Proposal to Build a Climate Solution Website

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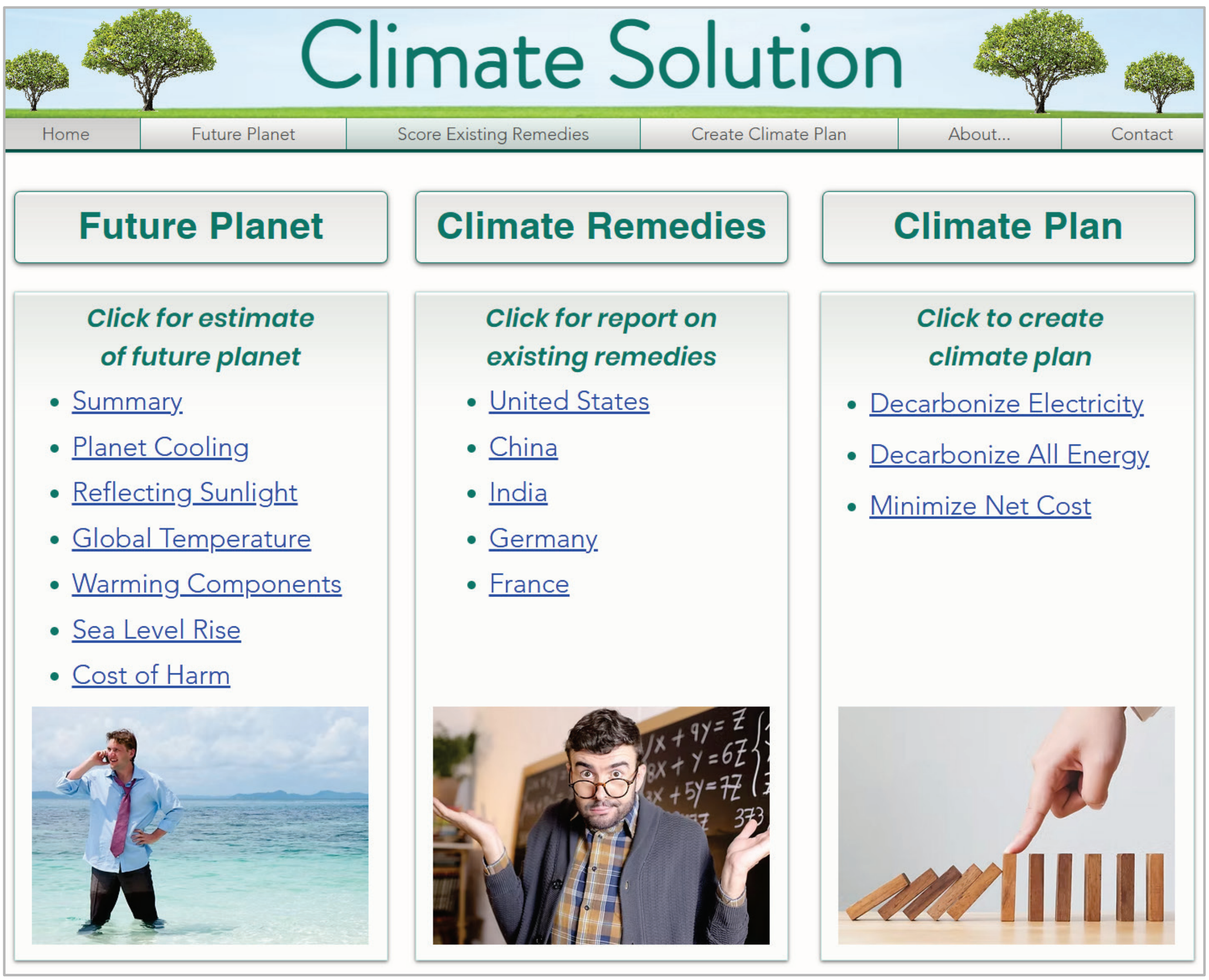
1. Executive Summary

To survive climate change, the public needs to understand the problem *and* the solution. This is difficult to describe in a document. Therefore, we propose a website be built that breaks the problem down into four parts:

Part 1	Score Climate Remedies:	*Quantify impact of decarbonization remedies*
Part 2	Generate Decarbonization Plan:	*Create plan that reduces CO_2 emissions*
Part 3	Assess Climate Situation:	*Summarize climate problem with several graphs*
Part 4	Generate Reflectivity Plan:	*Generate plan that increases atmosphere's reflectivity*

We call this website "Climate Solution," and we built a non-functional prototype that demonstrates the concept, pictured below. The document you are reading is open-source, which means anyone can copy (i.e., bifurcate), modify, and rename for free via the CC BY 4.0 license. For original files, click here.



Website Part 1 - Score Climate Remedies

From an economics perspective, decarbonization involves initiatives that reduce CO_2 emissions. Each initiative has a cost to society, and an amount of CO_2 that is reduced. One can divide these two numbers to calculate the cost to reduce emission by one metric ton of CO_2.

For example, when homeowners install solar panels, it typically cost over $100 to reduce CO_2 emissions by one ton of CO_2. Conversely, when building solar farms or wind farms, it typically cost less than $20 per ton.

The first part of the website evaluates decarbonization initiatives, and presents the results in a Summary Remedy Table (SRT). Within this table, initiatives are listed in rows, while columns show cost to society ($), CO_2 reduced (mtCO_2), and cost per metric ton of CO_2 reduced ($/mt$CO_2$).

The table is sorted by cost per ton, placing the most cost-effective programs at the top. In theory, policymakers could expand effective programs, while reducing others.

The website supports multiple nations, since everyone needs to decarbonize—not just one nation.

Website Part 2 - Generate Decarbonization Plan

It is unlikely lawmakers would support significant changes to their economy without a detailed decarbonization plan. While such plans currently do not exist, they could be generated using software and existing economic energy models (such as NEMS).

The proposed website creates a climate plan after the user specifies a strategy. For example, a user might request a plan to "Decarbonize nation Z, over X years, in lowest-cost order, without taxes or subsidies, driven by gov't requirements, and with additional costs passed directly onto consumers."

A decarbonization plan consists of a set of tables, one table per year, where individual initiatives are shown in rows, and key parameters (e.g., cost, tons of CO_2 reduced, and cost per ton) are shown in columns. Also, summary parameters are displayed at the bottom of each table (e.g., total societal cost per year, total CO_2 reduced per year, and average cost per ton).

How Much Does It Cost to Fix This?

A climate plan answers the critical question, "How much would it cost to solve the entire climate problem?" This question is of profound importance, yet rarely discussed. An example answer is shown below.

		Year 1	Year 2	Year 3	…	Year 10	…	Year 20	…	Year 30
Decarbonization	R&D	$8	$8	$8	…	$8	…	$8	…	$8
	Operations	$10	$20	$32	…	$142	…	$445	…	$727
Reflecting Sunlight	R&D	$5	$5	$5	…	$5	…	$5	…	$5
	Operations				…	$27	…	$27	…	$27
TOTAL		$22	$33	$45	…	$182	…	$485	…	$767

In this table, costs values are in units of dollars per American per year, although Europeans would see similar numbers. These costs would manifest as an increase in the price of goods and services, in addition to government and foundation expenditures for climate change.

The first two rows refer to a Decarbonization Plan, while the last two rows refer to a Sunlight Reflectivity Plan. The user clicks on rows to “drill-down” and see a breakdown with more information.

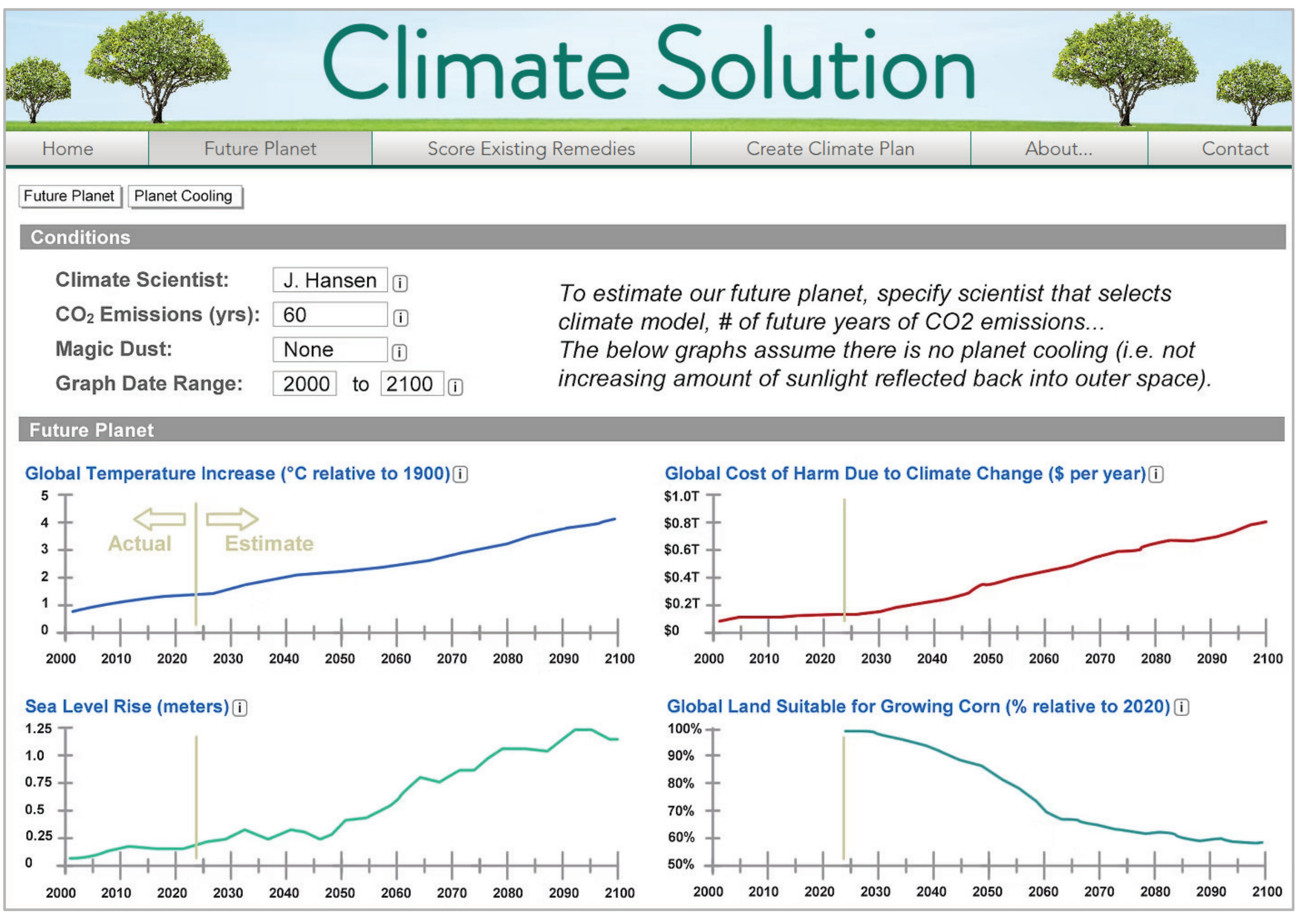
This example table assumes a steady decarbonization rate over a 30-year period, with initial “green premium” costs starting at $20 per ton of CO_2 reduced, and gradually rising over 30 years to $80 per ton. In theory, these costs can be reduced with more R&D.

The left portion of the table represents Years 1, 2, and 3 (the “early years”), whereas the right portion covers Years 10, 20, and 30 (the “later years”). The early years are relatively easy, since green premium costs are proportional to the amount of CO_2 reduced, and initially this would be small.

For a video that further explains this table, click here.

Website Part 3 - Assess Climate Situation

The “Future Planet” section of the website summarizes the climate problem with several graphs. These estimate changes over the next century, including global temperature increase, sea-level rise, reduction in food production, amount of planet cooling needed to prevent cascading tipping points, costs associated with planet cooling, and economic losses due to climate change. A concept illustration of these graphs is shown below.



This data would be generated by climate models. However, selecting a model and its driving parameters is complicated. Therefore, climate models would be selected and set up by leading scientists, and the website user would choose a scientist, instead of a model. For example, one user might trust the leader of the IPCC, while another prefers the leader of NOAA.

