SOCIETY OF ACTUARIES

# Pullanta's Carbon Emission Reduction Proposal


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# Contents

# 1 EXECUTIVE SUMMARY

This report analyzes historical carbon emission of Pullanta and collects related research to explores how Pullanta can achieve goals of reducing carbon emissions to 25% below the 2018 level by the end of 2030 and generate revenue to fund climate change mitigation. Towards these goals, this report offers a comprehensive proposal including the design of carbon credit and financial instruments. complete with impact analysis and enterprise risk management.

This report identifies three types of carbon credit issuance methods, with corresponding issuance quantity and validity period. Secondly, the environmental and social costs of carbon credit are determined using the biological rent and DICE models, respectively, as the basis for pricing. The pricing result is 892 Pulo in 2020, which is then decreasing annually to 712 Pulo in 2030. Finally, the secondary market trading system and punishment mechanism for carbon credit are also designed, and the economic, legal and environmental impact of these designs on government and enterprises are also analyzed.

Moreover, we identifies three quarterly interest-bearing carbon bonds with different-maturities and two European options with different maturities. Then, in accordance with the principles of liquidity and stability, the number of bonds issued at each maturity each year is determined, and the risks and costs of government and enterprise, as well as the advantages and disadvantages, are analyzed.

The report concludes with enterprise risk analysis of the entire design, including over-emission and economic risk. The results of the sensitivity and scenario analysis show that the amount of carbon over-emissions is more sensitive to the number of enterprises emitted illegally, and the probability of completing the 90% of annual goal under the base scenario is 90.88%; Government revenue is more sensitive to changes in GDP, and government revenue will increase and decrease by approximately 44 billion Pulo in the best and worst scenarios, respectively.

# 2 ANALYSIS METHODOLOGY

## 2.1 PURPOSE AND BACKGROUND

In recent years, with the development of industrial civilization and social economy, climate change and its countermeasures have gradually become a global hot spot. Greenhouse gas emissions are considered as a social and environmental cost, and avoiding or reducing emissions is an increase in social and economic benefits. IPCC (Intergovernmental Panel on Climate Change) paid special attention to issues such as ”global warming at 1.5 °C” and ”climate change and land” in the sixth assessment report[1]. Energy and industrial systems have also proven to be important causes of climate change.

Pullanta is a virtual developed country. Based on the data provided by Pullanta, we will develop a carbon emission reduction plan for Pullanta, and explore the relationship between the carbon credit trading market, the financial system and social costs. With the expectation of reducing carbon emissions for Pullanta by the end of 2030, the purpose of initially establishing a carbon credit market is set.

## 2.2 ENVIRONMENT ANALYSIS

The environmental problem is getting increasingly serious that the government has paid more attention to it, carrying out many instructions to control the carbon emission amount. Despite the tax measure, EU has set up the first carbon emission exchange proposal in January 2005 which has been a great success. Our report is conducted based on the past trading mechanism, adding some new schemes to better solve the environmental problem in Pullanta.

Alternative approaches or mechanisms to encourage reduction of carbon emissions is given in Table 1. Risk and cost of government, corporation and investor are given in Table 2.

**TABLE 1:** ALTERNATIVE APPROACHES OR MECHANISMS TO ENCOURAGE REDUCTION OF CARBON EMISSIONS

| | Domestic taxes on carbon emission | Tariffs on carbon emission | Raise the price of carbon emission right appropriately | Trading market on carbon emission right |
|---|---|---|---|---|
| Detailed on Measures | Carbon emissions tax is a pollution tax. The more carbon is emitted, the higher the cost. Government departments will first set a price for each ton of carbon emissions, and then use this price to convert taxes on electricity, natural gas or oil. | It is generally referred to the imposition of carbon dioxide emission tariffs on high energy-consuming imported products. This is actually a means by which developed countries rely on advanced environmental protection technology to set special standards to prevent other countries' products from entering their own markets, thereby protecting their trade, which is essentially protecting trade in the name of environmental protection. That is, trade tariffs are levied on imports from countries that have not implemented carbon emission reduction limits. | In order to reduce carbon emissions and control excessive carbon dioxide emissions, the government appropriately raises the price of carbon emission rights based on the current price of carbon emission rights in the carbon trading market. | Carbon emissions trading is a market mechanism adopted to promote global greenhouse gas emission reductions and reduce global carbon dioxide emissions. The two parties to the carbon transaction signed a contract, and the buyer obtained the greenhouse gas emission reduction amount by paying the seller, and used the purchased emission reduction amount to mitigate the greenhouse effect, thereby achieving its emission reduction target. At present, the carbon dioxide trading market is mainly divided into a project-based trading market and a quota-based trading market. |
| Advantages | 1. Increase government revenue;<br>2. Taxation makes the cost of using polluting fuels higher, which will prompt public utilities, commercial organizations and individuals to reduce fuel consumption and improve energy efficiency;<br>3. Help developed countries achieve their greenhouse gas reduction goals, but also the income can be used to help developing countries cope with climate change, as an important source of funding for developed countries. | 1. For developed countries, the implementation of carbon tariffs is conducive to enhancing global competitiveness and international influence, consolidating their leading position in the future green economy with low carbon as the core, and balancing developing countries;<br>2. For developing countries, the opportunity to develop a green economy can be actively used to change the economic structure. | 1. The International Energy Agency believes that the rise in carbon prices is a high-tech solution to climate change and is economically attractive;<br>2. Incentivize carbon emitters to adopt new technologies, which will help reduce carbon emissions;<br>3. Rising consumer costs will stimulate consumers to increase energy use or purchase relatively inexpensive low-carbon energy resources, which indirectly promotes carbon emission reduction and energy structure optimization. | 1. Carbon trading is an important institutional innovation that uses market mechanisms to control and reduce greenhouse gas emissions and promote green and low-carbon transitions in economic development methods. It is an important policy tool to strengthen the construction of ecological civilization and fulfill international commitments to reduce emissions;<br>2. Increasing the asset boundary of an enterprise, and at the same time setting a clear standard for such assets, so that the enterprise can directly or indirectly benefit from it. Therefore, the carbon trading mechanism is an incentive and constraint mechanism to increase enthusiasm;<br>3. The carbon trading system can effectively broaden the scope of financial services and improve the financial service system. With the gradual maturity of the carbon trading market, a series of carbon financial products such as carbon financing projects, carbon wealth management products, carbon option futures trading have emerged at the historic moment, which has greatly promoted financial product innovation and diversified development of the financial market. |

| | | | | |
|---|---|---|---|---|
| Disadvantages | 1. Levying a carbon emission tax can reduce oil consumption and reduce carbon dioxide emissions in the non-transport and petroleum sectors, but it is difficult for the transportation and petroleum sectors to replace oil with other factors of production. Levying a carbon emission tax may even increase its emissions Increased. The rise in oil prices is much higher than the changes in the consumer price index, showing that the imposition of carbon tax on the reduction of the transport sector and carbon dioxide emissions is not significant;<br>2. Carbon emissions tax has increased the cost of fossil fuels, but it will not necessarily promote the process of reducing the use of fossil fuels through technological progress. | The imposition of high penalties on foreign products that do not meet the carbon emission standards of developed countries will have a great impact on the trade exports of developing countries, because the export products of developing countries are mostly low-end products. The carbon content is relatively high. If developed countries adopt a non-discriminatory carbon tax policy on developing countries, it will definitely affect the trade of developing countries. Developing countries also need financial and technical support. | Faced with the increase in the price of carbon emission rights, carbon emitters may raise prices and pass on the increased costs to consumers. This will not reduce carbon emissions, but will increase the burden on consumers and lower the happiness index. | Developing countries are in the position of price receivers in terms of carbon pricing in the international market. Due to the asymmetry of information, developed countries are allowed to buy reduced emissions at low prices and then package and sell to earn rich profits. Most of this is due to the imperfect carbon trading market in developing countries, and the government has not provided an effective platform for participating companies to obtain sufficient transaction information to understand the transaction market to set a reasonable sale price. So this will have a negative economic impact on developing countries. |

**TABLE 2:** RISK AND COST OF GOVERNMENT, ENTERPRISE AND CONSUMER

| | Government | Enterprise | Consumer |
|---|---|---|---|
| Risks in carbon reduction plans | The government plays a leading role in macro-control in the carbon emission reduction plan, but it also faces the risk that the carbon reduction plan will not be successfully implemented due to force majeure and other factors, and the national macro-control carbon emission reduction requirements cannot be achieved. Government officials at all levels are under pressure to complete carbon emission reduction assessment tasks. | Enterprises are the backbone of energy-saving and emission-reduction participants. As a rational individual seeking to maximize economic benefits, the amount of results brought by investing in energy-saving and emission-reduction work directly determines the effectiveness of the enterprise's emission-reduction work. However, the government usually devotes most of its energy to large state-owned enterprises with high pollution and high energy consumption, and small and medium-sized enterprises need to invest a lot of funds if they want to update equipment for energy conservation and emission reduction. This is a huge risk for them. | Companies may transfer part of the cost of purchasing carbon credits to commodity prices, so consumers will face the risk of rising prices, such as coal and gasoline. At the same time, under a wide range of emission reduction plans, some consumers, such as freight drivers, may also face certain use and travel restrictions. |

