

Data Limitations

Limited data required more assumptions to be made, which have an impact on projections and analysis.

- When calculating the social cost of carbon, an important consideration is the country's geography – such as amount of coastline. Without knowing specific geographical features, we were somewhat limited in estimating its social cost of carbon.
- Company data is limited – the only data provided are yearly reported emissions, which prevents us from taking a company's individual practices into account, such as whether a large amount of emissions are due to wastefulness or simply the company's size. Roughly 27% of the yearly emission data for businesses are zeroes. Without context for these zeroes, it requires more uncertainty such as the amount of carbon to allow companies to emit before requiring credits. (See Appendix C1)
- Little data for estimating the expenses of the program in Pullanta. With knowledge about what resources Pullanta already has to implement this program, more precise estimates of expenses could be given.

Assumptions

- Interest rate and inflation rates of 4.5% and 2% respectively were chosen for pricing based on historical inflation and 10-year Treasury Bond data in the United States.
- In order to approximate revenue and emission totals, we chose 0.5% of purchased credits are sold back to the government per year, and 50% of those credits are resold

through secondary emission supplements. These numbers were conservative and unlikely to drastically understate the true values.

- The proportion of metal emission bonds sold were set as 70% Bronze, 20% Silver, and 10% Gold, predicting that most companies will choose to finance primarily with Bronze emission bonds.
- The Transportation emission bond awards floating amounts of carbon credits to companies depending on the previous year's emissions. To estimate the number of credits the bond will award per year, we assume that companies would be slower to reduce in the first few years and have greater reductions as the program continues. This would correspond to lower numbers of credits in early years when compared to the Bronze bond and have better returns in later years. The assumption for the number of credits per year are shown in Table 3.
- The currency exchange rate: one Pula = $.60. It impacts the social cost of carbon calculation.

Table 3: Transportation Credit Assumption Chart

Year	Carbon Credits Granted
2020	100
2021	65
2022	63
2023	71
2024	72
2025	69
2026	67
2027	75
2028	72
2029	78
2030	83

Sensitivity Analysis

We selected our assumptions described above through careful research and the use of our actuarial judgement. Despite this, these values may vary from our expectations. To account for these potential fluctuations, we performed a sensitivity analysis to see how it will affect aggregate revenue and emissions.

Revenue Sensitivity

- The assumption regarding the percentage of unused credits sold back to the marketplace, increasing from .5% to 1.5%, resulted in minor changes to yearly revenue. (Table 4)
- The assumption regarding the percentage credits resold through the secondary market changing from 50% to 60%, resulted in a minor change in yearly revenue. (Table 4)

Table 4: Impact of proportion of credit sold back (increase) and proportion of credits resold (increase) on revenue

Year	Percent Change in Revenue (due to proportion of credits sold back)	Percent Change in Revenue (due to proportion of credits resold)
2020	-0.254%	0.065%
2021	-0.240%	0.069%
2022	-0.234%	0.070%
2023	-0.238%	0.069%
2024	-0.245%	0.072%
2025	-0.238%	0.073%
2026	-0.232%	0.074%
2027	-0.238%	0.076%
2028	-0.236%	0.076%
2029	-0.231%	0.080%
2030	-0.227%	0.083%

- Interest rate and inflation rate are the most likely to vary due to their volatile nature. A 1% increase in the interest rate and the inflation rate result in about a 4% decrease and 4.5% increase in 2030 revenue respectively, while a 1% decrease in each led to a 4.4% increase and 4.2% decrease in 2030 revenue. (Figure 5 and Figure 6)

Figure 5: Impact of Interest Rate Change

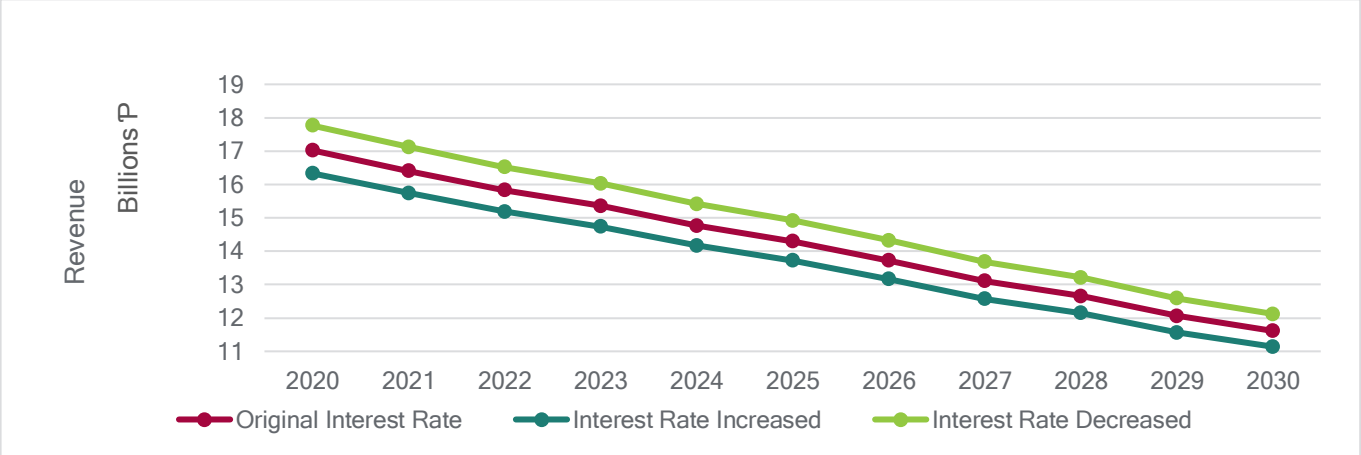
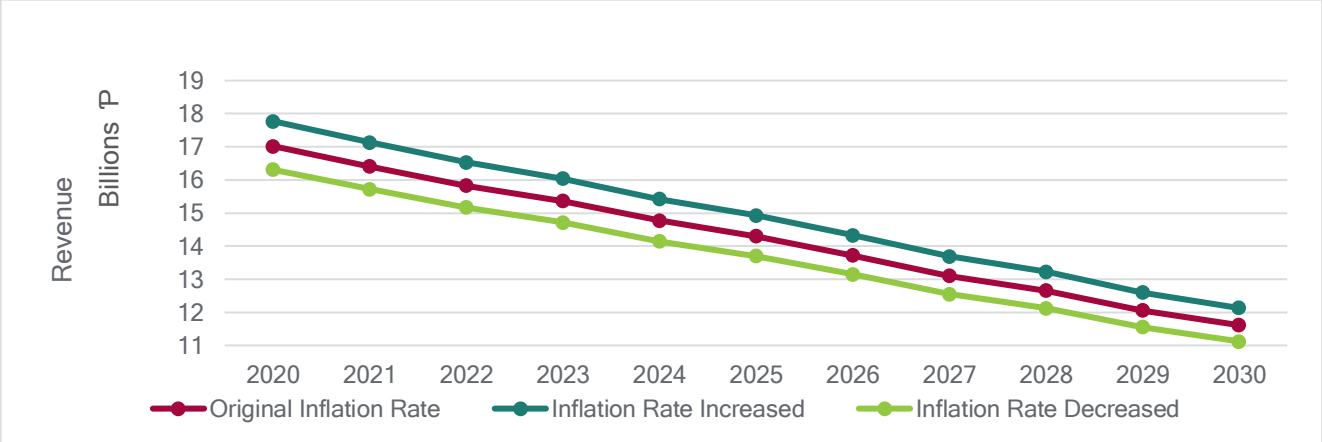


