Proposal to Develop On-Line Climate Policy Making Tools

By Glenn Weinreb

1 The Climate Solution

This document is a proposal to develop website-based tools that help lawmakers understand the cost and impact of various decarbonization policies. Chapters 1 of this document summarizes the climate problem and how one might approach it, while other chapters propose the development of policy-making tools. Chapters 3, 4 and 5 focus on reducing CO_2 from electrical power generation, while later chapters focus on reducing CO_2 from all energy-related sources.

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

1.1 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.

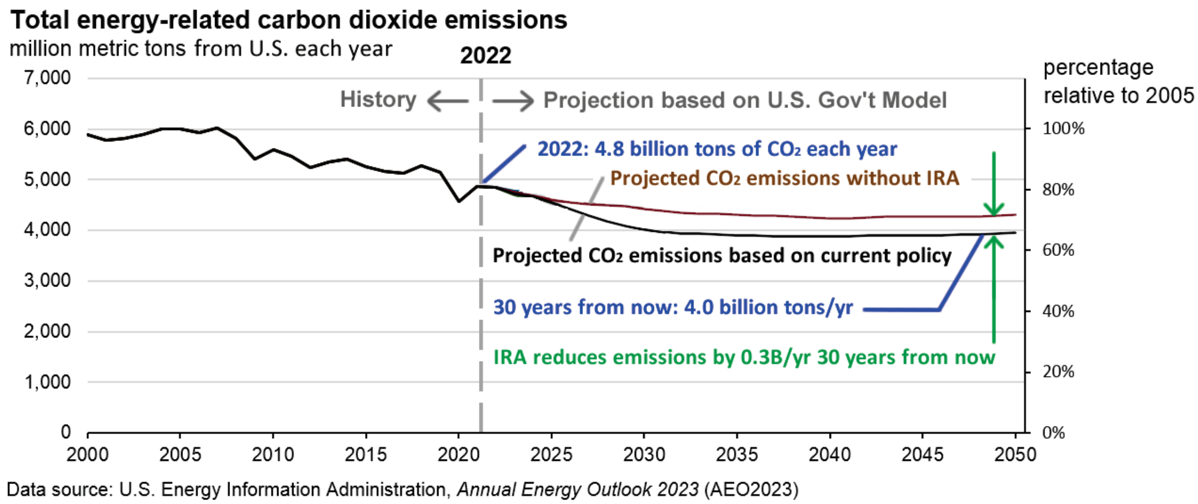

Figure 1.1: U.S. government's official projection of CO_2 emissions from the U.S. over the next 30 years in units of billions of tons each year.

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.

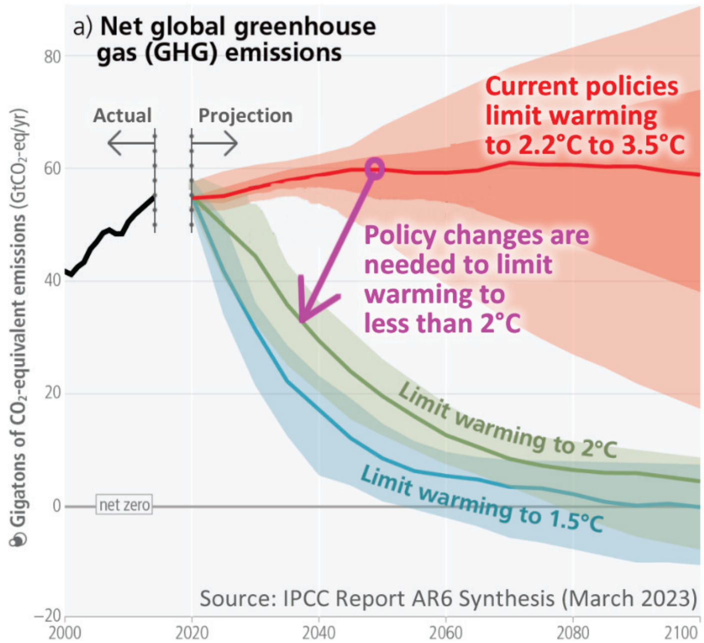

Figure 1.2: Impact of global CO_2 emissions over next 80 years.

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.

1.2 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.

