

**LIFE CYCLE ASSESMENT OF ENVIRONEMENTAL IMPACT OF
UNITED STATES DOLLAR NOTE AND COIN**

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Our task was to determine which dollar is better for the environment, the paper one-dollar note, or the Sacagawea one dollar coin.

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Which Dollar is Better, Coin or Paper?

The introduction of the Sacagawea Coin Dollar into the American economy is a result of the Coin Dollar Act of 1997. The coin dollar has different attributes than its predecessor the Susan B. Anthony Coin Dollar, because it was required to have a golden luster, and smoothed edge, with the same dimensions as the Susan B. Anthony Dollar. The introduction of the new coin dollar was to balance the inflationary use of the quarter. Vending machines, tolls, subway fares, and other products that cost approximately 25¢ in the 1960's now cost approximately \$1. It now takes an average of four coins to wash a load of laundry where it used to only cost one, and a New York Subway fare now is \$1.25 where it was 35¢ only thirty five years ago. Introduction of the new coin would make it easier to use the public transportation systems, and other pay machines.

The introduction of the new coin also asked the question, is one form of the dollar better for the environment? If the coin dollar is better, should we replace the paper dollar with its coin equivalent? If the paper dollar is better, and Americans trust the paper dollar more than the coin, wouldn't it be prudent to stop introducing new coins into the American economy?

This study examined the life cycle of the coin dollar and the paper dollar (note) to determine if one was better for the environment. Economic, health and social impacts were also examined as well. Information was collected from the United States Federal Government through the Department of the Treasury, the Bureau of Engraving and Printing, and the United States Mint. To prevent counterfeiting, these sources did not provide all details to the process, requiring some assumptions about the process to be made. However, the most important facts include the lifetime for the coin and note, 30 years and 1.5 years respectively, and the recycling and disposal of the two types of dollars. The coin is completely recycled into the production process after leaving circulation, where 90% of the dollar note is placed in landfill after leaving circulation. Based on our conclusions, we were able to recommend that the one-dollar note be phased out and completely replaced by the coin dollar.

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Abstract

The new Sacagawea dollar coin was introduced into the American economy in 2000, to replace the Susan B. Anthony dollar, which often became confused with the quarter due to color and feel. The new dollar coin has a golden color and no ribbing along the sides to prevent mistaking the dollar coin for a quarter. Because the United States Government is producing two different types of one-dollar denomination currency, one would think that one form should be better for the environment than the other. Disregarding the appeal of the dollar note, and noting that Americans have not drastically changed the currency system in America in almost a century, the idea that one form might be better for the environment was explored. A material balance on the lifetime of the dollar note (paper one-dollar bill) and the dollar coin (Sacagawea dollar coin) was performed. The Federal Government's reluctance to put forth details about the manufacturing of currency due to the threat of counterfeiting has required some generalizations about the life cycle assessment of the dollar coin and note. The results demonstrate that the coin is completely recyclable, and has a lifetime of thirty years, and the dollar note has a lifetime of one and a half years before becoming landfill. If the coin dollar is more environmentally friendly, then it should be used to replace the paper note; otherwise, the coin dollar should be phased out again like the Susan B. Anthony dollar, leaving only one type of currency for the American consumer.

Purpose of the Study

The purpose of this study involves the determination of which dollar is better for the environment, the Sacagawea coin dollar, or the paper dollar note. The aim of this study is to determine if it would be favorable to remove either the dollar coin or the dollar note from circulation based on environmental considerations.

Formulation of Purpose

The most commonly used currency in the United States is the one-dollar bill. The passage of the Efficient Currency Act of 1997, required the Federal Government to produce a new dollar coin similar in size to the Susan B. Anthony dollar but with a golden luster^{1,2,3,4,5}. The advent of this new coin opens the opportunity to phase out the dollar note, which can be replaced with the two-dollar bill, which is still manufactured, but under utilized. In addition the new coin can be used to replace tokens on many mass transit systems in the United States⁵.

Canada has successfully replace their dollar note with a one-dollar coin siting inflation as one of the underlying reasons. However, the United States has been reluctant to follow suit. One reason behind the creation of the coin dollar was to determine if it would be economically feasible, and beneficial to phase out the dollar note and replace it with the coin dollar⁵.

The paper note is made from a 75% virgin cotton 25% linen blend of paper, and industrial oil based ink is used to produce the coloring on the paper. A reusable metal plate is used to imprint the design on the note. Only non-recycled cotton and linen may be used in the

printing of the paper note. The paper dollar is bleached and shredded after circulation and only 10% is recycled as roofing shingles. The other 90% is placed in landfills^{2,3,6}.