The website user would also specify how many more years they expect our society to emit CO_2 (e.g., 30, 40, 60, or 120 years). Many economists expect emissions to continue for over 100 years, whereas climate activists prefer less than 40.

After the user selects a scientist and decarbonization timeframe, graphs would summarize the climate problem, and indicate what it takes to avoid tipping points. In other words, for a given level of decarbonization and planet cooling, the user can see expected outcome.

Website Part 4 - Generate Reflectivity Plan

In theory, reflecting more sunlight back into outer space could cool the planet and prevent climate tipping points. However, it might take several decades and tens of billions of dollars to build up this capability. This presents us with a risk—by the time this capability is established, it might be too late. To help manage this risk, the website generates a sunlight reflectivity R&D plan based on objectives specified by the user (e.g., avoid a specific tipping point).

Solving the Entire Climate Problem

If a foundation, university or government wants to solve the entire climate problem, it should consider writing software that creates a **Comprehensive Climate Plan** based on user requirements. This would include reflecting sunlight plans for the entire planet, and decarbonization plans for individual nations. To be truly useful, it would need to support requirements sought by lawmakers. These include things like “solve the entire climate problem at the lowest cost” and “drive down the cost of green energy to below that of carbon-based energy using R&D.”

Spending Billions of Dollars to Save Trillions

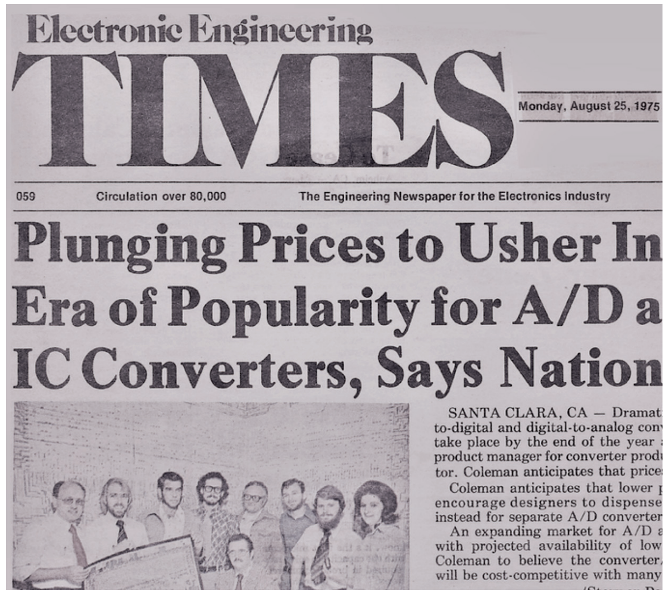
Currently, the world spends $4T each year on fossil fuel. This includes $2.5T for oil, $1T for coal, and $0.5T for natural gas. If the world decarbonized, then $4T *instead* would be spent annually to produce green energy. This includes things like paying down the mortgage on solar farms and wind farms.

Ok, let's focus on this $4T number for a moment. In a green new world, this is roughly how much money would be spent to produce green energy each year. Also, this cost can be reduced with targeted R&D. For example, if $20B was spent annually over 5 years on additional R&D ($100B total), and this caused 30 years of green energy costs to decrease by 20%, then each R&D dollar would save 240 green energy production dollars ($4T x 20% x 30yrs / $100B). In other words, we should think about how to spend billions of dollars on R&D, to save trillions of dollars.

What R&D?

Ok, but what R&D? Or more specifically, what can we develop that is currently not being developed, that has the potential for significant impact?

AspenCore Climate Solutions Research Center


Electronic Engineering

TIMES

Monday, August 25, 1975

059 Circulation over 80,000 The Engineering Newspaper for the Electronics Industry

Plunging Prices to Usher In Era of Popularity for A/D a IC Converters, Says Nation

SANTA CLARA, CA — Dramat
to-digital and digital-to-analog con
take place by the end of the year
product manager for converter prod
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Coleman anticipates that lower
encourage designers to dispense
instead for separate A/D converter
An expanding market for A/D
with projected availability of low
Coleman to believe the converter
will be cost-competitive with many

Answering this question is the job of the AspenCore Climate Solutions Research Center.

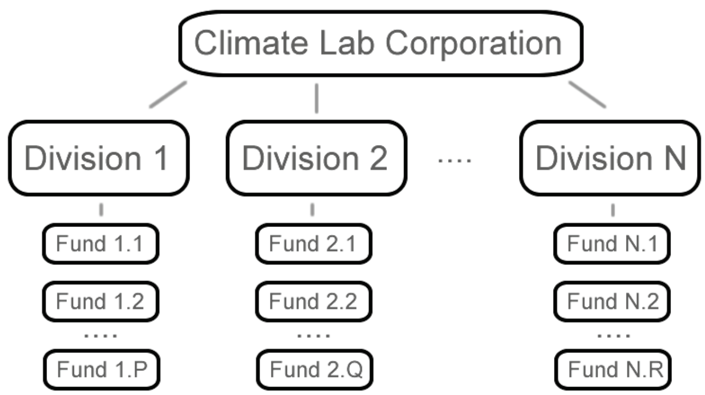
AspenCore is the largest publishing company in the electronics industry. They publish Electronics Design News, Power Electronics, and EE Times.

EE Times has been active for over 50 years. For example, in 1972 they snail mailed a weekly physical newspaper to 60,000 electrical engineers.

Fast forward to modern times and we have AspenCore CEO Cyrus Krohn noticing many readers are interested in electrical power, energy, and climate change. He responded by setting up a Climate Solutions Research Center to identify how to solve the entire problem at the lowest cost to society via engineering. Over 50 climate solution articles and over 13 climate solution videos have been published, and highlights have been copied into a Climate Lab Business Plan.

AspenCore does not pay people to do R&D, and does receive money to do R&D. Instead, they publish free suggestions for others. Climate solution research is not easy. For example, 25 researchers were interviewed for the fission and fusion chapters of the lab business plan.

R&D Packages



Additional R&D for climate change can be broken down into separate R&D areas, or "Packages," where each is supported by multiple R&D Funds. An R&D Fund is an account with money, and an R&D Fund Manager is a human with the authority to issue purchase orders.

The Climate Lab Business Plan devotes one chapter to each of eight suggested R&D Packages. These include: (a) develop a climate solution website, (b) achieve economic fusion within a few years, (c) automate the construction of nuclear power sites, (d) develop underground nuclear power plants, (e) develop an automated system that places solar material directly onto soil, (f) develop a swappable car battery standard, (g) develop next generation building automation & control standards, and (h) determine how to reflect approximately 1% of sunlight back into outer space at a reasonable cost without harm. These R&D areas are currently not being worked on in a significant way, and have the potential for significant impact.

The Climate Lab Business Plan has two purposes: (a) it helps to set up a virtual R&D laboratory that is tasked with solving the entire climate problem, and (b) it helps to describe R&D Packages within a Comprehensive Climate Plan for society.

Small Money First

Initial R&D does not need to be expensive. One often spends small money before medium money, and medium money before big money—and only advances if technically and economically feasible. Small typically involves rough designs, cost models, and proposal writing. Medium typically entails detailed designs and prototypes. And big typically involves more software, more refinements, and small scale operations.

One might refer to small, medium, and large as Phase I, II and III activity. A climate plan would specify the following for each phase within each fund: (a) estimated cost, (b) estimated duration, and (c) brief description. This information would help populate the budget table for each R&D Package.

Giving Technology Away For Free

Companies typically focus on increasing the value of their stock, while foundations and governments typically focus on solving the climate problem. In theory, foundations and governments could support R&D that drives down the cost of green energy to below that of fossil fuel. And to facilitate global decarbonization, they could then give this technology away for free.

There is two types of R&D. One is Product R&D and the other is Production R&D. The former involves product development, while the later involves developing a factory that mass produces a product. In some cases, the factory is 100-times more complicated than the product. If a company devotes 15% of its revenue to Product R&D, and 15% to Production R&D, for example, then costs decrease 30% if someone else pays for their R&D.

Open-Source Requirement

The climate problem is large, and it follows that the solution would be large too. For example, if $20B was spent each year on additional climate R&D, and $500K/year was devoted to each technical person, then 40,000 technical people would be needed ($20B ÷ $500K). This goes beyond what one university could handle. Therefore, money would need to flow to many organizations.

An open-source requirement is probably needed to coordinate many people at many organizations. In other words, people who receive money through a climate lab system would probably be required to place developed materials on the internet, and marked open-source. Subsequently, they could be used by others for free. The alternative would likely introduce inefficiencies that discourage funding sources from participating. In other words, to get money to flow, open-source probably needs to be required.

Also, open-source is needed to distribute developed technology to companies, to reduce green energy costs worldwide, to reduce global CO_2 emissions.

Working with Costs

Comprehensive Climate Plans involve several types of costs. These include decarbonization operations costs ("green premium"), decarbonization R&D costs, reflecting sunlight operations costs, reflecting sunlight R&D costs, and climate harm costs. These costs are often interdependent. For example, if decarbonization operations costs *decrease*, then climate harm costs will probably *increase*. Or if decarbonization R&D costs *increase*, then decarbonization operations costs will probably *decrease*.

The website estimates these costs, and helps the user find a path that meets their satisfaction. Also, the website calculates the cost of the various options, and identifies the lowest cost approach.

Developing this website requires climate scientists that work with climate models, energy economists that work with economic models, and computer programmers that write software.

What is the Role of For-Profit Companies?

If $120T was spent to produce green energy over 30 years at $4T per year, for example, it would need to flow to for-profit companies who provide products and services. In some cases, these companies would utilize open-source technology developed by others.

Who Pays For What?

It is not necessary for a Comprehensive Climate Plan to specify: (a) where R&D money comes from, (b) where R&D money goes, (c) organizations that maintain R&D Funds, (d) R&D Fund Managers who have the authority to issue purchase orders, and (e) researchers who receive money for work. This information is important; however, funding sources would first need to specified requirements. For example, a national government might support several R&D Funds at a specific level, and require money be spent locally.

R&D Funds: Climate Solution Website Development (CSW)

Below is a list of suggested R&D Funds that support the development of software that creates a Comprehensive Climate Plan. Doing this to the satisfaction of multiple national governments would probably exceed the capabilities of one research group; therefore, we advocate R&D Funds be established that support this kind of work.

- R&D Fund: **Website Development - Score Climate Remedies**
  Support the creation of websites that evaluate existing decarbonization initiatives. For each initiative, the following parameters are estimated: cost to society, amount of CO_2 reduced, and cost per metric ton of CO_2 reduced (ref).

- R&D Fund: **Website Development - Generate Decarbonization Plan**
  Support the creation of websites that generate a decarbonization plan based on user-defined criteria. For example, a website user might request a plan that reduces U.S. carbon dioxide emissions by 1/30th each year over 30 years, in lowest-cost order, driven by gov't requirements, without taxes or subsidies, and with additional costs passed onto consumers.

- R&D Fund: **Website Development - Assess Climate Situation**
  Support the creation of websites that summarize the climate problem with several graphs, after the user specifies a climate model (via a well-known scientist) and number of years they expect our society to emit carbon dioxide.

- R&D Fund: **Website Development - Generate Reflectivity Plan**
  Support the creation of websites that calculate how much sunlight needs to be reflected back into outer space to achieve a user-defined objective (e.g., prevent the collapse of the West Antarctic Ice Sheet), and generate a corresponding R&D plan.

2. Solving the Entire Problem at the Lowest Cost

The website creates a Comprehensive Climate Plan that solves the entire climate problem at the lowest cost to society.

Lowest Cost Order

Each decarbonization initiative has a cost to society, and an amount of CO_2 that is reduced. One can divide these two numbers to calculate the societal cost to reduce emission by one metric ton of CO_2 ($/mt$CO_2$). In theory, a nation could decarbonize in lowest cost order. Or more specifically, average $/mt$CO_2$ could increase each year. For example, average $/mt$CO_2$ might be $5 in year #1, $10 in year #2, $15 in year #3, etc.

Approximately one-third of carbon dioxide emissions are from electrical power generation, another third from material and chemical production, and a final third from transportation. Also, a small percentage is from natural gas based building heat. If these were tackled in lowest-cost order, inexpensive intermittent electrical power (i.e., solar farms and wind farms) would come first, followed by more costly areas.