1.3 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?"

1.4 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.

1.5 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. 1/30th 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.

1.6 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.

For more information on climate solutions, click here.

2 Calculating Cost and Impact of Climate Policy

2.1 Climate Policy Modeling

To calculate the effect of U.S. decarbonization legislation, one typically needs help from engineers at the U.S. Energy Information Administration (EIA) and the U.S. National Renewable Energy Laboratory (NREL). In theory, U.S. lawmakers can request a graph that shows projected U.S. CO_2 emissions, with and without a government initiative. The difference between the two is the effect of the initiative. A theoretical example is shown below.

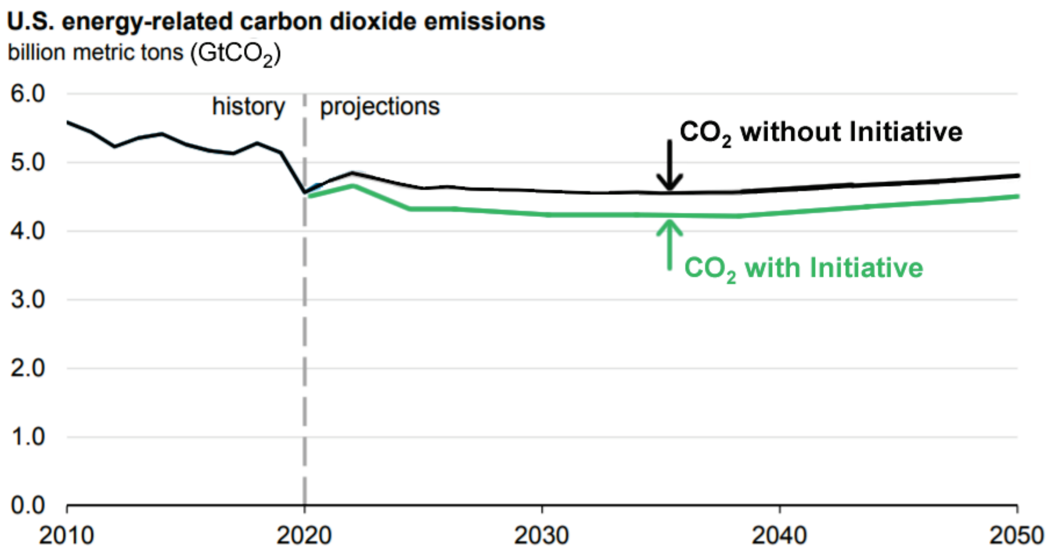

Figure 2.1: Conceptual projection of CO_2 emissions, with and without a decarbonization initiative.

The *difference* between the two plots is the amount of CO_2 reduced each year due to the initiative (e.g. $GtCO_2$/yr). And one can divide this difference by the cost of the initiative ($/yr) to calculate the cost to reduce emissions by one ton of CO_2 ($/$mtCO_2$). Also, one can divide cost ($/yr) by population to calculate cost-per-person-per-year ($/person/yr).

One can calculate cost and impact of many different initiatives. For example, "What happens when 5% of electricity is decarbonized each year?" Or 3% each year? In theory, multiple reports can identify how to get to zero at the lowest cost.

2.2 Change the Climate with a Website

A website could potentially analyze different policies in different countries. For example, it could look at what happens when electricity is required to decarbonize at X percent-per-year at lowest cost, over Y years, in country Z. Anyone with a web browser could then specify X, Y, and Z and instantly see cost and impact.

The website could also support individual states and metropolitan areas. For example, state and city officials might want to see the cost and impact of different amounts of required decarbonization.

Calculation models already exist. For example, the U.S. government has a model called "NEMS", and it can be downloaded for free. However, website user interface, support for user input, and support for different regions is lacking.

2.3 Trust is Required

Many models are not trusted and are subsequently ignored. However, much can be done to elicit trust. This includes: (a) building on top of existing models that are already trusted by government, (b) collaborating with government engineers, (c) requiring materials be made open source, (d) paying scientists to review models, (e) requiring reviews be made public, and (f) paying others to copy and improve.

Developing a trusted system might cost 10-times more than developing an ignored system.