Figure 6: Impact of Inflation Rate Change



- The proportions of the metal bonds have a noticeable effect on total revenue. The worst impact would be 2.4% decrease in 2030 revenue. (Figure 7, Figure 8, and Figure 9)
- Appendix C2 summarizes the impact of these changes on 2030 revenue.

Figure 7: Impact of Increase in Sales of Bronze Bond. Our initial assumptions were 70% Bronze bonds 20% Silver bonds, and 10% Gold Bonds. 80% Bronze was tested against our assumptions.

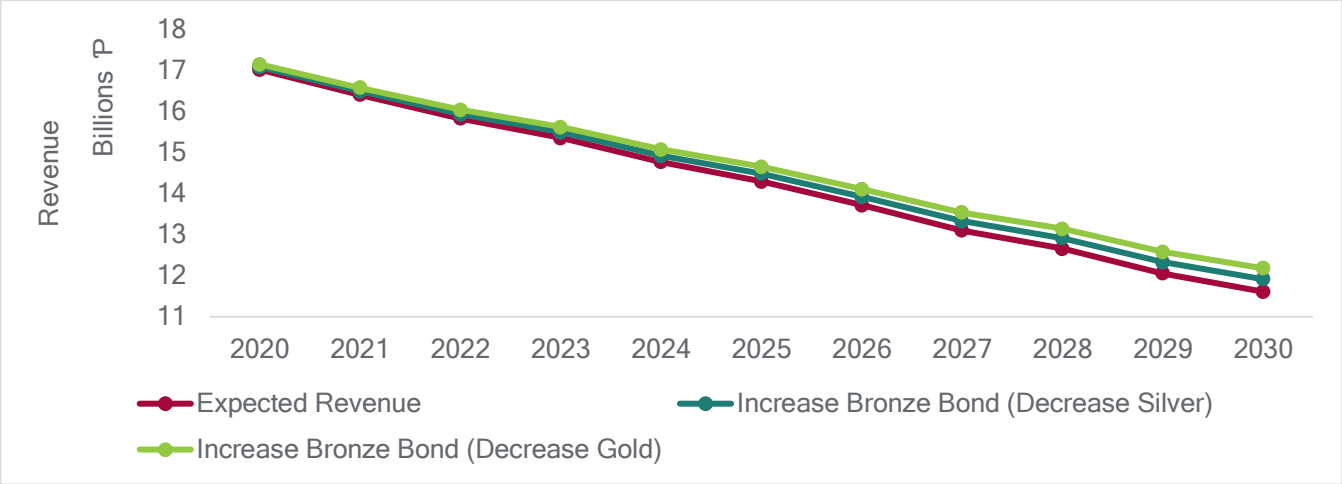


Figure 8: Impact of Increase in Sales of Silver Bond. Our initial assumptions were 70% Bronze bonds 20% Silver bonds, and 10% Gold Bonds. 25% Silver was tested against our assumptions.

