COLUMBIA | SIPA
School of International and Public Affairs

S.4013 ENERGY SECURITY AND INDEPENDENCE ACT OF 2022

August 17th, 2022

ACKNOWLEDGEMENTS

Manager: Manasi Gupta

Deputy Manager: Vanessa Lincoln

Report Design: Xinran Wu and Emma Sease

Team: Nicole Cornell, Manasi Gupta, Tal Henig-Hadar, Erin Machida-Kwok, Vanessa Lincoln, Bevin Pan, Emma Sease, Holly Sullivan, Katyana Azlia Wardhana, Xinran Wu, Brett Wieland

Faculty Advisor: Steven Cohen

CONTENTS

EXECUTIVE SUMMARY

S.4013, or the “Energy Security and Independence Act of 2022” aims to establish a viable renewable energy manufacturing supply chain in the United States. It plans to do this by designating ‘energy’ as a strategic and critical material under the Defense Production Act of 1950, a federal law that enables the president to expand supply of materials and services deemed of national importance. By allocating several billion dollars through loans and grants to private companies seeking to set up renewable energy related manufacturing processes, and ensuring that they do so while prioritizing environmental justice, the bill marks a new promising era of clean energy transition in the United States.

In this report, we will first discuss the major provisions of the bill. This will be followed by an overview of the science behind the main problem the bill is trying to solve, climate change. We will then examine some of the impacts of climate change and how those impacts are felt unequally by specific communities.

After this we discuss three specific solutions proposed by the bill, understand nuances of renewable energy and the barriers to transitioning to clean energy. Lastly, we will demonstrate the different indicators that could be used to measure the success of the solutions proposed by the bill and the challenges we foresee with measurement of said indicators. Measuring progress on the key provisions of the bill would be essential to the United States’ ambitious goal of halving its carbon emissions by 2030.

SUMMARY OF THE BILL

Introduced to Congress by Senator Bernie Sanders, S.4013, or the Energy Security and Independence Act of 2022, aims to promote United States energy security and independence by bolstering the United States' Renewable Energy supply chain infrastructure.

The primary goal of this bill is to develop a plan for the United States to achieve energy independence by establishing an operational domestic manufacturing supply chain for elements required in energy efficiency, renewable energy systems and technologies. In doing this, the bill uses the authority of the Defense Production Act of 1950, which allows the federal government to rapidly mobilize production of a needed resource or technology in the interest of national security. In order to peruse the provisions of the Defense Production Act, the bill proposes referencing energy-efficiency and renewable energy systems and technologies as critical and strategic materials.

Using the Defense Production Act, the President will be able to use the authorities under Title I and III of the DPA to deploy the 100 billion dollars allocated in financial assistance to reinvigorate a self-sufficient clean energy industrial base and create the capabilities to bolster domestic renewable energy supply chains.

The Act proposes establishing a domestic renewable energy industrial base task force including a holistic group of experts in manufacturing, engineering, science and planners in areas such as equitable energy, energy democracy, environmental justice and labor unions. They will work alongside the Secretary of Energy, Secretary of Transportation, the Secretary of Labor and other relevant Federal, State and Local agencies on this resolution.

MAJOR PROVISIONS

Within the first 180 days of the bill's enactment, the Secretary of Energy must establish a financial assistance program which would designate $10 billion over the next decade to renew existing as well as develop new manufacturing facilities for renewable energy systems and technologies.

The amendment of Section 422 of the Energy Conservation and Production Act will allocate $3 billion to weatherization per annum and $10 billion to the procurement and installation of public heat pumps over the course of the next decade.

Under the bill, minimum labor standards must be upheld in all projects subsidized, specifically ‘employee status’ designation, prevailing wages, and protection for all project labor contracts. The legislation also emphasizes the guarantee that environmental justice communities such as communities of color, low-income communities or indigenous communities will receive no less than 40% of the total amount of federal support and assistance.

This bill was introduced on behalf of Senators Padilla, Booker, Warren, Markey, Murphy and Merkley on April 6th, 2022 and is currently awaiting approval from the Senate.

Key Definitions & Scope

Renewable energy system refers to a system of renewable energy technologies, from the renewable energy generation to energy-efficiency measures within physical infrastructure.

Environmental justice community refers to a community with significant representation of 1 or more communities of color, low-income communities, or tribal or indigenous communities that experience, or are at risk of experiencing adverse human health or environmental effects as compared to other communities.

Weatherization is the practice of decreasing heating and cooling costs through installation of measures that increase energy efficiency.

Heat Pumps are devices that can heat or cool buildings by transferring thermal energy indoors or outdoors using electricity or mechanical energy S.4013 refers to public heat pumps, which are owned or operated by a unit of federal, state or local government or a cooperatively owned entity.

WHAT IS CLIMATE CHANGE?

The Carbon Cycle

Carbon is the essential building block of life. Every organism requires it to carry out its life functions. However, in order to remain an accessible element, it must be cycled through the atmosphere, through organisms, and through the very earth itself. The carbon cycle is the process by which carbon atoms travel from the earth to the atmosphere, then back to the earth in a continuous loop. Most carbon present in earth systems is stored in rocks, sediments, the ocean, or living organisms (SERC Carleton; The National Ocean Service).

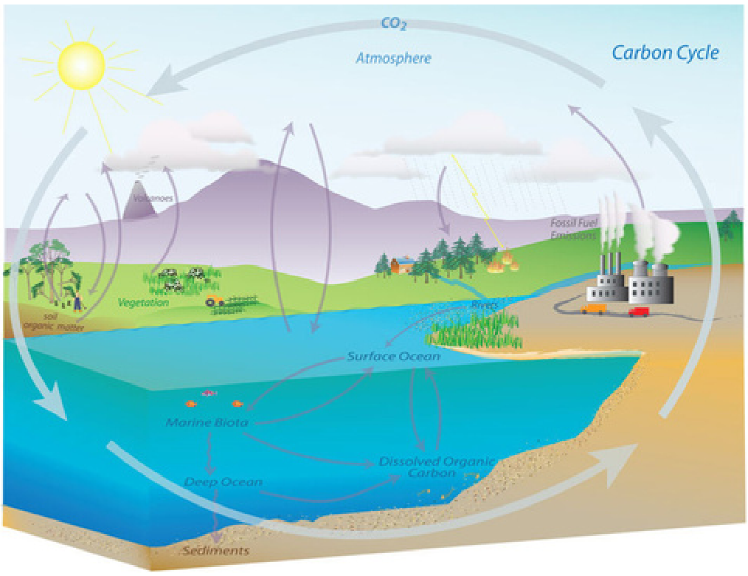


Figure 3: The Carbon Cycle

Source: NOAA

Sometimes these factors feed into one another. For instance, when organisms die their bodies decompose into soil and sediment, taking their stored carbon with them. Eventually, after being subjected to immense pressure, these sediments are formed into rocks, retaining the same carbon from the original organism. The carbon in storage is then naturally released back to the atmosphere through respiration, volcanos, fires, and gas exchange at the surface of the ocean (National Oceanic and Atmospheric Administration 2019).

The Greenhouse Effect

Carbon in its gas forms, primarily carbon dioxide and methane, contributes to an atmospheric phenomenon known as the greenhouse effect. The greenhouse effect is the process that occurs when gas in the atmosphere traps heat energy (Denchak 2019). This heat primarily is the result of the earth's surface absorbing the sun's energy and re-emitting it back upwards (Australian Government Department of Agriculture, Water and the Environment). The presence of greenhouse gasses, of which carbon dioxide and methane are two, makes earth around 33° C warmer and thus more habitable than it would be without them (Denchak 2019). Other greenhouse gasses include water vapor and nitrous oxide (NASA). The greenhouse effect as it naturally occurs is the reason why life can flourish on our planet.

WHAT IS CLIMATE CHANGE?

The Combustion of Fossil Fuels

Since the beginning of the industrial revolution, the burning of fossil fuels has provided most of the energy that we use in our day to day lives. In 2022, fossil fuels still contribute to 80% of our energy usage. Fossil fuels are made up of the fossilized remains of living organisms, and thus have a high carbon content. When they are burned, this carbon is then emitted back into the atmosphere, accelerating the release step of the carbon cycle. Carbon is released not only through fossil fuel burning, but also through extraction. Carbon dioxide and methane, along with other harmful particulate matter, are released from wells, mines, processing plants, and vehicles (NRDC 2022). From the wells, mines, transportation, and processing of fossil fuels, carbon dioxide and methane are released along with other harmful particulate matter. When burned, additional carbon dioxide and methane are released into the atmosphere as well as poisonous gasses such as carbon monoxide and nitrous oxide (NRDC 2022).

Anthropogenic Climate Change

The burning of fossil fuels for energy has a large impact on the greenhouse effect that leads to global climate change. In fact, human activities are responsible for almost all of the increase in greenhouse gasses in the atmosphere over the last 150 years (The Climate Reality Project 2019). When we add carbon-based greenhouse gasses to the atmosphere through the burning of fossil fuels, we increase the number of heat-trapping molecules, thereby increasing the capacity of the atmosphere to cling to heat. This results in an increase in temperature of the atmosphere, oceans, and land surface. This leads to adverse effects such as flooding of coastal cities, the desertification of fertile areas, the melting of glacial masses, the proliferation of devastating hurricanes and so on.