2.4 Some Regions Make Money by Decarbonizing

Modeling different cities and regions is important since some make money by decarbonizing locally, and these need to be identified. For example, pipes that carry natural gas into the city of Boston, MA, USA are too small. And this has created a regional natural gas shortage, which has increased the price of natural gas and electricity. If Boston decarbonized electricity, the local price of natural gas and electricity would probably decrease.

States that *import* carbon-based fuels would probably benefit from lower fuel prices, and are therefore more inclined to support significant decarbonization. The same is true with nations that import fuel. For this reason, it would be helpful to have a website that identifies cities, regions and nations that benefit from decarbonization. These would then be more inclined to decarbonize locally, and to form coalitions that favor decarbonization.

One might begin by modeling green electricity subsidies (e.g. subsidize green electricity by X ¢/kWh) and green electricity requirements (e.g. electricity is required to decarbonize at Y %/yr). And calculate cost of initiative, cost-per-person, tons of CO_2 emissions reduced, decarbonization cost ($/mt$CO_2$), natural gas price, coal price, savings-per-person due to cheaper fuel, savings-per-person due to cheaper food, number of carbon jobs-lost, number of green jobs-added, and locations of lost and added jobs.

2.5 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, so that customers can 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 “Automate the Construction of Power Transmission Towers” in this document.
- 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.

2.6 Climate Policy Making Tools Help Lawmakers Reduce Costs

Significant decarbonization would be more feasible if voters had a better sense of cost-per-person and lawmakers had a better sense of how jobs-gained offset jobs-lost. Or in the case of regions that import fuel, how job-gained are local, and jobs-lost are elsewhere.

Creating databases, models, and simulations for many regions worldwide and many policy options might seem expensive. However, the alternative is to encourage people, companies and regions to decarbonize. And these entities rarely have the ability to do so at the lowest cost. In other words, it is probably less costly to accurately model lowest-cost decarbonization, and have these models drive policy, than to operate blindly and pay more. Also, high-cost decarbonization puts one at risk of paralysis due to fatigue, before achieving significant results.

3 Electricity Power Decarbonization - WEBSITE

It is proposed that a website be developed that calculates the cost and impact of decarbonizing electrical power generation. An illustration of what this might look like is shown below.

National Electrical Power Decarbonization Calculator

Calculate cost and impact of electrical power decarbonization. This mostly entails replacing natural gas & coal based electricity with solar/wind farms, hydroelectric dams, nuclear, etc.

U.S.	Nation	*Pull-down menu selects a country (e.g. U.S., China, Japan)*
5%	Amount of electricity decarbonized each year. For example, if 40% is green today and one increases 5%/yr, then 45% would be green after yr #1, 50% after yr #2, etc.	
1.66	Maximum decarbonization growth rate per year.	
90%	Stop decarbonizing electrical power generation when this amount of total electricity is made without emitting CO_2.	

Report: *Pull-down menu:*

- ◦ CO_2 emissions from all energy sources (e.g. cars + electricity + burn fuel 4 heat)
- ◦ CO_2 emissions from electrical power generation (e.g. burn fuel for electricity)
- ◦ Natural Gas Consumption
- ◦ Natural Gas Production
- ◦ Coal Consumption
- ◦ Coal Production
- ◦ Electricity Consumption
- ◦ Electricity Production
- ◦ Energy Jobs

Report Scope: (◦) Entire Nation
( ) Region: Colorado *Pull-down menu selects U.S. state (e.g. Florida, Oregon, Texas)*

Report Value: (◦) Absolute quantities
( ) Change due to decarbonization

Export Data -- Press button to download decarb data.

Report Quantity: (◦) Entire Region per year
( ) Per person per year

Place one of 9 different Reports here...

This website analyzes annual electrical power decarbonization increments of 0%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9% and 10% ("11 decarbonization scenarios"). For example, if 40% of U.S. electricity is green today (i.e. generated without producing CO_2) and increment is set to 5%, then 45% would be green after one year, 50% after two years, 55% after three years, etc.

As of February 2023, U.S. decarbonization is in part driven by a subsidy on green electricity (e.g. investment tax credit). However, in this website, we assume green electricity subsidies do not exist. And we do not specify what drives the above stated decarbonization legislatively. There are several possibilities; however, these are not relevant to this study. Instead, we focus on impact that electricity decarbonization has on: (a) price of natural gas and coal, (b) cost of greener electricity, (c) and number of jobs gained and lost, and where. In other words, this study identifies who benefits and who loses from decarbonization, and to what extent.