The coin dollar is made from 88.5 % copper (Cu), 6% zinc (Zn), 3.5% manganese (Mn), and 2% nickel (Ni). The process allows for a complete recycle of the metal used to manufacture the coin, including the final coin when it comes out of circulation, and all metal waste from the process itself^{1,2}.

The purpose of this study is to examine the environmental impact of the dollar bill and dollar coin under current production and decide which would have a greater impact on the environment. The dollar note is produced at a cost of 4 cents with an average lifetime of 18 months. The dollar coin is produced at a cost of 8 cents with an average lifetime of 30 years. The amount of material taken out of the environment and the waste produced from each process were examined in the process and used to determine which type of dollar is better for the environment^{1,2,3,4,5}.

Figure 1. Coin dollar life cycle

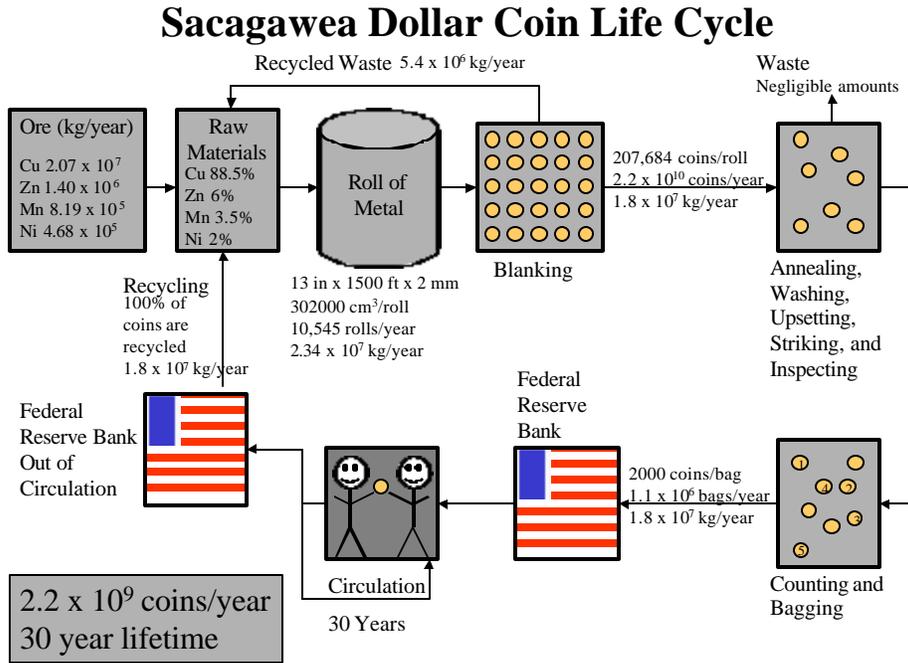
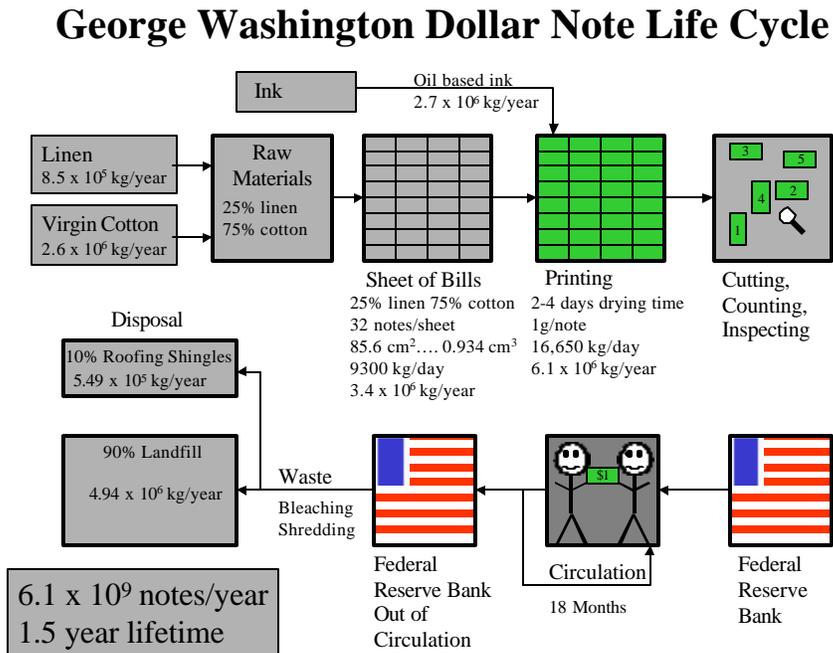


Figure 2. Paper dollar life cycle



Decision Analysis

The analysis of the flowchart reveals the impact of the dollar note on landfill and the coin dollar on resource depletion. Even though the coin dollar is recyclable and has a 30-year lifetime, the need to produce more coins to meet inflation will mean that the metals used for the production of the coin must be removed from the environment. The paper dollar also has a limited resource in the oil based inks used in the printing process. As more dollars are produced, the amount of oil based ink produced must be increased. The cotton and linen are renewable resources, however, the use of virgin cotton and linen, and procedure of disposing the used bills in landfill limit the renewability of the paper resource.

