How to Reduce CO_2 at the Lowest

By Glenn Weinreb

1. The Climate Solution

This chapter summarizes how to resolve climate change at the lowest cost.

The world currently burns coal, natural gas, and oil-based products to generate electricity, push vehicles, heat buildings, and fabricate materials. Unfortunately, the exhaust contains carbon dioxide (CO_2), a greenhouse gas that warms the planet. A little warming is ok; however, harmful amounts of warming are expected this century.

In theory, carbon-based fuels could be replaced with energy created at solar farms, wind farms, hydro-electric dams, and nuclear power plants. However, replacement is not occurring fast enough. For example, the U.S. government projects U.S. CO_2 emissions to decrease from 4.8 billion tons in 2022 to 4.0 billion tons in 2052. This is a 20% reduction over 30 years, and is far short of our planet's needs.

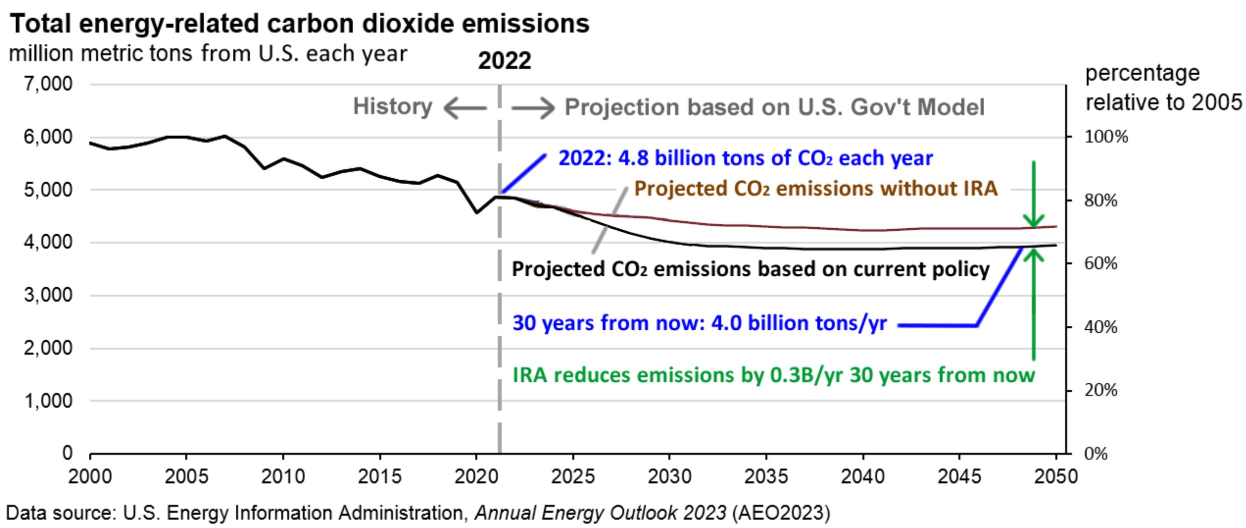

Figure 1.1: U.S. government's official projection of CO_2 emissions from the U.S. over the next 30 years in units of billions of tons each year.

As one can see from the above graph, President Biden's $391B Inflation Reduction Act (IRA) caused the 2052 expectation to drop from 4.3 to 4.0 billion tons a year. In other words, the IRA did little.

The U.S. government does not have a plan to reduce CO_2 significantly, and when it spends money on climate, it is often not effective. This is due to several reasons that include: (a) the hi-jacking of climate (i.e. organizations use climate to make money), (b) a lack of websites that model cost and impact of policy *before* it is enacted, and (c) government leaders often delegate to entities that do not have the physical ability to reduce CO_2 at the lowest cost and at large scales.

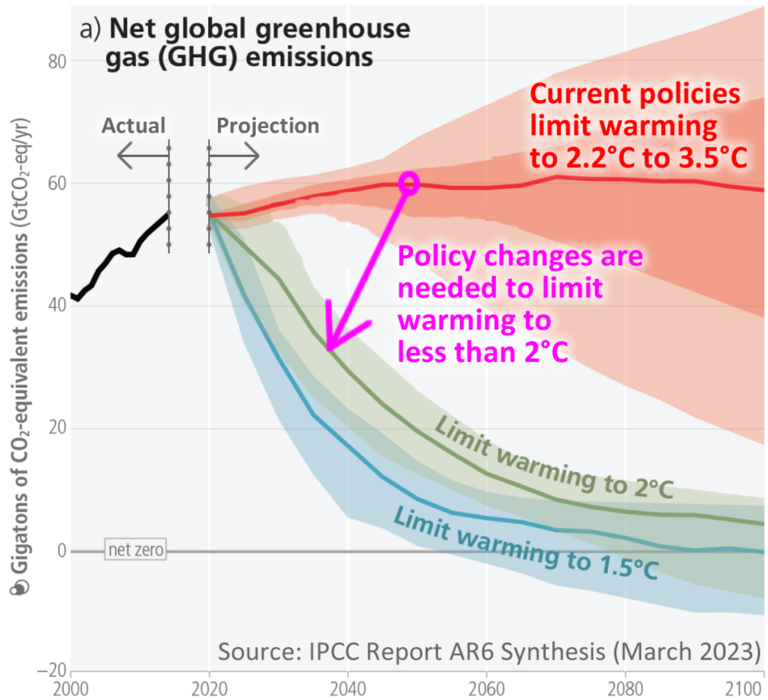

Figure 1.2: Impact of global CO_2 emissions over the next 30 years on planetary warming.

The Intergovernmental Panel on Climate Change (IPCC) 6th Report expects current national policies to facilitate warming between 2.2°C and 3.5°C, as illustrated above. This would lead to catastrophic amounts of sea level rise, damage from storms, and increased food costs due to drier land. In other words, nations need to change their current policies to avert disaster.