| | | | |
|---|---|---|---|
| Probable cost | 1. In the preparation of carbon emission reduction reports, if local governments require the reporting of local carbon emission reduction data within their jurisdictions, it will involve the preparation of carbon emission reduction reports, training of report writing staff, and large carbon emission users. Being audited by an independent third party, etc., these will increase the cost of the government;<br>2. During the whole process of carbon emission reduction, the government also took time and effort to manage the personnel involved in the plan. | 1. Purchasing carbon emission reduction equipment or eliminating backward production capacity equipment, purchasing or self-developing carbon emission reduction technology all require huge expenditures;<br>2. In terms of carbon emission trading, activities such as training of carbon emission trading personnel, finding counterparties, negotiating carbon emission quotas with the Government Development and Reform Commission, and determining transaction prices will increase costs. | 1. Additional daily costs, while some travel conveniences will also disappear;<br>2. Some industrial and construction consumers may increase their purchase and negotiation costs, etc. |
| The advantages that these risks and costs brought about | 1. Taxes and fines during carbon trading have increased government revenue;<br>2. The effective implementation of a national emission reduction plan can increase the country's international influence and consolidate its leading position in the future green economy with low carbon as its core. | It can promote enterprises to transform to a low-carbon and green development path while gaining economic benefits and develop a green economy. | 1. With development of carbon emission technology, the unit energy production capacity will increase, the price of goods may also decrease, and the quality of goods will improve;<br>2. Relevant products using renewable energy will be further promoted, and consumers can profit from it, such as being able to buy new energy vehicles at lower prices, etc. |
| The disadvantages that these risks and costs brought about | If the carbon emission trading market is highly developed, the excess carbon emission quotas saved by carbon emission reduction activities can be sold to those who need carbon emission rights, which will increase the profit path of carbon emission reduction activities. However, at present, it has not achieved the particularly desirable results. Governments of all countries must assume social responsibility and implement various carbon and carbon emissions trading plans strictly and responsibly. Otherwise, there may be a situation where the cost of carbon emission reduction is higher than the benefits of carbon emission reduction. | 1. Due to the limitation of carbon emission reduction technology, insufficient development and reserves of low-carbon technology, the backwardness of carbon emission reduction technology and the huge amount of funds needed to develop carbon emission reduction technology will undoubtedly increase the uncertainty of the outlook;<br>2. Small and medium-sized enterprises have no incentive and ability to carry out energy conservation and emission reduction work if there isn't any incentive mechanism put forward by the government;<br>3. In terms of carbon emission reduction government subsidies, the amount of subsidies is often lower than the cost of emission reduction. | 1. The daily cost of ordinary consumers will increase slightly;<br>2. Consumers in the carbon industry, as individuals involved in carbon emissions, will be more affected. Not only will the purchase cost increase, but there will also be certain use restrictions. |

## 2.3 DATA LIMITATION AND ASSUMPTIONS

Some assumptions shown in Table 3 are made referring to plenty of data, articles and experience to make our design and analysis for carbon credit and financial instruments more practical.

**TABLE 3:** ASSUMPTIONS DUE TO DATA LIMITATION

| Assumptions | Data limitation | References | Reasons |
|---|---|---|---|
| **Rate of return**: yield at 2.5% | The past yield rate is unknown in Pullanta. | Federal funds rate from 1994 to 2018. | The interest rate market in Pullanta has been similar to that of the United States. The arithmetic mean of Federal funds rate from 1994 to 2018 is 2.5%, so we assume that the rate in Pullanta would be around 2.5%. |
| **Consumption**: Consumption takes up 75% of GDP, namely $C_t = 0.75GDP_t$. | The consumption in Pullanta is unknown. | The percentage of consumption in GDP between 1995 and 2018 of ten representative countries including America, China, Japan, Germany, India, France, Britain, Italy, Brazil and Canada. | Consumption takes up 75% of GDP on average among the ten countries. |
| **Utility**: The social cost of carbon in Pullanta is risk-neutral. | The preference to carbon emission is unknown in Pullanta. | Yang P, Yao Y F, Mi Z, et al (2018)[2]. Tol, Richard (2019)[3]. | It is common to assume risk as neutral in many researches. |

Related to the given data and variables, we also have some derivative assumptions as shown in Table 4.

**TABLE 4:** SOME OTHER ASSUMPTIONS BASED ON THE GIVEN DATA AND TABEL 1

| Assumptions | Variables | Reasons |
|---|---|---|
| **Population**: The number of people grows linearly. Setting 2019 as the basic year, the population at the following end of the year is calculated by $L_t = 20,000,000 + 157,090t$ ($t = 1$ represents at the end of year 2020) | Population | After testing the historical data from 1995 to 2019 by linear regression method, the growth of population is found to be obviously linear. (See Figure 1) |
| **GDP**: GDP grows linearly. Setting 2019 as the basic year, the population at the following end of the year is calculated by $GDP_t = 725,747,352,744 + 20,734,283,275t$ ($t = 1$ represents at the end of year 2020) | Gross Domestic Product (current P) | There has been a general uptrend in GDP from 1995 to 2019 and a linear growth in the recent five years. (See Figure 1) |
| **The relation between consumption and carbon emission**: $C_t = 6.603 \times 10^{-16}(E_t)^{2.978}$ | Gross Domestic Product (current P), Total CO2e Emissions by Sector/Source (metric tonnes) | We have assumed that consumption accounts for 30% of the GDP. With the GDP data, the amount of consumption and the relationship between consumption and carbon emission can be calculated. (See Figure 1) |

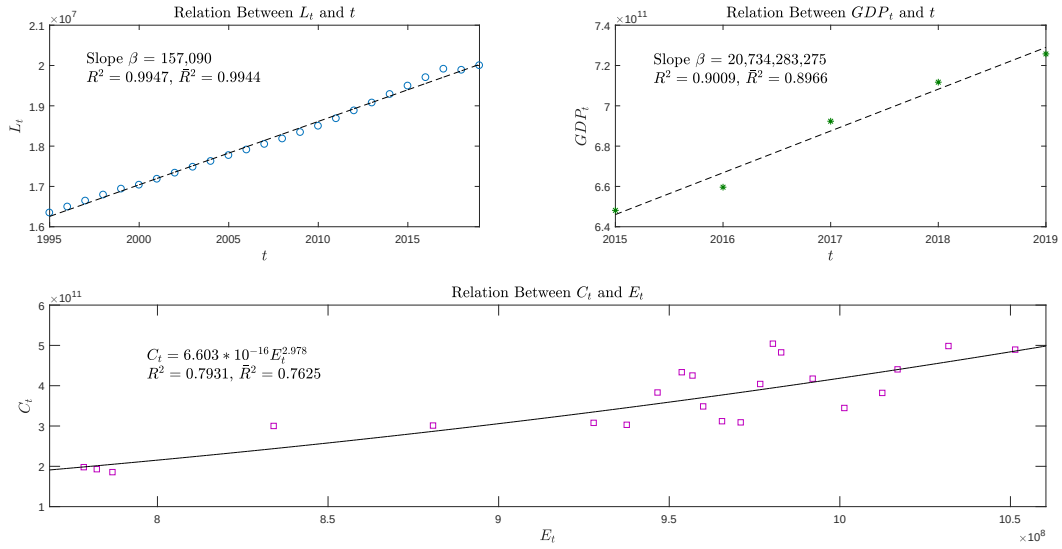



**FIGURE 1:** THE RELATION BETWEEN DIFFERENT VARIABLES

## 2.4 METHODOLOGY

The main issues raised in this report and the corresponding methods in each chapter is concluded in Table 5.

**TABLE 5:** THE MAIN ISSUES AND SOLUTIONS

| Content | Main Issues | Solutions |
|---|---|---|
| Design of Carbon Credit | Issue Arrangement of Carbon Credit | Gather relative regulations about carbon credit and design a suitable one for Pullanta. |
| | Price of Carbon Credit | Collect paper, establish carbon social cost and environmental cost models to give carbon credit a set-up proper prices. |
| | Design of Carbon Credit's Market | Collect market exchange laws and adjust according to the reality situation in Pullanta. |
| | Design of Carbon Credit's Punishment | Collect relative regulations on the over-emission punishment and design based on collected regulations. |
| | Impact of Carbon Credit's Design | Analysis on the basis of the design result of issuing and pricing, secondary market and punishment institution. |
| Design of Financial Instrument | General Characteristic of Financial Instrument | Design the financial instrument based on the design of Carbon Credit and the specific condition in Pullanta. |
| | Issue Arrangement of Financial Instrument | Build models to get the distribution amount of each financial products, ensuring that the quantity issued each time is about the same. |
| | Price of Financial Instrument | Use pricing formula. |
| | Impact of Financial Instrument's Design | Analysis on the basis of the design result of issuing and pricing . |

| | | |
|---|---|---|
| Enterprise Risk Management | Carbon Over-emission Risk | Assuming that the average number of over-emission company and the average amount of over-emission of carbon subject to log-normal distribution and normal distribution respectively. Analysis the effect on annual and final goal caused by the mean value and variance. |
| | Economic Risk | Setting that market yield and GDP vary in the certain ranges and use the tables to determine their effect on the revenue of government |

# 3 DESIGN OF CARBON CREDIT

## 3.1 ANNUAL AND ULTIMATE GOAL OF CARBON EMISSION

We first set up our annual and final goal for Pullanta in the year 2020 to 2030. The final emission goal in 2030 is $75\%$ of that in 2018$(922,441,064)$, namely 691830798$(922,441,064 \times 75\% = 691,830,798)$.

We consider a practical proposal to be regular so that the affected companies and consumers can adjust their behaviors and judgements in accordance with the regular fluctuation of the variables. **As a result, the annual goal varies once a year in a fixed rate based on the emission level in 2018, making it easier for the companies to adjust their own arrangement.** The annual and final goal of carbon emission level is given in Table 6.

**TABLE 6:** THE ANNUAL AND ULTIMATE GOAL OF CARBON EMISSION

| Year | Annual Goal of Aggregate Carbon Emission (mtCO2e) |
|---|---|
| 2018 | 922,441,064 |
| 2020 | 901,476,495 |
| 2021 | 880,511,925 |
| 2022 | 859,547,355 |
| 2023 | 838,582,786 |
| 2024 | 817,618,216 |
| 2025 | 796,653,646 |
| 2026 | 775,689,077 |
| 2027 | 754,724,507 |
| 2028 | 733,759,938 |
| 2029 | 712,795,368 |
| 2030 | **691,830,798 (Ultimate Goal)** |
| Reduction of Annual Goal | 20,964,569 or 20,964,570 |

## 3.2 ISSUE ARRANGEMENT OF CARBON CREDIT

Carbon credit is the emission right of the company. Government would supervise the amount of carbon emission and carbon credit. Once a company discharge over the upper limit, companies will get their punishment of which detailed regulations will be discussed later after our introduction of the issue, pricing of carbon credit(in 3.5).