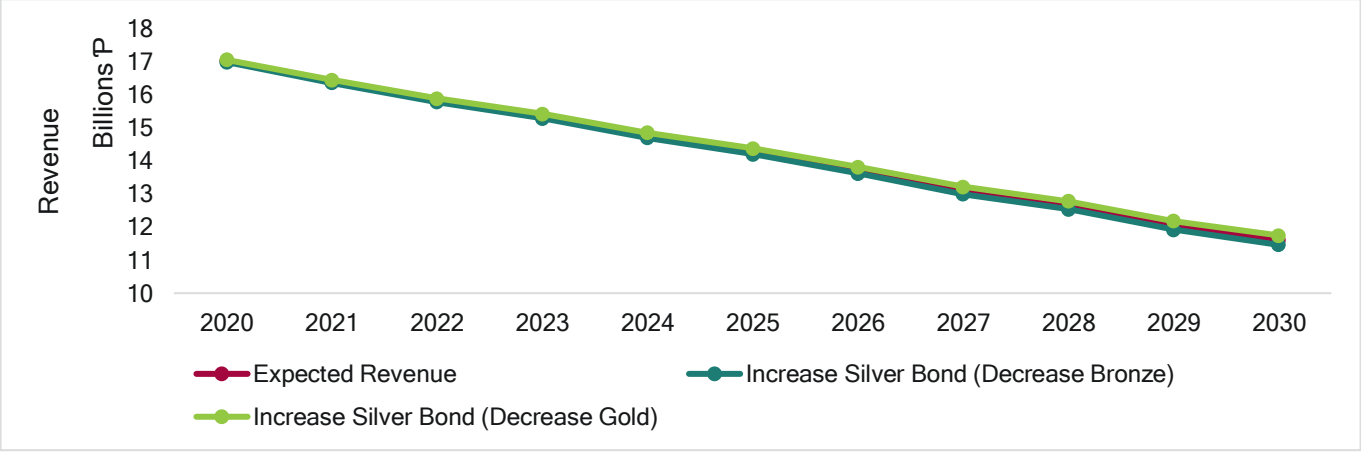
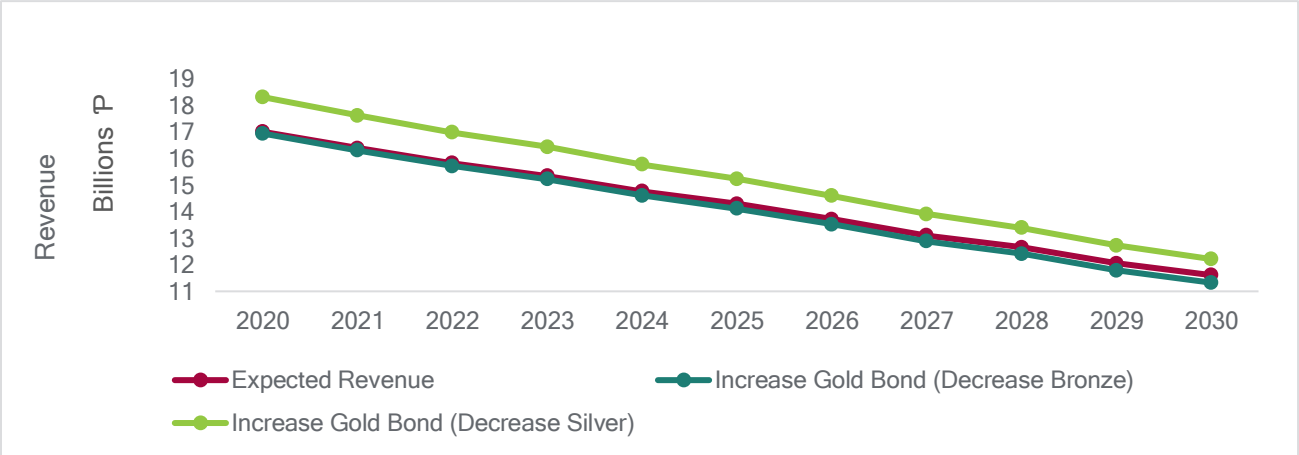


Figure 9: Impact of Increase in Sales of Gold Bond. Our initial assumptions were 70% Bronze bonds 20% Silver bonds, and 10% Gold Bonds. 15% Gold was tested against our assumptions.



Emissions Sensitivity

Changes in the number of credits awarded by the Transportation emission bond will impact the total emissions in Pullanta, and ultimately determine the success of the program. A 15% increase in the number of total credits awarded was distributed throughout the years and applied to test sensitivity. This results in about a 4% increase in projected 2030 total emissions. (Figure 10 and Table 5)

Figure 10: Increase in Transportation Bond Credits vs. Bronze Bond Credits by Year