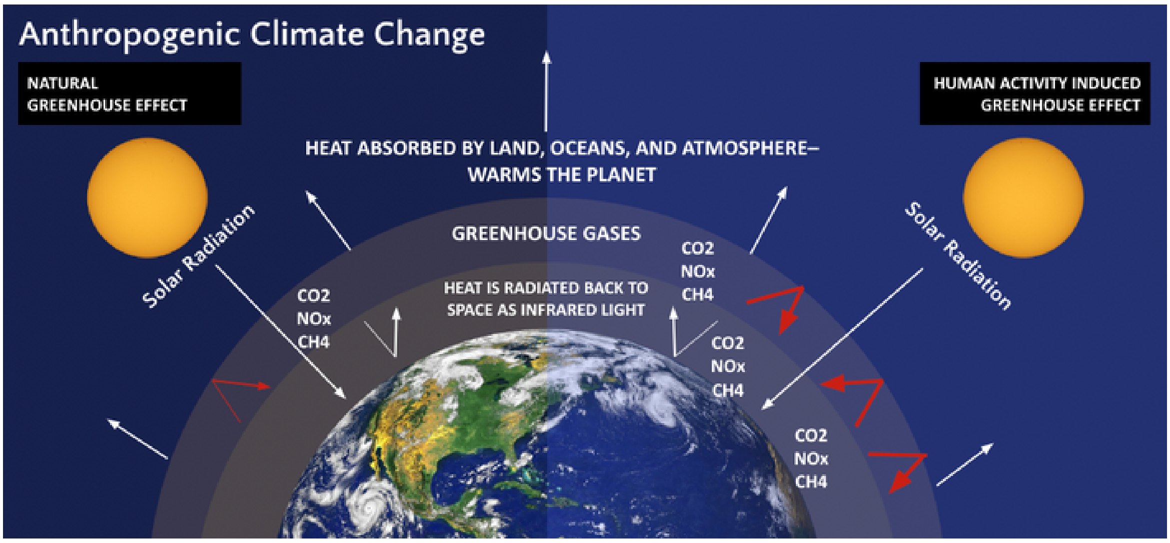


Figure 4: Anthropogenic Climate Change

WHAT IS CLIMATE CHANGE?

We know that the increase of global temperatures is a result of human activity for a variety of reasons. Firstly, there is a strong positive correlation between the emission of carbon dioxide and the rise in temperatures (The Climate Reality Project 2019). Additionally, other sources of carbon emissions have been extraordinarily low compared to anthropogenic emissions. For instance, the United States Geological Survey reported that volcanoes emit less than a percent of the carbon dioxide humans do each year. Similarly, the emissions from forest fires produce around 0.05% as many emissions as human activities (Abnett 2021).

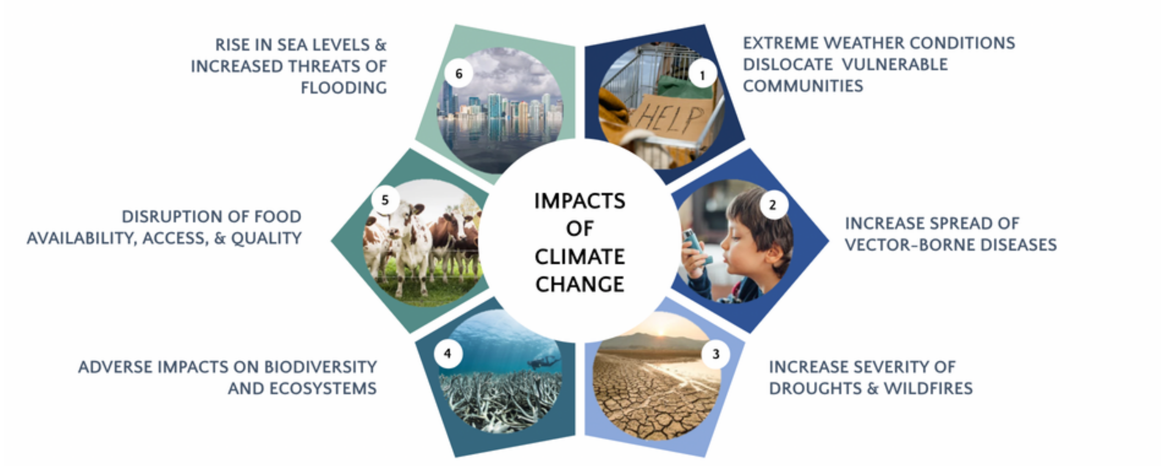


Figure 5: Effects of Climate Change

Effects of Greenhouse Gas Emissions on Human Health

Not only does the burning of fossil fuels create adverse effects for our environment, but it also takes a toll on the well-being of our citizens. Greenhouse gasses can produce harmful effects for human health in several ways, including exposure-related illness and heat-related illness.

Exposure-related illnesses can develop in those who have constant exposure to carbon emissions as well as the other byproducts of fossil fuel extraction and combustion. During extraction, the benzene and formaldehyde are released, both of which are cancer causing compounds. Additionally, the fumes can cause or worsen respiratory conditions such as asthma. Some 17.6 million Americans are exposed to these conditions daily (NRDC 2022). During the combustion of fossil fuels in engines and motors, carbon monoxide and nitrous oxide are produced. Both of these compounds are considered poisonous and create smog in big cities. These compounds also contribute to adverse respiratory conditions.

Lastly, climate change has been proven to cause the hottest days of the year to gradually become hotter. This added heat can worsen existing conditions, such as cardiovascular diseases, or spark new illnesses such as heat stroke or heat exhaustion. In 2018, the EPA recorded around 2.9 million deaths where heat was a main or contributing cause (2021).

WHAT ARE THE IMPACTS OF CLIMATE CHANGE?

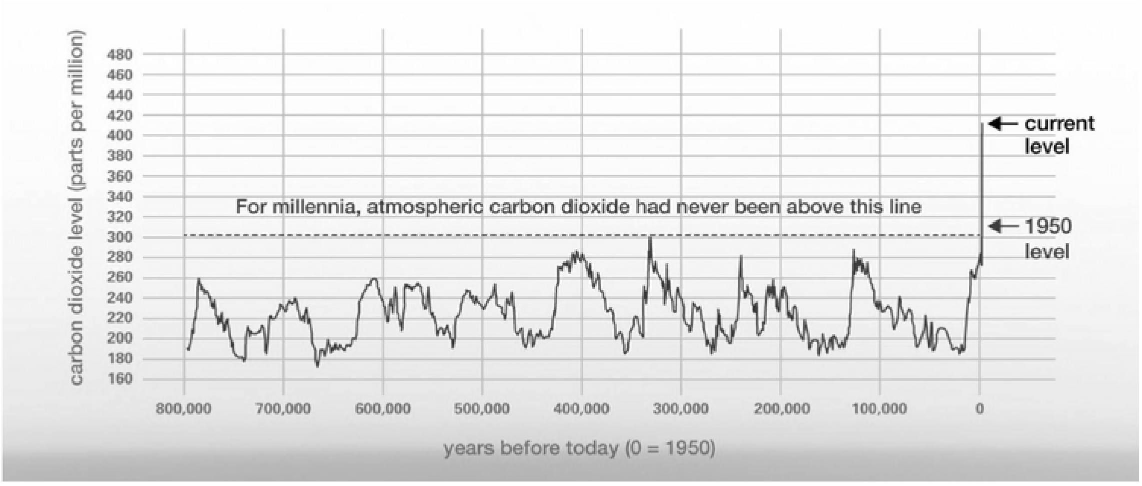


Figure 1: Global Temperature and Carbon Dioxide

Source: NASA

Climate Change

Climate change is the major environmental problem indirectly addressed by the bill. The atmospheric build-up of greenhouse gas such as carbon dioxide is one of the main drivers of climate change (U.S. EPA, 2017). The United States produced 5,222 million metric tons of carbon dioxide in 2020, making it the world's second-largest emitter of greenhouse gasses after China (U.S. EPA, 2017). Petroleum contributes the most (45%) to the country's greenhouse gas emissions, followed by natural gas (36%) and coal (19%) (U.S. Energy Information Administration, 2021). The Energy Security and Independence Act of 2022 addresses the complex issue and impacts of climate change as a result of the increased concentrations of atmospheric greenhouse gasses from fossil fuel combustion.

Other Environmental Effects

In addition to climate change, the Energy Security and Independence Act of 2022 also aims to alleviate detrimental impacts of other negative environmental externalities such as fine particulate matter air pollution (PM2.5) from the burning of fossil fuels. The extraction of natural gas and oil through hydraulic fracturing processes also leads to contamination of groundwater. PM2.5 air pollution and the leaking of "fracking fluids" are large environmental risk factors for human health and well-being. Inadvertently, the Act tackles the source of PM2.5 air pollution and contamination of water resources from fracking by prioritizing and allocating capital to projects that would benefit environmental justice and high-risk communities that are disproportionately impacted by challenges posed by climate change.