Many lawmakers who are concerned about climate ask "Why spend $200 to reduce carbon dioxide emissions by one ton, when we can do it for $20?" This implies they are uncomfortable with waste, and they favor decarbonizing in lowest cost order. Also, our climate plan creation software needs to make decisions. For these reasons, the website *assumes* decarbonization occurs in lowest cost order.

A Beautiful Decarbonization

We define a "Beautiful Decarbonization" (BD) as one where costs to society are negligible over the entire decarbonization period. In other words, decarbonization occurs in lowest cost order, and R&D is successful at keeping green energy costs below fossil fuel costs as one goes through time. The Climate Lab aims to perform a beautiful decarbonization.

As noted previously, $20B/year for additional R&D is small, relative to the amount of money that would be saved, and we are to create a plan that solves the entire problem at the lowest cost. Therefore, the website estimates the amount of open-source R&D that would be needed to perform a Beautiful Decarbonization.

The website user, on the other hand, specifies the amount of global support for BD R&D (0...100%), the amount of BD R&D that is shouldered by the specified nation ("BD R&D Portion"), and the amount that this R&D meets its green energy cost reduction goal (0...100%).

If BD is underfunded or achieves less than 100% success, then government intervention (e.g., taxes, subsidies, requirements) is needed to achieve the specified decarbonization goal (e.g., "reduce emissions 1/30th a year in lowest cost order").

Who Pays for What?

To solve the entire problem at the lowest cost, someone needs to financially support: (a) a surge in open-source R&D that drives down the cost of green energy, (b) sunlight reflectivity R&D, and (c) sunlight reflectivity operations.

The website creates a Comprehensive Climate Plan for a specific nation, and the above three costs benefit the entire planet. Therefore, the website user would need to specify how much of global costs are shouldered by the selected nation. The website refers to this as “BD R&D Portion”, “RS R&D Portion”, and “RS Operations Portion”.

If global BD R&D is estimated as costing $20B/year, and the website user creates a plan for the U.S. with BD R&D Portion set to 50%, for example, then BD R&D costs for the U.S. would be $10B/year.

In practice, climate R&D is typically supported by entities concerned about climate change. This includes governments, high net worth individuals, and foundations. Sunlight reflectivity operations, on the other hand, would probably be supported by nations who reflect to save money.

Comprehensive Climate Plan

The website generates Comprehensive Climate Plans that solve the entire climate problem at the lowest cost to society. This is different from a website that evaluates a proposed climate policy.

For example, one might propose the U.S. government enact a law that requires power companies to build solar farms to the point of saturation within N years, and pass any additional costs onto consumers. Given this proposed policy, one could theoretically calculate: (a) additional cost or savings per state per year, (b) number of workers added/subtracted per industry per state per year, and (c) amount of CO_2 reduced. If the proposed policy reduced CO_2 from the U.S. by 10% and the U.S. is 16% of global total, it would decrease global CO_2 emissions by 1.6% (10% × 16%). Unfortunately, this would have a negligible impact, and many climate models suggests runaway climate change is likely even with moderate decarbonization. Therefore, a policy that accelerates U.S. solar farm construction, for example, would do little. A Comprehensive Climate Plan, on the other hand, looks at what it takes to solve the entire problem.

Being Smart with R&D

As noted previously, $4T is spent globally each year on fossil fuel, and in a decarbonized world this would be replaced by green energy. Yet what might this green energy cost? If it came in at $6T per year, for example, the additional cost would be $2T per year. In theory, tens of billions of dollars for additional R&D could reduce this cost. Yet what might be developed? In theory, we could develop things we know can be developed. For example, we know we can build machines that automate the construction of nuclear power plants, and we know these machines would cost little relative to other costs. In other words, if we are smart with R&D, we can avoid risky scientific research, and instead tackle well-understood opportunities with good engineering.

3. Decarbonization Strategy

Much of what we do for climate is often wasteful. However, in theory, we can calculate the cost of the various options, and favor the lowest cost approach.

Decarbonizing to Save Money

In many regions, the cost of electricity from solar farms is dropping below the cost of electricity from fossil fuel. In these cases, we can expect green sources to be built up until saturation. Saturation occurs when the amount of green electricity exceeds the amount of electricity needed (i.e., green supply exceeds demand). At this point, green electricity is discarded and construction of new green sources stops.

The same is true for wind farms. In many regions, we can expect a build up until saturation.

In other words, when green costs less than carbon, we can expect decarbonization to occur (e.g., build solar farms and wind farms) until incurring a limit (e.g., saturation). After this, government intervention is needed to decarbonize further. This involves government requirements, taxes, and subsides.

The more persistent sources of green electricity (e.g., nuclear power, solar with batteries) typically cost more than fossil fuel-based sources, and the U.S. government does not expect this to change over the coming decades.

Approximately 20% of global CO_2 emissions can probably be eliminated by saving money. However, we still have another 80% which requires either (a) government intervention, or (b) additional R&D that drives down the cost of persistent green energy to below that of fossil fuel. Globally, we rarely see government intervention that reduces CO_2 at large scales, and we need support from many nations. Therefore, more R&D is probably needed.

30-Year Decarbonization

In theory, a region could steadily reduce carbon dioxide emissions by approximately 1/30th per year over 30 years, in lowest-cost order. Under this approach, power companies might be required to size solar and wind farm construction to meet each year's emission-reduction target. Initially, the costs would be minimal, as solar and wind are comparably priced with fossil fuels. However, after five to seven years, saturation would occur, and decarbonization costs would increase.

Decarbonizing Electrical Power Generation

Some decarbonization initiatives are driven forward by saving money, while others are driven forward by government intervention. For example, during 2024 in China, it cost less to generate electricity with a solar farm than with coal. For this reason they built 280 GW_e of solar farms during that year. For reference, this was 10-times more than that done in the U.S. during the same period. China's solar construction spree was done to save money, not to save the planet from climate change.

The U.S. Federal government subsidizes roughly 40% of U.S. solar farm and wind farm construction. This is the centerpiece of U.S. federal climate policy, and it has been in place since 2006.

Many states in the U.S. require power companies to decarbonize electrical power by a specific amount each year. This is referred to as a Renewable Portfolio Standard (RPS), and in the typical case 1% of electrical power generation is required to transition from fossil fuel to green sources each year.

U.S. federal and state programs have been undersized relative to what is needed. Also, the U.S. government has never produced a climate plan or a decarbonization plan, and this has made it difficult to recognize deficient or inefficient climate policy.

Replace, Not Block

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.

The Subsidy Efficiency Problem

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 revenue or equipment cost that are offset with money from government, possibly via 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 might eventually stop working.

The Tax Efficiency Problem

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 (i.e., high $/mt$CO_2$).

Government Requirements are 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, and pass additional costs, or savings, onto consumers. Already, many U.S. states have green electricity requirements (i.e., Renewable Portfolio Standards). However, they are not federal and they are often undersized relative to what is needed.

Regional Fuel Shortages

Modeling different cities and regions is important since some make money by decarbonizing, and these need to be identified. For example, pipes that carry natural gas into the city of Boston, MA, USA are too small. Unfortunately, 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 decrease.

The Boston resident pays approximately 8¢/kWh more for electricity than the average American due to this regional natural gas shortage, and green electricity typically cost approximately -1¢ to 2¢/kWh more than non-green electricity. Therefore, if Boston went green and cleared the shortage, residents would see a ≥ 6¢/kWh improvement in their electrical bill.

States that import carbon-based fuels would probably benefit from lower fuel prices, and are therefore more inclined to support decarbonization. The same is true with nations that import fuel. For this reason, it would be helpful to identifies cities, regions and nations that economically benefit from decarbonization. They would then be more inclined to decarbonize.

Decarbonizing Cars

A standardized swappable EV battery would help decarbonize cars at negligible costs, as noted in the *Swappable Battery* chapter within the Climate Lab Business Plan.

Decarbonizing Ships and Freight Trains

The website estimates decarbonization costs for the various ways to decarbonize ships and freight trains, and supports the lowest cost approach with more R&D.

For example, in theory, liquid ammonia could be made with a nuclear fusion or fission reactor via a low cost chemical process. This ammonia could then power ships and freight trains via high temperature fuel cells. We know how to transport and store ammonia, since it is used to make fertilizer. Also, it is already at ports and railyards. However, standardized refueling infrastructure would be needed if it were used for transportation. For details, click here.

Decarbonizing Cargo Trucks and Airplanes

Decarbonizing cargo trucks and airplanes at low cost is difficult, and can be addressed later.

Decarbonizing Natural Gas Based Building Heat

In warm regions, such as California, natural gas based building heat can be decarbonized at negligible costs with HVAC-based heat pumps. However, in cold regions, this technique is expensive. Consequently, decarbonizing natural gas-based building heat in cold regions can be addressed later. For details, click here.

Decarbonizing Industrial Processes

The website estimates decarbonization costs for the various ways to decarbonize industrial processes, and supports the lowest cost approach with more R&D. For details, see the *Automated Nuclear Power Construction* chapter within the Climate Lab Business Plan.

Extracting CO_2 from the Atmosphere (DAC)

Some climate scientists favor extracting CO_2 from the atmosphere. This is referred to as "Direct Air Capture" (DAC), and it costs roughly $1,000 per ton of CO_2 extracted.

Global CO_2 emissions are roughly 40 billion tons per year, and if one billion of these was later extracted at $1,000 per ton, for example, it would cost $1T (1B tons × $1000/ton). Unfortunately, this would provide little benefit since it is small relative to total. Also, $1T could be spent on decarbonization initiatives costing less than $30 per ton, yielding more benefit per dollar.

If a nation reduced CO_2 emissions 1/30th a year, in lowest cost order, for example, their decarbonization costs would probably be less than $150/mt$CO_2$ over 30 years. This would be less than the $1,000/mt$CO_2$ for DAC; therefore, DAC would not be economically competitive during this three decade period. Also, after achieving zero CO_2 emissions, reflecting sunlight via SAI would probably cost less than DAC.

In summary, DAC provides little benefit per dollar, and is not expected to be competitive with alternate approaches.

4. Climate Plan Tables

Lawmakers are not likely to support major changes to their economy without a detailed climate plan. These plans do *not* exist; however, they could be generated with software, existing economic energy models (e.g., NEMS), and existing climate models.

The proposed website creates a climate plan after the website user specifies a strategy. For example, the user might want to "Decarbonize nation Z, over X years, at lowest cost, in lowest cost order, with additional costs passed onto consumers."

Summary Budget Table (SBT)

To create a plan, the website user specifies requirements, clicks the **Calculate** button, and a Summary Budget Table (SBT) appears. An example of this is shown below.

The first two rows refer to a Decarbonization Plan, while the last two rows refer to a Sunlight Reflectivity Plan.

		Year 1	Year 2	Year 3	...	Year 10	...	Year 20	...	Year 30
Decarbonization	R&D	$8	$8	$8	...	$8	...	$8	...	$8
	Operations	$10	$20	$32	...	$142	...	$445	...	$727
Reflecting Sunlight	R&D	$5	$5	$5	...	$5	...	$5	...	$5
	Operations				...	$27	...	$27	...	$27
TOTAL		$22	$33	$45	...	$182	...	$485	...	$767

The user clicks on rows to "drill-down" and see more information. For a description of this table, see the *Executive Summary* chapter.

Cost to Society

Within this document, "cost" refers to cost-to-society. This is additional money spent by consumers to decarbonize ("green premium") *plus* donations by foundations and individuals to tackle climate change *plus* money spent by government to encourage decarbonization. Additional money for green energy shows up as an increase in the cost of goods and services.

The website displays cost values in units of dollars-per-person-per-year or in units of dollars-per-nation-per-year. These two differ by national population. Climate Plans are created for countries; therefore, the website user must specify a nation before pressing the **Calculate** button.

Annual Decarbonization Tables (ADT)

If the user clicks on the Decarbonization Operations row ("green premium") of the SBT, Annual Decarbonization Tables (ADT) appear for each year going forward, one table per year. Within these tables, decarbonization initiatives appear in rows, key parameters appear in columns (e.g., cost to society, tons of CO_2 reduced, cost per ton), and summation values appear under each table (e.g., total cost per year, total CO_2 reduced per year, average cost per ton). If the website user specifies that CO_2 emissions are to decrease 1/30th per year in lowest-cost order, for example, then this would be reflected in the summation values under each table. For more details, see this video.