Website controls are summarized as follows:

[Nation] Specifies nation (we begin with the U.S.).

[Increment] Specifies annual electricity decarbonization increment (i.e. 0% ... 10%).

[Max Growth] Annual construction of solar farms and wind farms cannot increase significantly over a short period of time without incurring shortages that drives up costs. For this reason, lawmakers might want to limit the amount of decarbonization growth each year. For example, if 1% of total electrical power is currently decarbonized each year, and one wants to increase this to 6% each year without shortages, then one might want to limit growth by 1.66 each year (i.e. decarbonize 1.66% of electricity in year #1 (1% x 1.66), 2.7% in year #2 (1% x 1.66^2), 4.5% in year #3 (1% x 1.66^3), and 6% in subsequent years).

[Stop Decarb] Electricity decarbonization stops when this level is reached. Lawmakers might prefer to stop at less than 100% due to the high costs associated with the last 15%.

[Report] Specifies one of nine different reports that are displayed under the controls. The next chapter describes each report.

[Report Scope] Specifies which region is reflected in the report (e.g. entire U.S. or one U.S. state).

[Report Value] Specifies: (a) absolute units or (b) additional amount due to decarbonization. For example, with number of green jobs, one can display (a) total number of green jobs per region, or (b) subtract decarbonization scenario 0% case from the N% to show *additional* green jobs due to decarbonization.

[Report Qty] Specifies data units to be one of: (a) amount per region per year, or (b) amount per person per year.

[Export Data] Button that downloads Excel Workbook to end user's computer. This contains data that reflects one of 11 scenarios (0%…10%). For details, see Chapter 5.

4 Electricity Power Decarbonization - REPORTS

The website's [Report] pull-down menu selects one of nine different reports, described below.

4.1 CO_2 emissions from all energy sources (e.g. cars + electricity + burn fuel for heat)

Annual CO2 emissions	[Report Value] selects one of:	[Report Quantity] selects one of:
from all energy sources (GtCO2/yr)	a) absolute amount	a) total from [Report Scope]
e.g. cars + electricity + indust. Process	b) reduction due to decarbonization	b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

4.2 CO_2 emissions from electrical power generation (e.g. burn fuel to make electricity)

Annual CO2 emissions	[Report Value] selects one of:	[Report Quantity] selects one of:
due to electricity only (GtCO2/yr)	a) absolute amount	a) total from [Report Scope]
	b) reduction due to decarbonization	b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

4.3 Energy Jobs

Energy Jobs	[Report Value] selects one of:	[Report Quantity] selects one of:
i.e. green+coal+natural gas	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per 1K people from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Green Jobs	[Report Value] selects one of:	[Report Quantity] selects one of:
	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per 1K people from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Natural Gas Jobs	[Report Value] selects one of:	[Report Quantity] selects one of:
	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per 1K people from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Coal Jobs	[Report Value] selects one of:	[Report Quantity] selects one of:
	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per 1K people from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

4.4 Electricity Consumption

Electricity Price (wholesale $/kWh)	[Report Value] selects one of:	[Report Quantity] selects one of:
	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Electricity Consumption (TWh/yr)	[Report Value] selects one of:	[Report Quantity] selects one of:
	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Cost of Consumption ($/yr)	[Report Value] selects one of:	[Report Quantity] selects one of:
	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per person from [Report Scope]

This reflects interests of consumers. They prefer to pay less.
Consumer cost and revenue differ by export (e.g. state produces $1B/yr, consumes $0.2B/yr and exports $0.8B/yr).

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

4.5 Electricity Production

Electricity Price (wholesale $/kWh)	[Report Value] selects one of:	[Report Quantity] selects one of:
	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Electricity Production (TWh/yr)	[Report Value] selects one of:	[Report Quantity] selects one of:
	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Revenue from Production ($/yr)	[Report Value] selects one of:	[Report Quantity] selects one of:
	a) absolute amount	a) total from [Report Scope]
	b) decrease/increase due to decarbonization	b) per person from [Report Scope]

This reflects interests of producers. They prefer revenue to increase.
Consumer cost and revenue differ by export (e.g. state produces $1B/yr, consumes $0.2B/yr and exports $0.8B/yr).