WHAT ARE THE IMPACTS OF CLIMATE CHANGE?

Impacts of Climate Change

The substantial and continuing increase in atmospheric greenhouse gasses from the use of fossil fuels to meet increasing energy demands, has adverse wide-ranging impacts and consequences on natural ecosystems, the social well-being of many diverse communities, and the economy. The magnitude of each impact as a result of climate change differs across different regions—but together, the spatial extent and temporal range of these extremes make climate change one of the most urgent long-term issues facing the world today. The following are some of its effects:

Increased Prevalence of Extreme Weather Events

Climate change is expected to worsen the frequency and intensity of extreme weather events. For example, tropical storm activity in the Atlantic Ocean, the Caribbean, and the Gulf of Mexico has increased over the past 20 years. Hurricane intensity during the 2020 season was impacted more strongly by climate change than other storms, with three-hourly rainfall amounts for hurricanes increasing by 11% (Smith, 2022).

Rising Sea Levels

The warming of the ocean and the partial melting of the glaciers is increasing sea levels. High tides together with sea-level rise increase the extent and frequency of flooding in many regions in the United States. Flooding is becoming more frequent along the U.S. coastline, especially on the East Coast. For example, Boston, Massachusetts, has exceeded the flood threshold most frequently—an average of 13 days per year—followed by Bar Harbor, Maine, and Sandy Hook, New Jersey which experienced floods at least five times more frequently than they did in the 1950s (US EPA, 2016).

Increased Severity of Drought and Wildfires

In recent decades, the western and southwest United States have warmed, and the frequency and severity of heatwaves and drought have increased. Warmer temperatures enhance evaporation and therefore dry out soils and vegetation (Environmental Defense Fund, 2021). The western drought has resulted in a decrease of approximately 41% of Glen Canyon Dam's generating capacity, which is currently at 870 MW (Patel, 2021). Additionally, at Lake Powell, record-low water levels are transforming the landscape and renewing standing disputes over the land the reservoir drowned (Rott, 2022). This significantly reduces the potential for more renewable energy production.

WHAT ARE THE IMPACTS OF CLIMATE CHANGE?

Environmental Justice

The impacts of climate change are not felt equitably across communities. A 2019 study of 108 urban areas in the U.S., found that 94% of studied areas that were redlined in the 1930s experienced surface temperatures significantly higher than other coded areas by as much as 7°C. (Hoffman, Shandas, and Pendleton 2019). Furthermore, racial-ethnic minorities in the United States are exposed to disproportionately high levels of ambient fine particulate air pollution (PM2.5) (Tessum, Paolella, Chambliss, Apte, Hill, Marsha).

This mainly stems from the fact that areas inhabited by low-income communities or communities of color often have low tree canopies and are more likely to be proximate to building complexes with large parking lots as well as highways and manufacturing facilities- all sources of heat and particulate emissions.

This creates a vicious cycle where communities of color are often both disproportionately at risk from the effects of climate change and also lack access to help when affected by health effects of extreme heat, emissions, and climate disasters, further exacerbating existing inequalities.

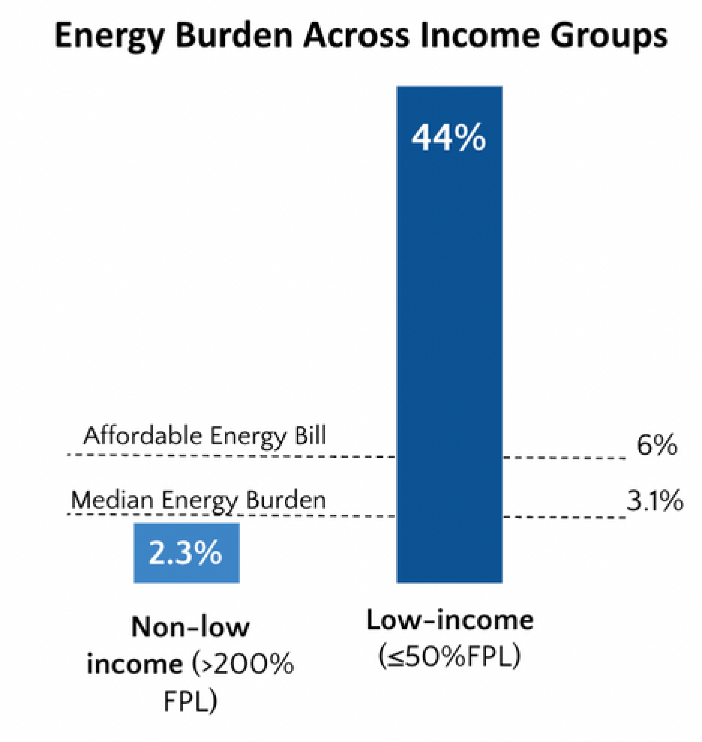


Figure 2: Burden of Energy in Low-income groups
Source: American Council for an Energy-Efficient Economy, 2020

Furthermore, our dependency on fossil fuels and the variability in their prices affects low-income communities that spend anything between 24-54% of their household income on energy. The threshold beyond which economists believe energy ceases to be "affordable" is 6 percent of a household's income. (Fisher, Sheehan & Colton, 2013).

A just energy transition focused on job creation in regions currently dependent on fossil fuel jobs could, in the long term, help resolve both the continuing emissions worsening the climate crisis as well as the high energy costs exacerbating social and economic inequity.

WHAT SOLUTIONS DOES THE BILL PROPOSE?

While it is facing the extreme effects of climate change, coupled with the insecurities of conflicts abroad, the United States must find a way to decrease its dependence on fossil fuels in general, but especially those it imports from other countries. S.4013 aims to do so in the following ways:

- **Funding the Defense Production Act to increase domestic production of renewable energy**
- **Investing in the renewable energy supply chain**
- **Investing in energy efficiency through weatherization and heat pumps**

Solution 01 | Funding the Defense Production Act to increase domestic production of renewable energy

Through the passage of this bill, in addition to any funds that are currently available, $100 billion would be made available to the president to establish, maintain, protect, or restore the domestic industrial base and manufacturing capabilities for covered energy-efficiency and renewable energy systems and technologies. This would include providing loan guarantees, loans, purchase agreements, and grants to manufacturing entities to expand the domestic productive capacity of those entities.

Through the use of the Defense Production Act (DPA), the president is given the authority to compel the private sector to produce essential goods during times of insecurity. There are two main parts to the DPA that give the president this power. The first is Title I: Prioritization and Allocation, which allows the president to determine which goods are "critical and strategic," ensuring the private sector accepts and prioritizes government contracts for producing these goods. Title III: Expansion of Productive Capacity and Supply, gives the president power to make loans and provide guarantees to businesses, purchase critical and strategic goods, and repurpose production facilities to increase capacity (Lawson & Rhee, 2020). Through S.4013, the president would have the ability to use the above titles in regard to renewable energy production

Solution 02 | Investing in the renewable energy supply chain

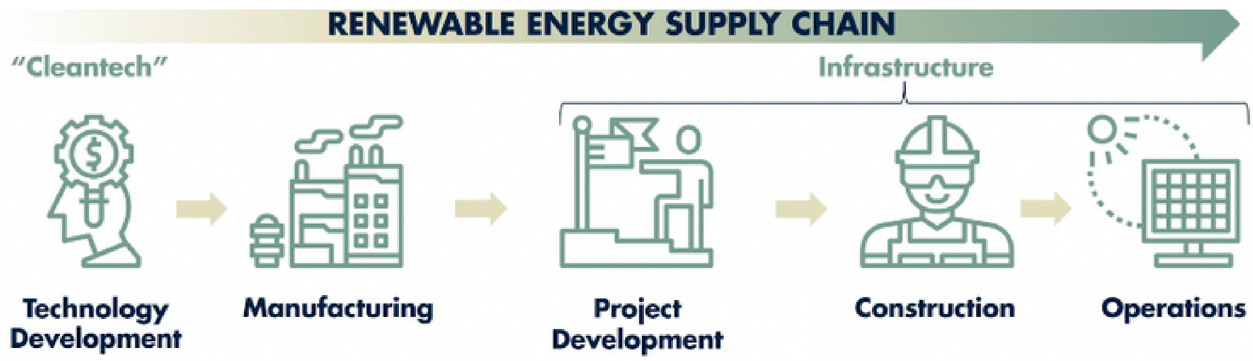
This bill specifies that no later than 180 days after passage, the Secretary of Energy must enact a program that designates how to provide financial assistance to renewable energy entities that will construct new and rebuild and repair existing facilities that will manufacture products for the renewable energy industry. These entities must submit an application to the Secretary of Energy in order to request such funding, and upon approval of such applications, the Secretary will allocate funds based on priority.

WHAT SOLUTIONS DOES THE BILL PROPOSE?

The bill outlines these priorities, stating that funds will go to projects that prioritize benefitting environmental justice communities, projects whose facilities are located in close proximity to one another in order to "create a geographic concentration of those manufacturers in the manufacturing supply chain," those that have the potential to create domestic jobs, those that will benefit the economies in areas that are in need, and projects that implement environmental review processes.