The process used to manufacture the dollar note and the dollar coin are efficient and produce a minimum amount of waste. The care taken to manufacture the dollars to prevent counterfeiting requires the processes utilized, and therefore no changes to the manufacturing processes can be suggested short of the elimination of one process or the other. The coin and note both meet the exact specifications set by the Federal Government, and can not be changed except by an act of Congress. The metal content of the coin and the paper content of the note are anti-counterfeiting measures taken by the United States Government, and therefore the modification of the product was not considered in this project.

The disposal process for the dollar coin and note is also unchangeable except by an act of Congress. The disposal process, controlled by the Federal Reserve Bank, is to landfill the paper notes, and recycle approximately 10% to make roofing shingles. The Federal Government did not release the reasoning behind the 10% recycle, so it is uncertain if a greater percentage of notes could be recycled in this way^{2,3}.

Scope Analysis

Overriding Constraints

The manufacturing process and disposal of the dollar note and coin dictate the scope of the study. This eliminates transportation effects and product design as both are transported in similar means and the design is rigidly fixed by the Federal Government. Data can be constrained to the raw materials for each process, the number of each type of dollar produced annually, and the amount of waste produced from each type of dollar annually.

Constraints due to Comparison

The transportation and circulation of the two types of dollars can be assumed to be similar due to the fact that the Government utilizing the Federal reserve banks to control the amount of money in circulation, the disposal of notes and the recycling of the coin dollar. The one-dollar note accounts for 45% of the paper notes produced per year. The reduction or elimination of the one-dollar note can be replaced by the production of higher denomination notes (\$2, \$5, \$10, \$20, \$50, and \$100), that have longer circulation rates, and not result in loss of jobs⁵. It can be assumed that the dollar note and the dollar coin circulate in a similar fashion.

Process Constraints

The waste produced from the washing of coins and bills can be considered to be equivalent. This assumption had to be made because the Federal Government has not released these figures to the public and information on the waste produced has yet to be acquired. The waste from the coin process is greater than that in the paper process due to the washing, however the paper note is bleached and shredded after circulation, where the coin is only recycled. Therefore the amount of waste from these two processes was assumed to be similar.

Data Constraints

The data collected is that released to the public. As counterfeiting of the dollar note process is a threat to national security, the Federal Government has not released all the information pertaining to the process. For example, it is not known how the metal plates are made, or the composition of the inks and dyes used. Some of this data was approximated with assumptions. For the coin process the Government did not release detailed information about the composition or the process, but instead described the coin process in vague terms and gave percentages of composition without detailing whether they are on a molar basis or a percent weight basis.

Lifetime Constraints

The lifetime of a dollar coin is approximately thirty years in circulation. The lifetime for a dollar note is approximately one and a half years. The life cycles of each dollar were measured over a one-year time frame and a thirty-year time frame. Neither time scale takes into account inflation^{1,2,3}.

Defining a Common Base Unit

The common base units are the one-dollar note and the one dollar coin. This study used two different lifetimes. First, the production of the coin and note over one year was used, as those were the figures given by the Federal Government. With the thirty-year lifetime of the coin, we also extrapolated the production and waste values to thirty years for each system. The time taken to meet the circulation numbers calculated from the data supplied from the Federal Reserve was also looked at, but can not be considered as one of the lifetimes used in this study⁷.

Life Cycle Stages

Raw Materials

The coin is made from an alloy containing copper, zinc, manganese, and nickel. The makeup of the coin is 88.5% Cu, 6% Zn, 3.5% Mn, and 2% Ni. These metals pose only slight health risks when found in the environment as pure metals, although they can exist as minerals with possible health hazards. Copper poses no health risks under normal circumstances, and making up for 88.5% of the coin results in a benign product. The fact that copper is a bactericide means the coin dollar actually can be healthier for people by killing microbes while passing from one person to the next. Zinc, nickel and manganese have some slight health risks associated with them, mostly due to metal allergies in people. The carcinogenic characteristics of nickel are not present when people are melting and working with nickel to create alloys. Higher concentrations of these metals always could pose higher health risks, however, the alloying process, combined with the high concentration of copper make the coin dollar a harmless health risk^{8, 9, 10, 11}.