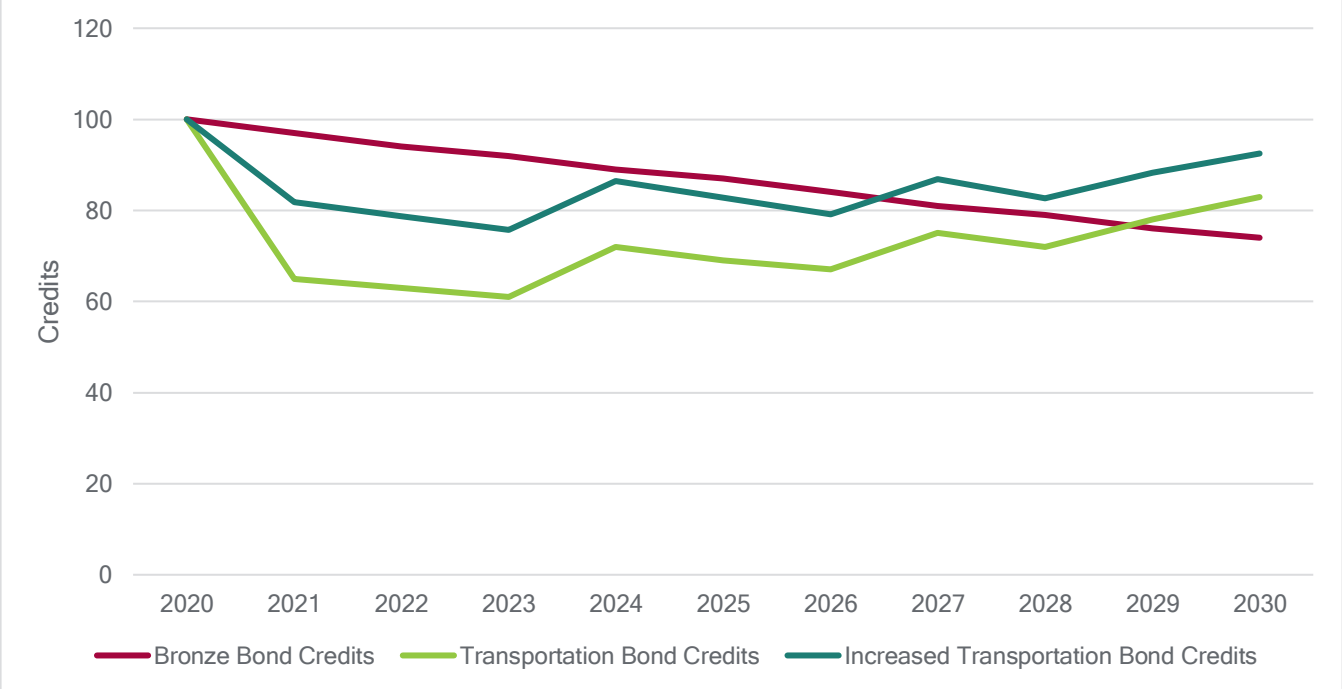


Table 5: Original Emissions vs Emissions with Increased Transportation Bond Credits

	Original Emissions	Emissions with Increase in Transportation Credits	% Change in Emissions	Emissions with Extreme Increase in Transportation Credits	% Change in Emissions
2020	908,835,705	908,835,705	0	908,835,705	0
2021	822,480,921	850,074,751	0.0325	889,721,012	0.0756
2022	793,012,370	819,112,074	0.0319	860,252,460	0.0782
2023	767,279,656	791,926,634	0.0311	834,519,747	0.0806
2024	760,391,583	783,396,036	0.0294	827,631,673	0.0812
2025	733,372,574	755,020,730	0.0287	800,612,664	0.0840
2026	702,742,757	723,075,605	0.0281	769,982,848	0.0873
2027	689,038,270	707,907,162	0.0267	756,278,361	0.0889
2028	662,513,182	680,161,013	0.0259	729,753,273	0.0921
2029	645,930,406	662,233,903	0.0246	713,170,497	0.0943
2030	633,688,759	648,712,703	0.0232	700,928,850	0.0959

Our program is designed to reduce carbon emissions within 90% of the ultimate goal with 90% certainty. It is possible that companies emit more carbon than allowed. To investigate this, we looked at companies who emitted more than 1.5 million tonnes. From 2017 to 2018 we found that 14.3% of these large companies had an increase in emissions, for a total increase of 23,610,568 tonnes. We consider the extreme case that these large companies emit more than allowed even when there is a penalty. It turns out the aggregate emission still stays within our desired range in Table 6.

Table 6: Yearly Emission Goals vs 90% Confidence Interval of Yearly Emissions

Year	Expected Emissions	Expected Emissions with Lower Limit	Expected Emissions with Upper Limit
2020	908,835,705	911,196,762	953,695,784
2021	822,480,921	824,841,978	867,341,000
2022	793,012,370	795,373,427	837,872,449
2023	767,279,656	769,640,713	812,139,735
2024	760,391,583	762,752,640	805,251,662
2025	733,372,574	735,733,631	778,232,653
2026	702,742,757	705,103,814	747,602,836
2027	689,038,270	691,399,327	733,898,349
2028	662,513,182	664,874,239	707,373,261
2029	645,930,406	648,291,463	690,790,485
2030	633,688,759	636,049,816	678,548,838

Extreme Deviations

- An increase in interest rate from 4.5% to 10% results in a 2030 revenue change of -23.87%. If we see extreme changes in our assumed inflation rate, an increase from 2% to 8%, 2030 revenue will increase by 23.56%. (Figure 11 and Figure 12)

Figure 11: Revenue with Extreme Interest Deviation

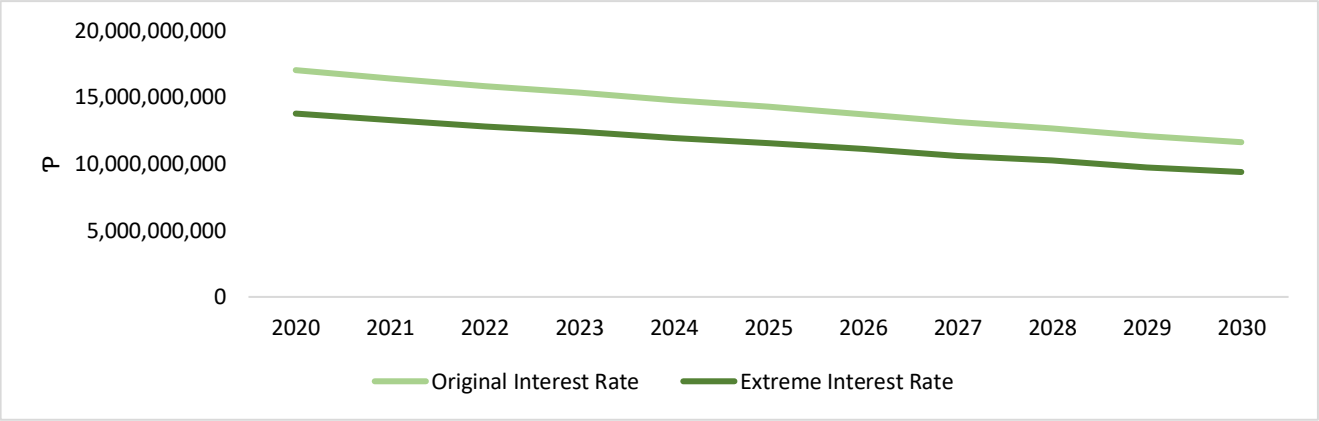
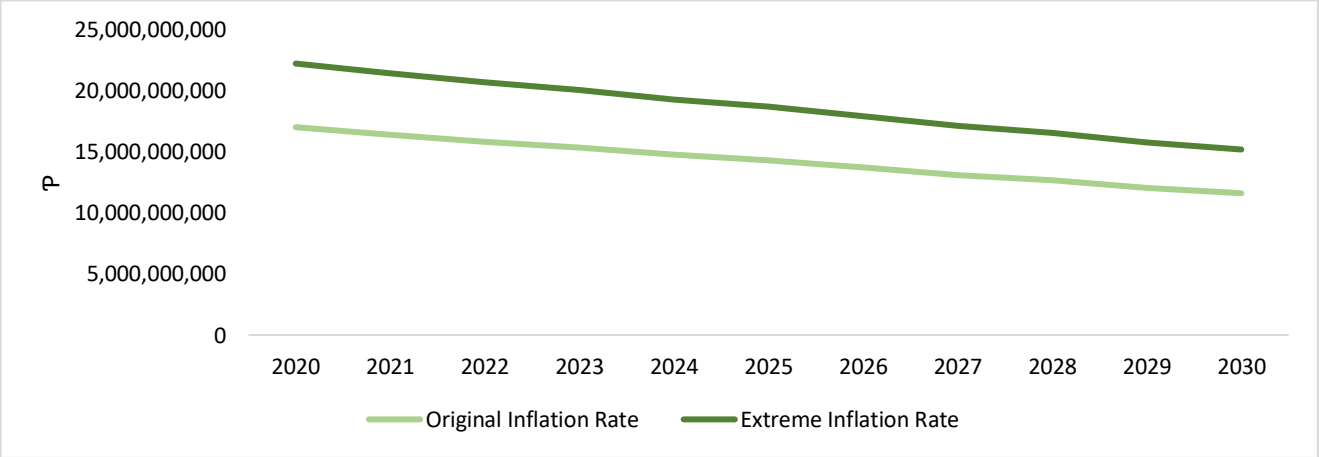