What is the Lowest-Cost Solution?

This begs the question, "What is the lowest cost way to make these policy changes and what would it cost?" One can look at U.S. gov't cost data and do a little math to see this would probably entail building solar farms and wind farms at a rate that is approximately 4-times greater than current construction levels. In the U.S. this would cost approximately $20 per person per year in year #1, $40 in year #2, $60 in year #3, etc. In the typical case, this would pay the mortgage on new solar farms and new wind farms, minus the cost of carbon-based fuels that were not burned due to being replaced with green electricity. Ultimately, these costs would appear as an increase in the cost of goods and services.

The Prisoner's Dilemma Problem

Companies, cities and states are not likely to spend significant amounts of money to reduce CO_2 since they do not benefit. In other words, they can reduce emissions to zero and the world will still emit CO_2 and cause them harm. This is referred to as a "prisoner's dilemma problem."

Therefore, decarbonization to zero over a reasonable duration, is not likely to occur unless required by law. And this law does not exist. This begs the question, "How does one structure an effective climate law that has majority support?"

U.S. Climate Politics

States that import natural gas and coal benefit from decarbonization in two ways: (a) they gain green jobs while carbon jobs are lost elsewhere, and (b) their costs decrease when the price of fuel decreases due to less consumption. The opposite is true for states that produce natural gas or coal. They are hurt by decarbonization due to loosing carbon jobs, and lower fuel price entails less revenue. Therefore, one can expect carbon producers, which is approximately one-third of the U.S. states, to not support significant decarbonization legislation.

According to survey, 40% of Republicans and 95% of Democrats are concerned about climate and want to decarbonize. We can do some math to see that approximately half of Americans want to decarbonize and are from states that do not produce natural gas or coal. In other words, we are close to majority support for significant decarbonization legislation.

This would need to meet the satisfaction of Republicans and Democrats who want to decarbonize. Republicans typically require two things: (a) lowest cost, and (b) minimal federal involvement. And Democrats typically require one thing: government engineers at EIA need to score the proposed initiative as reducing CO_2 significantly over a reasonable period of time.

What Might a Real Climate Law Look Like?

A federal law that meets that meets the above requirements might: (a) do more R&D, and (b) require states to reduce CO_2 emissions by 1/N each year relative to today. The later would cause emissions to decrease to zero over N years. For example, to decarbonize over 30 years, one would set N to 30 and reduce today's emissions $1/30^{th}$ each year (i.e. “30 Year Climate Law”).

Part (a) of this law uses R&D to decrease the cost of new green infrastructure. This infrastructure is likely to cost 100 trillion dollars globally over several decades. Therefore, spending billions of dollars to reduce this is reasonable. Yet what might one develop that is not already being worked on? And what might one develop that would have a big impact? One could work on these questions within a business plan for more R&D. This could be reviewed and reworked to the satisfaction of the various participants. Also, researchers could potentially be paid approximately $10K each to develop proposals for R&D referenced in the plan. For example, 50 proposals might cost $500K total.

Part (b) of this law (e.g. $1/30^{th}$ reduction) would probably require a website that models cost and impact. In other words, a website that calculates how much CO_2 is reduced, and cost per ton of CO_2, for each decarbonization initiative. Already some of this is done by the U.S. government's NEMS model. However, it needs a website user interface to be more useful.

Reasonable Next Steps

To move lowest cost decarbonization forward, universities, foundations, and non-profits can do several things:

- Develop websites that calculate the cost and impact of proposed laws.
- Hire researchers to write proposals for large R&D initiatives that are currently not being worked on and could potentially have a significant impact. These could be placed into an open-source business plan for a new R&D laboratory that tackles climate change at the lowest cost.
- Produce materials that explain politically feasible lowest cost decarbonization. For example, produce a documentary film called “The Climate Solution.” Documentaries typically explore Problems. This instead would focus on the Solution.

In summary, climate is a 100 trillion dollar problem and we need to think about how to spend billions of additional R&D dollars to save trillions; think about how to create better tools for lawmakers; and think about how to better educate the public on how to tackle climate at the lowest cost.

2. Decarbonize Electricity First

This chapter looks at the impact of decarbonizing 6% of U.S. electricity each year over 9 years.

How Much Would This Cost?

Currently, 38.4% of U.S. electricity is made without emitting CO_2 and if this were to increase 6% each year over 9 years, then 92% would be green in year #10 (38.4% + 6% x 9yrs).

The U.S. produces 4,100TWh of electricity each year and if 6% of this were decarbonized each year, then approximately 246TWh of coal and natural gas based electricity would be replaced with solar, wind, hydro and nuclear each year (4,100 x 6%).

Currently, 38% of U.S. electricity is made with natural gas, and 22% is made with coal. If 246TWh/yr were divided by these proportions, then 157TWh of natural gas and 89TWh of coal would be replaced with green electricity each year. Subsequently, CO_2 would decrease 65Mt/yr due to burning less natural gas, and decrease 90Mt/yr due to burning less coal (millions of metric tons per year). Total CO_2 reduction would be 154Mt/yr (65 + 90) and this would satisfy 90% of the 170Mt/yr requirement (154 / 170).

If half of the carbon-based electricity were decarbonized by constructing solar farms and half by constructing wind farms, for example, then 53GW of solar would be constructed each year, and 32GW of wind would be constructed each year. This is approximately 4-times more than the average between 2016 and 2021. The solar TWh-to-GW ratio is different than the wind ratio, since the wind blows more than the sun shines.

If decarbonization costs increased from \$10/mtCO_2 to \$50/mtCO_2 over a 9 year period (cost to reduce CO_2 by one metric ton), for example, then the cost of residential electricity would increase \$1 per-person-per-year in year #1.