The data from Annual Decarbonization Tables is used to populate three more tables that place decarbonization initiatives in rows, and future years in columns. One of these tables shows CO_2 reduced per year, another shows cost per year, and a third shows average cost per ton.

Green Energy Consumption

The website divides green energy consumption into three categories: (a) green energy that is consumed due to it costing less than non-green energy ("Consumers Save Money"), (b) green energy that costs more than non-green energy and is consumed without government intervention by individuals wanting to save the planet ("Consumers Pay Green Premium"), and (c) government intervention (e.g., taxes, subsidies, requirements, virtue signaling). The first row of each decarbonization cost table refers to the first type, the second row refers to the second type, and other rows refer to government funded programs.

Electrical Power Decarbonization Tables (EPDT)

"Electrical Power" is shown in the top row of each Annual Decarbonization Table, and one can click on this row to see Electrical Power Decarbonization Tables (EPDT). Cost values in the Consumers Save Money row are negative, while cost values elsewhere are positive. Examples of government initiatives are: (a) U.S. federal green energy construction tax credits (ITC), and (b) U.S. state renewable portfolio standards (RPS).

If open-source BD R&D (discussed previously) is successful at driving down the cost of green energy to below that of fossil fuel, then decarbonization cost tables only display a Save Money row. Otherwise, government intervention rows also appear. As noted previously, intervention would be designed to achieve decarbonization targets (e.g., reduce CO_2 emissions 1/30th per year) at the lowest cost to society.

Each row and each year within EPDT tables are associated with several values. These include cost, CO_2 reduced, and cost per ton. These parameters appear in multiple tables, in a manner described above (e.g., annual tables with one table per year and three parameters in columns, and three tables with years in columns).

Specifying More R&D

R&D can be broken down into separate R&D Packages, where each package is supported by multiple R&D Funds. An R&D Fund is an account with money, and an R&D Fund Manager is a human with the authority to issue purchase orders. For details, see the *Executive Summary* chapter.

R&D Budget Tables

If the user clicks on the R&D Row within the SBT, a Master R&D Budget Table (MRDT) appears that shows R&D Packages in rows, and future years in columns. After clicking on an R&D Package, an R&D Package Table (RDPT) appears that shows R&D Funds in rows, and future years in columns. Values in all tables refer to R&D costs.

Summation values appear under the MRDT, and these match the R&D Row within the SBT.

Summation values appear under the RDPT, and these match corresponding rows in the MRDT.

5. Hierarchical View of Comprehensive Climate Plan

A hierarchical view of a Comprehensive Climate Plan is shown below. For details on R&D Packages and R&D Funds, see the Climate Lab Business Plan.

Summary Budget Table (SBT)

- Reflecting Sunlight - Operations
- Reflecting Sunlight - R&D

    R&D Package: Determine how to reflect approximately 1% of sunlight (SAI)

    - R&D Fund: SAI Experiment Development
    - R&D Fund: Measure Aerosol Reflectivity
    - R&D Fund: SAI Spray Hardware R&D
    - R&D Fund: SAI Instrumentation R&D
    - R&D Fund: SAI Experimental Spray Plane R&D
    - R&D Fund: SAI Monitor Plane R&D
    - R&D Fund: Polar SAI Airplane R&D
    - R&D Fund: Equatorial SAI Airplane R&D
    - R&D Fund: SAI Airport Development
    - R&D Fund: Automated SAI Refueling R&D

- Decarbonization - Operations

    Annual Decarbonization Tables (ADT), one table per future year

    - Electrical Power Decarbonization Tables (EPDT), one table per future year
        - Consumers Save Money
        - Consumers Pay Green Premium
        - Federal Subsidy on Building Solar Farms and Wind Farms
        - State Renewable Portfolio Standard
    - Transportation Decarbonization Tables, one table per future year
        - Cars
        - Airplanes
        - Cargo Trucks
        - Cargo Trains
        - Cargo Ships
    - Chemical Production Decarbonization Tables, one table per future year
    - Material Production Decarbonization Tables, one table per future year

- Decarbonization - R&D

    Master R&D Budget Table (MRDT)

    - ✓ R&D Package: Develop climate solution websites (CSW)
        - R&D Fund: Website Development - Score Climate Remedies

- R&D Fund: Website Development - Generate Decarbonization Plan
- R&D Fund: Website Development - Assess Climate Situation
- R&D Fund: Website Development - Generate Reflectivity Plan

✓ R&D Package: Achieve economic fusion within a few years (EF)

- R&D Fund: Liquid Metal Wall R&D
- R&D Fund: Wide Tube Magnet Printing R&D
- R&D Fund: Narrow Tube Magnet Printing R&D
- R&D Fund: Baseplate Magnet Printing R&D
- R&D Fund: Exhaust Gas Processing R&D
- R&D Fund: Liquid Lithium Processing R&D
- R&D Fund: Experimental Tokamak with Liquid Metal Wall Design
- R&D Fund: Experimental Stellarator Design
- R&D Fund: Economic Stellarator Design

✓ R&D Package: Automate the construction of nuclear power sites (ANP)

- R&D Fund: Nuclear Power Automated Construction R&D
- R&D Fund: Automated Thermal Storage Construction R&D
- R&D Fund: Chemical Processing Platform Design
- R&D Fund: Chemical Processing Platform Factory Design
- R&D Fund: Chemical Processing Site Design
- R&D Fund: Chemical Processing Platform Standards Development
- R&D Fund: Chemical Processing Platform Transportation R&D
- R&D Fund: Double-Rail Transportation R&D
- R&D Fund: Double-Rail Concrete Processing R&D

✓ R&D Package: Develop underground nuclear power plants (UNP)

- R&D Fund: UNP Site Design
- R&D Fund: UNP Automated Construction R&D

✓ R&D Package: Develop an automated system that places solar material onto soil (SDS)

- R&D Fund: SDS Weather Modeling Research
- R&D Fund: SDS Material Manufacturing R&D
- R&D Fund: SDS Material Installation R&D
- R&D Fund: SDS Material Cleaning R&D
- R&D Fund: SDS Material Removal R&D
- R&D Fund: SDS Standards Development
- R&D Fund: SDS Site Preparation R&D
- R&D Fund: SDS Water Handling Research
- R&D Fund: SDS Material Anchoring Research

✓ R&D Package: Develop a swappable car battery standard (SEVB)

- R&D Fund: SEVB Mechanical Standards Development
- R&D Fund: SEVB Electrical Standards Development
- R&D Fund: SEVB Communications Standards Development
- R&D Fund: SEVB Swap Station R&D

✓ R&D Package: Develop a next generation building automation & control standard (NGBAC)

- R&D Fund: NGBAC Operating System Development
- R&D Fund: NGBAC User Interface Software Development
- R&D Fund: Standardized Plug-in Hardware Module Development
- R&D Fund: Light Power Cable Standards Development

- R&D Fund: Heavy Power Cable Standards Development
- R&D Fund: NGBAC Master Controller Hardware and Software Development
- R&D Fund: NGBAC Router Hardware and Software Development
- R&D Fund: NGBAC Power Company Interface Standards Development
- R&D Fund: Appliance Interface Standards Development
- R&D Fund: Smart LED Bulb Standards Development
- R&D Fund: Window Thermal Cover Standards Development
- R&D Fund: Replaceable Fan Standards Development
- R&D Fund: Replaceable Dampers Standards Development

Future Planet Graphs

Future Planet Summary

Planet Cooling

- Graph: Polar Region cooling (% of sunlight reflected above Polar Regions)
- Graph: Entire Planet cooling (% of sunlight reflected from entire planet)
- Graph: Cost of Planet Cooling ($/year)

Future Planet

- Graph: Global Temperature Increase (°C relative to 150 years ago)
- Graph: Sea Level Rise (meters)
- Graph: Global Land Suitable for Growing Corn (% relative to 2020)
- Graph: Global Cost of Harm Due to Climate Change ($/year)

Reflecting Sunlight

Recommended Reflectivity (RR) to Block Cascading Tipping Points

- Polar Region Recommended Reflectivity (% of sunlight reflected to block tipping points)
- Entire Planet Recommended Reflectivity (% of sunlight reflected to block tipping points)

Reflectivity Cost

- Cost of Recommended Reflectivity ($ per year)

Global Temperature

Global Temperature Increase Total (relative to 150 years ago)

- Graph: TOTAL - Average Global Temperature Relative to 150 years ago (°C)

Global Temperature Increase Components

- Graph: COMPONENT - Temp increase due to CO2
- Graph: COMPONENT - Temp increase due to methane
- Graph: COMPONENT - Temp decrease due to sunlight reflecting off aerosols
- Graph: COMPONENT - etc.

Global Warming Rate

Global Warming Rate Total

- Graph: TOTAL - Rate of Global Temperature Increase (°C/decade)

Global Warming Rate Components

- Graph: COMPONENT - Rate due to CO2

- Graph: COMPONENT - Rate due to methane emissions
- Graph: COMPONENT - Rate due to melting Arctic sea ice
- Graph: COMPONENT - Rate due to melting Antarctica sea ice
- Graph: COMPONENT - Rate due to sunlight reflecting off aerosols (negative °C/decade)
- Graph: COMPONENT - etc.

Sea Level Rise

Sea Level Rise Total

- Graph: TOTAL - Sea level rise (m)

Sea Level Rise Components

- Graph: COMPONENT - Sea level rise due to melting Greenland
- Graph: COMPONENT - Sea level rise due to melting West Antarctica Ice Sheet (WAIS)
- Graph: COMPONENT - Sea level rise due to melting East Antarctica
- Graph: COMPONENT - etc.

Cost of Harm due to Climate Change

Cost of Harm Total

- Graph: TOTAL - Cost of harm due to climate change, worldwide ($/year)

Cost of Harm Components

- Graph: COMPONENT - Money lost due to sea level rise
- Graph: COMPONENT - Money lost due to more intense storms
- Graph: COMPONENT - Money lost due to higher food prices, due to less moisture in soil
- Graph: COMPONENT - etc.

6. Working with Climate Models

This chapter focuses on how climate models can estimate the impact of policy, and it assumes the reader has already read the 3-page *Climate Science in Five Minutes* chapter within the Lab Business Plan.

Global Warming

According to physical measurements, the average temperature of our planet increased approximately 1.5°C over the last 150 years. This is commonly referred to as "global warming."

Global Warming *Rate*

The amount of global temperature increase over time is referred to as the "global warming *rate*", and it is often depicted in units of degrees Celsius increase per decade (°C/decade). This was measured at 0.18°C/decade between 1970 and 2010. And over the last 10 years, this rate increased 50% to 100%, to somewhere between 0.27°C/decade and 0.36°C/decade.

Global Warming Components

Global warming is driven by multiple components that add together, as illustrated below.

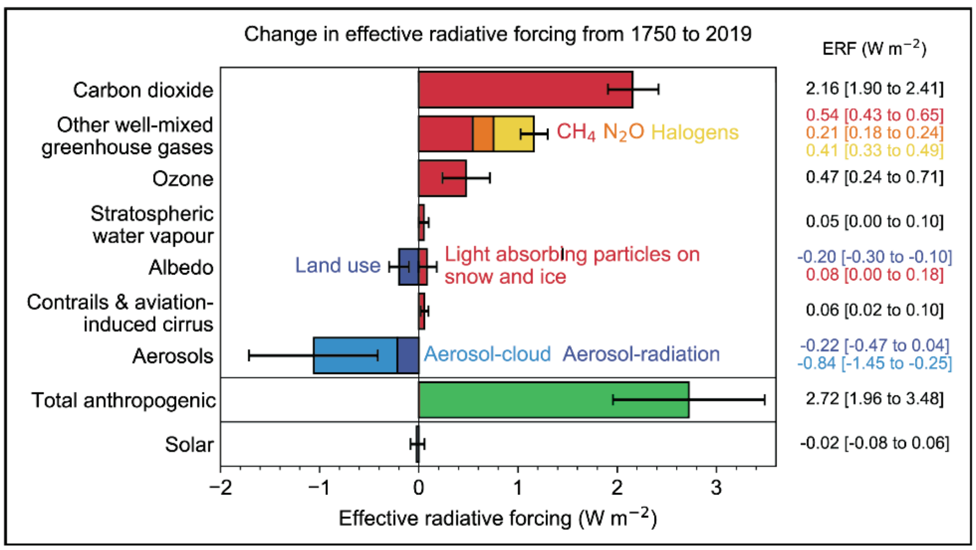


Figure 6.1: Sources of global warming and cooling in units of Watts per square meter of Earth surface area. Source: IPCC AR6 WG1 Figure 7.6.