The metals after mining are melted and alloyed into sheets with the correct composition. The sheets the coins are minted from are layered with a copper core and an alloy layer on the top and bottom. The metal is not distinguishable when freshly mined compared to when recycled from old coins or other metal sources. This makes the coin process able to feed itself after the coins are removed from circulation.

The paper used to manufacture the one-dollar note is made from 75% cotton and 25% linen. The inks used in the process are oil-based. The cotton and linen paper is required to be made from virgin materials, meaning the paper is not recycled from any source, and must come from cotton directly from farms. Paper is a bacterial growth medium, and can carry hazardous chemicals in its porous membranes⁵. The United States Government has not supplied the process for which the paper is made, however, the bleaching agents used in most industrial paper manufacturing processes are hazardous to humans. The paper is cleaned and bleached before the

printing processes, and is chemically benign after the printing process. The United States Government has not released the chemical makeup of the oil-based ink, however, it can be assumed that it is non-toxic to most humans. The effect of the ink that is wasted, when put in the environment is also not known, and for the purposes of this report was ignored. The life cycle of most paper dollars ends in landfills. While 10% of the dollar notes are recycled as roofing shingles, the majority of paper dollars end in landfills, which reduces the amount of usable land space, and can create pollution to the air and waterways¹².

Manufacturing

The manufacturing process associated with the coin and note dollar are efficient. The amount of ink, paper and metals are kept to a minimum to prevent waste. Assumptions that each process produces equal amounts of waste in the form of paper and ink from the note, which will go to landfill, and cleaning supplies, for the coins, reduce the need to explore the manufacturing processes for more environmental effects. The Government has not supplied data referring to the amount of waste generated in either process.

Packaging/Filling/Transportation/Distribution/Reuse/Storage

The Federal Reserve Bank distributes the note and coin into circulation and removes them as well. The cost and processes associated with counting, transportation and distribution were assumed to be similar for the coin and note dollar.

Recycling/Waste Management/Disposal

The Sacagawea coin dollar is completely recyclable. The United States Government can melt the metal from the coins to produce fresh new coins. Assuming that there is no loss due to coins not returning from circulation, the coins are completely recyclable.

The George Washington one-dollar note is not completely recyclable. The note is bleached of ink, which becomes waste, and the paper is shredded and put into landfill, or recycled as roofing tiles. Only 10% of the notes are recycled as roofing tiles leaving a large portion that becomes landfill. The effects of landfill are not beneficial to the environment. They pollute waterways with runoff, promote disease growth, increase methane, CO₂ and H₂S gas in the atmosphere, and reduce the amount of usable land¹².

Inventory Analysis

Data Collection

The relevant life cycle information was collected from the United States Mint and Department of Treasury. The Federal Reserve Bank, in Atlanta, Georgia and the Coin Coalition provided additional information. The manufacturing costs of the dollar coin and note were provided and include the cost of the materials, labor, and equipment depreciation. The material balance is based upon information provided by the Federal Government, and annual production numbers in terms of coins per year and notes per year.

The waste data was based upon the production values for the coin and note, after circulation. An assumption of zero loss to the circulation process was used, and no inflation was calculated into these values. No data on coin waste was provided, except that the coins are recycled after being taken out of circulation, in order to feed into the raw material stream. The coin dollar has only been in circulation for approximately two years and it has an expected lifetime of 30 years, so no coins have been removed from circulation at this time.

Stressors

The stressors for the dollar case study, based on the data collected include the raw material, the liquid discharge, and solid wastes. The energy usage can be considered to be similar for both processes, and will be needed for whichever dollar is chosen to be better for the environment. No data was reported with information regarding air emissions, radiation, or noise, and thus, are assumed to be negligible. The scale used involves positive values for beneficial stress placed on the environment, zero for neutral effects, and negative values for harmful effects.

Impact Categories

Definition

The impact categories for this study are sub-categories of the four basic impact categories of human health, ecological health, social welfare, and resource depletion. Under the category of health hazards, the effects include biological contamination, and disease transmission. The ecological health concerns include habitat loss, and pollution of waterways. The social welfare dealings include the economic impact and psycho-social impact. Resource depletion involves biotic resources, flow resources and stock resources.

Data

The data was calculated to fit the constraints of the problem, including no loss of dollars out of circulation, and no inflation. Table 1, shows the natural resources used for each process over one year. While using more resources, the coin dollar process produces fewer dollars, but the source is recyclable for coins where it is not for dollars. Table 2, identifies the amount of waste generated and the amount of mass coming out of circulation over a thirty year period.