Carbon credit would be allocated in three ways to the company(see Table 7), free allocation(50%), direct purchase(30%) and bonds(20%). Free allocation means that the companies can get the amount of carbon emission right for free. Direct purchase requires the companies to buy the carbon credit at the price set by the government directly. Companies can also buy bonds whose interest is allocated in the means of carbon credit. The reasons for setting the proportion of the three issuance methods will be explained in 3.2.1 and 3.2.2.

**TABLE 7:** THREE WAYS OF CARBON CREDIT'S ALLOCATION

| **Type** | Free Allocation | Direct Purchase | Bonds |
|---|---|---|---|
| **Percentage** | 50% | 30% | 20% |

### 3.2.1 THE DESIGN AND ARRANGEMENT OF FREE ALLOCATION

It is obvious that companies benefit a lot from free allocation, while there are two sides when it comes to the government. High percentage of free allocation brings out rapid development but also have a harmful influence on the reduction goal. On the contrary, less amount in free allocation makes the goal easier to be reached but go against the economic development. We set 50% of the total emission level in this report for the free allocation part referring to the regulation in Europe whose percentage is 40% [4]. We consider it a nice level that would balance the two sides.

**The period of carbon credit's validity lasts only for a year from the beginning of the year to the end and the right would be allocated again repeatedly.**

Zhang(2018)[5] introduces two ways in free allocation, one is historical method and the other is basic method. The former one allocate the carbon credit according to the company's historical emission amount and the latter one allocate averagely to each company. The advantage and disadvantage of historical method and basic method are given in Table 8.

**TABLE 8:** THE ADVANTAGE AND DISADVANTAGE OF HISTORICAL METHOD AND BASIC METHOD

| Method | Advantages | Disadvantages |
|---|---|---|
| **Historical method** | The free allocation of carbon credit is directly proportional to the company's own scale. The carbon credit could be used fully and it is also benefit to the economy. | It is unbeneficial to the small companies and makes it tougher for the newly-established company to enter this field. |
| **Basic method** | Friendly to all companies. | The small companies may waste a part of the carbon credit for they don't need that much, while the big company which needs more carbon credit to satisfy its own production may be restricted. |

**In our design, half of the free allocation is presented in historical method regarding to the previous percentage of emission and the rest in basic method. If the free allocation part exceeds more than twice the previous carbon emission, the company can only get twice the previous emission amount.** (Detailed reasons are explained in 3.2.2)

**The new-established company can get 0.5% of the surplus free allocation as its first year's free allocation part**. The number of zero carbon emission companies is given in Table 9.

(As you can see in the Table 9, considering that there may be some companies that are not exist or don't hand in their report on time, we estimate that the number of new-established company each year would be no more than 200. As we assumed that the companies are established in even distribution, we can easily set the free allocation part as $\frac{1}{200} = 0.5\%$)

**TABLE 9:** NUMBER OF ZERO CARBON EMISSION COMPANIES

| Year | 2019 | 2018 | 2017 | 2016 | 2015 |
|---|---|---|---|---|---|
| **Number of zero carbon emission** | 470 | 583 | 541 | 526 | 533 |

### 3.2.2 THE ARRANGEMENT OF DIRECT PRUCHASE AND BONDS

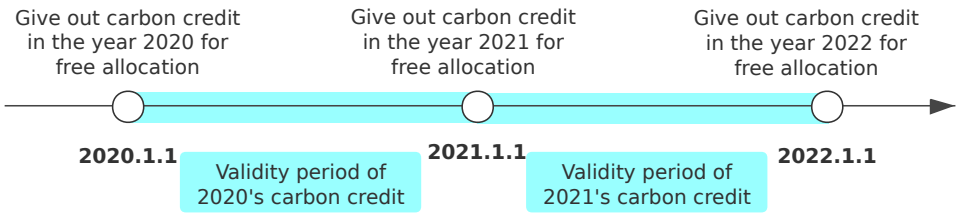
Besides free allocation part, companies can apply for carbon credit at a set of price via direct purchase and carbon bonds. They can get the fixed amount of carbon credit by direct purchase or get some flexible carbon credit by buying bonds. Because direct issuance is less difficult and has less procedures than bond issuance, direct issuance and bond issuance account for a total carbon credit of 30% and 20% when 50% of carbon credit has been issued for free.

**In our proposal, both the price and amount of carbon credit issued via direct purchase and carbon bonds are the same to all kinds of industries** otherwise those industries which get more carbon credit may sell a large quantity of carbon credit to the others, resulting in frequent fluctuation in the price of carbon credit, which could bring about uncertain market risk. In our design, even if there are some companies that need more carbon credit, they can get enough via the second market.

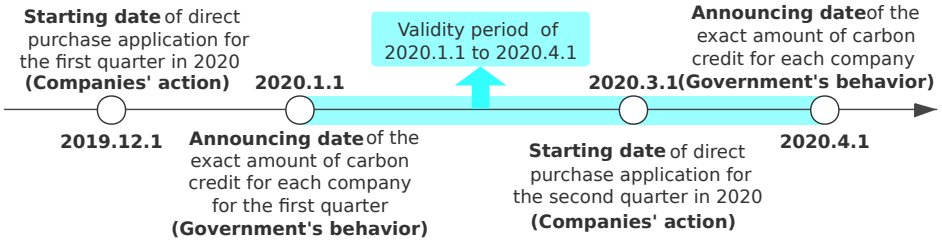
The detailed date and way of issuing is presented in Figure 2 comparing difference of three main ways.

**In the direct purchase and carbon bonds part, if the total applied amount of all the companies exceeds the total issue amount, the companies can only get company's** $\frac{\textit{Applied Amount}}{\textit{Total Applied Amount}} \times \textit{Issue Amount}$**. The upper amount of application of each company is set the twice of the actual emission amount of last quarter.** For the reason that after analyzing the 1930 companies' growth rate of carbon dioxide emission amount between 2015 to 2019, we find that only 92 companies have the growth rate of 100% and the rest are under 100%(see Appendix C-2). We

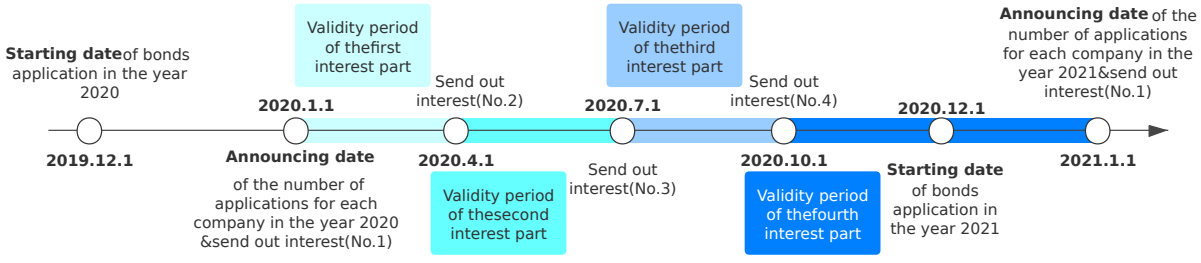
set twice as the upper limitation to make most of the companies fulfil their production plan. We will have further discussion about the upper limitation of carbon bonds application in charter 4.1.




(a) Free Allocation




(b) Direct Purchase




(c) Bond

**FIGURE 2:** DETAILED DATES AND WAYS OF ISSUING

### 3.2.3 DETAILED ARRANGEMENT OF CARBON CREDIT

We calculate the issue amount of the three parts in detail as shown in Table 10.

**TABLE 10:** ARRANGEMENTS OF THE ISSUE AMOUNT IN EACH YEAR

| Year | Free allocation | Direct purchase | Carbon bonds | Total issue amount |
|---|---|---|---|---|
| 2020 | 450,738,248 | 270,442,949 | 180,295,298 | 901,476,495 |
| 2021 | 440,255,963 | 264,153,578 | 176,102,384 | 880,511,925 |
| 2022 | 429,773,678 | 257,864,207 | 171,909,470 | 859,547,355 |
| 2023 | 419,291,393 | 251,574,836 | 167,716,557 | 838,582,786 |
| 2024 | 408,809,108 | 245,285,465 | 163,523,643 | 817,618,216 |
| 2025 | 398,326,823 | 238,996,094 | 159,330,729 | 796,653,646 |
| 2026 | 387,844,539 | 232,706,723 | 155,137,815 | 775,689,077 |
| 2027 | 377,362,254 | 226,417,352 | 150,944,901 | 754,724,507 |
| 2028 | 366,879,969 | 220,127,981 | 146,751,988 | 733,759,938 |
| 2029 | 356,397,684 | 213,838,610 | 142,559,074 | 712,795,368 |
| 2030 | 345,915,399 | 207,549,239 | 138,366,160 | 691,830,798 |

## 3.3 PRICE OF CARBON CREDIT

We take the environmental cost and social cost into consideration in our report to calculate the precise cost of carbon credit and eventually the price of carbon credit.

### 3.3.1 THE ENVIRONMENTAL COST OF CARBON

We use biocapacity and ecological footprint to evaluate the environmental cost. It is reported in Global Footprint Network[6] that the difference between biocapacity and ecological footprint could be conducted as the ecological surplus (+) or deficit (-) of a country. Kurt Kratena(2008)[7] found out that the ecological rent accounted for about 4% of GDP. So environmental cost each year can be conducted as equation 1, in which the divided 50% of carbon emissions represent carbon credits issued in non-free ways.

$$ECC_t = 0.04 \times GDP_t/(0.5E_t) \tag{1}$$

### 3.3.2 THE SOCIAL COST OF CARBON

Yang P, et al. (2018)[2] and Tol, Richard. (2019)[3] used **DICE** model to calculate the social cost of carbon with this utility function(see equation 2):

$$W = \sum_{t=1}^{T} \frac{C_t^{1-\alpha} L_t (1+\rho)^{-t}}{1-\alpha} \tag{2}$$

$\alpha$ is the coefficient of risk aversion.$\rho$ is the market rate of return.$T$ represents the length of observation. Basically, this utility function is the present utility value of the future.