As one can see, some components increase global warming (red), whereas others decrease global warming (blue). These combine to get total warming (green). Sunlight reflects off air pollution and back into outer space, effectively cooling the planet. This is depicted by the blue bar in the above illustration.

Each of the above bars are like physical blankets around the planet, where the length of each bar is proportional to blanket thickness. Also, the length of each bar is *roughly* proportional to its contribution to the global warming *rate* (e.g., temperature *increase* per decade).

The concentration of CO_2 in atmosphere was 280 parts per million (ppm) several hundred years ago, and fossil fuel combustion increased it to 420 ppm. It rose by 140 ppm, and this increase is roughly proportional to the length of the top bar (140 = 420 - 280).

What Would Happen if CO_2 Emissions Stopped Tomorrow?

Let's imagine we can sprinkle magic dust on the planet to set global CO_2 emissions to zero, all in one day.

How would this change the above picture?

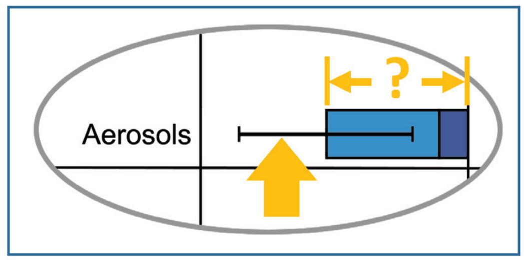
We would get a race condition between CO_2 slowly falling out of atmosphere, which slows global warming; and positive climate feedbacks, which increase global warming. It is not clear which of these would be stronger. If CO_2 emissions stopped completely, some climate models suggest: (a) climate feedbacks would outweigh CO_2 falling out of atmosphere, (b) tipping points would activate, and (c) global warming would continue for hundreds of years.

The website user can select a climate model, add magic dust, and see what happens.

What Would Happen if Fossil Fuel Combustion Stopped Tomorrow?

OK, now let's sprinkle more magic dust to stop all fossil fuel combustion, all in one day. This is similar to the above scenario, except planet cooling, due to air pollution, stops as well. In other words, the blue bar collapses to zero, the green bar grows by its length, and the situation worsens.

Notice the error bar associated with the blue bar. This means scientists do not know if this parameter is small or large. This is because it has never been measured, only estimated. If this parameter is actually large, and a large value is added to the green bar, then that would be worse than adding a small value. Scientists refer to this as "uncertainty," and the big error bar on the blue bar tells us they are quite uncertain.



What to do?

Fixing the climate problem is more complicated than "reduce CO_2."

We probably need to reflect approximately 1% of sunlight back into outer space. This would cause the above blue cooling bar to increase, and cause the green bar to become negative. In other words, reflecting sunlight could potentially convert global warming to global cooling, to the extent required to block tipping points.

Magic Dust

The "Future Planet" webpages support "magic dust," to help the public understand that CO_2 is the tip of the climate iceberg, no pun intended. More specifically, magic dust enables the user to see the impact of: (a) setting CO_2 emissions to zero in one day, or (b) setting fossil fuel combustion to zero in one day.

Global Warming Components

The Future Planet part of the website produces a graph that shows the expected average global temperature increase over the next 100 years. This appears after the user specifies: (a) a climate model via a climate scientist, and (b) number of years of expected CO_2 emissions *or* magic dust.

Also, the user can click to drill down for more information. This includes generating graphs that show components of global warming, where options determine how they are calculated. This includes support for components that correspond to the bars in the previous graphic.

7. Climate Solution Website Home Page

The website **Home Page** provides links to three areas, as illustrated below. These include: (A) Score Climate Remedies, (B) Create Climate Plan, and (C) Future Planet. Remedies and Plan relate to specific nations; whereas Future Planet relates to the entire planet.

To help developers get started, we built a non-functional website shell that demonstrates the climate solution website concept. To see this, visit https://manhattan2hq.wixsite.com/planet-dashboard.

The below concept was made with Microsoft Word, and can therefore be edited easily.

Home	Future Planet	Score Existing Remedies	Create Climate Plan	About...	Contact

Future Planet	Climate Remedies	Climate Plan
Click for estimate of future planet	Click for report on existing climate remedies	Click to create climate plan
• Summary • Planet Cooling • Reflecting Sunlight • Global Temperature • Warming Components • Sea Level Rise • Cost of Harm	• United States • China • India • Germany • France	• Decarbonize • Decarbonize and Reflect Sunlight

8. Website Area A - Score Climate Remedies

As noted in Chapter 1, from an economics perspective, decarbonization involves initiatives that reduce CO_2 emissions. Each initiative has a cost to society, and an amount of CO_2 that is reduced. One can divide these two numbers to calculate the dollars needed to reduce emission by one ton of CO_2.

Decarbonization costs ($/mt$CO_2$) vary significantly. Here's an 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.

Webpage: Remedy / Score Climate Remedies

The climate remedy part of the website scores initiatives and displays the results in a Summary Remedy Table (SRT). Within this table, initiatives are listed in rows, while columns show cost to society ($), CO_2 reduced ($mtCO_2$), and cost per metric ton of CO_2 reduced ($/$mtCO_2$).

The table is sorted by cost per ton; therefore, the most cost effective programs are shown at the top. In theory, lawmakers can increase the program size for initiatives at the top, and decrease the program size for less cost effective initiatives.

This website supports multiple nations, since everyone needs to decarbonize. Not just one nation.

The user clicks on an initiative for more information. This includes: (a) a list of component costs, (b) a list of components that make up CO_2 reduced, and (c) a graph of initiative cost-per-ton vs. initiative size.

[Future Planet/Remedy/Plan] [Summary/Temp Increase/Evaluate Decarbonization Initiatives/..]

Evaluate Decarbonization Initiatives

From an economics perspective, decarbonization involves initiatives that reduce CO_2 emissions. Each initiative has a cost to society ($), and an amount of CO_2 that is reduced ($mtCO_2$). One can divide these two numbers to calculate the cost to reduce emission by one metric ton of CO_2 ($/$mtCO_2$).

Nation:	[select nation] {i}

	Cost ($)	CO_2 Reduced ($mtCO_2$)	Cost Per Tonne ($/$mtCO_2$)
Decarbonization Initiative #1	$10	2	$5
Decarbonization Initiative #2	$10	2	$5
…	…	…	…
Decarbonization Initiative #N	$10	2	$5
TOTAL	$30	6	$5

9. Website Area B - Create Climate Plan

The website creates a Comprehensive Climate Plan based on criteria set by the user. More specifically, the website user specifies policy options, clicks the **Calculate** button, views a Summary Budget Table, and drills down for more information. Displayed information is described in previous chapters, while this chapter focuses on policy options available to the user.

For more ideas on values to display in a climate plan, see the Electrical Power Decarbonization Reporting Tool.

Future Planet

Future Planet graphs are also generated to provide a sense of what would happen to the planet if the created climate plan was implemented.

An astute observer might notice future planet graphs are influenced by settings that are not controlled by the selected nation. More specifically, the website user specifies the period over which the selected nation decarbonizes (e.g., 30 years), and also specifies how long they expect the world to emit CO_2 into atmosphere (e.g., 120 years). The created decarbonization plan is influenced by the former parameter, while the future planet graphs are influenced by the latter parameter.

The Great Disconnect

The disconnect between national behavior and global outcome might seem strange, and it is. However, this is how it works in the real world. Also, this is why many nations are slow to decarbonize. They don't benefit, and are instead inclined to display token efforts, while minimizing costs and encouraging others to act.

How do we fix this?

A surge of open-source R&D that drives down the cost of green energy to below that of carbon based fuels, and a surge of R&D that supports reflecting sunlight, funded by foundations and governments is a reasonable approach. Fortunately, this would cost little compared to the cost of harm from climate change.

Webpage: Create Climate Plan (Options)

[Future Planet/Remedy/Plan] [Climate Plan Options/Reflecting Sunlight R&D]

Climate Plan Options

Calculate Climate Plan

Climate plans are created for a specific Nation, while costs values in tables are displayed in units of dollars-per-citizen-per-year or dollars-per-nation-per-year.

Nation:	[select nation] {i}
Cost Units:	[$ per citizen per year/$ nation per year] {i}

Decarbonization Strategy

The creation of a comprehensive climate plan is guided by requirements set by the website user.

Period (years):	[30] {i}
Rate:	[linear] {i}
Cost Strategy:	[Lowest cost order] {i}
Policy Option #1:	[....] {i}
Policy Option #2:	[....] {i}

R&D Strategy

We define a “Beautiful Decarbonization” (BD) as one where costs to society are negligible over the entire decarbonization period. In other words, decarbonization occurs in lowest cost order, and R&D is successful at keeping green energy costs below fossil fuel costs as one goes through time. The Climate Lab aims to perform a beautiful decarbonization.

We estimate the amount of open-source R&D that would be needed to perform a Beautiful Decarbonization. The website user, on the other hand, specifies the amount of global support for BD R&D (0...100%), the amount of BD R&D that is shouldered by the specified nation (“BD R&D Portion”), and the amount that this R&D meets its green energy cost reduction goal (0...100%).

If BD is underfunded or achieves less than 100% success, then government intervention (e.g., taxes, subsidies, requirements) is needed to achieve the specified decarbonization goal (e.g., “reduce emissions 1/30th a year in lowest cost order”).

BD Support:	[0...100% support for beautiful decarbonization R&D] {i}
BD Success:	[0...100% success from expected cost reduction] {i}
BD R&D Portion:	[% of additional R&D paid for by specified nation] {i}

Climate Model

The website needs to calculate: (a) expected changes to the planet, (b) the cost of these changes, (c) when tipping points might activate, (d) the amount of sunlight that needs to be reflected to block such tipping points, and (e) a sunlight reflectivity plan. To make these calculations, the website user must specify a climate model via a climate scientist, and the number of years of expected CO_2 emissions.

Climate Scientist:	[select name] {i}
Global CO_2 Emissions:	[30/40/60/120 years] {i}
Graph Date Range:	<StartYear> to <Stop Year> {i}

Reflecting Sunlight (RS)

The website user specifies if reflecting sunlight is acceptable; and if so, how much of total cost is to be paid for by the selected nation.

Sunlight Policy:	[Block cascading tipping points with SRM/Ban SRM] {i}
RS R&D Portion:	[% of planet cooling R&D cost paid for by specified nation] {i}
RS Operations Portion:	[% of planet cooling operations paid for by nation] {i}

Webpage: Climate Plan - Summary Budget Table (SBT)

[Future Planet/Remedy/Plan] [Climate Plan Options/Climate Plan Summary]

Climate Plan Summary (SBT)

The first two rows refer to a Decarbonization Plan, while the last two rows refer to a Sunlight Reflectivity Plan. All costs are in units of dollars per citizen per year. These costs would manifest as an increase in the price of goods and services, in addition to government and foundation expenditures for climate change. The user clicks on rows to “drill-down” and see a breakdown with more information.

		Year 1	Year 2	Year 3	…	Year 10	…	Year 20	…	Year 30
Decarbonization	R&D	$8	$8	$8	…	$8	…	$8	…	$8
	Operations	$10	$20	$32	…	$142	…	$445	…	$727
Reflecting Sunlight	R&D	$5	$5	$5	…	$5	…	$5	…	$5
	Operations				…	$27	…	$27	…	$27
TOTAL		$22	$33	$45	…	$182	…	$485	…	$767

Webpage: Reflecting Sunlight R&D (SAI)

[Future Planet/Remedy/Plan] [Climate Plan Options/Reflecting Sunlight R&D]

Reflecting Sunlight R&D (SAI)

Scientists need to determine how to reflect approximately 1% of sunlight, at a reasonable cost, without harm. This requires more R&D, which is summarized below. For details, see the Reflecting Sunlight chapter in the Climate Lab business plan.