Figure 12: Revenue with Extreme Inflation Deviation



- A decrease in our assumed Bronze bond purchases of 40% in favor of the Silver bond will result in a change of 2030 revenue of -11.66%. If the Bronze bond purchases decreased by 40% in favor of the Gold bond, we will see a change in 2030 revenue of -24.39% (Figure 13). These changes will also decrease total emissions per year (Figure 14).

Figure 13: Revenue with Extreme Bond Distribution Deviation

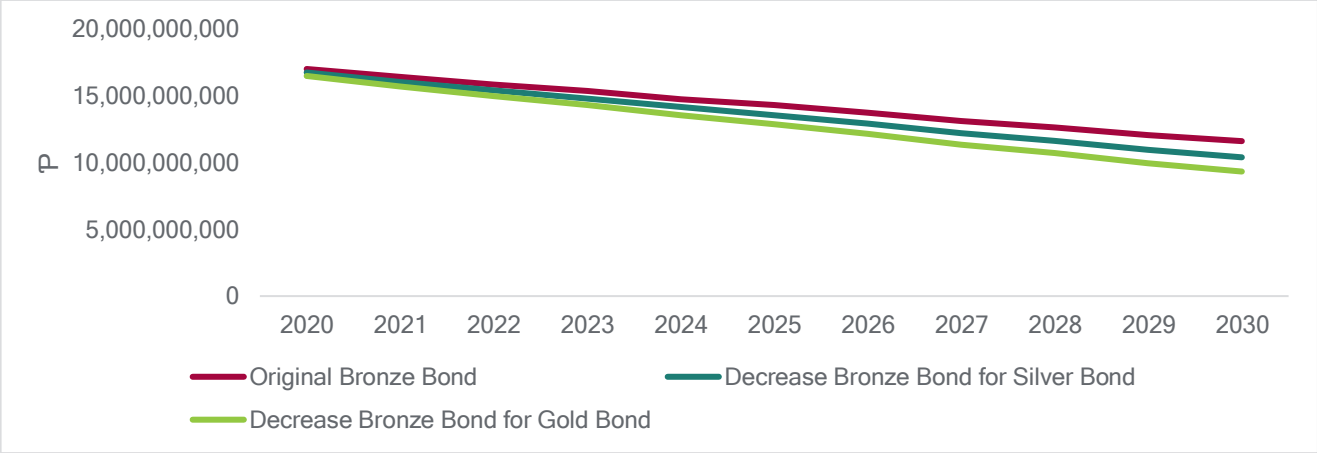
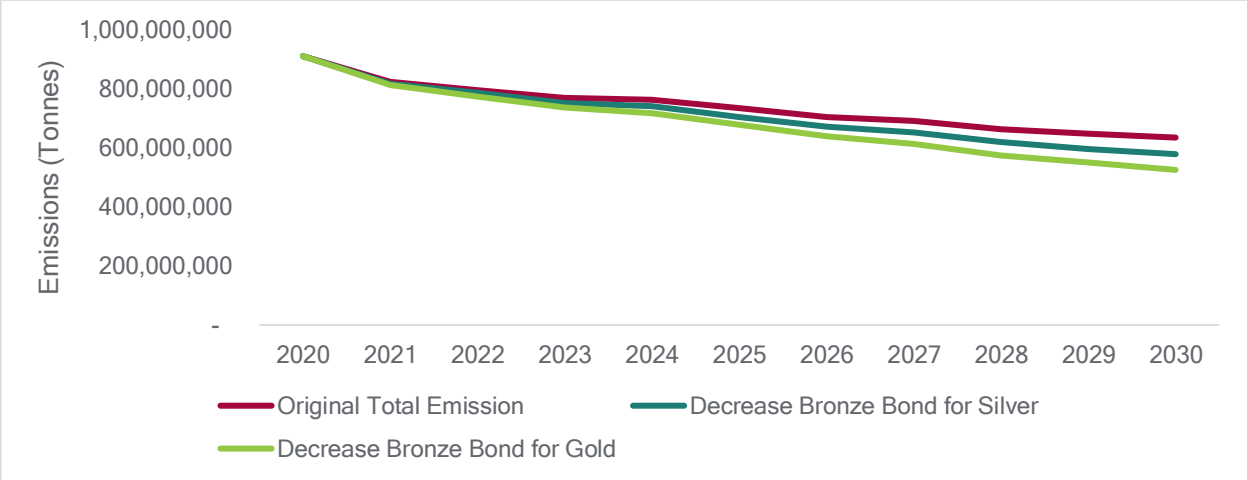
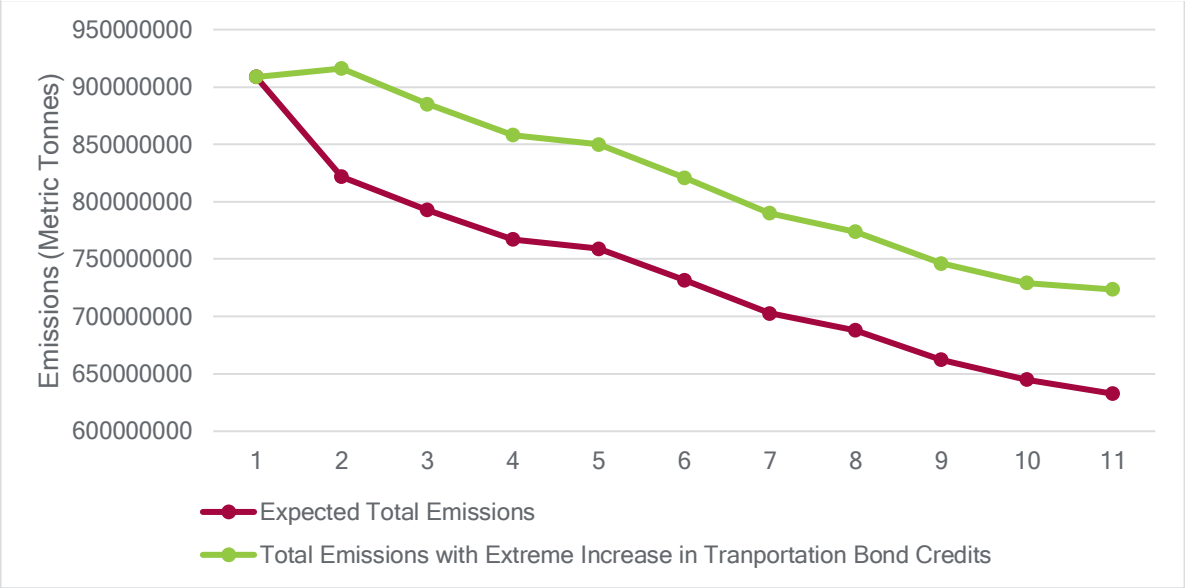