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

4.6 Natural Gas Consumption

Natural Gas Price (wholesale $/mcf)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Natural Gas Consumption (mcf/yr)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Cost of Consumption ($/yr)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

This reflects the interests of the Consumers. They prefer to pay less for product.
Consumer Cost and Producer Revenue differ by Export (e.g. state Produces $1B, Consumes $0.2B and Exports $0.8B).

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

4.7 Natural Gas Production

Natural Gas Price (wholesale $/mcf)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Natural Gas Production (mcf/yr)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Revenue from Production ($/yr)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

This reflects the interests of the Producers. They prefer Revenue to increase.
Consumer Cost and Producer Revenue differ by Export (e.g. state Produces $1B, Consumes $0.2B and Exports $0.8B).

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

4.8 Coal Consumption

Coal Price (wholesale $/MMbtu)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Coal Consumption (MMbtu/yr)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Cost of Consumption ($/yr)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

This reflects the interests of the Consumers. They prefer to pay less for product.
Consumer Cost and Producer Revenue differ by Export (e.g. state Produces $1B, Consumes $0.2B and Exports $0.8B).

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

4.9 Coal Production

Coal Price (wholesale $/MMbtu)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Coal Production (MMbtu/yr)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

Revenue from Production ($/yr)	[Report Value] selects one of: a) absolute amount b) decrease/increase due to decarbonization	[Report Quantity] selects one of: a) total from [Report Scope] b) per person from [Report Scope]

This reflects the interests of the Producers. They prefer Revenue to increase.
Consumer Cost and Producer Revenue differ by Export (e.g. state Produces $1B, Consumes $0.2B and Exports $0.8B).

graph between now and when electricity is decarbonized to max specified rate (e.g. 90%)

5 Electricity Power Decarbonization - DATA

The [Export Data] button in the previously described website downloads an Excel Workbook to the end user's computer. This contains data that reflects one of the 11 decarbonization scenarios (0%…10%). More specifically, this data is based on the [Nation] and [Increment] controls. However, it ignores the [Report], [Report Scope], [Report Value], and [Report Qty] controls.

In Excel lingo, "Work<u>sheet</u>" refers to a tab at the bottom of the spreadsheet window, and "Work<u>book</u>" refers to multiple Work<u>sheets</u>. The created workbook includes multiple tables, one worksheet per table. And each table provides data on multiple regions within a nation over the next 30 years. More specifically, within each table, columns represent years, and rows represent regions within a nation. For example, if working with the U.S., the top row indicates the entire U.S. whereas the 50 rows under it represent individual U.S. states. Each table is described below.

5.1 Price of Coal ($/metric ton)

Price of coal, wholesale, delivered to electrical power generation plant, in units of dollars-per-metric ton.

Less consumption leads to a lower price, which helps regions that import, and hurts regions that export.

5.2 Price of Natural Gas ($/MMBtu)

Same as above, yet natural gas instead of coal, in units of dollars per million British Thermal Units (MMBtu), wholesale, delivered to electrical power generation plant.

The heat content (i.e. amount of heat per volume of gas) of natural gas may vary by location and by type of natural gas consumer, and it may vary over time. In the typical case, 1 MMBtu of heat is produced when burning 0.964 thousand cubic feet (Mcf) of natural gas (i.e. 27.3 cubic meters).

5.3 Annual Coal Consumption (metric tons/yr)

Same as above, yet annual coal consumption from *all* sectors (e.g. electrical power generation, burn coal to create heat for industrial processes, etc).

5.4 Annual Natural Gas Consumption (MMBtu/yr)

Same as above, yet natural gas instead of coal.

5.5 Annual Total Wholesale Cost of Coal, all sectors ($B/yr)

Same as above, yet total wholesale cost of all coal purchased over a year by all sectors. This is the number of dollars a region spends on coal each year and is calculated by summing the product of price and volume for each sector. For example, if coke/industrial/commercial/electricity sectors are paying $120/$80/$60/$40 per tonne on average, and annual consumption is 17/25/1/502 million tonne per sector, then total annual consumption would be ($120*17 + $80*25 + $60*1 + $40*502) million dollars (i.e. $24.1B).