Figure 6: Renewable Energy Supply Chain

Source: PV Magazine



Solution 03 | Investing in energy efficiency through weatherization and heat pumps

The third solution proposed in this bill is amending Section 422 of the Energy Conservation and Production Act and designating $3 billion each year from 2023 to 2032 to the Weatherization Assistance Program. Additionally, out of any funds in the Treasury "not otherwise appropriated," $10 billion will be allocated to the Secretary of Energy through the Office of Energy Efficiency and Renewable Energy until September 30th, 2032, to install public heat pumps.

The Weatherization Assistance Program (WAP) is meant to address issues in the "whole home," such as by "installing insulation, updating heating and cooling systems, upgrading electrical appliances, and taking other common-sense actions that will make homes warmer in the winter and cooler in the summer with less energy usage." (Energy.Gov., 2022). Weatherization has been found to reduce residential and power plant emissions of carbon dioxide by 2.65 metric tons per year per home (Eisenberg, 2010). Through the passage of S.4013, the president will have the ability to allocate resources in the private sector to build upon programs such as this. The investments in public heat pumps also have the opportunity to decrease carbon emissions. Heat pumps have been found to decrease energy usage by about 50% compared to traditional heating methods, such as furnaces (Office of Energy Efficiency and Renewable Energy, 2022).

HOW DOES RENEWABLE ENERGY WORK?

This section will provide a brief description of the three main technologies S.4013 promotes to increase energy efficiency:

- **Solar energy**
- **Energy storage**
- **Heat pumps**

By investing in these technologies, the United States will be able to bolster energy security by importing less energy, specifically fossil fuels, and producing less carbon emissions.

Solar Energy

Solar energy is one of the most prominent renewable energy sources because of its potential to replace alternative energy sources, such as fossil fuels. Therefore, it was identified by the bill as a type of energy to be prioritized. For example, three weeks of energy from the sun would be able to produce more energy than is stored in all of Earth's reserves of oil, coal, and natural gas (Union of Concerned Scientists 2009). Other forms of renewable energy were also mentioned in this bill, such as tidal and wind, but in this report solar will be the focus due to its abundance and capability.

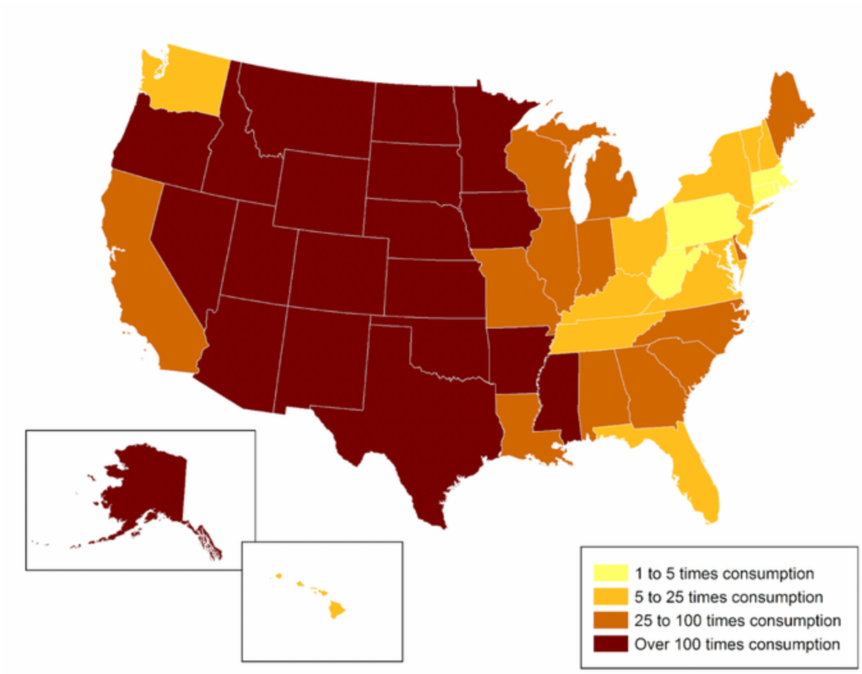


Figure 7: Potential of Solar Production
Source: Environmental America

The main way that solar energy is captured is through photovoltaic cells, also known as solar cells, which use semiconductors to harvest the incoming solar energy (Knier). The semiconductor material that is used in the majority of the current photovoltaic cells is silicon, which can absorb about one fourth of the solar energy available. There are multiple ways to increase this efficiency; for example, higher quality semiconductors or adding of additional layers, but these would come at an increased cost (Afework et al. 2021). The semiconductor has a positively charged side and a negatively charged side. When sunlight hits the semiconductor, photons in the light donate energy to the electrons in the semiconductor material, knocking them loose. The positive and negative charges trap these electrons, creating an electric current, more commonly known as electricity (Knier).

HOW DOES RENEWABLE ENERGY WORK?

Due to the abundance of potential energy from the sun, solar energy is a promising option for a transition to renewable energy in the United States. As stated previously, solar energy has the potential to fully replace the energy that is currently being generated from fossil fuels. The use of solar energy could drastically reduce carbon emissions over time. Solar cells have emissions associated with the manufacturing process, also known as carbon debt which is the amount of carbon emissions that came from the production of the solar cell. However, this debt is “paid-off” after three years of use. Solar cells also last for decades, which means they will continue to reduce the net carbon footprint of households using them (Cool Effect 2021). Additionally, the production of energy for the entire country would only require 0.4% of the total land in the United States (Energy.gov 2020). This makes solar energy a viable alternative to fossil fuels for energy production.

Energy Storage

Due to the variability of renewable energy such as solar and wind, it can be hard to predict the supply and demand of electricity (McBride and Siripurapu 2022). Therefore, an increase in renewable energy production would require an update to the grid system to include more energy storage. The addition of storage to the grid will not only solve the problem of inconsistent energy production from renewable sources, but it will also increase the resilience of the grid (Anthropocene Institute).

Batteries offer a portable energy storage system that can be utilized to capture the renewable energy being produced. A battery is a device that is charged with energy that can be used at a later time to create electricity (Govande 2021). Lithium batteries are popular because they are highly efficient and have a high energy density, which means they can store a large amount of energy relative to their size (Union of Concerned Scientists 2021). The movement of lithium ions in the battery creates free electrons in the anode, which is the negatively charged side of the battery. When the battery is connected to a device to be used, the electrical current flows through the device to the cathode, the positively charged side of the battery. This causes the anode to release the lithium ions to the cathode. This is possible since the negatively charged electrons are attracted to the positive side. When the battery is connected to a power source to recharge, this flow is reversed (Energy.gov 2017).

The production of lithium batteries for the storage of renewable energy would reduce carbon emissions, but there are some ethical concerns for the mining of the materials needed for the batteries. The mining of cobalt, which is required for the production of lithium batteries, has been fraught with human rights issues due to the abuse of labor in places like the Democratic Republic of the Congo in the mining process. The poor working conditions in the mines has led to deaths among the miners and the low wages force them to live in poverty (Frankel 2016).

HOW DOES RENEWABLE ENERGY WORK?

Lithium batteries will have a positive impact on the energy systems in the United States, but it is important to recognize the ethical concerns of where the materials are coming from. The location of these mines could also inhibit the U.S.'s ability to create a domestic supply chain since these materials are not available in large quantities within the U.S.

Heat Pumps

In addition to the investment in renewable energy, the bill aims to improve energy efficiency through weatherization and the installation of heat pumps in public buildings, both of which will decrease the U.S.'s carbon emissions. While heat naturally moves from warm areas to cool areas, heat pumps use a small amount of energy to move heat against this typical heat gradient. This is accomplished by a cycle of compression and evaporation that can be broken down into four main sections (Evergreen Energy 2017).

The cycle begins with the heat pump bringing in heat into a heat exchanger, known as an evaporator. This heat can come from a variety of sources, such as the air or ground, depending on the type of heat pump. The heat causes a refrigerant, which is a liquid that provides a cooling effect while expanding or vaporizing, to evaporate (Evergreen Energy 2017). The refrigerant is then moved into a compressor, where the temperature is raised by increasing the pressure (Zero Energy Project 2020). The refrigerant then moves into the condenser, where it transfers heat to the central heating system. In the condenser, the refrigerant is surrounded by cool water from the central heating system that absorbs the energy. Finally, the refrigerant moves into an expansion valve where the decrease in pressure causes the temperature of the refrigerant to lower. Since the refrigerant is now cool, it is ready to reenter the evaporator to start the cycle over again (Evergreen Energy 2017).