Sounds too good to be true? Total cost for year #1 would be \$1.54B (154Mt x \$10/mtCO_2), total electricity cost-per-person-per-year would be \$5 (\$1.54B / 330M population), and *residential* electricity cost-per-person-per-year would be \$1 (\$5 x 20%). We apply 20% since 1/5th of all electricity is residential.

The table below shows what this looks like for the first four years. This analysis assumes inflation and GDP growth are zero to make this easier to follow.

		Year #1	Year #2	Year #3	Year #4
Decarbonization Cost	\$/mtCO_2	\$10	\$15	\$20	\$25
% U.S. Electricity Decarbonized	%	44%	50%	56%	62%
Decarbonization "Mortgages"	\$B/yr	\$1.5	\$1.5	\$1.5	\$1.5
US NREL, LCOE, 2022, Class 4	"		\$2.3	\$2.3	\$2.3
	"			\$3.1	\$3.1
	"				\$3.9
Total cost	\$B/yr	\$1.5	\$3.9	\$6.9	\$10.8
Total cost for residential electricity (20%)	\$B/yr	\$0.3	\$0.8	\$1.4	\$2.2
Cost of residential electricity per person	\$/yr	\$0.9	\$2.3	\$4.2	\$6.5

Table 1: Calculated electricity decarbonization costs.

If one did not decarbonize in the lowest cost order and instead incurred \$50/mtCO_2 costs in year #1, then the total electricity cost-per-person-per-year in year #1 would be \$25 instead of \$5.

Getting it done at the Lowest Cost

About 30% of all U.S. CO_2 emissions are from making electricity and 70% are from burning carbon-based fuels to produce heat and force within vehicles, factories and buildings. If one wanted to decarbonize all energy over 30 years at the lowest cost, one might first focus on electricity, and decarbonize other areas after they had been cost-reduced via R&D. In other words, spend as little money as possible each year, over 30 years, while reducing CO_2 emissions by $1/30^{th}$ of today's emissions each year.

A strategy like this would result in constructing significantly more solar farms and wind farms. Yet how does one do that?

What Drives Solar/Wind Farm Construction?

The number of solar farms and wind farms built each year is primarily determined by the following factors:

i. **Government Requirements:** Legislation that requires power companies to generate more green electricity each year (e.g. RPS).

ii. **Government Subsidies**: Legislation that provides government money to help pay for green electricity to reduce its effective price (e.g. ITC).

iii. **Cost of Green Electricity:** Cost to generate green electricity (¢/kWh).

iv. **Cost of Carbon Fuel:** Cost of natural gas and coal fuel that are burned to produce carbon-based electricity (¢/kWh).

v. **Green Consumerism:** The number of consumers willing to pay more for green products.

In the above list, (i) and (ii) are controlled by lawmakers, (iii) improves each year due to technology and production advancements, (iv) varies up and down due to external factors, and (v) increases as climate change harm becomes more obvious.

Increase Solar Farm and Wind Farm Construction

To increase the rate of electricity decarbonization, one would need more of the above listed items. For example, U.S. federal *subsidies* on green electricity are approximately 1¢/kWh as of April 2023, and if these doubled, the affect would be significant. In another example, Massachusetts *requires* 35% of its electricity to be green by 2030. Other states are similar. However, these targets need to be significantly larger.

Climate Change Policy Options

Policy options can reduce decarbonization costs. Below are several examples.

- Establish a government office with authority to amend electricity purchase agreements between electricity customers and carbon-based power plants. This would help large customers to more easily replace carbon-based electricity with green electricity.

- Establish a government office with authority to *replace* existing power transmission lines with larger lines on a wider tract of land. For details, see the “Automate the Construction of Power Transmission Towers” chapter.
- Set up a green energy production zone program where communities voluntarily join to increase economic activity. In these zones, land-owners have the right to build solar farms and wind farms, a government office has the authority to demand right of way for new power transmission lines, etc.

Decarbonization Anxiety

Required decarbonization is scary is two ways:

Cost Anxiety: It is reasonable to be afraid of decarbonization costs, especially when nations rarely decarbonize at the lowest cost. For this reason, decarbonization law that requires lowest cost, and websites that calculate costs, are important.

Carbon Industry Anxiety: It is reasonable for regions with many carbon-based industries to be afraid of the social and economic pain associated with downsizing. One should not expect political support from these regions when tackling climate change at large scales.

3. Tackling Climate the Right Way

Reducing CO_2 “the right way” involves doing so at the lowest cost and at large scales.

Decarbonization Scale and Cost

Current CO_2 emissions from the U.S. are approximately 5 billion tons a year, and many Americans want to reduce significantly over several decades. The below theoretical CO_2 vs. time graph shows what this would look like if it occurred at a constant rate over 30 years.