Less consumption leads to a lower price, which helps regions that import, and hurts regions that export.

5.6 Annual Total Wholesale Cost of Natural Gas, all sectors ($B/yr)

Same as above, yet natural gas instead of coal.

5.7 Consumer Savings from Lower Coal Price and Less Consumption Due to Decarbonization ($B/yr)

With the previous cost of coal data, subtract the N% decarbonization scenario (i.e. 1%...10%) from the 0% scenario to calculate the amount of money saved by coal consumers due to buying less coal, and buying coal at a lower price.

5.8 Consumer Savings from Lower Natural Gas Price and Less Consumption Due to Decarbonization ($B/yr)

Same as above, yet natural gas instead of coal.

5.9 Average Wholesale Price of Electricity ($/kWh)

Calculate wholesale price of electricity in $/kWh units. This reflects the price of grid-based electricity that becomes greener due to decarbonization.

5.10 Annual Electricity Consumption (TWh/yr)

Calculate amount of electricity consumed each year, wholesale, in units of TWh-per-year.

5.11 Annual Wholesale Cost of All Electricity ($B/yr)

Calculate wholesale cost of all electricity consumed each year. This is calculated by multiplying the above price data by the above volume consumption data (i.e. $/kWh x TWh/yr = $B/yr)

5.12 Additional Cost of Greener Electricity Due to Decarbonization ($B/yr)

With the previous annual electricity wholesale cost, subtract the 0% decarbonization scenario from the N% scenario to calculate the additional money spent by consumers to get greener electricity.

5.13 Net Additional Decarbonization Cost ($B/yr)

Combine the following data to calculate *net* additional cost (or savings which show up as a negative number) due to decarbonization from the point of view of consumers: (a) additional money spent on greener electricity by consumers, (b) money saved by coal consumers (all sectors) due to lower coal price and less volume, (c) money saved by natural gas consumers (all sectors) due to lower natural gas price and less volume. The components need to be combined carefully since one does not want to double-count coal or natural gas that is consumed by electricity.

5.14 Net Additional Decarbonization Cost in units of $-per-person ($/yr)

This is similar to the above data; however data is displayed in units of dollars-per-person-per-year instead of dollars-per-region-per-year. One divides dollars-per-region-per-year by region-population to obtain dollars-per-person-per-year.

5.15 Additional Coal Jobs due to Decarbonization (# of jobs)

Calculate number of additional coal production jobs due to decarbonization (i.e. subtract 0% scenario from N% scenario since this is "additional"). This number would be negative since coal jobs would decrease due to decarbonization.

5.16 Additional Natural Gas Jobs due to Decarbonization (# of jobs)

Same as above, yet number of *additional* natural gas production jobs due to decarbonization.

5.17 Additional Green Energy Jobs due to Decarbonization (# of jobs)

Similar to above, yet number of *additional* green jobs due to decarbonization (e.g. from wind farms, solar farms, hydroelectric dams, additional power wires for green electricity, etc).

5.18 Additional Energy Jobs due to Decarbonization (# of jobs)

Similar to above, yet combine above 3 job types to calculate the total number of additional energy jobs due to decarbonization (i.e. coal jobs + natural gas jobs + green related jobs).

6 Decarbonization of All Energy Sources - WEBSITE

We currently burn natural gas, coal, and oil-based products to generate electricity, push vehicles, heat buildings, fabricate chemicals, and fabricate materials. This causes CO_2 to enter the atmosphere and warm the planet. In theory, these carbon-based fuels could be replaced with energy created by solar farms, wind farms, hydro-electric dams, and nuclear power plants.

It is proposed that a website be developed that calculates the cost and impact of national law that requires this replacement. More specifically, this websites looks at the effect of national law that requires regions within the nation to reduce CO_2 emissions from all energy sources by a specific amount each year (e.g. 0 to 10%). For example, if the U.S. government requires all U.S. states to reduce CO_2 by 3%/yr and a state is currently emitting 100 million tons CO_2 each year, then it would be required to emit ≤ 97%*100Mt/yr after year #1, ≤ 94%*100Mt/yr after year #2, etc.