Figure 14: Emissions with Extreme Bond Distribution Deviation



- An increase of 40 credits per year in the transportation emission bond would result in an increase in projected 2030 total emission of 9.6% (Figure 15).

Figure 15: Increase in Yearly Total Emissions with Extreme Increase in Transportation Bond Credits



CONCLUSION

- Under the program outlined above, we expect emissions to gradually decrease from 2020 to a 2030 emission total equal to 633,688,759 metric tonnes. Pullanta's goal for 2030 emissions is below 691,830,798 metric tonnes. The sensitivity analysis and extreme deviation test show we are 90% confident that 2030 emissions will be within 90% of the target totals.
- This program is predicted to generate over ₱17 billion in 2020, with that number steadily decreasing to ₱11.6 billion by 2030 as emission totals reduce. This is expected to be enough to cover the costs of implementing, maintaining, and regulating this program, as well as providing enough revenue to fund additional climate change mitigation efforts.

APPENDIX

APPENDIX A: PROGRAM DESIGN

Section A1: 2020 ARIMA Model R Code

```
#Loading Packages and Emissions Data
EmissionsData <- read_excel("EmissionsData.xlsx")
View(EmissionsData)
library(readxl)
library(forecast)
library(ggplot2)
library(tseries)
library(lmtest)

#Testing stationary aspects and creating arima model for the Building sector
Building.Data <- ts(Buildings, start = 1, end = 25, frequency = 1)
Building.DataClean <- tsclean(Building.Data)
kpss.test(Building.DataClean)  #Data appears to be stationary
plot(Building.DataClean)
acf(Building.DataClean, lag.max = 20)
pacf(Building.DataClean, lag.max = 20)
BuildingARIMA1 <- auto.arima(Building.DataClean, trace = TRUE)
predict(BuildingARIMA1, n.ahead = 1)  #137,283,942

#Testing stationary aspects and creating arima model for the Industry sector
Industry.Data <- ts(Industry, start = 1, end = 25, frequency = 1)
Industry.DataClean <- tsclean(Industry.Data)
kpss.test(Industry.DataClean)
Industry.Data.Stationary <- diff(Industry.DataClean, differences = 1)
kpss.test(Industry.Data.Stationary)   #Stationary
Industry.ARIMA <- auto.arima(Industry.Data.Stationary, trace = TRUE)
predict(Industry.ARIMA, n.ahead = 1)   # difference of -2,975,764

#Testing stationary aspects and creating arima model for the Energy sector
Energy.Data <- ts(Energy, start = 1, end = 25, frequency = 1)
Energy.Data.Clean <- tsclean(Energy.Data)
kpss.test(Energy.Data.Clean)     #Stationary
Energy.ARIMA <- auto.arima(Energy.Data.Clean, trace = TRUE)
predict(Energy.ARIMA, n.ahead = 1)      #478,690,473

#Testing stationary aspects and creating arima model for the Other sector
Other.Data <- ts(Other, start = 1, end = 25, frequency = 1)
Other.Data.Clean <- tsclean(Other.Data)
kpss.test(Other.Data.Clean)     #Stationary
Other.ARIMA <- auto.arima(Other.Data.Clean, trace = TRUE)
predict(Other.ARIMA, n.ahead = 1)      #3,000,644

#Testing stationary aspects and creating arima model for the Transportation
sector
```

```
Transportation.Data <- ts(Transportation, start = 1, end = 25, frequency = 1)
Transportation.Data.Clean <- tsclean(Transportation.Data)
kpss.test(Transportation.Data.Clean)
Transportation.Data.Difference <- diff(Transportation.Data.Clean, differences
= 1)
kpss.test(Transportation.Data.Difference)
Transportation.secondDiff <- diff(Transportation.Data.Difference, differences =
1)
kpss.test(Transportation.secondDiff)
Transportation.ARIMA <- auto.arima(Transportation.secondDiff, trace = TRUE)
predict(Transportation.ARIMA, n.ahead = 1)     #2nd difference of -150,018

#Testing stationary aspects and creating arima model for the Waste sector
Waste.Data <- ts(Waste, start = 1, end = 25, frequency = 1)
Waste.Data.Clean <- tsclean(Waste.Data)
kpss.test(Waste.Data.Clean)
Waste.ARIMA <- auto.arima(Waste.Data.Clean, trace = TRUE)
predict(Waste.ARIMA, n.ahead = 1)     #38,014,318
```