	Year 1	Year 2	Year 3	…	Year 10	…	Year 20	…	Year 30
SAI Experiment Development	$1	$1	$1	…	$1	…	$1	…	$1
Measure Aerosol Reflectivity	$1	$1	$1	…	$1	…	$1	…	$1
SAI Spray Hardware R&D	$1	$1	$1	…	$1	…	$1	…	$1
SAI Instrumentation R&D	$1	$1	$1	…	$1	…	$1	…	$1
SAI Experimental Spray Plane	$1	$1	$1	…	$1	…	$1	…	$1
SAI Monitor Plane R&D	$1	$1	$1	…	$1	…	$1	…	$1
Polar SAI Airplane R&D	$1	$1	$1	…	$1	…	$1	…	$1
Equatorial SAI Airplane R&D	$1	$1	$1	…	$1	…	$1	…	$1
SAI Airport Development	$1	$1	$1	…	$1	…	$1	…	$1
Automated SAI Refueling R&D	$1	$1	$1	…	$1	…	$1	…	$1
TOTAL	$9	$9	$9	…	$9	…	$9	…	$9

Webpage: Decarbonization R&D (MRDT)

[Future Planet/Remedy/Plan] [Climate Plan Options/Decarbonization R&D]

Decarbonization R&D (MRDT)

Additional R&D can be broken down into separate R&D areas, or "Packages," where each is supported by multiple R&D Funds. An R&D Fund is an account with money, and an R&D Fund Manager is a human with the authority to issue purchase orders. The below Master R&D Budget Table (MRDT) estimates the cost of R&D Packages that reduce decarbonization costs. In theory, each Package could be set up as a Division within an R&D laboratory. One can click on a row for more information.

	Year 1	Year 2	Year 3	…	Year 10	…	Year 20	…	Year 30
Develop climate solution websites (CSW)	$1	$1	$1	…	$1	…	$1	…	$1
Achieve economic fusion within a few years (EF)	$1	$1	$1	…	$1	…	$1	…	$1
Automate the construction of nuclear power sites (ANP)	$1	$1	$1	…	$1	…	$1	…	$1
Develop underground nuclear power plants (UNP)	$1	$1	$1	…	$1	…	$1	…	$1
Develop an automated system that places solar material onto soil (SDS)	$1	$1	$1	…	$1	…	$1	…	$1
Develop a swappable car battery standard (SEVB)	$1	$1	$1	…	$1	…	$1	…	$1
Develop a next generation building automation & control standard (NGBAC)	$1	$1	$1	…	$1	…	$1	…	$1
TOTAL	$7	$7	$7	…	$7	…	$7	…	$7

Webpage: Develop Climate Solutions Website (CSW)

[Future Planet/Remedy/Plan] [Climate Plan Options/Develop Climate Solutions Websites]

R&D Package: Develop Climate Solutions Websites (CSW)

The following R&D Funds support the development of websites that explain both the climate problem and the solution.

	Year 1	Year 2	Year 3	...	Year 10	...	Year 20	...	Year 30
Website Development - Score Climate Remedies	$1	$1	$1	...	$1	...	$1	...	$1
Website Development - Generate Decarbonization Plan	$1	$1	$1	...	$1	...	$1	...	$1
Website Development - Assess Climate Situation	$1	$1	$1	...	$1	...	$1	...	$1
Website Development - Generate Reflectivity Plan	$1	$1	$1	...	$1	...	$1	...	$1
TOTAL	$7	$7	$7	...	$7	...	$7	...	$7

List of R&D Funds

Each of the following R&D Packages are supported by a webpage. As noted previously, each Package could be set up as a Division within an R&D laboratory.

- Achieve economic fusion within a few years (EF)
- Automate the construction of nuclear power sites (ANP)
- Develop underground nuclear power plants (UNP)
- Develop an automated system that places solar material onto soil (SDS)
- Develop a swappable car battery standard (SEVB)
- Develop a next generation building automation & control standard (NGBAC)

Webpage: Annual Decarbonization Tables (ADT)

[Future Planet/Remedy/Plan] [Climate Plan Options/Decarbonization Costs]

Decarbonization Costs

Annual Decarbonization Tables (ADT)

Annual Decarbonization Tables (ADT) estimate the additional cost for green products. This includes additional money spent by consumers to decarbonize (“green premium”) *plus* donations by foundations and individuals to tackle climate change *plus* money spent by government to encourage decarbonization. One can optionally view CO_2 reduced ($mtCO_2$), and cost per ton ($\$/mtCO_2$) for each year, within each sector (i.e., electrical power, transportation, chemical production, and materials production). One can click on a row for details.

Table Type: [one table per year/cost/CO_2 reduced/$ per ton] {i}
Year: [select a year between 1 and 30] {i}

	Year 1	Year 2	Year 3	…	Year 10	…	Year 20	…	Year 30
Electrical Power	$1	$1	$1	…	$1	…	$1	…	$1
Transportation	$1	$1	$1	…	$1	…	$1	…	$1
Chemical Production	$1	$1	$1	…	$1	…	$1	…	$1
Material Production	$1	$1	$1	…	$1	…	$1	…	$1
TOTAL	$4	$4	$4	…	$4	…	$4	…	$4

10. Website Area C - Future Planet

The Future Planet area of the website summarizes the climate problem with several graphs. These show what is expected to happen to the planet, each year, over the next hundred years or so. This includes global temperature increase, sea level rise, food production decrease, planet cooling needed to block cascading tipping points, cost of that cooling, and amount of money lost due to global warming.

These graphs are generated by climate models. Unfortunately, selecting a model is inherently confusing. Therefore, models are selected and managed by top scientists, and the website user selects a scientist, not a model. For example, one website user might trust the leader of the IPCC, while another user trusts the leader of NOAA.

The website user also specifies how many years they expect our society to emit CO_2 (e.g., 30, 40, 60 or 120 years), or magic dust as explained previously. Many economists expect CO_2 to be emitted for over 100 years, while climate activists prefer less than 40 years.

After the user selects a climate scientist, and a decarbonization profile, the graphs appear. These are important, since they help one better understand the climate problem. And they illustrate how, when and why we might block tipping points by reflecting sunlight back into outer space.

Components Graphs

The user can either look at a Summary with multiple Primary graphs, or view components that make up each Primary graph. For example, global temperature increase is a Primary graph, and it is the sum of temperature increase from CO_2, temperature increase from melting sea ice, temperature increase from thawing permafrost, etc. Component graphs are helpful since they illustrate more specifically what is expected to happen when, where, and to what extent. One might think of this as the expected sequence of events.

Tipping Points

Tipping points are activated by heat, and after being activated, they create more heat. In other words, they activate each other, and are therefore like dominos. For example, melting North Pole sea ice is expected to cause snow on Greenland to melt, which will reduce ocean currents, which will decrease moisture in soil, which will reduce food production.

Blocking Tipping Points

In theory, we can block cascading tipping points by cooling the planet, and we can cool the planet by reflecting sunlight back into outer space.

Reflecting Sunlight

There are two physical regions from which to reflect sunlight. One is above the North and South Poles ("Polar Regions") and the other is above the entire planet. The Polar Regions can be addressed with existing airplanes. However, new airplanes with larger wings would be needed to cool the entire planet, and developing these would take time. Therefore, if sunlight was reflected, Polar Regions would be cooled first, followed by the entire planet.

Polar cooling would be done to block tipping points and positive feedbacks associated with the Poles. These includes melting North Pole sea ice, melting Greenland, thawing permafrost, collapse of Atlantic Ocean Currents, and collapse of the West Antarctic Ice Sheet.

If we lose West Antarctica, sea levels would rise 3m (10ft), and this would affect coastal areas. Click here to see what this would do to Miami, Florida; and click here to see what this would do to New York City.

There are several ways to reflect sunlight, one of which is to inject sulfur into the upper atmosphere, above where airplanes typically fly. Sulfur is contained within coal and oil, and is therefore commonly emitted upon combustion. In theory, we can filter it out before combustion, move the harvested sulfur to an airplane, and emit it at a high altitude, instead of at ground level.

For details, see the *Reflecting Sunlight* chapter in the open-source Climate Lab Business Plan.

Recommended Reflectivity (RR)

After the user selects a climate model and number of years of CO_2 emissions, the future planet graphs appear, and the website looks for runaway climate change (i.e., cascading tipping points). If projected, the website calculates how much sunlight would need to be reflected to avoid it. This includes the amount of sunlight reflected above the poles, and the amount reflected above the entire planet. The website refers to this as “Recommended Reflectivity” (RR), and typical amounts are 1% of sunlight. The website also creates a plan that reflects this sunlight at the lowest cost.

The future planet graphs (e.g., expected global temperature increase, sea level rise, etc.) can be generated with or without Recommended Reflectivity. If RR is enabled, the future planet graphs show a better behaving planet.

Planet Cooling: [None/Recommended Reflectivity (RR)] {i}

For the most part, no one wants to “tinker” with the atmosphere. However, we need to compare reflecting sunlight, with not reflecting sunlight. The RR settings helps users evaluate both options.

For details on reflecting sunlight, see the European Union's 240-page report on this topic.

The Timing Problem

If we reflected 1% of sunlight starting 10 years from now, much would need to be done between now and then. For example, we would need to develop better instrumentation for measuring material in atmosphere, develop equipment that injects small amounts for purposes of field experiments, run experiments with different material and look for harm, design equipment that injects large amounts of material, and build large quantities of that equipment. The R&D needed to achieve 1% reflectivity within 10 years would be significant, and the world is not moving at this pace. In other words, we currently have a timing problem.

Reflectivity Plan

There are different ways to achieve the Recommended Reflectivity (e.g., SO_2, H_2SO_4, and MCB) and for each there is a cost, and a list of things that would need to be done between now and full scale production. The website refers to this list as a “Reflectivity Plan”.

The website summarizes the different reflectivity methods in a table with reflectivity method name in column #1, cost in column #2 (e.g., $ cost to reflect 1% of sunlight), and a link to suggested reflectivity plan in column #3.

Notes

Notes are shown at the bottom of each webpage, an example of which is shown here. These explain the graphs and the 'Conditions' fields.

Future Planet {i}

Graph: Global Temperature Increase (°C relative to 150 years ago)

Graph: Sea Level Rise (meters)

Graph: Global Land Suitable for Growing Corn (% relative to 2020)

Graph: Global Cost of Harm Due to Climate Change ($/year)

Notes

- Future planet graphs provide an estimate of our future. These are based on climate models and an expected number of years of CO_2 emissions. Setting up models is a complicated process. Therefore this is done by invited climate scientists, and the website user selects a scientist, not a model.
- Many models suggest bad things will still occur even if the world quickly reduces CO_2 emissions (e.g. sea level rise). For this reason, we might need to reflect a small percentage of sunlight back into outer space to cool the planet (e.g. via high altitude airplanes). The planet dashboard calculates how much would need to be reflected. This is referred to as "Recommended Reflectivity (RR)", and it is described with a plot of percent of sunlight reflected vs time. For details, see the 'Reflecting Sunlight' webpage.
- The 'Planet Cooling' field enables the website user to specify how much sunlight is reflected (e.g. via injecting material into stratosphere), and the Future Planet graphs reflect this treatment. Planet Cooling is specified as either 'none' or a percentage of RR (e.g. 25%, 50%, 100%, 200%, or 400%).

Information

The user clicks the {i} information icon for more information.

Article Webpages

The system supports entire webpages that are devoted to explaining information to the website user. These are referred to as “Article Webpages”, and each has a title (H1), URL suffix, subtitles (H2), and text.

Documentation Database

The website maintains a database of Notes, Information, and Articles. Each climate scientists can either keep these as is, or update to their satisfaction. If they update, then their version appears if their name is selected in the 'Climate Scientist' field.

An HTML editor enables climate scientists to edit after they login into the system. They can also add Notes, remove existing Notes, and add Articles. Also, the HTML editor enables them to add links to climate solution webpages, or external webpages.

Climate Scientist Registration

As mentioned previously, top climate scientists are invited to select climate models, and to specify parameters that drive that them. And then the website user selects a scientist, not a model (since models are confusing). To support this, the climate solution website provides a way for scientists to register, login, specify models, and edit description text.

Climate Scientist User Interface

A Climate Scientist Summary webpage displays a table that summarizes selections made by the participating climate scientists. Scientist names appear in rows, and selections appear in columns. The website user can click on a scientist name to open a webpage that displays information about that scientists and their selections. Scientists can add Notes, described earlier, to their description page. In many cases, files (e.g., XML) describe how a climate model is set up. A copy of these are stored in a read-only folder on google drive, and the website user can access these via links on the scientist's description webpage.