In **DICE** model, the social cost of carbon(**SCC**) can be written as equation 3

$$SCC = \frac{\partial W}{\partial E_t} / \frac{\partial W}{\partial C_t} \tag{3}$$

We assume that the carbon emission would be sustained at 2030's level after 2030 and $T = 10$. Under the assumptions in Table 3 and Table 4, we can get equation 4

$$SCC_t = 1.996 \times 10^{-15} \times \frac{\sum_{i=1}^{10} (E_{t+i})^{1.978} L_{t+i} (1+2.5\%)^{-i}}{\sum_{i=1}^{10} L_{t+i} (1+2.5\%)^{-i}} \tag{4}$$

Eventually, we design the price of carbon credit to be the sum of environmental cost and social cost(see Table 11).

**TABLE 11:** PRICE OF CARBON CREDIT

| Year | Environment Cost of Carbon Credit | Social Cost of Carbon Credit | Price of Carbon Credit |
|---|---|---|---|
| 2020 | 66 | 826 | 892 |
| 2021 | 70 | 785 | 854 |
| 2022 | 73 | 747 | 821 |
| 2023 | 77 | 714 | 792 |
| 2024 | 81 | 686 | 767 |
| 2025 | 85 | 662 | 747 |
| 2026 | 90 | 641 | 731 |
| 2027 | 95 | 625 | 720 |
| 2028 | 99 | 613 | 713 |
| 2029 | 105 | 605 | 710 |
| 2030 | 110 | 601 | 712 |
| 2031 | 113 | 601 | 714 |

## 3.4 DESIGN OF CARBON CREDIT'S MARKET

**Pullanta should deliver carbon credit and carbon financial instruments through the primary market, since it needs to set a beginning price for a given credit or bond to macro-control**

**carbon emissions, with the hope of achieving its annual goal.** But we also recommend setting up a platform to provide a carbon trading venue between companies, which will be discussed in detailed later.

As for the design for the secondary market, we highly recommend to set up a platform, like Carbon Trade Exchange (**CTX**), which is the world's first electronic exchange for carbon credits and operates spot in multiple global environmental commodity markets. **Such exchange is best suited for creating liquidity on secondary market because it provides a platform for each company to sell their redundant carbon credits, or to buy what they need, at specific trading time.**

In order to facilitate carbon trading among all the entities by promoting a system of good business practice, we modify the existing rules "Carbon Trade Exchange Rules and Regulations for the Voluntary Carbon Market 22 May 2018" provided by **CTX**[8], making it possible to meet the requirements of the implementation plan given in this paper.

The adjustments we made are as following:

**FRAME 1**: ADJUSTMENTS

- Carbon credits got via financial instruments will expire at the end of each seasons, while carbon credits that are originally given for free or sold the government will expire at the last day of the year. Selling members are responsible for providing the expiration date of the carbon credits whenever they post a Selling List in the trading platform.
- Companies are not required to provide the type of Unit to which the Sales Listing relates. Since the transaction only includes carbon credit, while types of Unit in **CTX** includes not only carbon but also Renewable Energy Certificates (RECs) and water.

**At the end of each season, the government will check whether each entity has enough**

**carbon credits to emit the carbon dioxide that they emitted during that season**. Therefore, each entity just need to make sure that they have sufficient carbon credits at the end of each season, otherwise they need to pay massive fines.

## 3.5 DESIGN OF CARBON CREDIT'S PUNISHMENT

The companies ought to follow the contract or they could get relevant punishment. To standardize the carbon credit exchange market so as to reach our goal, we set our punishment rules referring to the European criterion[9]. The over-emission company whose total carbon emission of the quarter calculated on the last day quarterly, namely the settlement date, overpasses the upper limit would get the following punishments:

**FRAME 2**: PUNISHMENTS

1. 1000 Pulo is required as penalty for per over-emission part.
2. The company's free allocation credit in the next year would reduce 110% of the amount of over-emission.
3. Related announcement would be made as a warning.
4. Extra taxation will be imposed on the company.
5. Some mandatory measures in law would be taken when necessary.

## 3.6 IMPACT OF CARBON CREDIT'S DESIGN

Impact of carbon credit's design and engagement measures are given in Table 12.

**TABLE 12:** IMPACT OF CARBON CREDIT'S DESIGN AND ENGAGEMENT MEASURES

| | Government/Society | Enterprises | Factors and actions that can be considered and taken by government |
|---|---|---|---|
| Laws Aspect | 1. Formulate regulations to clarify the rights and obligations of various functional departments and enterprises related to carbon credit;<br>2. Accounting department needs to issue relevant accounting regulations;<br>3. Various functional departments have issued provisions to announce and clarify the distribution methods to enterprises;<br>4. Construction of carbon credit purchase platform;<br>5. The government regularly announces the time and price of the issue and reminds companies to apply in time;<br>6. The government regularly punishes and warns companies for excessive emissions;<br>7. Exchange platform issues regulations to ensure that carbon trading is legal and smooth. | 1. Cooperate with the supervision of government departments in accordance with the provisions of laws and regulations;<br>2. Accounting will be more complicated;<br>3. Need to clearly understand the issuance method of carbon credit, and choose the appropriate purchase plan according to their own needs;<br>4. Open an account on the exchange platform and trade in accordance with regulations. | **Differences in domestic industries and regions:** Due to the different levels of resource accumulation and use of each industry, the unified carbon credit price and quota have different degrees of impact on different industries. Similarly, regions with different levels of development are affected differently. **The government can consider the carbon emissions of different industries and the economic differences in different regions, give appropriate subsidies to resource-intensive enterprises and areas with underdeveloped economic development, help companies through the difficult period of improving energy efficiency, and can effectively curb the development of the black market**.<br><br>**Impact of neighboring countries' carbon emission reduction plans on their own carbon emission reduction plans:** If neighboring countries also implement carbon emission reduction plans, if the carbon reduction plans of the two countries have different degrees of impact on enterprises, it may cause domestic companies to flow to foreign countries or the inflow of foreign companies into the country which may reduce the possibility of achieving their national carbon reduction targets. At the same time, relevant arrangements in the plan also need to be continuously adjusted (such as the number of free quotas and the number of bonds issued). In addition, the difference in the improvement of the living environment after the implementation of the carbon emission reduction plan will also cause residents to migrate between the two countries, and also affect related indicators in the plan (such as the pricing of carbon credit). **Based on this, neighboring governments should strengthen cooperation and exchanges to discuss the impact of their respective emission reduction plans on enterprises and residents in their own countries and other countries to ensure that the carbon emission reduction plans formulated by each country have a minimum impact on neighboring countries**. |
| Economy Aspect | 1. Economic development will slow down to some extent due to carbon emission reduction; Carbon emission reduction technology accelerates development, and the scale of the technology industry increases;<br>2. Carbon emissions are reduced, but the scale of renewable energy use will increase, which has two sides for companies in the energy industry;<br>3. The government obtains corporate subscription income and tax revenue, and the government budget increases;<br>4. Carbon raw materials and reprocessing industries will suffer;<br>5. Encourage the development of the primary industry. | 1. Need to pay the government in exchange for carbon credit;<br>2. Add additional taxes and transaction costs;<br>3. There is a risk of excess discharge, which may result in severe penalty losses;<br>4. Adopt more advanced carbon emission reduction technology and improve energy utilization rate and increase unit energy income;<br>5. After reducing carbon emissions, excess carbon credits can be sold for income. | |
| Environ-ment Aspect | 1. Direct reduction of CO2 emissions, contributing to curbing global warming;<br>2. The area of arable land and forest land will increase, and biodiversity will develop;<br>3. Increase biocapacity, decrease biological footprint and turn ecological deficit into ecological surplus;<br>4. Increase use of renewable energy. | Reduce carbon emissions; Seek the use of renewable energy. | |

# 4 DESIGN OF FINANCIAL INSTRUMENT

## 4.1 GENERAL CHARACTERISTIC OF FINANCIAL INSTRUMENT

Our financial instrument includes options and bonds whose interest is presented in the form of carbon credit. In our proposal, we design three different terms of bonds and options. Detailed feature is shown in Table 13 and Table 14.

**TABLE 13:** THE BASIC FEATURE OF BONDS

| Financial Instrument | Term | Periodic interest | Release Period | Principal | Interest return date | Principal Value Return Date |
|---|---|---|---|---|---|---|
| Bonds | One year | 1 unit of carbon credit | Every year | 1,000 | The beginning of each quarter | The end of each relative year(At maturity) |
| | Six years | 5 units of carbon credit | Every six years | 5,000 | | |
| | Twelve years | 10 units of carbon credit | Every twelve years | 10,000 | | |

**TABLE 14:** THE BASIC FEATURE OF OPTIONS

| Financial Instrument | Term | Issue date | Strike Price | Category |
|---|---|---|---|---|
| Options | Three months | Beginning of each quarter | The strike price is 80% to 120% of the price set in direct purchase part, every 5% is counted. There are nine various strike price. | Call and put option, European features |
| | One year | Beginning of each year | | |

There are three different bond terms as shown above, representing short, medium and long terms of bonds to let different scales of companies set up their production plan more convenient and precise. For those large companies which require more carbon credit to match their

production can choose longer term bonds. In this way they can get more interest, namely carbon credit. Government can also benefit from it by obtaining more principal from the companies.

Once we introduce the options exchange into secondary market, companies and investors can benefit a lot from it, trading at a reasonable price.

**There is also an upper limit as explained in the direct purchase part, the total interest (carbon credit) of the whole year ought to be no more than twice its actual emission amount last year.**

There is no limitation in the option issue quantities. The trading rule is similar to the stock market, centralized price bidding and continuous auction institute. It is the trading between companies and investors, which means that governments will only charge fees instead of taking part in it. Moreover, we use cash instead of carbon credit to make settlement. Therefore, the traders can only have enough cash as margin not carbon credit.

## 4.2 ISSUE ARRANGEMENT OF FINANCIAL INSTRUMENT

The interest is almost the same among the same bonds so that the companies can get stable carbon credit to produce, reducing the possibility of wasting and discontinued production. Meanwhile, we issue more short term bonds because of their flexibility and mobility. The newly-established companies have a preference for these bonds. As shown in Table 10 that the total subscription of bonds each year has risen up to 100 million, we assume that 50 million of carbon credit would be used by the large companies. Eventually we get our deign of carbon credit bonds shown in the Table 15.