This helps to understand the cost and impact of an encompassing region that requires internal sub-regions to decarbonize using their own methods. In theory, this could apply to the U.S. and its 50 states, Europe and its 44 countries, or China with its 31 provinces. We begin with the U.S.; however, this could be expanded to support more nations.

The previously described website looks at electrical power decarbonization required by a national gov't. Alternatively, the following website looks at sub-regions who define their own policy. This helps to resolve differences between regions. And helps to gain political support from national lawmakers who favor delegating to local lawmakers.

The proposed website has four sections:

National Requirement: User specifies nation and amount of required decarbonization each year. Also, one specifies when to stop decarbonization. For example, one might stop after reducing by 90% due to the high cost associated with the more difficult areas.

Regional Quota: User specifies region within nation and website calculates total emissions from region, and amount that they need to reduce each year (i.e. decarbonization “quota”).

Regional Policy: User specifies which decarbonization initiatives are enacted within region and their scale. For example, a region might require electrical power companies to decarbonize electricity with a 5% increment to meet their quota.

Regional Report: The website calculates the following for each decarbonization initiative: (a) millions of tons of CO_2 reduced each year, (b) percent of quota, (c) cost per tonne of CO_2 reduced, (d) cost per region per year, and (e) cost per person per year. Data is displayed in a table, and one looks for initiatives that sum to ≥ 100% of quota. Also, the user might favor initiatives that have a low cost per tonne of CO_2 reduced. An illustration of what this might look like is shown below.

Decarbonization Calculator for U.S. States

Calculate cost & impact of requiring states to decrease CO_2 from fossil fuels. This mostly entails replacing natural gas, coal, and oil-based products with solar farms, wind farms, hydroelectric dams, and nuclear (i.e. decarbonize electrical power, transportation, building heat, and material/chemical production).

Federal Decarbonization Requirement for States

3%	Amount of CO_2 from fossil fuels decarbonized each year relative to today. For example, if one decarbonizes 3% per year and 5B tons are emitted today, then one would emit 5B*97% after year #1, 5B*94% after year #2, etc.
90%	Stop decarbonizing after this level of CO_2 has been reduced relative to today.

State Quota

Iowa	U.S. State	*Pull-down menu selects a U.S. state (e.g. Florida, Oregon, Texas)*
100	Mt/yr	Current annual CO_2 emissions (i.e. millions of metric tons of CO_2 emitted each year)
3	Mt/yr	Required decarbonization (i.e. millions of annual tons of CO_2 reduced each year)

State Decarbonization Initiatives

☒ State requires electrical power generation to be decarbonized (e.g. RPS)

5%	Amount of electricity decarbonized each year. For example, if 40% is green today and one increases 5%/yr, then 45% would be green after yr#1, 50% after yr#2, etc.

☒ State provides free LED lightbulbs

☒ State requires new HVAC installations to support heating via electricity

State Decarbonization Performance and Cost   Year: 2024

Policy	Decarbonization (Mt/yr)	% of quota	Cost per tonne ($/mtCO$_2$)	Cost per U.S. state ($M/year)	Cost per Person ($/year)
Electrical Power	2.559	85.3%	$23	$58.86	$50.21
LED lightbulbs	0.015	0.5%	$830	$12.45	$0.06
Electric Heat Requireme	0.036	1.2%	$112	$4.03	$0.05
		87.0%		$75.34	$50.32

7 Modeling Assumptions

The proposed websites makes the following assumptions:

- Many nations already have decarbonization policies in place. This includes things like subsides on green electricity and carbon taxes. This website assumes these do not exist. We do this to make it clear what happens when specific policies are enacted. Alternatively, if one looks at the impact of one policy on top of another policy, then it is not clear what is being done by each policy.

8 Acknowledgments

8.1 National Energy Modeling System (NEMS)

U.S. Government energy and emissions modeling system (website, documents, report)

8.2 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

8.3 This Document is 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/study

8.4 Acknowledgments

We would like to thank Dr. Maurizio Di Paolo Emilio for editing material previously published in EETimes.com and PowerElectronicsNews.com. This document reprints some of this with the permission of publisher AspenCore.