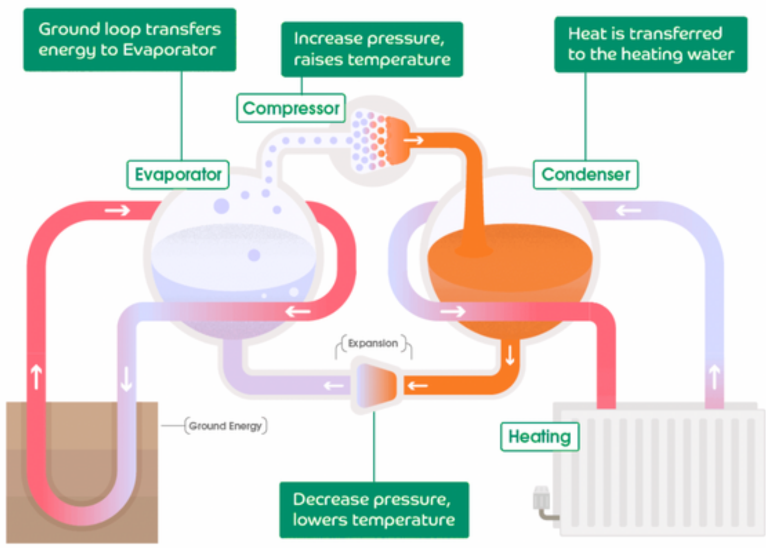


Figure 7: Diagram of How Heat Pumps Work
Source: Evergreen Energy

HOW DOES RENEWABLE ENERGY WORK?

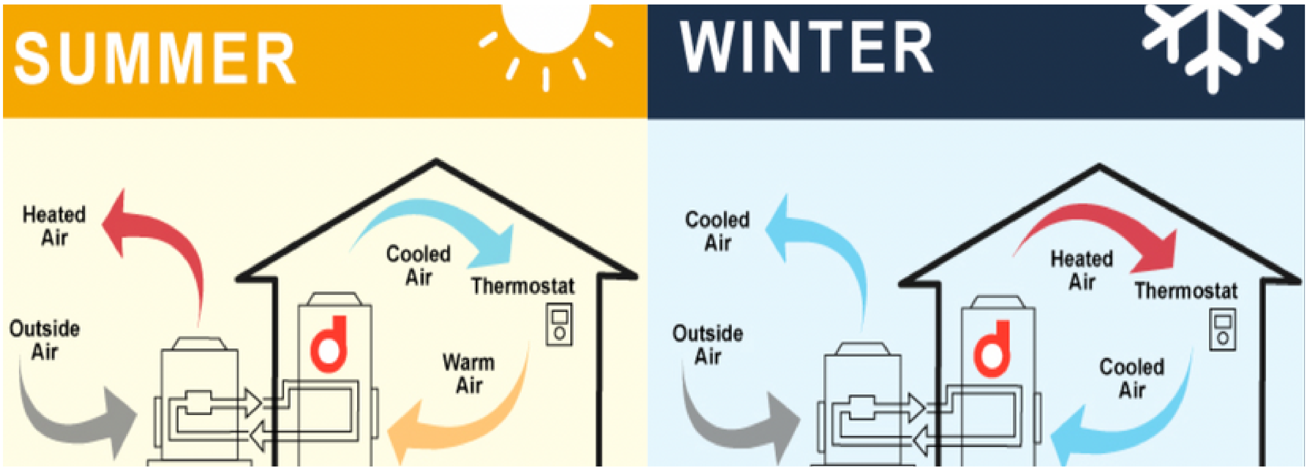


Figure 8: Diagram of Heat Pumps in Different Seasons

Source: AAA Heating and Cooling Inc.

There are two main types of heat pump, air source and ground source. Air source heat pumps, the most popular type, work like an air conditioner in reverse. The heat from the sun warms the air, and this is extracted by the evaporator, beginning the cycle. Ground source heat pumps use the energy that is stored in the earth beneath the frost line. Pipes underground absorb the heat naturally being stored underground and the same cycle occurs (Evergreen Energy 2017).

Heat pumps produce less carbon emissions than other sources of heat and are more efficient than their natural gas counterparts. Heat pumps can produce three units of heat for each unit of energy consumed, while natural gas heaters make between 0.60-0.95 units of heat per unit of fuel burned. Additionally, there is no direct consumption of fossil fuels for the daily use of a heat pump (Zero Energy Project 2020). However, the refrigerants being used in the system could potentially have negative effects on the environment if not properly contained. While these refrigerants are ozone friendly unlike the chlorofluorocarbons (CFCs) that have been used in the past, they have a significant global warming potential (GWP) due to being greenhouse gasses (Zero Energy Project 2020). While there could be potential leaks of greenhouse gasses when installing heat pumps, this risk is significantly smaller than the guaranteed emissions of a natural gas furnace, and the overall impact of the heat pumps would be a positive one due to their efficiency and lack of fossil fuel combustion.

It is important to understand the processes behind renewable energy, storage, and energy efficiency in the context of the proposed solution of S. 4013. Each of these technologies benefit the environment by reducing greenhouse gas emissions.

WHAT ARE THE CONCERNS WITH THE TRANSITION?

While there exists wide consensus on the science of the underlying issue of the bill - climate change - this consensus degrades in relation to the causes and appropriate actions to combat climate change, as well as the feasibility of a renewable energy transition as a key element of the solution.

Several of these scientific issues or controversies stand in the way of the passage of S.4013. The discussion of these obstacles can be divided into 3 categories:

- **Belief in climate change and anthropogenic causes.**
- **Impediments to large scale support of climate change mitigation action.**
- **Specific controversies or challenges of key renewable energy sources or infrastructure systems.**

ISSUES AND CONTROVERSIES

Belief in Climate Change and Anthropogenic Causes

There exists wide consensus among climate scientists that climate change is occurring and is caused or exacerbated by human activities. A report looking at 11,944 climate abstracts found a 97.2% consensus in papers that expressed an opinion on anthropogenic global warming (“AGW”). This report also found a growing consensus, with the highest percentage in recent papers (Cook et al. 2013). Other studies have found similar results among biophysical scientists and climatologist researchers (Carlton et al. 2015; Doran and Zimmerman 2009). Outlier studies report lower scientific consensus, however within these are studies that draw on non-climate experts and self-selected groups of climate deniers and count non-comments as dissent (Tol 2016). Overall, the data strongly supports a consensus among climate scientists in support of AGW, with a report compiling studies on consensus estimates finding a 90%-100% agreement (Cook et al. 2016).

Among the American public, a wide majority believe that climate change is happening (72%) with a smaller majority believing that it is caused by human activities (57%) (Howe et al. 2015). 67% of the American public believes the government is not doing enough to combat climate change. Specifically related to energy generation, 90% of Democrats and 62% of Republicans felt the U.S. should prioritize developing alternative energy over expanding fossil fuels (Funk and Hefferon 2019), and 79% of voters believe it is important to rely on U.S. made materials and manufacturing in this development (Morningstar Consult 2022).

Potential drivers for climate denial by politicians despite scientific consensus are fossil fuel industry campaign contributions ($61 million in lifetime contributions to the 139 deniers in the 117th Congress) (Drennen and Hardin 2021).

WHAT ARE THE CONCERNS WITH THE TRANSITION?

Impediments to Large Scale Support of Climate Change Mitigation Action

Even where a consensus exists regarding belief in anthropogenic climate change and the need for more action by the government, there are barriers to understanding the scale of the problem as well as to support for large-scale climate change mitigation action. The primary barrier is the prioritization of other issues, most significantly, the economy. A 2022 Pew Research study found that 71% of Americans listed strengthening the economy as a primary concern, followed by reducing health care costs, improving education and others. Dealing with climate change was ranked 14th, listed by 42% of people. This number is divided along party (D-63%, R-16%) and racial and ethnic lines (White-37%, Black-54%, Hispanic-56%) (Doherty et al. 2022). These numbers were even lower in a recent New York Times/Siena College poll, where only 1% of voters listed climate change as the most important issue in the U.S. (Weisman and Ulloa 2022). This dramatic decline in the view of climate change as a priority when compared with other issues versus when viewed on its own illustrates an obstacle to large-scale climate action, as this prioritization of other issues drives voting patterns and incentivizes elected officials to focus on economic growth over environmental action.

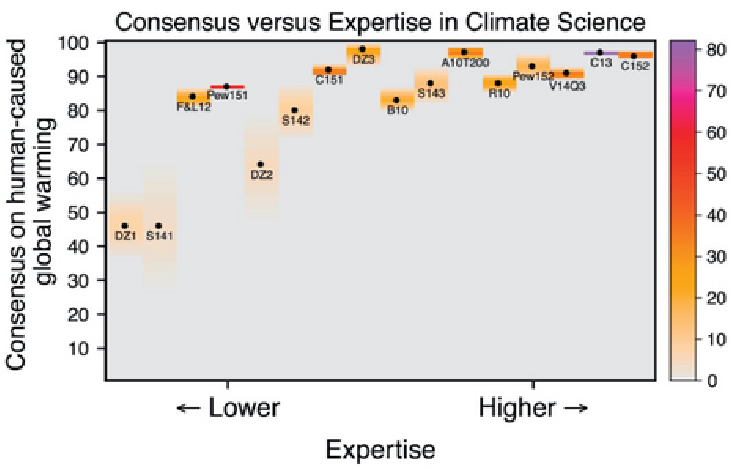


Figure 9: Relationship between Expertise and Belief in Human Caused Climate Change

Source: Environmental Research Letters

Other obstacles to climate change action include but are not limited to the following:

- The public's potential overconfidence in technological solutions to climate change (McLaren and Nils 2020), both in their level of efficiency (Moseman 2021) and political will for implementation in light of the economic priority outlined previously (Koerth 2019).
- The public's view of global climate change as a far-off problem (Weisman and Ulloa 2022).