**TABLE 15:** THE ARRANGEMENT OF CARBON CREDIT BONDS

| Year | Total issue amount | | | Interest of the whole year | | | Total interest of the whole year | |
|---|---|---|---|---|---|---|---|---|
| | One year's bond | Six years' bond | Twelve years' maturity | One year's bond | Six years' bond | Twelve years' bond | Due amount | Actual counted amount |
| 2020 | 32,573,825 | 1,500,000 | 500,000 | 130,295,300 | 30,000,000 | 20,000,000 | 180,295,300 | 180,295,298 |
| 2021 | 31,525,596 | 0 | 0 | 126,102,384 | 30,000,000 | 20,000,000 | 176,102,384 | 176,102,384 |
| 2022 | 30,477,368 | 0 | 0 | 121,909,472 | 30,000,000 | 20,000,000 | 171,909,472 | 171,909,470 |
| 2023 | 29,429,139 | 0 | 0 | 117,716,556 | 30,000,000 | 20,000,000 | 167,716,556 | 167,716,557 |
| 2024 | 28,380,911 | 0 | 0 | 113,523,644 | 30,000,000 | 20,000,000 | 163,523,644 | 163,523,643 |
| 2025 | 27,332,682 | 0 | 0 | 109,330,728 | 30,000,000 | 20,000,000 | 159,330,728 | 159,330,729 |
| 2026 | 26,284,454 | 1,500,000 | 0 | 105,137,816 | 30,000,000 | 20,000,000 | 155,137,816 | 155,137,815 |
| 2027 | 25,236,225 | 0 | 0 | 100,944,900 | 30,000,000 | 20,000,000 | 150,944,900 | 150,944,901 |
| 2028 | 24,187,997 | 0 | 0 | 96,751,988 | 30,000,000 | 20,000,000 | 146,751,988 | 146,751,988 |
| 2029 | 23,139,769 | 0 | 0 | 92,559,076 | 30,000,000 | 20,000,000 | 142,559,076 | 142,559,074 |
| 2030 | 22,091,540 | 0 | 0 | 88,366,160 | 30,000,000 | 20,000,000 | 138,366,160 | 138,366,160 |

## 4.3 PRICE OF FINANCIAL INSTRUMENT

We take the pricing in direct purchase as references and also take the present value of principal and interest into consideration, pricing is given in Table 16.

**TABLE 16:** ARRANGEMENT OF THE PRICING OF CARBON CREDIT BONDS

| Year | Price | | |
|---|---|---|---|
| | One year maturity | Six years maturity | Twelve years maturity |
| 2020 | 4,512 | 95,405 | 327,917 |
| 2021 | 4,361 | - | - |
| 2022 | 4,228 | - | - |
| 2023 | 4,113 | - | - |
| 2024 | 4,016 | - | - |
| 2025 | 3,936 | - | - |
| 2026 | 3,873 | 84,502 | - |
| 2027 | 3,828 | - | - |
| 2028 | 3,800 | - | - |
| 2029 | 3,789 | - | - |
| 2030 | 3,796 | - | - |

## 4.4 IMPACT OF FINANCIAL INSTRUMENT

The impact of financial instrument's design and engagement measures are given in Table 17.

**TABLE 17:** IMPACT OF FINANCIAL INSTRUMENT'S DESIGN AND ENGAGEMENT MEASURES

| | Government | Enterprises | Factors and actions that can be considered and taken by government |
|---|---|---|---|
| Advan-tages | 1. When a company purchases bonds, its carbon emissions can be better estimated, and the government can make further emission reduction measures accordingly;<br>2. The government can obtain principal, transaction fees and taxes to meet the various needs of government functions;<br>3. Medium and long-term bonds can ensure the normal production of enterprises for a long time, and at the same time give enterprises a longer time to develop emission reduction technologies;<br>4. The risk of over-emissions has greatly decreased after the company purchased bonds. | 1. Carbon bonds can enable enterprises to obtain a fixed carbon credit and reduce the shortage of carbon credit;<br>2. Interest and spread income can also be obtained by purchasing carbon bonds. | **The degree of perfection of the trading system of the carbon credit financial instrument market**: After an enterprise purchases carbon bonds or purchases carbon options, in addition to reducing the risk of carbon credit shortage, it also has investment and speculative purposes. Therefore, the improvement of the financial instrument market trading system is important to improve corporate participation. **The government needs to formulate and continuously improve relevant laws and regulations, and at the same time set up special supervision departments to maintain the orderly operation of the carbon financial market**.<br><br>**Diversity of financial products**: If government want to encourage companies to participate in carbon trading markets, government can also research and develop more carbon financial services, such as carbon funds and carbon repurchases. Diversity of financial products can increase the diversity of carbon financial markets. **The government can unite financial institutions to develop carbon credit-based financing leasing business, carbon fund wealth management products, factoring business, etc**. |
| Disadvan-tage | 1. There is a certain market risk, namely the influx of large numbers of speculators, increasing market volatility;<br>2. The medium and long-term bond issuance of carbon credit has a long cycle, and there may be a risk of excess carbon credit issuance. | 1. There is a purchase risk, namely the actual allocation quota is much smaller than its purchase quota, resulting in a large gap in carbon credit;<br>2. Part of the funds need to shift from financial assets with higher returns to carbon assets with lower returns, reducing overall investment returns. | |

# 5 ENTERPRISE RISK MANAGEMENT

## 5.1 CARBON OVER-EMISSION RISK

We assume that the average number of over-emission companies each year$(n)$ and the average emission amount of carbon dioxide$(q)$ obey log-normal distribution $LN(\mu_1, \sigma_1^2)$ and normal distribution $N(\mu_2, \sigma_2^2)$ respectively to evaluate the risk level. They are independent so the total emission amount is $nq$. Therefore, generally, we assume $\mu_1 = 4, \sigma_1 = 1, \mu_2 = 10,000$ and $\sigma_2 = 2,500$. $n$ is greater than 0 and varies within a small range, so the log-normal distribution is assumed, with $\mu_1$ and $\sigma_1$ be 4 and 1, respectively, indicating that $n$ is around 90, which is close to the reality. On the contrary, $q$ is not easy to control, so the normal distribution with a larger change than the log-normal is used. $\mu_2$ and $\sigma_2$ are set to 10,000 and 2,500 respectively, therefore the over-emission of most enterprises (99.7%) is concentrated between 2500 and 17,500, which is resonable. When one distribution is determined in the general situation, we can observe the variation of the parameter in the other distribution from Figure 3.

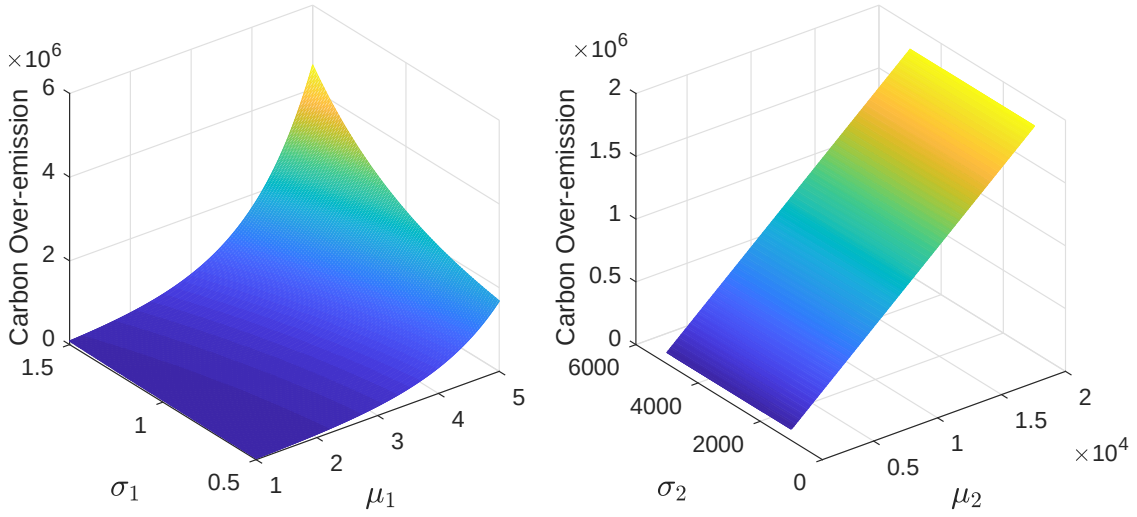



**FIGURE 3:** THE EFFECT ON THE EXPECTED OVER-EMISSION AMOUNT CAUSED BY THE DISTRIBUTION PARAMETER OF $N$ AND $Q$

As shown in Figure 3, when the distribution of $q$ is certain, the expected over-emission

amount has positive correlation with $\mu_1$ and $\sigma_1$ (in the distribution $n$). The expected over-emission amount is more sensible to the distribution of $n$ with the bigger amount of $\mu_1$ and $\sigma_1$. When the distribution of $n$ is certain, the expected over-emission amount has positive correlation with $\mu_2$ and $\sigma_2$ (in the distribution $q$) and certain sensibility.

Table 18 and Table 19 shows the ranges of the parameters when the other distribution parameter is certain under the 90% possibility of 90% of the plan (90% of the due reduction of carbon dioxide emission, namely the over-emission amount ought to be less than $2,096,456$). We can figure out the conclusion that control over average number of over-emission companies$(n)$ is more vital than the average over-emission amount$(q)$.