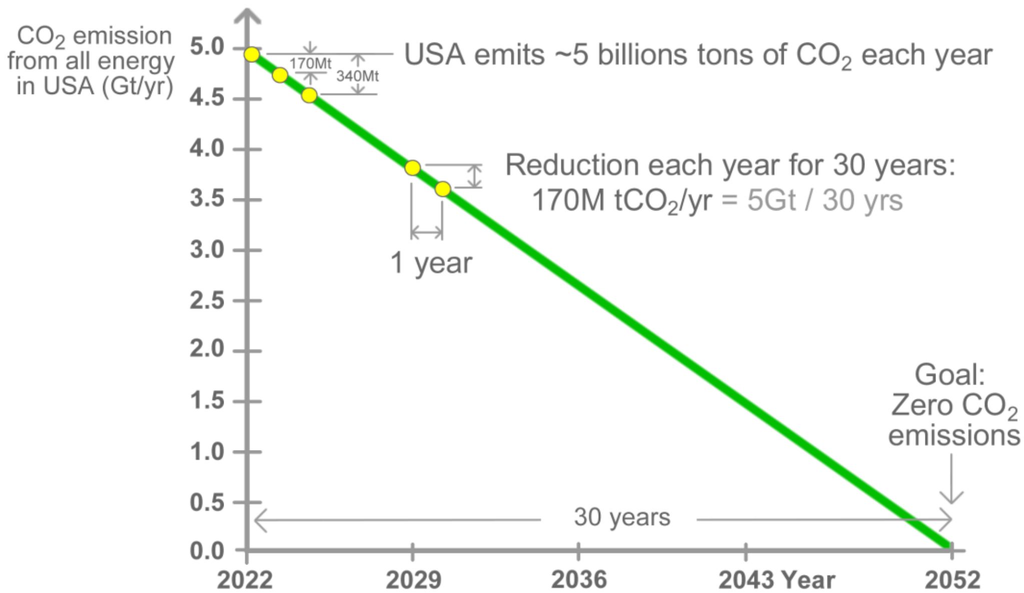

Figure 3.1: Theoretical U.S. decarbonization over 30 years at a constant rate.

When implementing the above Green Line, one must contend with two important parameters: Decarbonization Cost and Decarbonization Scale.

Decarbonization Cost refers to the amount of money required to reduce CO_2 and is typically measured in dollars per metric ton of CO_2 reduced ($/mt$CO_2$).

Decarbonization Scale, on the other hand, refers to the amount of CO_2 emissions that are reduced each year. For example, if the goal is to eliminate the U.S. 5 billion ton per year emissions over a 30 year period, then one would need to reduce by ~170 million tons each year on average. This is because 5 billion divided by 30 years is ~170 million.

Three Areas that Need Decarbonizing

There are roughly three areas that need decarbonizing: (a) electrical power generation, (b) fabrication of materials and chemicals, and (c) transportation. Electricity can be decarbonized now at large scales and low costs; whereas other areas have a scale problem, a cost problem, or both. And one can improve the other areas with R&D *while* decarbonizing electricity.

Electrical Power Generation is Ready to Decarbonize at Large Scales and Low Costs

In the near future there is only one way to reduce CO_2 emissions at low cost (e.g. < $50/mt$CO_2$), large scales (e.g. 170M ton/yr reduction in the U.S.) and with government oversite. This is to enact laws that require power companies to decarbonize electrical power generation. These companies typically do this by building new solar farms, new wind farms and new hydroelectric dams. And this causes less natural gas and less coal to be burned for electricity.

Already the state of California requires their power company to decarbonize power generation by approximately 3% each year. For example, if 50% of their electricity is green today, then 53% would be green after one year, 56% after two years, etc. If this was implemented at the federal level and increased to a rate of 6% each year, it would be possible to reduce emissions by approximately 170 million tons each year for approximately 9 years, and do the Green Line at the lowest cost.

Transportation is Not Ready to Decarbonize at Large Scales and Low Costs

The U.S. currently makes approximately 1 million EVs each year and each EV reduces CO_2 approximately 3.5 tons a year. This reduces CO_2 emissions by 3.5 million tons each year (1M x 3.5mt) and is far short of the 170 million needed to get to zero over several decades. In other words, we currently have a Scale problem with transportation. One might look at increasing production; however, this would entail trying to keep the cost of rare materials down as increased consumption makes them more rare.

According to the U.S. Government, the average EV cost $0.47/mile, the average gas car cost $0.30/mile, the average EV emissions is 179gCO_2/mile (grams of CO_2 emissions per mile), and the average gas car emissions is 425gCO_2/mile. One can do a little math to calculate decarbonization cost of $691 per metric ton of CO_2 reduced (($0.47 - $0.30) / ((0.425 - 0.179) / 1000)). In other words, transportation currently has a Decarbonization Cost problem.

Heat Driven Manufacturing is Not Ready to Decarbonize at Large Scales and Low Costs

Many manufacturing processes use high-temperature heat to make chemicals (e.g. hydrogen, ammonia) and to make materials (e.g. plastics, metals, ceramics, glass, cement).

One can replace heat made by burning coal or natural gas with heat made with green electricity. However, as discussed in the CCS chapter, this cost ~$140 per metric ton of CO_2 reduced when replacing heat made with natural gas, and ~$80/mt$CO_2$ when replacing heat made with coal.

Decarbonizing electrical power generation (e.g. building solar farms and wind farms) typically costs $10 to $50/mt$CO_2$. In other words, if one is paying money to reduce CO_2 in the near future, they would probably favor decarbonizing electrical power generation over heat driven manufacturing since it costs less. And after electrical power generation is decarbonized, society is likely to tackle material and chemical fabrication at large scales.

Tracking Systems Are Needed

If we had a market for green cement (i.e. made without emitting CO_2) and non-green cement, then "entrepreneurs" would move the lower cost non-green cement to a green cement warehouse (at 3am). Economists refer to this as "shuffle". In other words, it is easier to claim a product is green, than to actually make a green product. To deal with this, one would need an international system that tracks the production, transportation, storage and consumption of materials and chemicals. This system does not exist; however, in theory, it could be developed. Electricity does not have this problem since electrical power meters and anti-tamper laws are already in place.

Two Phase Decarbonization Strategy

If the U.S. wanted to reduce 170M tons each year over 30 years at the lowest cost, it would end up with two decarbonization phases. Phase I would be approximately 9 years and would be achieved mostly with electrical power decarbonization. And the following 21 year Phase II would involve other areas that are more costly. To better prepare for Phase II, one could do more R&D during Phase I.