- Americans with religious affiliation are less likely to believe in AGW, with the lowest percentage of 28% among white Evangelicals, with the combined Protestant percentage being 40% (Funk and Alper 2015; Shao 2017).
- The public perception that severe weather occurrences are impacted by climate change has been increasing (Koerth 2019), however, recency bias affects opinions, and studies have shown that short-term weather trends impact views of AGW (Hamilton and Stampone 2013).
- Social and environmental justice issues impact climate action as well. The EPA reports that climate change will disproportionately impact socially vulnerable populations (2021), and these communities report AGW as a higher priority than the overall U.S. population (Funk and Hefferon 2019; Doherty et al. 2022). Yet, these most affected communities face the greatest challenges to voting and thus applying political pressure to policy makers (Brennan Center for Justice 2022).

Specific Controversies or Challenges of Key Renewable Energy Sources or Infrastructure Systems

As is commonly the case with emerging or existing technologies that transition from niche to widespread usage, there exists a skepticism within the public of an energy transition as outlined in S.4013. The population is familiar with the existing system and fundamentally changing the way America generates energy - the very basis of everyday life - creates an environment prone to amplification of concerns and downplaying of positives. While many of the concerns do not align with the scale of the controversy, there do exist scientific challenges to a renewable transition, a selection of which will be discussed below.

Solar Power Controversies

In a transition to fully renewable energy, solar is expected to play the largest role (Shukla et al. 2022). The reasons for this include mature technology and flexibility of installation location and size. However, the primary reason for the centrality of solar power as a renewable energy source is its abundance. This supply of energy is not uniform throughout the world nor consistent, varying with time of day and weather, leading to controversies regarding its reliability or intermittency. Intermittency is an obstacle whose impact will grow with greater reliance on renewable energy (Tan 2011), but the predictability of solar power allows it to be addressed via several means such as power storage and coupling with wind power (Kline 2018).

PV production also uses a number of hazardous chemicals, and the cells contain heavy metals that may be environmentally harmful and require careful end-of-life disposal. An estimated 7.5 to 10 million tons of PV waste will be produced in the U.S. by 2050 (Office of Energy Efficiency & Renewable Energy (EERE)), an issue the U.S. Department of Energy is addressing through support of development of recovery and recycling programs, as well as funding research to develop updated PVs with less energy-intensive manufacturing and longer use lifetimes (U.S. Energy Information Administration 2022).

Wind Power Controversies

The intermittency issue is a source of controversy for wind power as well. For onshore wind, which currently accounts for 99% of U.S. wind farms (Kornei 2021), lower predictability of wind does not allow for mitigation of intermittency as it does for solar. The onshore locations where wind is most consistent and where land is available for wind farms tend to be remote, leading to further obstacles in the need for installation of new transmission lines (EERE). Both intermittency and land availability point to offshore wind, a solution that possesses its own controversies, many relating to engineering. The difficulty of locating suitable foundations in the Atlantic continental shelf and near-shore deep waters of the Pacific present challenges, as do maintenance of offshore turbines (Kornei 2021).

Controversies on potential negative ecological impacts of offshore wind are largely related to "secondary entanglement" whereby marine life may become entangled in discarded nets and debris that is itself caught on the turbine structures. Offshore wind farms may also displace marine animals due to noise or related ship traffic (Loomis and Kershaw 2021). With these controversies considered, the Office of Energy Efficiency & Renewable Energy determines that wind can be a viable source of energy production for every state by 2050 (2017).

Power Storage Controversies

To fully recognize the electricity generation potential of the renewable sources outlined in S.4013, as well as to reduce or remove the issue of intermittency, a significant increase in capacity of U.S. battery or other energy storage methods is required. The International Energy Agency estimates a needed capacity of 585 GW by 2030 (Groom 2022), and the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) projects a 932 GW capacity for a zero-carbon grid by 2050. The current U.S. capacity is an estimated 28 GW (Jorgenson et al. 2022). Several of the national large scale battery projects have been delayed due to international supply chain challenges, further enforcing the need for a national supply chain as included in S.4013 (Groom 2022).

WHAT ARE THE CONCERNS WITH THE TRANSITION?

With this battery capacity demand comes a significant increase in need for the necessary minerals, from a total of 0.4 Mt in 2020 to 21.5 Mt by 2040 (IEA 2021). This mineral need gives rise to several controversies, the first being mineral location. While oil and natural gas supplies are more distributed around the globe, energy transition minerals are more concentrated with >75% of global output controlled by 3 nations. The second controversy is ecological and human rights. Examples include the human rights violations in the Democratic Republic of the Congo (Frankel 2016), which controls 69% of the global cobalt supply, and ecological and indigenous water and land rights in Chile, which controls 22% of global lithium, the mining of which is water intensive (Watkins 2021) New and diversified supply sources as well as mineral recycling and supply chain sustainability will be vital to increased battery capacity (IEA 2021).

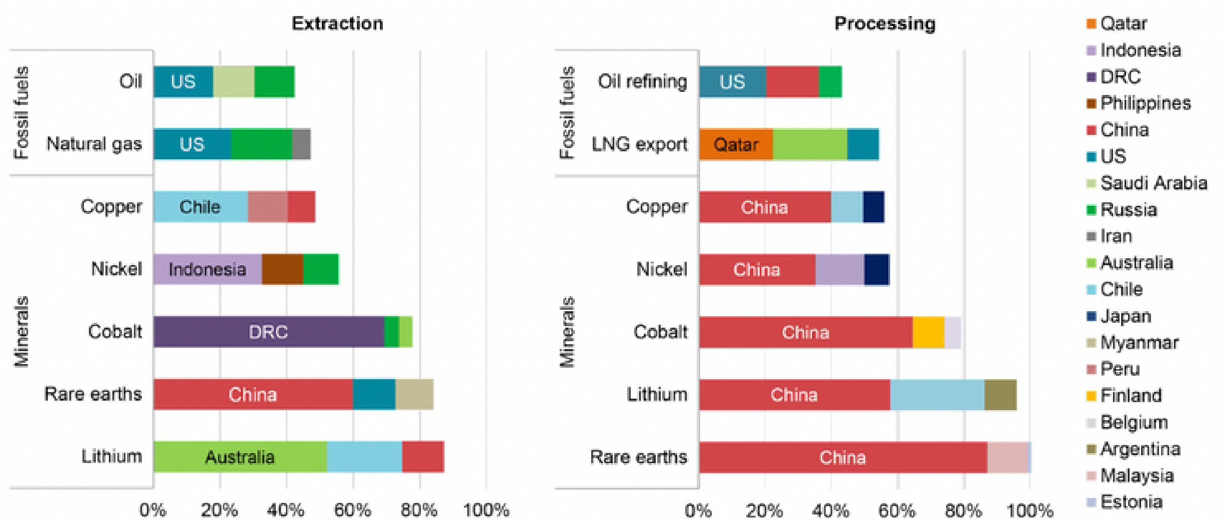


Figure 10: Resource Extraction and Processing by County

Source: IEA

Continuing to innovate new battery technology and non-battery energy storage systems will be increasingly important in a renewable energy transition. Redox flow batteries provide an alternative to lithium-ion batteries with relatively low cost and reduced fire hazard; however, they require larger installations due to lower energy density (Gordon 2022). Non-battery storage options include pumped hydro (which has been in use in the U.S. for decades), pumped thermal, compressed air and liquid air (Blair et al. 2022).

The scientific data and opinion on anthropogenic global warming are nearly universal, and public belief is widely held, however, this consensus is not yet reflected in governmental action and policy due to prioritization of other national concerns and social justice issues. For the paths to a fully renewable energy base included in S.4013, there are issues and controversies surrounding their development, but it is important to consider these within the context of what they are replacing, and the potential future they are working to avert.

HOW WOULD WE MEASURE SUCCESS?

INDICATORS OF SUCCESS AND OUTCOMES

For each of the three solutions we have identified in the bill, we have decided on 2-4 indicators of success. To select these indicators, we first identified the desired outcomes relevant to each solution and in some cases modeled them off of relevant targets and indicators of the United Nations Sustainable Development Goal (SDG) #7 (Ensure access to affordable, reliable, sustainable, and modern energy for all). We then determined the method of measurement for each outcome and the metric that each measurement would use. Next, we will describe the indicators for each solution in detail. All indicators are summarized in a table at the end of this section of the report.

Success Indicators for Solution 01: Funding the DPA to Increase Domestic Production of Renewable Energy

Since Solution 01 is primarily focused on transitioning the domestic energy sector to renewable energy, our first indicator of success is centered around the growth of domestic production of renewable energy. In order for S.4013 to be successful, there needs to be an increase in domestic renewable energy infrastructure and technology. This indicator is modeled off of the indicator for Target 7.b of the SDGs, which is based on infrastructure expansion and technologies for renewable energy in developing countries (United Nations Department of Economic and Social Affairs). We modified the SDG indicator to apply to S.4013 by removing the mention of developing countries and defining the method of measurement as the installed capacity of renewable energy generation, which would be measured in megawatts (MW) (Office of Nuclear Energy 2020). The installed capacity of renewable energy generation in the U.S. was 209,000 MW as of 2021 (U.S. Energy Information Administration 2022), and this would need to increase in order for S.4013 to be successful.