**TABLE 18:** THE MAXIMUM PARAMETER IN DISTRIBUTION N WHEN $Q = 10,000$

| $\sigma_1$ is known | | $\mu_1$ is known | |
|---|---|---|---|
| The value of $\sigma_1$ | The possible maximum value of $\mu_1$ | The value of $\mu_1$ | The possible maximum value of $\sigma_1$ |
| 0.2 | 5.0894 | 3.00 | 1.8324 |
| 0.4 | 4.8334 | 3.25 | 1.6370 |
| 0.6 | 4.5774 | 3.50 | 1.4417 |
| 0.8 | 4.3214 | 3.75 | 1.2464 |
| 1.0 | 4.0654 | 4.00 | 1.0511 |
| 1.2 | 3.8094 | 4.25 | 0.8558 |
| 1.4 | 3.5534 | 4.50 | 0.6605 |
| 1.6 | 3.2974 | 4.75 | 0.4652 |
| 1.8 | 3.0414 | 5.00 | 0.2699 |

**TABLE 19:** THE MAXIMUM PARAMETER IN DISTRIBUTION $Q$ WHEN $N = 90$

| $\sigma_2$ is known | | $\mu_2$ is known | |
|---|---|---|---|
| The value of $\sigma_2$ | The possible maximum value of $\mu_2$ | The value of $\mu_2$ | The possible maximum value of $\sigma_2$ |
| 500 | 22,650 | 2,000 | 16,632 |
| 1,000 | 22,010 | 4,000 | 15,070 |
| 1,500 | 21,370 | 6,000 | 13,507 |
| 2,000 | 20,730 | 8,000 | 11,945 |
| 2,500 | 20,090 | 10,000 | 10,382 |
| 3,000 | 19,450 | 12,000 | 8,820 |
| 3,500 | 18,810 | 14,000 | 7,257 |
| 4,000 | 18,170 | 16,000 | 5,695 |
| 4,500 | 17,530 | 18,000 | 4,132 |

Table 20 also gives the possibility in the accomplishment of 90% of the annual goal in the extreme condition.

**TABLE 20:** THE POSSIBILITY OF ACHIEVING 90% OF THE ANNUAL GOAL IN EXTREME SITUATION

| Parameters | Scenario Analysis | | |
|---|---|---|---|
| | Worst Scenario | Base Scenario | Best Scenario |
| $\mu_1$ | 5 | 4 | 3 |
| $\sigma_1$ | 1.8 | 1.0 | 0.2 |
| $\mu_2$ | 18,000 | 10,000 | 2,000 |
| $\sigma_2$ | 4,500 | 2,500 | 500 |
| The Possibility of **NOT** Achieving Maximum Over-emission | 45.41% | 90.88% | 100% |

## 5.2 ECONOMIC RISK

The effect that brought about by the changes of market yield and GDP are the main uncertainty to the government's benefit, taking economic risk which means the influence of social economic circumstances into regard. We have already had assumptions on market yield, GDP in Table 3 and Table 4 so we can have several results on sensitivity analysis in Table 21. It is shown in Table 21 that, government's revenue surplus is calculated by government's revenue under given market yield or GDP minus revenue of base scenario (our original assumption). It is shown in Table 21 that government's revenue is more sensible to the changes of GDP.

**TABLE 21:** THE SENSIBILITY ANALYSIS OF ECONOMIC RISK

| Market yield | | GDP | |
|---|---|---|---|
| Market Yield | Government Revenue Surplus (P) | Real GDP/ Estimated GDP | Government Revenue Surplus (P) |
| 2.0% | -7,423,110,927 | 90% | 37,342,383,406 |
| 2.1% | -5,915,342,882 | 92% | 29,873,906,725 |
| 2.2% | -4,419,260,632 | 94% | 22,405,430,044 |
| 2.3% | -2,934,750,705 | 96% | 14,936,953,362 |
| 2.4% | -1,461,700,844 | 98% | 7,468,476,681 |
| 2.5% | 0 | 100% | 0 |
| 2.6% | 1,450,461,691 | 102% | -7,468,476,681 |
| 2.7% | 2,889,792,917 | 104% | -14,936,953,362 |
| 2.8% | 4,318,101,206 | 106% | -22,405,430,044 |
| 2.9% | 5,735,492,940 | 108% | -29,873,906,725 |
| 3.0% | 7,142,073,368 | 110% | -37,342,383,406 |

The government's revenue surplus in extreme situation is shown in Table 22.

**TABLE 22:** THE GOVERNMENT'S REVENUE SURPLUS IN EXTREME SITUATION

| Parameters | Scenario Analysis | | |
|---|---|---|---|
| | Worst Scenario | Base Scenario | Best Scenario |
| Market yield | 2.0% | 2.5% | 3.0% |
| Real GDP/ Estimated GDP | 110% | 100% | 90% |
| **Government revenue surplus (P)** | **-44,883,143,962** | **0** | **44,370,413,340** |

# 6 CONCLUSION

This report develops a reasonable and detailed plan for Pullanta's carbon reduction and environmental funding goals, including a series of design and impact analysis of carbon credit and carbon financial instruments, as well as internal risk analysis. Under our plan and risk analysis, the government has a more than 90% chance of achieving 90% of the annual goals, and at the same time can obtain profits of about 2,900 billion to 3,800 billion Pulo to finance environmental activities. Therefore, it's strongly recommend that Pullanta adopts the implementation plan in this report.