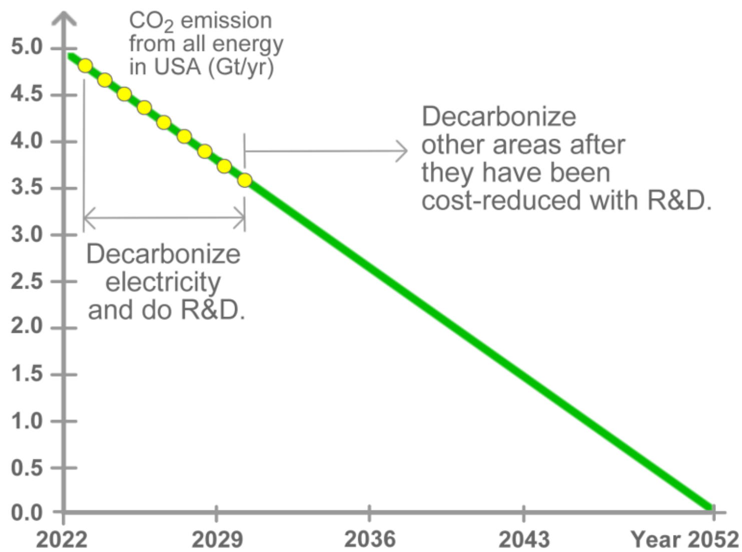

Figure 3.2: Two Phase Decarbonization Strategy.

What Does this Cost?

Yet how much would this cost the consumer? The answer is complicated since required decarbonization would result in reducing the consumption of natural gas, and this would cause the price of this fuel to decrease. And savings from lower fuel costs would offset the cost of building more solar farms and wind farms. Yet to what extent?

To get an accurate assessment one would need government engineers to calculate the impact of specific decarbonization legislation on fuel price. In theory, lawmakers can request this; however, government engineers' ability to satisfy requests is limited by their time. For an example of what a request might look like, visit www.APlanToSaveThePlanet.org/study

If one does *not* model the impact on fuel price and one decarbonizes at $40-per-ton of CO_2 reduced, for example, then 170M tons would cost the U.S. $7B in year #1 (170Mt x $40), 340M tons would cost $14B in year #2, 510M tons would cost $21B in year #3, etc. This would cost each U.S. citizen $20 in year #1 ($7Bt / 330M population), $40 in year #2, $60 in year #3, etc. In the typical case, this would pay the mortgage on new solar farms and new wind farms, minus the cost of carbon-based fuel that was not burned due to being replaced with green electricity. Ultimately, these costs would appear as an increase in the cost of goods and services.

	Year 1	Year 2	Year 3
Cost/Person/Yr	$20	$40	$60
CO_2 Reduced	170M tons	340M tons	510M tons

Figure 3.3: Decarbonization cost per person per year.

Decarbonize in Lowest Cost Order

In theory, one can tackle climate change in the lowest cost order. For example, tackle \$10/mtCO_2 projects first, followed by \$13/mtCO_2, etc. If one uses the fruit analogy, this entails consuming the lowest hanging fruit first, followed by the layer above.

Evidence of climate change increases each year; therefore, tolerance of decarbonization costs are also likely to increase. To decarbonize, costs need to stay below tolerance of costs as one goes through time. For this reason, decarbonizing in lowest cost order might be required by the public.

There are not enough Democrats from U.S. states who benefit economically from decarbonization; therefore, a real climate law would need support from Republicans concerned about climate.

Republicans only support lowest cost decarbonization. For example, they oppose gov't intervention that promotes: (a) residential solar, (b) electric cars, and (c) restrictions on oil drilling. These reduce CO_2, yet not at lowest cost. In effect, Republicans require lowest cost order; and their support is required to form a majority.

What does a Real Climate Law Look Like?

A federal law that decarbonizes in lowest cost order might consists of three main provisions:

1. CO_2 emissions from human activity are *required* to decrease to zero, over 30 years, at a constant rate, at the lowest cost, and in lowest cost order (i.e. follow the Green Line).
2. U.S. electricity is *required* to decarbonize at 6% per year, over a period of 9 years, at lowest cost. For example, 38% of electricity is made without emitting CO_2 today, 44% after year #1, 50% after year #2, etc. In other words, power companies are required to build more solar farms, more wind farms, etc.
3. A new R&D laboratory is set up to further reduce decarbonization costs.

Political Support

As of this writing, political support for a real climate law does not exist. However, as evidence of climate change increases each year, it is likely significant climate legislation will appear some time this decade.

Planet Saving Websites

Suppose a region is considering decarbonizing X% of electricity each year over a period of Y years. To assess impact, one would need to calculate: (a) lowest cost approach, (b) amount of CO_2 reduced, (c) cost per ton of CO_2 reduced, (d) cost per person per year, (e) savings due to lower fuel price, (f) number of jobs gained and lost, and their locations.

Currently, this information is not easily obtained. Therefore, a website is needed that calculates the above parameters after the user specifies X, Y, and region.

Doing detailed modeling for all nations, regions, and metropolitan areas worldwide might cost many millions of dollars. However, without this website, lowest-cost global decarbonization might be impossible.

What to Do If Your Competitor's Factory Costs Zero Dollars

Reports often compare the cost of a green product with its carbon-based counterpart when both production factories are built from scratch. However, this typically does not occur when decarbonizing. Instead, the carbon-based factory is already built and paid for. And we would like the new green factory to cost less than the incremental cost of operating the old factory. In most cases, new green fails economically against existing carbon. This is one reason why economists' CO_2 predictions are so dour.

In theory, new laws could require decarbonization, with additional costs passed onto consumers. The public is not comfortable with these at this time; however, it is likely they will appear this decade due to increasing evidence of climate change. To prepare for that day, one can do R&D to reduce decarbonization costs via automation and standardization, both in factories and at heat-driven industrial processing sites.

Multiple R&D Moonshots

A "moonshot" refers to a large R&D initiative that is implemented over a relatively short period of time. In theory, multiple moonshots could be done to reduce decarbonization costs. They would probably focus on areas that are currently not being worked on, and have potential for significant impact.