Table 1. Resources used in dollar production.

RESOURCES USED (kg/year)	Coin	Note
Copper	20709000	0
Nickel	468000	0
Zinc	1404000	0
Manganese	819000	0
Oil Based Ink (Black and Green)	0	2700000
Virgin Cotton	0	2550000
Unrecycled Linen	0	850000
Transportation	same	same
Raw Energy	same	same
Misc. Resources	same	same
Cleaning (pre-circulation)	x	0
Cleaning (post-circulation)	0	x
Total Amount	23400000	6100000

Table 2. Waste generated in dollar process over 30 years.

	Coin	Note
Resources used (kg/year)	23400000	6100000
Years to produce circulation volume	7.6	27.4
Resources used to meet circulation volume (kg)	177627273	167000000
Used Resources at current production levels (kg/30 years)	379470000	183000000
Saved Resources over 30 years	201842727	16000000
Landfill Waste Generated (kg)	0	164700000

The Government also will benefit from the dollar coin economically. It costs \$0.08 to produce one coin and \$0.04 to produce one note, however the coin and note have lifetimes of 30 years and 18 months respectively^{1,2,5}. For every dollar coin put into circulation the government receives a 30-year loan of \$0.92 (\$0.08 to make and sold to the public for \$1) where for every dollar note put into circulation it only gives an 18-month loan of \$0.96. Because the coin is completely recyclable, the coins bought back from the circulation in the public will decrease the cost of the next batch of coins as the government is buying the resources to make new coins. This will decrease the total cost of making the coins, and will increase the amount of revenue the government receives from every coin manufactured.

Streamlining

The impact categories analyzed include the pre-manufacturing components, for each type of dollar, and the recycle and disposal of each. A scale of zero to five was used with zero having no, or negligible impact on the environment, and five having a great impact on the environment. The impact analysis can be seen below in Tables 3 and 4. It can clearly be shown that the paper dollar note has a greater average impact on the environment than the dollar coin.

Table 3. Impact Analysis of the Sacagawea Coin Dollar.

		Human Health	Ecological Health	Resource Depletion	Row Average
Pre-manufacture	Copper	0	0	3	1
	Zinc	0	0	2	0.667
	Manganese	0	0	2	0.667
	Nickel	0	0	2	0.667
Recycle		0	0	0	0
Disposal		0	0	0	0
				Average	0.5

Table 4. Impact Analysis of the Paper Dollar Note.

		Human Health	Ecological Health	Resource Depletion	Row Average
Pre-Manufacture	Cotton	0	0	3	1
	Linen	0	0	2	0.667
	Ink	0	0	3	1
Recycle		0	0	0	0
Disposal		2	2	1	1.667
				Average	0.867

In addition to the environmental impact, some economic factors favor the coin dollar. Due to inflation many coin operated machines and vending machines now require a one dollar fee, where in the 1960's the fee for these products was about one quarter. The dollar coin would remove the need to carry four quarter to operate a coin-operated laundry machine, or buy a soda from a vending machine. The one dollar coin can also replace tokens in public transportation systems⁵.

Conclusions

The life cycle assessment of the dollar coin and note has demonstrated that the coin is better for the environment than the note. Economics also favor the coin dollar with its longer lifetime, and recyclable nature. The coin dollar has a need in our economy, replacing the need to carry four quarters to operate vending machines that only required one in the 1960's. Overall, due to the nature of the dollar to be put into landfills, the environmental impact of the paper dollar is greater than the coin dollar.

Recommendations

The coin dollar can replace the dollar note in the American economy, as the Canadians have succeeded in doing. The Department of Engraving and Printing can then increase production of the \$2 note, which has a longer lifetime than the \$1 note, and can replace the one-dollar note in the cash register drawer. This will reduce the rate at which the used notes are placed in landfill, allow the dollar coin to be utilized as tokens for mass transit systems, and reduce the number of quarters needed for vending machines.

The economics also lend themselves to the increased production of the coin dollar, and replacing the one-dollar note with a two-dollar note. Most cash register drawers have five places for bills, and five places for coins. With our recommended solution, these slots would all be filled with different denominations, and none would be left empty. The cash drawer would have spaces for five coins (penny, nickel, dime, quarter, dollar) and five bills (two, five, ten, twenty, and large bills/checks). In addition, the ability of the coin to replace the overuse of quarters in vending machines, and the ability to use the coin as tokens in public transportation systems, add to the usefulness of the coin.

Overall, our recommendation is for the United States Federal Government to replace the paper dollar note with the Sacagawea coin dollar, and manufacture more \$2 notes, which have a longer lifetime and will not fill landfills as quickly.

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