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# APPENDICES

## APPENDIX A-1 FEDERAL FUNDS RATE IN 1995-2018

**TABLE 23:** FEDERAL FUNDS RATE IN 1995-2018

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995/1/1 | 5.53 | 1999/3/1 | 4.81 | 2003/5/1 | 1.26 | 2007/7/1 | 5.26 | 2011/9/1 | 0.08 | 2015/11/1 | 0.12 |
| 1995/2/1 | 5.92 | 1999/4/1 | 4.74 | 2003/6/1 | 1.22 | 2007/8/1 | 5.02 | 2011/10/1 | 0.07 | 2015/12/1 | 0.24 |
| 1995/3/1 | 5.98 | 1999/5/1 | 4.74 | 2003/7/1 | 1.01 | 2007/9/1 | 4.94 | 2011/11/1 | 0.08 | 2016/1/1 | 0.34 |
| 1995/4/1 | 6.05 | 1999/6/1 | 4.76 | 2003/8/1 | 1.03 | 2007/10/1 | 4.76 | 2011/12/1 | 0.07 | 2016/2/1 | 0.38 |
| 1995/5/1 | 6.01 | 1999/7/1 | 4.99 | 2003/9/1 | 1.01 | 2007/11/1 | 4.49 | 2012/1/1 | 0.08 | 2016/3/1 | 0.36 |
| 1995/6/1 | 6.00 | 1999/8/1 | 5.07 | 2003/10/1 | 1.01 | 2007/12/1 | 4.24 | 2012/2/1 | 0.10 | 2016/4/1 | 0.37 |
| 1995/7/1 | 5.85 | 1999/9/1 | 5.22 | 2003/11/1 | 1.00 | 2008/1/1 | 3.94 | 2012/3/1 | 0.13 | 2016/5/1 | 0.37 |
| 1995/8/1 | 5.74 | 1999/10/1 | 5.20 | 2003/12/1 | 0.98 | 2008/2/1 | 2.98 | 2012/4/1 | 0.14 | 2016/6/1 | 0.38 |
| 1995/9/1 | 5.80 | 1999/11/1 | 5.42 | 2004/1/1 | 1.00 | 2008/3/1 | 2.61 | 2012/5/1 | 0.16 | 2016/7/1 | 0.39 |
| 1995/10/1 | 5.76 | 1999/12/1 | 5.30 | 2004/2/1 | 1.01 | 2008/4/1 | 2.28 | 2012/6/1 | 0.16 | 2016/8/1 | 0.40 |
| 1995/11/1 | 5.80 | 2000/1/1 | 5.45 | 2004/3/1 | 1.00 | 2008/5/1 | 1.98 | 2012/7/1 | 0.16 | 2016/9/1 | 0.40 |
| 1995/12/1 | 5.60 | 2000/2/1 | 5.73 | 2004/4/1 | 1.00 | 2008/6/1 | 2.00 | 2012/8/1 | 0.13 | 2016/10/1 | 0.40 |
| 1996/1/1 | 5.56 | 2000/3/1 | 5.85 | 2004/5/1 | 1.00 | 2008/7/1 | 2.01 | 2012/9/1 | 0.14 | 2016/11/1 | 0.41 |
| 1996/2/1 | 5.22 | 2000/4/1 | 6.02 | 2004/6/1 | 1.03 | 2008/8/1 | 2.00 | 2012/10/1 | 0.16 | 2016/12/1 | 0.54 |
| 1996/3/1 | 5.31 | 2000/5/1 | 6.27 | 2004/7/1 | 1.26 | 2008/9/1 | 1.81 | 2012/11/1 | 0.16 | 2017/1/1 | 0.65 |
| 1996/4/1 | 5.22 | 2000/6/1 | 6.53 | 2004/8/1 | 1.43 | 2008/10/1 | 0.97 | 2012/12/1 | 0.16 | 2017/2/1 | 0.66 |
| 1996/5/1 | 5.24 | 2000/7/1 | 6.54 | 2004/9/1 | 1.61 | 2008/11/1 | 0.39 | 2013/1/1 | 0.14 | 2017/3/1 | 0.79 |
| 1996/6/1 | 5.27 | 2000/8/1 | 6.50 | 2004/10/1 | 1.76 | 2008/12/1 | 0.16 | 2013/2/1 | 0.15 | 2017/4/1 | 0.90 |
| 1996/7/1 | 5.40 | 2000/9/1 | 6.52 | 2004/11/1 | 1.93 | 2009/1/1 | 0.15 | 2013/3/1 | 0.14 | 2017/5/1 | 0.91 |
| 1996/8/1 | 5.22 | 2000/10/1 | 6.51 | 2004/12/1 | 2.16 | 2009/2/1 | 0.22 | 2013/4/1 | 0.15 | 2017/6/1 | 1.04 |
| 1996/9/1 | 5.30 | 2000/11/1 | 6.51 | 2005/1/1 | 2.28 | 2009/3/1 | 0.18 | 2013/5/1 | 0.11 | 2017/7/1 | 1.15 |
| 1996/10/1 | 5.24 | 2000/12/1 | 6.40 | 2005/2/1 | 2.50 | 2009/4/1 | 0.15 | 2013/6/1 | 0.09 | 2017/8/1 | 1.16 |
| 1996/11/1 | 5.31 | 2001/1/1 | 5.98 | 2005/3/1 | 2.63 | 2009/5/1 | 0.18 | 2013/7/1 | 0.09 | 2017/9/1 | 1.15 |
| 1996/12/1 | 5.29 | 2001/2/1 | 5.49 | 2005/4/1 | 2.79 | 2009/6/1 | 0.21 | 2013/8/1 | 0.08 | 2017/10/1 | 1.15 |
| 1997/1/1 | 5.25 | 2001/3/1 | 5.31 | 2005/5/1 | 3.00 | 2009/7/1 | 0.16 | 2013/9/1 | 0.08 | 2017/11/1 | 1.16 |
| 1997/2/1 | 5.19 | 2001/4/1 | 4.80 | 2005/6/1 | 3.04 | 2009/8/1 | 0.16 | 2013/10/1 | 0.09 | 2017/12/1 | 1.30 |
| 1997/3/1 | 5.39 | 2001/5/1 | 4.21 | 2005/7/1 | 3.26 | 2009/9/1 | 0.15 | 2013/11/1 | 0.08 | 2018/1/1 | 1.41 |
| 1997/4/1 | 5.51 | 2001/6/1 | 3.97 | 2005/8/1 | 3.50 | 2009/10/1 | 0.12 | 2013/12/1 | 0.09 | 2018/2/1 | 1.42 |
| 1997/5/1 | 5.50 | 2001/7/1 | 3.77 | 2005/9/1 | 3.62 | 2009/11/1 | 0.12 | 2014/1/1 | 0.07 | 2018/3/1 | 1.51 |
| 1997/6/1 | 5.56 | 2001/8/1 | 3.65 | 2005/10/1 | 3.78 | 2009/12/1 | 0.12 | 2014/2/1 | 0.07 | 2018/4/1 | 1.69 |
| 1997/7/1 | 5.52 | 2001/9/1 | 3.07 | 2005/11/1 | 4.00 | 2010/1/1 | 0.11 | 2014/3/1 | 0.08 | Average rate in 1995-2018 | 2.53 |
| 1997/8/1 | 5.54 | 2001/10/1 | 2.49 | 2005/12/1 | 4.16 | 2010/2/1 | 0.13 | 2014/4/1 | 0.09 | | |
| 1997/9/1 | 5.54 | 2001/11/1 | 2.09 | 2006/1/1 | 4.29 | 2010/3/1 | 0.16 | 2014/5/1 | 0.09 | | |
| 1997/10/1 | 5.50 | 2001/12/1 | 1.82 | 2006/2/1 | 4.49 | 2010/4/1 | 0.20 | 2014/6/1 | 0.10 | | |
| 1997/11/1 | 5.52 | 2002/1/1 | 1.73 | 2006/3/1 | 4.59 | 2010/5/1 | 0.20 | 2014/7/1 | 0.09 | | |
| 1997/12/1 | 5.50 | 2002/2/1 | 1.74 | 2006/4/1 | 4.79 | 2010/6/1 | 0.18 | 2014/8/1 | 0.09 | | |
| 1998/1/1 | 5.56 | 2002/3/1 | 1.73 | 2006/5/1 | 4.94 | 2010/7/1 | 0.18 | 2014/9/1 | 0.09 | | |
| 1998/2/1 | 5.51 | 2002/4/1 | 1.75 | 2006/6/1 | 4.99 | 2010/8/1 | 0.19 | 2014/10/1 | 0.09 | | |
| 1998/3/1 | 5.49 | 2002/5/1 | 1.75 | 2006/7/1 | 5.24 | 2010/9/1 | 0.19 | 2014/11/1 | 0.09 | | |
| 1998/4/1 | 5.45 | 2002/6/1 | 1.75 | 2006/8/1 | 5.25 | 2010/10/1 | 0.19 | 2014/12/1 | 0.12 | | |
| 1998/5/1 | 5.49 | 2002/7/1 | 1.73 | 2006/9/1 | 5.25 | 2010/11/1 | 0.19 | 2015/1/1 | 0.11 | | |
| 1998/6/1 | 5.56 | 2002/8/1 | 1.74 | 2006/10/1 | 5.25 | 2010/12/1 | 0.18 | 2015/2/1 | 0.11 | | |
| 1998/7/1 | 5.54 | 2002/9/1 | 1.75 | 2006/11/1 | 5.25 | 2011/1/1 | 0.17 | 2015/3/1 | 0.11 | | |
| 1998/8/1 | 5.55 | 2002/10/1 | 1.75 | 2006/12/1 | 5.24 | 2011/2/1 | 0.16 | 2015/4/1 | 0.12 | | |
| 1998/9/1 | 5.51 | 2002/11/1 | 1.34 | 2007/1/1 | 5.25 | 2011/3/1 | 0.14 | 2015/5/1 | 0.12 | | |
| 1998/10/1 | 5.07 | 2002/12/1 | 1.24 | 2007/2/1 | 5.26 | 2011/4/1 | 0.10 | 2015/6/1 | 0.13 | | |
| 1998/11/1 | 4.83 | 2003/1/1 | 1.24 | 2007/3/1 | 5.26 | 2011/5/1 | 0.09 | 2015/7/1 | 0.13 | | |
| 1998/12/1 | 4.68 | 2003/2/1 | 1.26 | 2007/4/1 | 5.25 | 2011/6/1 | 0.09 | 2015/8/1 | 0.14 | | |
| 1999/1/1 | 4.63 | 2003/3/1 | 1.25 | 2007/5/1 | 5.25 | 2011/7/1 | 0.07 | 2015/9/1 | 0.14 | | |
| 1999/2/1 | 4.76 | 2003/4/1 | 1.26 | 2007/6/1 | 5.25 | 2011/8/1 | 0.10 | 2015/10/1 | 0.12 | | |

# APPENDIX A-2 CONSUMPTION% OF GDP IN TEN MAJOR CONTURIES IN 1995-2018

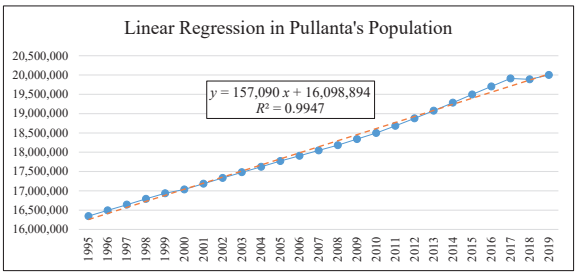
**TABLE 24:** CONSUMPTION% OF GDP IN TEN MAJOR CONTURIES IN 1995-2018

| | Final consumption expenditure (% of GDP) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | United States | China | Japan | Germany | India | France | United Kingdom | Italy | Brazil | Canada |
| 1995 | 79.90227166 | 59.01204259 | 68.85305137 | 75.26641367 | 74.2407284 | 77.88705816 | 81.17864595 | 76.29723129 | 84.63436358 | 77.73256789 |
| 1996 | 79.49197349 | 59.99802585 | 68.70120951 | 76.02327494 | 74.88610785 | 78.5957616 | 81.0782093 | 76.11424411 | 84.90822573 | 77.43794507 |
| 1997 | 78.77907426 | 59.59809157 | 68.99203864 | 75.54659256 | 74.94055852 | 77.53510466 | 81.71576786 | 76.78723802 | 84.84492449 | 76.98406903 |
| 1998 | 78.83702215 | 60.40270219 | 69.66787143 | 74.75069747 | 75.71862376 | 76.57319794 | 82.4047998 | 77.23234744 | 84.21283234 | 77.18615804 |
| 1999 | 79.23607178 | 62.52089643 | 71.32660755 | 75.44394702 | 76.18497615 | 76.24402302 | 83.18698787 | 77.98619665 | 84.4628102 | 75.82885496 |
| 2000 | 79.98304416 | 63.48985625 | 71.2635512 | 75.34377386 | 75.68681661 | 76.18324276 | 83.2822678 | 78.28554983 | 83.36054608 | 73.88684332 |
| 2001 | 81.30005862 | 61.82998775 | 72.77939981 | 75.41297283 | 75.90830732 | 76.26270966 | 83.82822325 | 77.89342345 | 83.45100339 | 74.86709835 |
| 2002 | 82.18162596 | 60.85254874 | 73.99368433 | 74.97334085 | 74.34374182 | 76.69434177 | 84.18941358 | 77.67175614 | 81.70809738 | 76.06015207 |
| 2003 | 82.64874706 | 57.86049515 | 73.90731134 | 75.78910005 | 72.37996752 | 77.38776672 | 84.33653499 | 78.36508416 | 80.92212891 | 75.83924717 |
| 2004 | 82.41011307 | 55.04567401 | 73.62968827 | 74.96039814 | 68.75625029 | 77.09767321 | 84.91131163 | 78.14823052 | 78.67416111 | 74.38894394 |
| 2005 | 82.15171096 | 54.15778574 | 73.74113965 | 75.31444603 | 67.74487013 | 77.46192462 | 84.56821512 | 78.92945487 | 79.3942532 | 73.61731737 |
| 2006 | 82.04129425 | 52.28278908 | 73.83734845 | 74.01319872 | 65.91241587 | 76.99554852 | 83.85793699 | 78.86358666 | 79.47659338 | 73.88338213 |
| 2007 | 82.37868421 | 50.43810925 | 73.6238269 | 71.84897282 | 65.6226268 | 76.54942927 | 83.43279643 | 78.09333161 | 78.81793519 | 74.17275276 |
| 2008 | 83.79566133 | 49.32465143 | 75.0031159 | 72.4802375 | 67.21529714 | 77.0284785 | 84.68159939 | 78.98881199 | 78.57018556 | 74.36553306 |
| 2009 | 84.93921993 | 49.56083632 | 78.12537666 | 76.43243531 | 67.41955589 | 79.45824825 | 86.6592184 | 81.11168898 | 81.60709829 | 79.73892488 |
| 2010 | 84.68472751 | 48.28651788 | 77.24200811 | 74.67189206 | 65.73246563 | 79.34494702 | 85.90778481 | 81.2782873 | 79.23966126 | 78.65866168 |
| 2011 | 84.62470237 | 49.39582361 | 78.43970953 | 73.45661504 | 67.29165678 | 78.72704068 | 85.24862271 | 80.93250074 | 78.9431496 | 77.22888353 |
| 2012 | 83.48946017 | 50.33845304 | 78.89219512 | 74.18382623 | 67.14481002 | 78.66937252 | 85.33312387 | 81.1067223 | 79.94197011 | 77.26408925 |
| 2013 | 82.51022004 | 50.6503282 | 79.12581612 | 74.18777456 | 67.94092623 | 78.74738627 | 84.97605926 | 80.70869948 | 80.60772546 | 76.85577898 |
| 2014 | 82.11607771 | 51.19640508 | 78.54906631 | 73.0112761 | 68.56857391 | 78.43559645 | 84.2841215 | 80.14526311 | 82.11309521 | 76.24315389 |
| 2015 | 81.78430552 | 52.80907633 | 76.39641888 | 72.43852452 | 69.43557179 | 77.85412512 | 83.96689231 | 79.87895044 | 83.74161724 | 78.86965984 |
| 2016 | 82.42770536 | 54.03746513 | 75.60245932 | 72.42305606 | 69.64465588 | 77.99567527 | 84.21902711 | 79.15368815 | 84.62553882 | 79.59951063 |
| 2017 | 82.46830483 | 53.26216384 | 75.16214263 | 72.15140879 | 70.01304813 | 77.69255136 | 83.67812008 | 79.10502569 | 83.96194416 | 78.80893256 |
| 2018 | 82.27559102 | 53.35283033 | 75.33149236 | 72.03993577 | 70.61824541 | 77.31812213 | 84.01170315 | 79.33994116 | 84.04865204 | 79.01875753 |
| Average | 81.93573614 | 54.98764816 | 74.25777206 | 74.25683795 | 70.55628324 | 77.61413856 | 83.9557243 | 78.85071892 | 81.9278547 | 76.60571741 |
| Total Average | **75.49484314** | | | | | | | | | |
| Data From | THE WORLD BANK | | | | | | | | | |