To survive climate change, we need to reduce CO_2 emission, and we probably need to reflect sunlight back into outer space. The climate solution website produces plans for both.

11. Website Area C - Future Planet Webpages

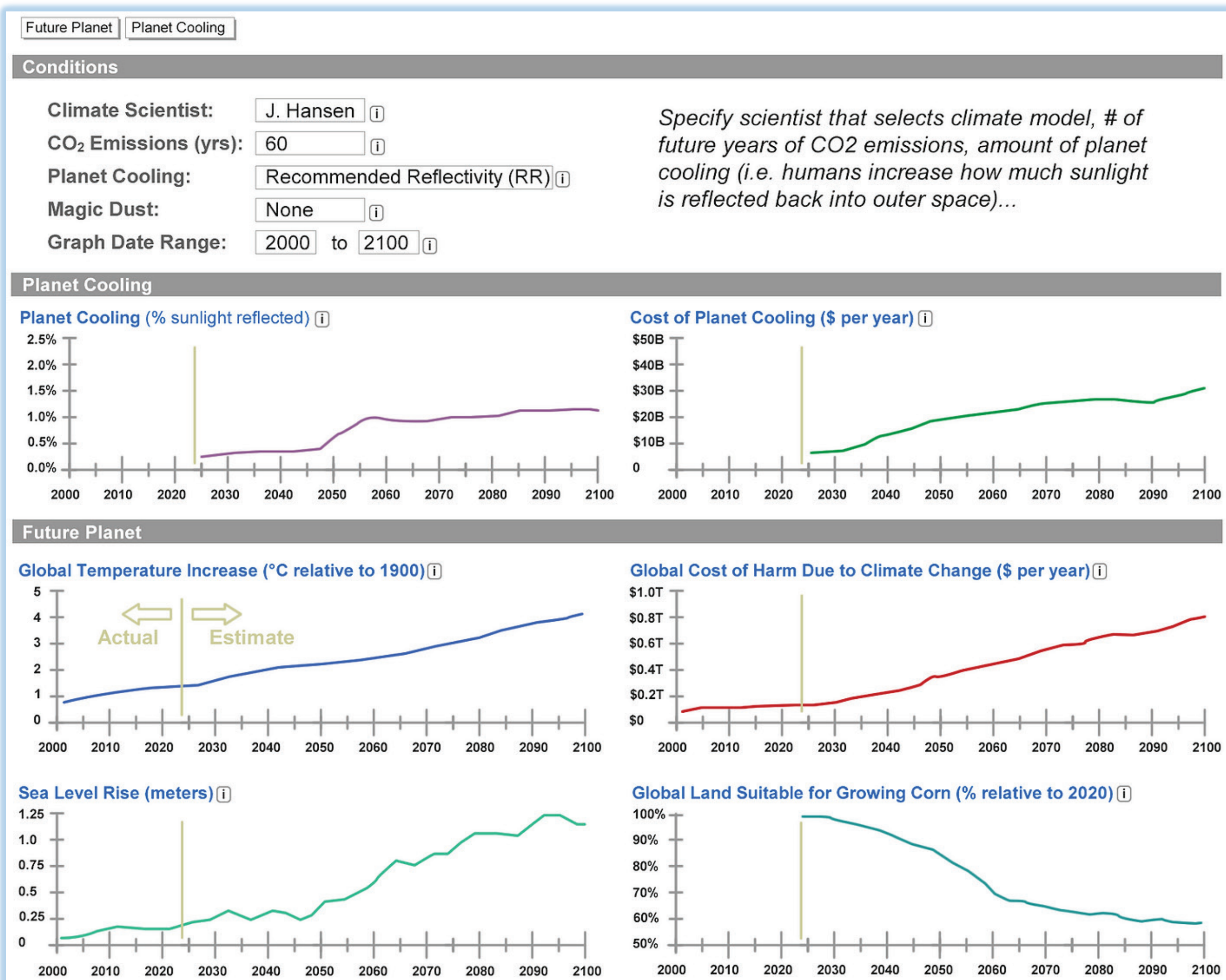
Webpage: Future Planet / Summary

This webpage summarizes the planet problem with multiple graphs that assume humans are not intentionally cooling the planet (e.g., airplanes are *not* spraying SO_2 into stratosphere).

The user selects a climate scientist, number of years of future CO_2 emissions, magic dust (described previously), and horizontal axis date range (e.g., year 2000 to 2100).

The user selects either No Added Reflectivity or Recommended Reflectivity (RR). As noted previously, RR is the amount of sunlight that needs to be reflected back into outer space to block cascading tipping points.

Click here to see an online prototype of this webpage.



Shown below is a Microsoft Word version of this webpage:

[Future Planet/Remedy/Plan] [Summary/Global Temperature/Warming Components/..]

Conditions {i}

Climate Scientist: [select name] {i}

CO_2 Emissions: [30/40/60/120 years] {i}

Planet Cooling: [None/Recommended Reflectivity (RR)] {i}

Magic Dust: [none/stop CO_2 emissions/stop fossil fuel combustion] {i}

Graph Date Range: <StartYear> to <StopYear> {i}

Planet Cooling {i}

Graph: Polar Region cooling (% of sunlight reflected above Polar Regions)

Graph: Entire Planet cooling (% of sunlight reflected from entire planet)

Graph: Cost of Planet Cooling ($/year)

Future Planet {i}

Graph: Global Temperature Increase (°C relative to 150 years ago)

Graph: Sea Level Rise (meters)

Graph: Global Land Suitable for Growing Corn (% relative to 2020)

Graph: Global Cost of Harm Due to Climate Change ($/year)

Notes

- Future planet graphs provide an estimate of our future. These are based on climate models and an expected number of years of CO_2 emissions. Setting up models is a complicated process. Therefore this is done by invited climate scientists, and the website user selects a scientist, not a model.
- Many models suggest bad things will still occur even if the world quickly reduces CO_2 emissions (e.g., sea level rise). For this reason, we might need to reflect a small percentage of sunlight back into outer space to cool the planet (e.g., via high altitude airplanes). The climate solution website calculates how much would need to be reflected. This is referred to as “Recommended Reflectivity (RR)”, and it is described with a plot of percent of sunlight reflected vs time. For details, see the 'Reflecting Sunlight' webpage.

Webpage: Future Planet / Reflecting Sunlight

This webpage summarizes the different ways to reflect sunlight. As noted previously, Recommended Reflectivity (RR) is the amount of sunlight that needs to be reflected back into outer space to block cascading tipping points.

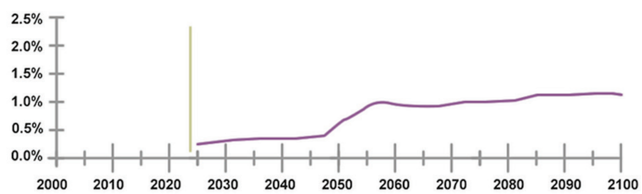
[Future Planet/Remedy/Plan] [Summary/Global Temperature/Reflecting Sunlight/..]

Recommended Reflectivity (RR) to Block Cascading Tipping Points {i}

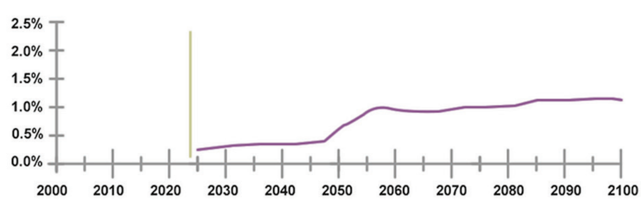
Climate Scientist: [select name] {i}

CO_2 Emissions: [30/40/60/120 years] {i}

Polar Region Recommended Reflectivity (% of sunlight reflected to block tipping points)



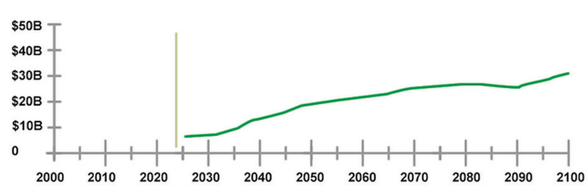
Entire Planet Recommended Reflectivity (% of sunlight reflected to block tipping points)



Reflectivity Cost {i}

Reflectivity Method: [SO_2/H_2SO_4/MCB] {i}

Cost of Recommended Reflectivity ($ per year)



Reflectivity Options {i}

Planet Cooling Method {i}	Cost ($/%ref)	Reflectivity Plan

Inject SO_2 into stratosphere	C1	Plan…
Inject H_2SO_4 into stratosphere	C2	Plan…
Marine cloud brightening	C3	Plan…

Notes

Webpage: Future Planet / Global Temperature

This webpage shows the total global temperature increase, relative to 150 years ago, along with components that make up that total.

[Future Planet/Remedy/Plan] [Summary/Global Temperature/Warming Components/..]

Conditions {i}

Climate Scientist: [select name] {i}

CO_2 Emissions: [30/40/60/120 years] {i}

Planet Cooling: [None/Recommended Reflectivity (RR)] {i}

Magic Dust: [none/stop CO_2 emissions/stop fossil fuel combustion] {i}

Graph Date Range: <StartYear> to <StopYear> {i}

Global Temperature Increase (relative to 150 years ago) {i}

Graph: TOTAL - Average Global Temperature Relative to 150 years ago (°C)

Components {i}

Graph: COMPONENT - Temp increase due to CO_2

Graph: COMPONENT - Temp increase due to methane

Graph: COMPONENT - Temp decrease due to sunlight reflecting off aerosols

Graph: COMPONENT - etc.

Notes

Webpage: Future Planet / Warming Rate Components

The Warming Components page breaks the global warming problem down into component parts. Components sum together to yield the total global warming *rate*, which is the average global temperature increase in units of degrees Celsius increase per decade (°C/decade).

The public is not comfortable with terms like “EEI”, “radiative forcing” and “W/m^2”; therefore, we work with °C/decade. This is roughly proportional to the earth equilibrium imbalance (EEI), which is similar to radiative forcing. If EEI was $1W/m^2$ for example, then some of this energy would flow into ocean water and some into air, and this ratio might change over time. Therefore, rate of change of surface air temperature over land and water is *roughly* proportional to EEI, yet not directly proportional.

An example component is methane emissions, and an example sub-component is primary sources of methane emissions (e.g., leaks from natural gas production, agriculture, wetlands, thawing permafrost). Also, one can divide this up further and include things like thawing permafrost from each region (e.g., Canada, Siberia, Greenland, etc.).

Many components correspond to “tipping points” (e.g., melting Arctic sea ice, melting Antarctica sea ice).

Understanding components and sub-components is important since it gives one an idea of what is expected to happen when, where and to what extent. For example, if thawing permafrost in Canada increases exponentially, it might “blow up” at some point, and dominate other methane sources.

The user specifies how much information is displayed via the Components field. For example, if set to “Primary”, then only a handful of primary components are displayed. If set to “Secondary”, then secondary components are added to each primary graph (e.g., several sources of methane are added to graph that shows total methane). And if set to “Tertiary” then even more graphs are added (e.g., methane from Canada permafrost, methane from Siberian permafrost, etc.).

[Future Planet/Remedy/Plan] [Summary/Global Temperature/Warming Components/..]

Conditions {i}

Climate Scientist: [select name] {i}

CO_2 Emissions: [30/40/60/120 years] {i}

Planet Cooling: [None/Recommended Reflectivity (RR)] {i}

Magic Dust: [none/stop CO_2 emissions/stop fossil fuel combustion] {i}

Components: [Primary/Secondary/Tertiary] {i}

Graph Date Range: <StartYear> to <StopYear> {i}

Total Global Warming Rate {i}

Graph: TOTAL - Rate of Global Temperature Increase (°C/decade)

Components {i}

Graph: COMPONENT - Rate due to CO_2

Graph: COMPONENT - Rate due to methane emissions

Graph: COMPONENT - Rate due to melting Arctic sea ice

Graph: COMPONENT - Rate due to melting Antarctica sea ice

Graph: COMPONENT - Rate due to sunlight reflecting off aerosols (negative °C/decade)

Graph: COMPONENT - etc.

Notes

Webpage: Future Planet / Sea Level Rise

This webpage shows total sea level rise, relative to 150 years ago, along with components that make up that total.