Section A2: Aggregate Emission Yearly Goal Table

Year	B	E	I	O	T	W	Total
2020*	137,283,942	478,690,473	85,519,741	3,000,644	168,599,530	38,014,318	911,108,648
2021	134,975,790	465,002,599	84,742,825	2,974,567	163,669,226	37,774,876	889,139,882
2022	132,667,638	451,314,726	83,965,909	2,948,489	158,738,921	37,535,433	867,171,116
2023	130,359,485	437,626,852	83,188,992	2,922,412	153,808,617	37,295,991	845,202,350
2024	128,051,333	423,938,978	82,412,076	2,896,334	148,878,313	37,056,549	823,233,584
2025	125,743,181	410,251,105	81,635,160	2,870,257	143,948,009	36,817,107	801,264,818
2026	123,435,029	396,563,231	80,858,244	2,844,179	139,017,704	36,577,664	779,296,051
2027	121,126,876	382,875,357	80,081,327	2,818,102	134,087,400	36,338,222	757,327,285
2028	118,818,724	369,187,484	79,304,411	2,792,025	129,157,096	36,098,780	735,358,519
2029	116,510,572	355,499,610	78,527,495	2,765,947	124,226,791	35,859,338	713,389,753
2030	114,202,420	341,811,736	77,750,579	2,739,870	119,296,487	35,619,895	691,420,987

*2020 emissions based on ARIMA model predictions

Section A3: Nearest Neighbor for Social Cost of Carbon Development

Country	Share of Global Emissions	Population	GDP	Social Cost
India	6.82%	1.358 B	3.16 T	$86
USA	14.58%	329 M	21.41 T	$48
Saudi Arabia	**1.76%**	34.2 M	790 B	$47
China	27.21%	1.4 B	15.47 T	$24
UAE	0.64%	9.7 M	**449.13 B**	$24
Italy	0.98%	60.3 M	2.09 T	$1.60
Australia	1.14%	**25.6 M**	1.48 T	$5
Turkey	1.24%	82 M	809.55 B	$0.89
Pullanta	2.39%	20M	435 B	$12.67

*Nearest Neighbor in each category is bolded

Section A4: Entering Mid-Program

If a company is entering late in the program, the bond awards credits on-level with other bonds of its kind.

For example: if a new company enters the program in mid-2025, and they want to purchase a Bronze emission bond, they would receive 87 credits for 2025, the same number of credits that an old company holding a Bronze bond since 2020 would receive in 2025. This new company would also pay the same amount in 2025 that the old company would pay in 2025. Payments and credit disbursements in subsequent years would also match exactly. This is analogous for all other bonds.

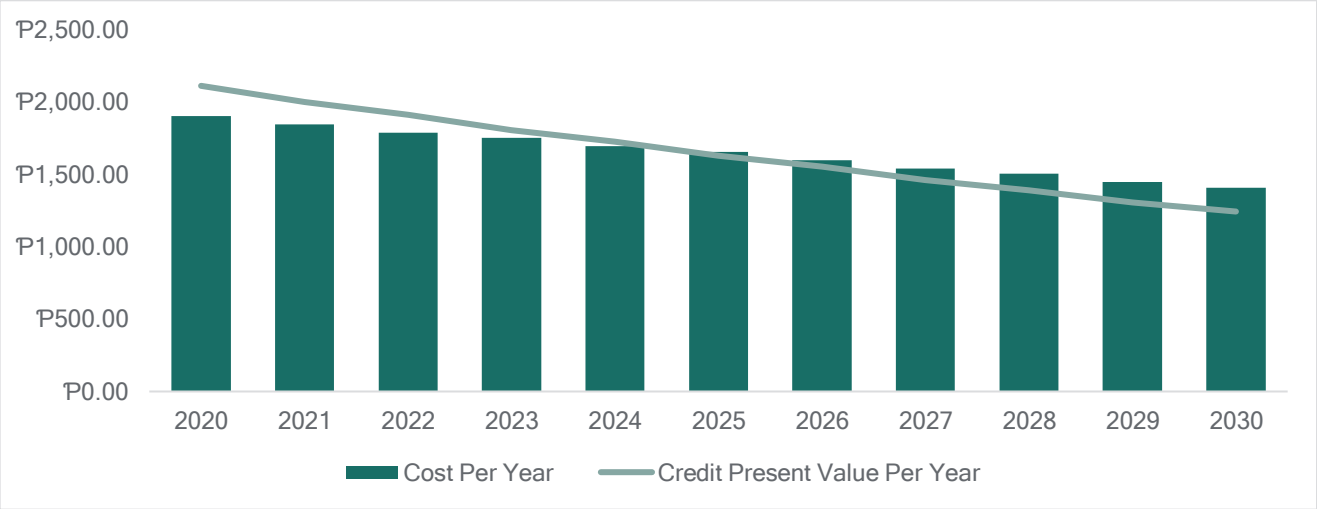
Section A5: Bond Pricing Equations

$$Bronze\ Price = \sum_{t=0}^{10} \frac{(100 - 2.5 \times t) \times 21.12 \times (1 + .02)^t}{(1 + .045)^t} = 18{,}137.92$$