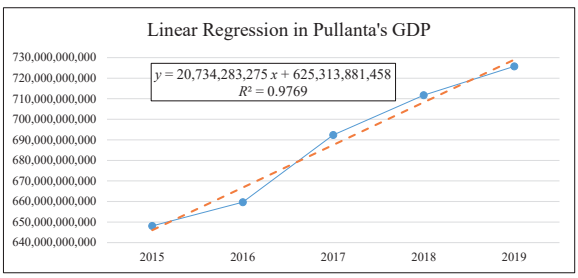
# APPENDIX B-1 ESTIMATE OF FUTURE POPULATION AND GDP

**TABLE 25:** ESTIMATED GDP AND ESTIMATED POPULATION

| Year | Estimated GDP | Estimated Population |
|---|---|---|
| 2020 | 746,481,636,019 | 20,157,090 |
| 2021 | 767,215,919,294 | 20,314,180 |
| 2022 | 787,950,202,569 | 20,471,270 |
| 2023 | 808,684,485,844 | 20,628,360 |
| 2024 | 829,418,769,119 | 20,785,450 |
| 2025 | 850,153,052,394 | 20,942,540 |
| 2026 | 870,887,335,669 | 21,099,630 |
| 2027 | 891,621,618,944 | 21,256,720 |
| 2028 | 912,355,902,219 | 21,413,810 |
| 2029 | 933,090,185,494 | 21,570,900 |
| 2030 | 953,824,468,769 | 21,727,990 |
| 2031 | 974,558,752,044 | 21,885,080 |
| 2032 | 995,293,035,319 | 22,042,170 |
| 2033 | 1,016,027,318,594 | 22,199,260 |
| 2034 | 1,036,761,601,869 | 22,356,350 |
| 2035 | 1,057,495,885,144 | 22,513,440 |
| 2036 | 1,078,230,168,419 | 22,670,530 |
| 2037 | 1,098,964,451,694 | 22,827,620 |
| 2038 | 1,119,698,734,969 | 22,984,710 |
| 2039 | 1,140,433,018,244 | 23,141,800 |
| 2040 | 1,161,167,301,519 | 23,298,890 |




(a) Population




(b) GDP

**FIGURE 4:** LINEAR REGRESSION RESULT

# APPENDIX B-2 FIT RESULT OF CONSUMPTION AND CARBON EMISSION

**TABLE 26:** CARBON EMISSION AND CONSUMPATION

| Year | Carbon Emission[1] | Consumption[2] | Carbon Emission (Three-order Moving Average) | Consumption (Three-order Moving Average) |
|---|---|---|---|---|
| 1999 | 773,801,464 | 199,739,197,319 | - | - |
| 1998 | 780,690,381 | 203,965,756,216 | 778,399,239 | 197,913,813,823 |
| 1996 | 780,705,871 | 190,036,487,933 | 782,222,048 | 192,879,774,780 |
| 1995 | 785,269,891 | 184,637,080,191 | 786,809,969 | 185,586,843,124 |
| 1997 | 794,454,145 | 182,086,961,248 | 834,055,033 | 300,172,933,089 |
| 2018 | 922,441,064 | 533,794,757,829 | 880,766,614 | 301,158,978,992 |
| 2001 | 925,404,633 | 187,595,217,899 | 927,839,499 | 307,855,994,027 |
| 2002 | 935,672,800 | 202,178,006,352 | 937,537,321 | 303,013,456,174 |
| 2017 | 951,534,529 | 519,267,144,270 | 946,565,123 | 383,143,008,670 |
| 2009 | 952,488,040 | 427,983,875,387 | 953,660,484 | 433,455,784,322 |
| 2006 | 956,958,884 | 353,116,333,310 | 956,807,627 | 425,274,065,879 |
| 2016 | 960,975,959 | 494,721,988,940 | 959,943,275 | 348,631,357,155 |
| 2000 | 961,894,982 | 198,055,749,214 | 965,461,151 | 311,940,485,818 |
| 2003 | 973,512,511 | 243,043,719,299 | 970,936,352 | 309,064,268,411 |
| 2015 | 977,401,563 | 486,093,336,720 | 976,657,663 | 404,283,948,147 |
| 2008 | 979,058,916 | 483,714,788,421 | 980,371,821 | 504,240,677,343 |
| 2014 | 984,654,985 | 542,913,906,887 | 982,802,688 | 482,666,900,098 |
| 2007 | 984,694,165 | 421,372,004,987 | 992,035,772 | 417,512,718,268 |
| 2004 | 1,006,758,165 | 288,252,242,930 | 1,001,317,400 | 344,709,041,490 |
| 2005 | 1,012,499,870 | 324,502,876,553 | 1,012,430,611 | 382,145,982,143 |
| 2013 | 1,018,033,799 | 533,682,826,948 | 1,016,910,082 | 440,527,255,992 |
| 2010 | 1,020,196,579 | 463,396,064,475 | 1,031,829,245 | 498,435,323,633 |
| 2012 | 1,057,257,356 | 498,227,079,476 | 1,051,390,929 | 489,548,329,219 |
| 2011 | 1,076,718,852 | 507,021,843,707 | - | - |

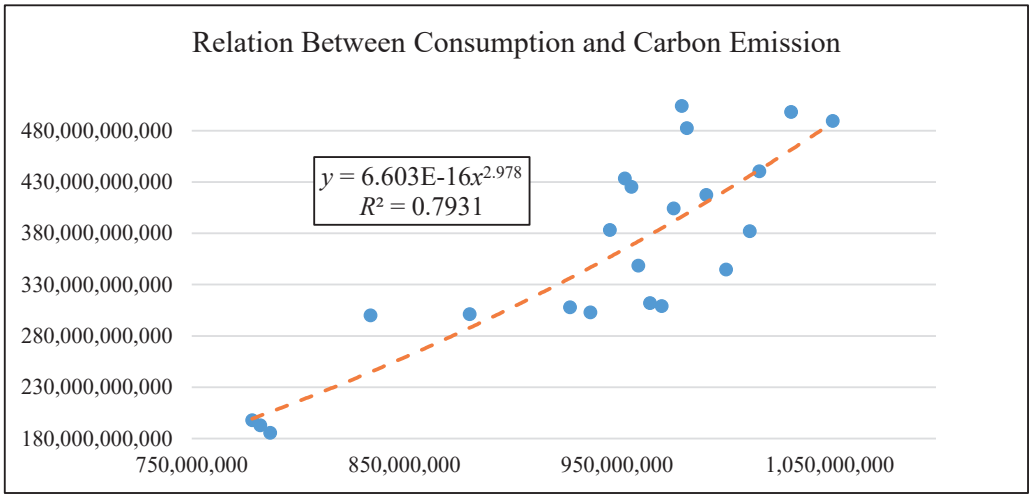



**FIGURE 5:** FIT RESULT OF CONSUMPTION AND CARBON EMISSION

[1]Sorted ascending
[2]Calculated by 75% of GDP
[3]Calculated by total ecological footprint minus total biocapacity

## APPENDIX C SUPPORTING CALCULATION AND STATISTICS

Appendix C-1 Annual and Ultimate Goal of Carbon Emission.xlsx is referred to the specific calculation of Table 6.

Appendix C-2 Statistics of Carbon Emission of Each Company.xlsx is referred to the specific calculation of Table 9 and carbon emission annual growth in each company.

Appendix C-3 Issue Arrangement of Carbon Credit.xlsx is referred to the specific calculation of Table 10.

Appendix C-4 Calculation of Carbon Credit's Cost and Price.xlsx is referred to the specific calculation of Table 11.

Appendix C-5 Issue Arrangement of Carbon Bonds.xlsx is referred to the specific calculation of Table 15.

Appendix C-6 Issue Price of Carbon Bonds.xlsx is referred to the specific calculation of Table 15.

Appendix C-7 Sensitivity Analysis - Carbon Over-emission Risk.xlsx is referred to the specific calculation of Table 18, 19, 20.

Appendix C-8 Sensitivity Analysis - Economic Risk.xlsx is referred to the specific calculation of Table 21, 22.