If the Components field is set to 'Primary', a handful of components are shown (e.g., Greenland, West Antarctica, and East Antarctica). Alternatively, if set to 'Secondary', more are shown (e.g., different parts of Greenland).

Climate scientists Dr. James Hansen expects multiple meters of sea level rise between 2050 and 2150.

[Future Planet/Remedy/Plan] [Summary/Global Temperature/Sea Level Rise/..]

Conditions {i}

Climate Scientist: [select name] {i}

CO_2 Emissions: [30/40/60/120 years] {i}

Planet Cooling: [None/Recommended Reflectivity (RR)] {i}

Magic Dust: [none/stop CO_2 emissions/stop fossil fuel combustion] {i}

Components: [Primary/Secondary] {i}

Graph Date Range: <StartYear> to <StopYear> {i}

Total Sea Level Rise {i}

Graph: TOTAL - Sea level rise (m)

Components {i}

Graph: COMPONENT - Sea level rise due to melting Greenland

Graph: COMPONENT - Sea level rise due to melting West Antarctica Ice Sheet (WAIS)

Graph: COMPONENT - Sea level rise due to melting East Antarctica

Graph: COMPONENT - etc.

Notes

Webpage: Future Planet / Cost of Harm due to Climate Change

This webpage shows total cost of harm due to climate change worldwide, along with components that make up that total.

Costs pertain to one of the following: (a) one nation, (b) all nations, (c) one citizen in one nation, or (d) all citizens on planet (e.g., $ cost per human). To select one of these, the website user specifies a nation or “Global” in the Nation field; and specifies “Entire Nation” or “One Citizen” in the Cost field. For example, if 'USA' and 'One Citizen' are selected, then costs are displayed in units of dollars cost, per American, per year. One can divide cost-per-nation by population, to calculate cost-per-citizen.

[Future Planet/Remedy/Plan] [Summary/Global Temperature/Cost of Harm/..]

Conditions {i}

Nation: [Select one specific nation or “Global”] {i}

Cost: [Entire Nation/One Citizen] {i}

Climate Scientist: [select name] {i}

CO_2 Emissions: [30/40/60/120 years] {i}

Planet Cooling: [None/Recommended Reflectivity (RR)] {i}

Magic Dust: [none/stop CO_2 emissions/stop fossil fuel combustion] {i}

Components: [Primary/Secondary/Tertiary] {i}

Graph Date Range: <StartYear> to <StopYear> {i}

Total Cost of Harm {i}

Graph: TOTAL - Cost of harm due to climate change, worldwide ($/year)

Components {i}

Graph: COMPONENT - Money lost due to sea level rise

Graph: COMPONENT - Money lost due to more intense storms

Graph: COMPONENT - Money lost due to higher food prices, due to less moisture in soil

Graph: COMPONENT - etc.

Notes

12. Website Cost Calculations

The website displays cost-to-society in multiple tables, which ultimately constitute a climate plan.

Costs to Society

As noted previously, the website defines cost-to-society as additional money spent by consumers to decarbonize ("green premium") *plus* donations by foundations and individuals to tackle climate change *plus* money spent by government to encourage decarbonization. Additional money for green energy shows up as an increase in the cost of goods and services.

Costs can be categorized in different ways. For example, costs can be divided into decarbonization costs, and sunlight reflectivity costs; or divided into operations costs, and R&D costs.

R&D costs support scientists and engineers who do research and development. There are 180 top-tier research universities in the United States, and together they do tens of billions of dollars of R&D annually. Sunlight reflectivity R&D supports SAI, while decarbonization R&D reduces the cost of green energy. For details, see the Climate Lab Business Plan.

Sunlight reflectivity operations costs refer to money spent to reflect sunlight. For a cost estimate, click here.

Decarbonization operations costs refer to additional money spent by consumers on green energy. This is sometimes referred to as the "green premium."

Governments and foundations support programs that supposedly reduce CO_2 emissions. Each program has a cost, estimated CO_2 reduced, and cost per ton. An economic simulator can simulate an economy with and without a program, and subtract the two scenarios to estimate program cost and impact.

Energy Economics

CO_2 is emitted into the atmosphere when coal, natural gas, and oil-based products are burned.

Each nation consumes a known amount of fuel at a known price. One can multiply quantity by price to calculate the cost to consumer, and this adds to the cost of goods and services. For example, if coal sells for $30 per ton wholesale and a nation consumes 1 billion tons a year, then total wholesale cost would be $30B.

$$\text{Non-Green Energy Costs} = (\text{Coal}_{consumption} \times \text{Coal}_{price}) + (\text{Oil}_{consumption} \times \text{Oil}_{price}) + (\text{NaturalGas}_{consumption} \times \text{NaturalGas}_{price})$$

Electricity generated without emitting CO_2 is referred to as "Green Electricity" and typical sources include solar, wind, hydro and nuclear power. The amount of electricity generated, multiplied by the wholesale price, adds to a nation's cost of goods and services.

$$\text{Green Energy Costs} = (\text{ElectricityGeneratedByRenewablesAndNuclear} \times \text{ElectricityPrice})$$

Energy cost to society is roughly the sum of four components:

Energy Cost to Society	=	Money spent by gov't for energy related activities
	+	Donations for climate/energy by foundations/individuals
	+	Non-Green Energy Wholesale Costs
	+	Green Energy Wholesale Costs

Carbon Dioxide Emissions

A known amount of CO_2 is emitted into the atmosphere for each unit of fossil fuel that is burned. For example, 2.75 grams of CO_2 is emitted into atmosphere for each gram of natural gas that is burned. The weight increases since natural gas (CH_4) mixes with oxygen (O_2) in atmosphere to form water (H_2O) and carbon dioxide (CO_2). Fossil fuel consumption is well known (e.g., number of tons of coal burned each year in any given nation); therefore, one can easily calculate CO_2 emissions.

$$
\begin{aligned}
CO_2\ \text{Emissions} = &\ (\text{Coal}_{consumption} \times \text{Coal}_{CO2\text{-}per\text{-}unit}) \\
+ &\ (\text{Oil}_{consumption} \times \text{Oil}_{CO2\text{-}per\text{-}unit}) \\
+ &\ (\text{NaturalGas}_{consumption} \times \text{NaturalGas}_{CO2\text{-}per\text{-}unit})
\end{aligned}
$$

Economic Energy Models

One can use an economic energy model (e.g., NEMS) to estimate the above values for future years (i.e., fossil fuel price/quantity, electrical power generation price/quantity per source). Also, one can simulate an economy with no climate initiatives, and simulate an economy with one initiative. And then subtract these two to calculate the initiate's cost (i.e., Energy Cost to Society) and impact (i.e., CO_2 Emissions Reduced).

Electrical Power Costs

One can subtract the cost of green energy from the cost of fossil fuel to calculate the cost to decarbonize electrical power. For details, see the *Decarbonizing Electrical Power* chapters within the Climate Lab Business Plan.

13. Website Development Strategy

In theory, *multiple* climate solution websites could be developed by different teams.

The resulting websites would probably differ in multiple ways, including: (a) funding source and their requirements, (b) user interface, (c) language, (d) nations supported by decarbonization plan generator, (e) policy options supported by plan generator, (f) information displayed in decarbonization reports, and (g) and climate scientists that specify climate models.

For example, Chinese policymakers might want a website in Mandarin that is overseen by energy economists employed by the Chinese government. They might focus on how climate change influences the cost of food in China. And German policymakers might want a website overseen by energy economists employed by the EU that focus on AMOC.

The document you are reading is open source, and can therefore help interested parties get started. Also, if website source code is open-source (i.e., free), participants can make use of it and advance more quickly.

Achieving Relevance

In order for a climate solution website to be relevant, it would need to meet the satisfaction of policy makers. To do this, developers might need to: (a) introduce an initial version, (b) show to policy makers, (c) receive suggestions for improvement, (d) produce improved versions, and (e) repeat.

Eliciting Trust

It is easy for someone to produce phony numbers, either wittingly or unwittingly. Policymakers and economists realize this, and are therefore often skeptical. However, much can be done to elicit trust. This includes: (a) building on top of existing models that are already trusted by policymakers, (b) collaborating with law makers and gov't economists, (c) requiring materials be made open source, (d) paying trusted professionals to review, (e) requiring reviews be made public, and (f) improve based on feedback. Developing a trusted website might cost 10-times more than developing an ignored website.

Budget

A budget for a climate solution website could potentially vary dramatically (e.g., $100K to $10M). This is because it cost more money to support: (a) more nations, (b) more policy options, (c) more reporting, and (d) more iterations (i.e., receive feedback, improve, and repeat). Funding sources and developers need to agree on exactly what is being developed, when, by whom, and at what cost.

14. Website User Interface

Below are notes on the website user interface.

Home Page and Menubar

The home page and menubar are summarized below.

Homepage	*Menubar*	*Content*
Future Planet	Future Planet	
Summary	*same as homepage*	*Summary graphs*
Planet Cooling		*Summary graphs, cooling on*
Reflecting Sunlight		*Reflecting sunlight options*
Global Temperature		*Global temperature components*
Warming Components		*Warming rate components*
Sea Level Rise		*Sea level rise components*
Cost of Harm		*Cost of harm components*
Climate Remedies	Score Climate Remedies	
US | China | EU		
Climate Plan	Create Climate Plan	
Policy Options	Policy Options	*Climate plan options*
Climate Plan Summary	Climate Plan Summary	*Summary Budget Table (SBT)*
Decarbonization		
R&D	Decarbonization / R&D	*Master R&D Budget Table (MRDT)*
Operations	Decarbonization / Operations	*Annual Decarbonization Tables (ADT)*
Reflecting Sunlight		
R&D	Reflecting Sunlight / R&D	*SAI Division, table listing multiple funds*
Operations	Reflecting Sunlight / Operations	

Website Buttons

The website supports the following buttons

Export User clicks **Export** button to export data to picture png file or data to csv text file.

{i} User clicks {i} information icon to see more information.

PDF Report Generator

The climate solution website displays information on webpages, and the user can drill down for details.

Also, all webpages include a **Report** button that generates a PDF report that relates to that webpage. After clicking this button, the user enables checkboxes to specify what appears in the generated report. For example, an electric power decarbonization report might include a table that shows net jobs gained and lost, per state, per year (e.g., states appear in rows, and years appear in columns).

Website URL Coding

Options specified on webpages are coded into the displayed URL. Subsequently, the website user can email a URL to a colleague and the same information will be displayed.

Coding is abbreviated to minimize URL length. For example, "n=us" might indicate a Nation field is set to the United States.

Website URL Structure

Website directory names adhere to a reasonable structure, an example of which is shown below.

Area A - Evaluate Decarbonization Initiatives

www.domain.org/	remedy/	nation/	…

Area B - Create Climate Plan

www.domain.org/	plan/	nation/	sbt/	pcrd/	
				pcop/	
				adt/	
					power/
					trans/
					chem/
					mat/
				mrdt/	
					web/
					fus/
					fis/
					unp/
					sds/
					sevb/
					ngbac/

Area C - Future Planet

www.domain.org/	planet/	scientist/	summary
			global-temperature
			global-warming-rate
			sea-level-rise
			cost-of-harm
			cooling-needed

15. Related Material

Videos by Glenn Weinreb

A Plan to Save the Planet (27-minute video)
https://www.youtube.com/watch?v=9RY1943xlRI

How Much Does it Cost to Fix the Climate Problem? (CS11)
https://www.youtube.com/watch?v=Q0TyImEEk9I

How to Decarbonize the Making of Materials & Chemicals (CS10)
https://www.youtube.com/watch?v=nqGALLC-R1k

Policy Tools are Needed to Tackle Climate Change (CS8)
https://www.youtube.com/watch?v=gwPMe29F8Ag

How to Resolve Climate Change at the Lowest Cost to Society (CS7)
https://www.youtube.com/watch?v=VBSsRb4SeoI

The Politics of Climate Change (CS5)
https://www.youtube.com/watch?v=UJ72hDDguyc

The Easiest Way for Government to Tackle Climate Change (CS3)
https://www.youtube.com/watch?v=QvlOVtCi-qw

YouTube Videos by Weinreb
http://www.aplantosavetheplanet.org/climate-solution-videos

Articles & Books by Glenn Weinreb

Climate solution articles by Weinreb: www.manhattan2.org/#articles

Free climate book: www.APlanToSaveThePlanet.org/pdf

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/lab

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