One might proceed with the following steps for each initiative: (a) establish goal, (b) write several page summary, (c) pay researchers approximately $10K each to write proposals to implement that described in summary, (d) spend several million dollars on initial R&D, and (e) proceed with more proposals and more money if project appears economically and technical viable.

A foundation, government or wealthy individual might set up a $500K fund that supports 50 proposals, for example. Also, they might require proposals be open-source, which means they would appear publically for anyone to use for free, to reduce further dependence on authors.

New green infrastructure is likely to cost 100 trillion dollars globally over several decades. Therefore, spending additional billions of dollars on R&D, to save trillions, is reasonable.

Always Begin with Plan

Plan writing forces one to break a problem down into component parts, put together a solution for each, and make sure each solution is feasible. With climate change, this entails putting together an economic strategy, a political strategy, and a technical strategy. Economic strategy involves decarbonizing at the lowest cost. Political strategy involves groups that have at least 51% political support who benefit from lowest-cost decarbonization. And technical strategy involves reducing decarbonization costs with more R&D.

The world has not had a plan to tackle climate change in the past, and this has led to wasted time and money.

Business schools and engineering schools teach "Always begin with a plan".

We should apply this to climate change.

You Can Save the Planet Too!

Governments, foundations and researchers can develop plans to save the planet too. To make this easier, this book's original Microsoft Word file, spreadsheets, and illustrations are available to copy and modify for free at www.APlanToSaveThePlanet.org/open

If a plan involves more R&D, it might include a business plan for a new laboratory. For an example, visit www.APlanToSaveThePlanet.org/lab

If a plan involves a new federal law, it might include a one page summary and another document that explains why this is the easiest way to solve the problem. For an example, see www.APlanToSaveThePlanet.org/da202x

If a plan involves a website that calculates the cost and impact of decarbonize policy, it might include an open-source proposal to develop this tool. For an example, see www.APlanToSaveThePlanet.org/study

4. Tackling Climate the *Wrong* Way

Tackling climate change "the wrong way" involves doing so at high costs, low scales, and without broad political support.

Past U.S. Decarbonization Efforts Have Been Deficient

The amount of U.S. green electricity as a percentage of total increased from 35% to 37% over the last 5 years. In other words, U.S. electricity is decarbonizing at a rate of 0.5% each year ((37.6% - 35.4%) / 4yrs). Alternatively, if the U.S. fully decarbonized its electricity over 10 years, for example, this increase would need to be 6% each year ((100% - 38%) / 10yrs)). Other countries, like China, are similar.

Future U.S. Decarbonization Efforts are Expected to be Deficient

The U.S. Energy Information Administration (EIA) is an organization within the U.S. government that studies energy and CO_2 emissions. They expect CO_2 emissions over the next 30 years to remain approximately constant, as shown in the graph below. In other words, according to the U.S. government, the U.S. is not reducing CO_2 emissions to zero. Other countries are similar.

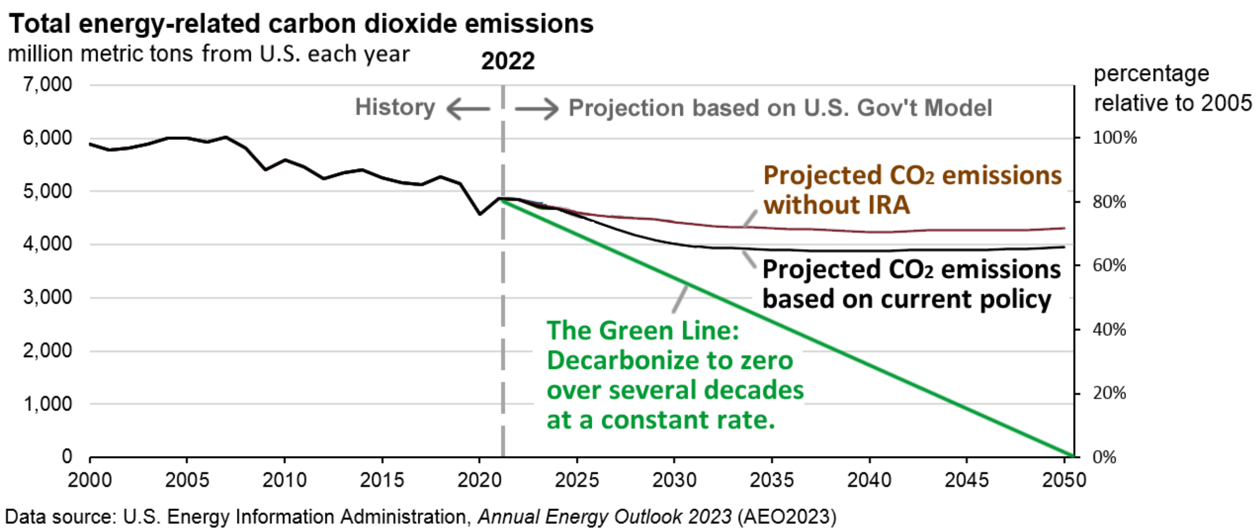

Figure 4.1: U.S. government's official projection of CO_2 emissions from the U.S. over the next 30 years in units of billions of tons each year

The reader may have seen decarbonization scenarios that show CO_2 emissions dropping to zero over several decades. These show what would happen if decarbonization did occur, an example of which is the Green Line in the previous graph. Projections, on the other hand, are based on existing laws and observed behavior.

Decarbonization does Not Occur Unless Required by Law

If a consumer has a choice between buying a product that emits CO_2, and buying a product that does not, they often ignore CO_2 and select the lower cost option. Many people consider their own CO_2 to be insignificant, and prefer the world's other inhabitants buy green and pay more. This is observed behavior, and is consistent with economic theory. Subsequently, to do the Green Line, decarbonization would need to be required by law.