S.4013 utilizes the DPA to give the president the authority to create a domestic renewable energy industrial base task force. One of the duties of this task force is to allocate a portion of the federal funds mentioned in the bill to environmental justice communities (Energy Security and Independence Act 2022). Based on this duty, we have identified an increase in access to renewable energy for environmental justice populations as a second indicator for success for Solution 01. The method of measurement for this indicator would be the proportion of energy usage in environmental justice communities that comes from renewable sources. This would be measured as a percentage, and this percentage would need to increase and eventually reach 100% for S.4013 to be successful.

HOW WOULD WE MEASURE SUCCESS?

Similarly to the previous indicator, S.4013 also mentions prioritizing economic development of economically distressed areas, as well as the creation of jobs in low income or underrepresented communities (Energy Security and Independence Act 2022). Given these priorities, a third indicator of success for Solution 01 would be the economic development of low income and environmental justice communities through the bolstering of the domestic renewable energy supply chain. To measure this, we would need to track the percentage of jobs created in the renewable energy sector for low income communities and underrepresented groups. This proportion would need to increase, and an end goal would need to be set for this metric to determine if S.4013 has achieved success.

Success Indicators for Solution 02: Investing in the Renewable Energy Supply Chain

Solution 02 focuses on the expansion of the renewable energy supply chain in the U.S., so we chose indicators of success that would illustrate the increase in the amount of renewable energy produced in the U.S. The first indicator of success would be a reduction in the U.S. energy sector's contributions to climate change. In order to measure this, we would need to know the total greenhouse gas (GHG) emissions from fossil fuel combustion in U.S. energy production per year. As we showcased in our section on the science of the problem in S.4013, GHG emissions are the primary driver of climate change (2019), so there would need to be a reduction in these emissions to reduce the energy sector's contributions to climate change. The typical unit of measurement for GHGs is tons of CO_2 equivalent (CO_2e) (Municipal Climate Change Action Center 2020), so for this indicator the method of measurement would be megatons of CO_2e ($MtCO_2e$) since it is on a large scale. In 2021, 4,860 $MtCO_2$ was emitted by fossil fuel combustion in the U.S. energy sector (Kemp 2022). This number would need to decrease and over time reach zero for S.4013 to be successful.

The second indicator of success under Solution 02 is an increase in the share of energy coming from renewable sources. This indicator was inspired by Target 7.2 of the SDGs, which states that by 2030 the share of renewables in global energy production will increase (United Nations Department of Economic and Social Affairs). The method of measurement for this indicator would be the percentage of U.S. energy consumption fueled by renewable energy. As of 2021, this percentage was only 12% (U.S. Energy Information Administration 2022). As stated in S.4013, the goal of the bill is to reach 100% renewable energy as soon as possible (Energy Security and Independence Act 2022), meaning this measurement would need to increase rapidly.

HOW WOULD WE MEASURE SUCCESS?

The third indicator of success for Solution 02 would be the growth of the domestic renewable energy supply chain. This would be measured by the proportion of renewable energy generation components produced and installed within the U.S. Since the goal of the bill is to have a renewable energy supply chain that is 100% domestic (Energy Security and Independence Act 2022), in order for it to be successful the resulting supply chain must be completely within the U.S. from beginning to end. As an example of just one of the technologies mentioned in the bill, in 2018, 80% of solar panels installed in the U.S. were manufactured in another country (Rhodes 2018). This number shows just how far there is to go in terms of the goal of S.4013 to develop a completely domestic supply chain.

Another indicator of the growth of the renewable energy supply chain would be an increase in financial investment in domestic renewable energy. The metric of measurement for this indicator would be the amount of funds disbursed to the domestic renewable energy sector. An increase in investment would indicate that the sector is continually expanding, which is the goal of S.4013.

Success Indicators for Solution 03: Investing in Renewable Energy through Weatherization and Heat Pumps

The primary indicator of success regarding the provision in S.4013 to install heat pumps in public buildings would be an increase in energy efficiency in those buildings. To measure this, we would need to compare the annual energy usage of all of the public buildings covered by the provision pre- and post-heat pump installation. This would be measured in megawatt hours (MWh) rather than kilowatt hours (kWh) because the energy usage being measured is on a large scale.

S.4013 also includes a provision for the allocation of money to the Weatherization Assistance Program (WAP) (Energy Security and Independence Act 2022). The main indicator of success for this measure would be increased energy efficiency in the households that are a part of the WAP. In order to increase the overall energy efficiency provided by the program, more households would need to be weatherized. To differentiate the impact of S.4013 from other sources of funding for the WAP such as the Bipartisan Infrastructure Law (Office of Energy Efficiency & Renewable Energy), we would need to measure the number of houses weatherized under the program pre- and post-passage of S.4013. The program currently weatherizes approximately 35,000 homes per year using funds from the U.S. Department of Energy (Office of Energy Efficiency & Renewable Energy). In order for S.4013 to be deemed successful, this number would need to increase after its contribution of funds to the WAP.

HOW WOULD WE MEASURE SUCCESS?

	INDICATOR OF SUCCESS	METHOD OF MEASUREMENT
SOLUTION 1 Funding the DPA to increase domestic production of renewable energy	Increase in domestic renewable energy infrastructure and technology	Installed capacity of renewable energy generation
	Increase in access to renewable energy for environmental justice populations	Proportion of energy usage in environmental justice communities that comes from renewable sources
	Economic development of low income or environmental justice communities	Percentage of jobs created in the renewable energy sector for low income communities and underrepresented groups
SOLUTION 2 Investing in the renewable energy supply chain	Reduction in U.S. energy sector's contributions to climate change	Total U.S. energy sector GHG emissions from fossil fuel combustion per year
	Increase in share of energy from renewable sources	Percentage of U.S. energy consumption fueled by renewable energy
	Growth of domestic renewable energy supply chain	Proportion of renewable energy generation components installed and made in the U.S.
	Increase in investment in domestic renewable energy	Amount of funds disbursed to the domestic renewable energy sector
SOLUTION 3 Investing in renewable energy through weatherization and heat pumps	Increased energy efficiency in public buildings	Annual energy usage pre- vs. post-heat pump installation
	Increased energy efficiency in households under the WAP	Number of houses weatherized pre- and post- bill implementation

Figure 11: Table of Metrics of Success by Solution

CHALLENGES WITH MEASURING SUCCESS

The challenges in the evaluation of the success of S.4013 are threefold. Firstly, for the methods of measurement that are related to GHG emissions, it is important to take into account that CO_2 emission measurements are estimates. Typically, CO_2 emissions are not measured directly, but rather estimated based on the amount of fossil fuel combustion (Evans 2021). This means that all CO_2 measurements are projections, and projections can sometimes be incorrect. Given this, the indicators of success we have identified that use the metric of $MtCO_2e$ may not always accurately reflect the success of S.4013 and should be viewed within that context.

HOW WOULD WE MEASURE SUCCESS?

Secondly, for the indicators related to environmental justice communities, the challenge lies in fully defining what an environmental justice community is. S.4013 defines an environmental justice community as “a community with significant representation of 1 or more communities of color, low-income communities, or Tribal or indigenous communities that experience, or are at risk of experiencing, higher or more adverse human health or environmental effects as compared to other communities.” (Energy Security and Independence Act 2022). Despite this, however, some clarification issues still exist in terms of determining what constitutes “at risk.” In order to measure the success of S.4013 with these indicators, a full definition of environmental justice community must be decided on.

Finally, for the indicator having to do with funds, it will be challenging to discern the level of investment that indicates success due to inflation and other changes in the value of money over time. An investment made directly following the passage of the bill will not be worth the same amount as an investment made ten years later, which will make evaluation of this indicator difficult. Additionally, for the funds allocated annually over ten years the amount of money disbursed in the tenth year will not be able to fund as much activity as the first year. This should be taken into account when decisions are made as to what to prioritize in terms of funding.

CONCLUSION

Global warming triggered by anthropogenic climate change is a threat multiplier, and the world is experiencing its far reaching effects in the form of increased incidence of natural disasters, rising sea levels and extreme weather events, to name a few.

The United States has been a significant contributor to fossil fuel emissions since the industrial revolution, and has the responsibility to reduce its domestic emissions. With disruptions to the global renewable energy supply chain during the pandemic, as well as increased concerns of human rights violations in countries that export crucial renewable energy minerals, there is a dire need for the US to shore up its domestic energy infrastructure, while reducing dependence on fossil fuels.

Due to the abundance of potential energy from the sun, solar energy is a promising option for a transition to renewable energy in the United States. When supplemented with innovation in renewable storage technologies, it has the potential to improve access to clean, safe, and low cost energy while reducing domestic emissions.

The Energy Security and Independence Act (S.4013) aims to bolster U.S. energy independence by expanding its renewable energy supply chain. It does this by investing in renewable energy systems and technologies, setting up a domestic supply chain while also prioritizing environmental justice communities.