$$Silver\ Price = .95 * \sum_{t=0}^{10} \frac{(100 - 4.4 \times t) \times 21.12 \times (1 + .02)^t}{(1 + .045)^t} = 15{,}431.66$$

$$Gold\ Price = .9 * \sum_{t=0}^{10} \frac{(100 - 6.3 \times t) \times 21.12 \times (1 + .02)^t}{(1 + .045)^t} = 12{,}931.69$$

Section A6: Payment Structure Example with Bronze Emission Bond



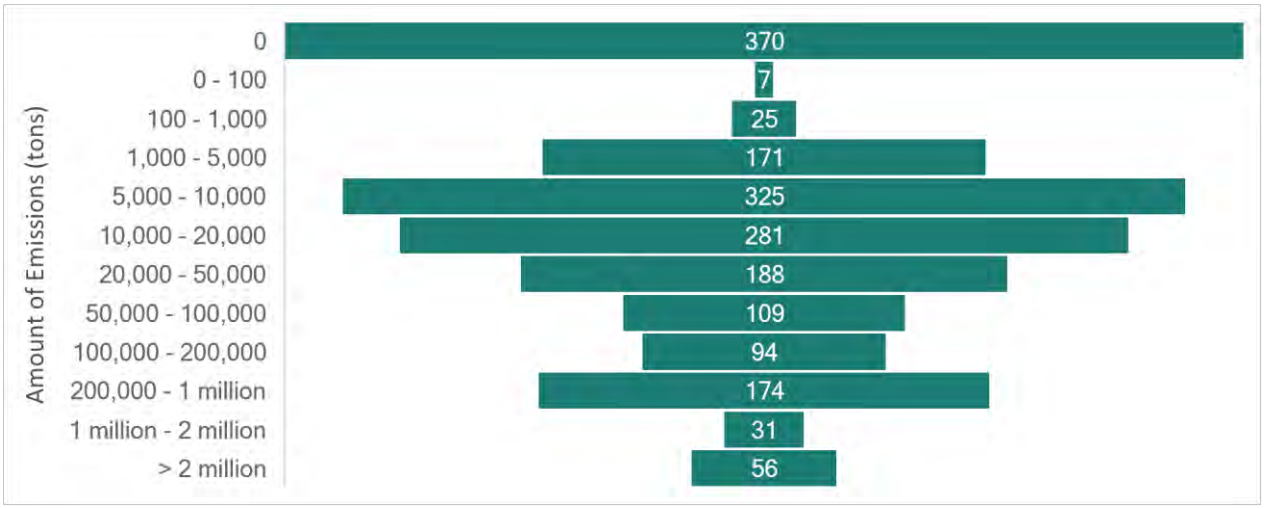
APPENDIX B: RECOMMENDATIONS

Section B1: Revenue Usage/Forecasting Expenses

Quebec has a program which is revenue neutral. They invest all revenue earned from carbon pricing back into the economy. Taking the ratio of monitoring costs to the total of all others, we conclude that 1.69% of reinvested revenue goes towards monitoring costs. We also find that 10.48% of revenue could go towards investing into social programs. The final 87.83% of revenue will go to funding further climate change efforts.

APPENDIX C: DATA LIMITATIONS, ASSUMPTIONS & SENSITIVTY ANALYSIS

Section C1: Distribution of Companies by Emission Level (2019)



Section C2: Sensitivity Analysis by Revenue Table

Sensitivity Analysis by Revenue					
Variable	**Original Value**	**New Value**	**New 2030 Total Revenue**		**% Change in 2030 Total Revenue**
Interest Rate	0.045	0.055	$	11,139,570,777	-4.07392%
Inflation Rate	0.02	0.03	$	12,130,771,200	4.46160%
Proportion of Credits Sold Back	0.005	0.015	$	11,584,748,713	-0.24036%
Proportion Repurchased	0.5	0.6	$	11,620,706,246	0.06928%
Bond Proportion	**Original Value**	**New Value**	**New 2030 Total Revenue**		**% Change in 2030 Total Revenue**
Increase Bond 1 (Decrease 2)	0.7	0.8	$	11,916,634,874	2.61761%
Increase Bond 1 (Decrease 3)	0.7	0.8	$	12,182,735,206	4.90907%
Increase Bond 2 (Decrease 1)	0.2	0.25	$	11,461,763,740	-1.29942%
Increase Bond 2 (Decrease 3)	0.2	0.25	$	11,746,437,622	1.15199%
Increase Bond 3 (Decrease 1)	0.1	0.15	$	11,328,713,574	-2.44515%
Increase Bond 3 (Decrease 2)	0.1	0.15	$	11,480,337,290	-1.13948%
Extreme Deviations	**Original Value**	**New Value**	**New 2030 Total Revenue**		**% Change in 2030 Total Revenue**
Interest Rate	0.045	0.1	$	9,374,498,226	-23.8750%
Inflation Rate	0.02	0.08	$	15,192,833,573	23.5649%
Decrease Bronze bond (Increase Silver)	0.7	0.3	$	10,399,671,281	-11.6637%
Decrease Bronze bond (Increase Gold)	0.7	0.3	$	9,335,269,956	-24.3956%

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