The Prisoners Dilemma Problem

A person, city, state or nation can decarbonize to zero while CO_2 emissions from the rest of the world causes them harm. In other words, eliminating one's own CO_2 has close to no impact. Subsequently, many people are not inclined to incur additional decarbonization costs. Economists refer to this as a "prisoner's dilemma" problem.

The trade deficit between the U.S. and China is an example of prisoner's dilemma. Americans complain about the deficit while buying Chinese made products at Walmart. In response, U.S. manufacturers occasionally promote "Made in USA". However, this is largely ignored. In other words, consumers favor lowest cost since one person buying American-made has close to no impact.

The Rising Global GDP Problem

If 100% of global infrastructure was replaced over 30 years at a constant rate, for example, then 3.3% would be replaced each year (100% / 30yrs). Global gross domestic product (GDP) increases approximately 3% each year. Therefore, to keep up with GDP growth and decarbonization, one would need to build green at a rate of 6.3%/yr (3% + 3.3%). This is not happening, and this is one reason why global CO_2 emissions are increasing.

Carbon Offsets, Not Really

Many companies want to report they emit little or no CO_2. To do this, they pay organizations to supposedly reduce CO_2 emissions, to offset their own emissions. These are referred to as "carbon offsets", and they often sell for $3 to $5 per metric ton of CO_2 reduced.

Unfortunately, there are many offset schemes that are economically invalid, scientifically invalid, or fraudulent. For example, if someone is paid to not do tree farming on one parcel of land, to supposedly reduce CO_2, tree farming will be done elsewhere. This is due to lumber production being set by demand. In other words, if one parcel of land is blocked, the home builder will get his 2x4 boards from a different parcel of land.

Some schemes supposedly reduce CO_2 by planting trees. However, this only works if the trees and their offspring persists for thousands of years at no additional cost, which is often unlikely.

Capital needs to flow to where it is needed most. Therefore, government should consider shutting down schemes with inaccurate claims.

Corporate Social Responsibility, Not Really

Some companies buy carbon offsets that match their own CO_2 emissions. This is referred to as "net zero," and it is often done to appear more socially responsible. Also, these companies must decide if they want to pay more, and be at real net zero, or pay less and be at less than net zero. For example, a company that emits 10 million tons of CO_2 each year could buy $15-per-ton real offsets for $150M each year, or $3-per-ton fraudulent offsets for $30M. In both cases, they report net zero. However, in the latter case, their profit is $120M higher.

Replace Carbon, Do Not Block Carbon

Environmentalists sometimes advocate restricting the production of carbon-based fuels. For example, they might advocate reducing the number of drilling permits for natural gas. At first glance, this might seem reasonable. However, it does not reduce CO_2 at the lowest cost. Instead, it leads to fuel shortages, high fuel prices, inflation, high-interest rates, and increased risk of recession.

To decarbonize at the lowest cost, one must build a solar farm or a wind farm *before* reducing the output of the nearby carbon-based power plant. In other words, replace carbon, do not block carbon.

Block vs. Replace

Now, let's compare block with replace. Suppose we block carbon and create an oil shortage that causes the price to increase by $10 per barrel. The U.S. consumes 7.2B barrels each year; therefore, this would cost $72B each year.

Alternatively, one could use the $72B to build solar farms. They cost approximately $1.12-per-watt (CAPEX, NREL, 2022). Therefore, one could build 64GW of solar with $72B ($1.12 x 64GW). Over a year, they typically produce 2,334 watt-hours of electricity for each watt of capacity. Therefore, this would produce 149 TWh of electricity each year (64GW x 2,334).

When one replaces 1 TWh of natural gas based electricity with green electricity, CO_2 emissions decrease by 0.41 million tons. Therefore, this would reduce CO_2 by 61 million tons each year (149 TWh x 0.41 $MtCO_2$).

One can typically sell electricity wholesale for approximately $0.03/kWh. Therefore, this solar farm would produce 4.5 billion dollars of revenue each year for 30 years ($0.03 x 149e12 x 0.001). What would you prefer?

a) Pay $72B with little benefit.
b) Pay $72B to reduce CO_2 by 61Mt/yr and receive $4.5B/yr for 30 years.

Creating a shortage that increases price is almost always a terrible way to solve a problem.

Subsidizes Are Not Efficient

Consumers typically disfavor green products because they cost more. However, in theory, government can change this by paying a portion. This is referred to as a “subsidy” and it is typically implemented with a percentage of electricity revenue or percentage of equipment cost that are offset with a tax credit.

The goal is to cross over a tipping point where the subsidized green product costs less than the carbon-based product. This works fine in theory; however, prices of both green and carbon-based products typically vary over time and place. For example, the price of natural gas in the U.S. varied between 2¢ and 4¢/kWh between 2017 and 2021 (i.e. fuel cost per kWh of electricity) and was 20% more in California than nearby Utah.

Due to these fluctuations, fixed subsidies are often not helpful, or are too helpful. For example, if the green premium starts at +1.5¢ (i.e. difference between green product and carbon-based product), then lowering it to +0.5¢ with a 1¢ subsidy still does not make the green product cheaper. Or if the green premium starts at +0.5¢, then lowering it to -0.5¢ with a 1¢ subsidy wastes public money.

Subsidizing electricity is tricky since natural gas consumption decreases when it is replaced by renewables. And this causes its price to decrease, which causes the green premium to increase, which leads to an ineffective subsidy. In other words, if the subsidy is working, it will eventually stop working.

Taxes Are Not Efficient

Taxes designed to change behavior are often inefficient. For example, a 0.1¢ tax on non-green electricity (per kWh) will not reduce much CO_2 if the green premium is 1¢ (i.e. the subsidized price is still 0.9¢ away from the tipping point). However, the market is forced to incur an additional 0.1¢ expense, which ultimately leads to a high decarbonization cost.

Required Electricity Decarbonization is the Lowest Cost Approach

Instead of subsidies or carbon taxes, one can require power companies to obtain more green electricity each year. This avoids the above-stated problems, and power company engineers can implement at the lowest cost. Already, many U.S. states have green electricity requirements. They are commonly referred to as "Renewable Portfolio Standards" (RPS). However, they are not federal and are often undersized relative to what is needed.

Our *Economic* Decarbonization Strategy Is Flawed

The current economic decarbonization strategy is to encourage individuals, companies, cities, and states to reduce CO_2 emissions. At first glance, this might seem reasonable. However, it is flawed since these entities rarely have the physical ability to do this at the lowest cost. This is like asking a city mayor to build a car from scratch in the local shop. Can he do it? Yes. However, it might cost him 100 times more than factory mass production. Instead, the mayor should let the automobile industry handle mass production in the same way we should let power companies decarbonize at massive sales and at lowest costs.

Here's another example. Imagine trying to place 20 solar panels onto a million different homes. One would incur project overhead cost a million times (e.g. customer acquisition, system design, permitting, inspection, etc.). Alternatively, if one installs 20 million panels at a large solar farm, they would not see overhead every 20 panels. This is why solar farm cost-per-unit-electricity is approximately 3-times less than residential solar.

Decarbonization Politics

There are two kinds of regions -- those that produce and export carbon-based fuels, and those that import fuels. One might think of these as *fuel exporters* and *fuel importers*.

In many cases, regions that produce a fuel will not politically support eliminating it.

Fuel *exporters* are hurt by decarbonization. However, the opposite is true for *importers*. They benefit in two ways:

1. Local green jobs are created when nearby wind and solar farms are constructed. This occurs while carbon jobs are lost elsewhere.
2. Money is saved when decarbonization causes fuel prices to decrease, due to less fuel consumption, due to decarbonization.

Fuel Producing Regions in the U.S.

The maps below indicate where fuels are produced in the U.S. Two-thirds of U.S. states do not produce natural gas or coal. In other words, more than half of U.S. lawmakers are not likely to resist significant electricity decarbonization.

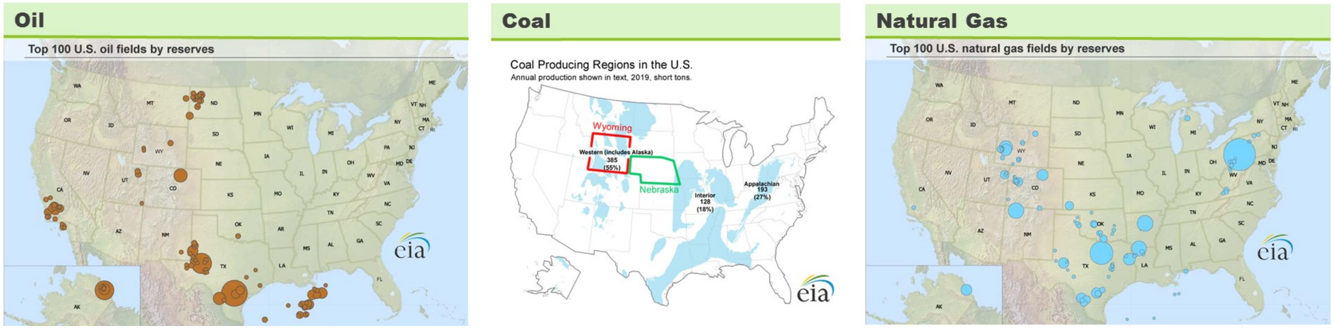

Figure 4.2: U.S. suppliers of oil, coal and natural gas.

Our *Political* Decarbonization Strategy Is Flawed

Existing decarbonization legislation in the U.S. was drafted by a political coalition of environmentalist, labor unions, domestic manufacturers, and the automobile industry. At first glance, this might seem reasonable. However, it is fundamentally flawed since labor and manufacturers must focus on their own financial interests, not getting to zero at the lowest cost.

Alternatively, to decarbonize electricity at the lowest cost, one would need a coalition of lawmakers that benefit from exactly that, lowest-cost electricity decarbonization. This is not labor or auto. Instead, this would be the two-thirds of the U.S. states that import natural gas and coal.

The Hi-Jacking of Climate

Many organizations use climate to make money. For example, domestic manufacturers have encouraged government to subsidize the making of solar panels in the U.S. Unfortunately, making panels in the U.S. instead of China does not reduce CO_2. Ironically, many provisions within climate legislation do not reduce CO_2, or do not do so at the lowest cost. And instead they implement protectionism (i.e. favor domestic manufacturers over foreign).

Lawmakers Need to Be Better Informed

To fix the climate problem, federal lawmakers need to realize three things:

a) Lawmakers need to lead (e.g. require electricity decarbonization and more R&D) instead of delegate to cities, states, companies, and domestic manufacturers.

b) In order to gain the support of Republicans concerned about climate, decarbonization legislation must rely on R&D and on markets (e.g. builders of solar farms and wind farms compete with each other to drive down costs).

c) Majority support is likely to come from regions that import carbon-based fuel.

5. Document History

This document draws its inspiration from a book entitled *A Plan to Save the Planet* by Glenn Weinreb.

For a free PDF file of this book, visit www.APlanToSaveThePlanet.org/pdf

For a TEDx video summary, search "KIJsu2n5j1w" at YouTube.

For YouTube videos by Weinreb, see www.YouTube.com/@GlobalClimateSolutions

Open-Source

To the author's knowledge, the concepts discussed in this document are public knowledge and no patents are pending.

For original files, visit www.APlanToSaveThePlanet.org/da202x

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