Given the multifaceted nature of the bill, a range of different indicators will need to be monitored in order to gauge the bill's success in achieving its several goals. Among them are the increase in domestic renewable energy infrastructure, the increase in share of energy from renewable sources, and increased energy efficiency in households and public buildings.

The road to 100% renewable energy is lined with several challenges for the U.S. but the cost of inaction on climate change is far too severe to let those challenges stall our transition to clean energy.

REFERENCES

1. Abnett, K. (2021, December 10). This is How Much Carbon Wildfires Have Emitted This Year. Retrieved from World Economic Forum: https://www.weforum.org/agenda/2021/12siberia-america-wildfires-emissions-records-2021

2. Afework, B., Boechler, E., Hanania, J., Stenhouse, K., Suarez, L. V., Yyelland, B., & Donev, J. (2021, December 20). Photovoltaic cell. Energy Education. https://energyeducation.ca/encyclopedia/Photovoltaic_cell

3. Beagle, E. A. (2022, June 7). Biden throws US solar installers a lifeline with tariff relief, but can incentives bring manufacturing back? The Conversation. http://theconversation.com/biden-throws-us-solar-installers-a-lifeline-with-tariff-relief-but-can-incentives-bring-manufacturing-back-184537

4. Biden administration announces investments to make homes more energy efficient and lower costs for american families. (n.d.). Energy.Gov. Retrieved July 8, 2022, from https://www.energy.gov/articles/biden-administration-announces-investments-make-homes-more-energy-efficient-and-lower

5. Blair, N., Augustine, C., Cole, W., et al. (2022). Storage Futures Study: Key Learnings for the Coming Decades. National Renewable Energy Laboratory. (NREL/TP-7A40-81779). https://www.nrel.gov/docs/fy22osti/81779.pdf

6. Boyce, D. and Wirfs-Brock, J. (May 18, 2016). High Utility Costs Force Hard Decisions for the Poor. Inside Energy. Retrieved from: http://insideenergy.org/2016/05/08/high-utility-costs-force-hard-decisions-for-the-poor/

7. Brennan Center for Justice. (2022, January 10). The Impact of Voter Suppression on Communities of Color. Brennan Center for Justice. https://www.brennancenter.org/our-work/research-reports/impact-voter-suppression-communities-color

8. Carbon Cycle. (2019, February 1). Retrieved from National Oceanic and Atmospheric Administration: https://www.noaa.gov/education/resource-collections/climate/carbon-cycle

9. Carbon Footprint of Solar Panel Manufacturing. (2021, June 1). Cool Effect. https://www.cooleffect.org/solar-carbon-footprint

10. Carey, C. (2009). The impacts of climate change on the annual cycles of birds. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1534), 3321–3330. https://doi.org/10.1098/rstb.2009.0182

11. Carlton, J. S., Perry-Hill, R., Huber, M., & Prokopy, L. S. (2015). The climate change consensus extends beyond climate scientists. Environmental Research Letters, 10(9), 094025. https://doi.org/10.1088/1748-9326/10/9/094025

12. Climate and The Carbon Cycle: Unit Overview. (n.d.). Retrieved from SERC Carleton: https://serc.carleton.edu/eslabs/carbon/index.html

13. Climate Change Indicators: Heat-Related Deaths. (2021, April). Retrieved from EPA: https://www.epa.gov/climate-indicators/climate-change-indicators-heat-related-deaths

14. Cook, J., Nuccitelli, D., Green, S. A., Richardson, M., Winkler, B., Painting, R., Way, R., Jacobs, P., Skuce, A. (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. Environmental Research Letters, 8(2), 024024. https://doi.org/10.1088/1748-9326/8/2/024024

15. Cook, J., Oreskes, N., Doran, P. T., Anderegg, W. R. L., Verheggen, B., Maibach, E. W., Carlton, J. S., Lewandowsky, S., Skuce, A. G., Green, S. A., Nuccitelli, D., Jacobs, P., Richardson, M., Winkler, B., Painting, R., & Rice, K. (2016). Consensus on consensus: A synthesis of consensus estimates on human-caused global warming. Environmental Research Letters, 11(4), 048002. https://doi.org/10.1088/1748-9326/11/4/048002

16. Cool2 Effect. (2021, June 1). Carbon Footprint of Solar Panel Manufacturing. Cool2 Effect. https://www.cooleffect.org/solar-carbon-footprint

17. Deetjen, T. A., Walsh, L., & Vaishnav, P. (2021). US residential heat pumps: The private economic potential and its emissions, health, and grid impacts. Environmental Research Letters, 16(8), 084024. https://doi.org/10.1088/1748-9326/ac10dc

18. Deloitte. (n.d.). 2022 renewable energy industry outlook. Retrieved July 8, 2022, from https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/renewable-energy-outlook.htm

19. Denchak, M. (2019, July 16). Greenhouse Effect 101. Retrieved from NRDC: https://www.nrdc.org/stories/greenhouse-effect-101

20. Doherty, C., Kiley, J., Asheer, N., Jordan, C. (2022).Public's Top Priority for 2022: Strengthening the Nation's Economy. Pew Research Center. https://www.pewresearch.org/politics/2022/02/16/publics-top-priority-for-2022-strengthening-the-nations-economy/

21. Doran, P. T., Zimmerman, M. K. (2009). Examining the Scientific Consensus on Climate Change. Eos, Transactions American Geophysical Union, 90(3), 22. https://doi.org/10.1029/2009EO030002

22. Drennen, A., Hardin, S. (2021, March 30). Climate Deniers in the 117th Congress. Center for American Progress. https://www.americanprogress.org/article/climate-deniers-117th-congress/

23. Eisenberg, J. F. (2010, March). Weatherization Assistance Program Technical Memorandum Background Data and Statistics. Weatherization. Retrieved July 12, 2022, from https://weatherization.ornl.gov/wp-content/uploads/pdf/2006_2010/ORNL_TM-2010-66.pdf

24. Electrify Everything. (n.d.). Anthropocene Institute. Retrieved July 15, 2022, from https://anthropoceneinstitute.com/innovations/grid/

25. Energy policies of IEA Countries: United states 2019 review – analysis. https://www.iea.org/reports/energy-policies-of-iea-countries-united-states-2019-review

26. Energy Security and Independence Act. S.4013, 117th Cong. (2022). https://www.congress.gov/bill/117th-congress/senate-bill/4013

27. Environmental Defense Fund. (2021, April 30). How climate change is worsening drought. Environmental Defense Fund. https://blogs.edf.org/climate411/2021/04/30/how-climate-change-is-worsening-drought/

28. EPA. (2021). Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA, 430-R-21-003. https://www.epa.gov/system/files/documents/2021-09/climate-vulnerability_september-2021_508.pdf

29. Evans, S. (October 5, 2021). Analysis: Which countries are historically responsible for climate change? Carbon Brief. Retrieved from https://www.carbonbrief.org/analysis-which-countries-are-historically-responsible-for-climate-change/

30. Frankel, T. C. (2016, September 30). The Cobalt Pipeline. The Washington Post. https://www.washingtonpost.com/graphics/business/batteries/congo-cobalt-mining-for-lithium-ion-battery/

31. Funk, C., Alper, B.A. (2015). Religion and Views on Climate and Energy Issues. Pew Research Center. https://www.pewresearch.org/science/2015/10/22/religion-and-views-on-climate-and-energy-issues/

32. Funk, C., Hefferon, M. (2019, November 25). U.S. Public Views on Climate and Energy. 37. Pew Research Center. https://www.pewresearch.org/science/2019/11/25/u-s-public-views-on-climate-and-energy/

33. Global Warming Potential (IPCC Second Assessment Report). (n.d.). Retrieved from UNFCCC: https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-

34. Gordon, O. (2022, June 22). Can flow batteries supercharge the energy transition? Energy Monitor. https://www.energymonitor.ai/tech/energy-storage/can-flow-batteries-supercharge-the-energy-transition

35. Govande, A. (2021, November 8). Green Energy Needs Green Storage. Science in the News. https://sitn.hms.harvard.edu/flash/2021/green-energy-needs-green-storage/

REFERENCES

36. Groom, N. (2022, June 9). How a battery shortage is hampering the U.S. switch to wind, solar power. Reuters. https://www.reuters.com/business/sustainable-business/how-battery-shortage-is-hampering-us-switch-wind-solar-power-2022-06-09/
2.Gross, S. (2021, May 10). Republicans in Congress are out of step with the American public on climate. Brookings. https://www.brookings.edu/blog/planetpolicy/2021/05/10/republicans-in-congress-are-out-of-step-with-the-american-public-on-climate/

37. Hall, E. R., Wickes, L., Burnett, L. E., Scott, G. I., Hernandez, D., Yates, K. K., Barbero, L., Reimer, J. J., Baalousha, M., Mintz, J., Cai, W.-J., Craig, J. K., DeVoe, M. R., Fisher, W. S., Hathaway, T. K., Jewett, E. B., Johnson, Z., Keener, P., Mordecai, R. S., … Styron, J. (2020). Acidification in the U.S. Southeast: Causes, Potential Consequences and the Role of the Southeast Ocean and Coastal Acidification Network. Frontiers in Marine Science, 7. https://www.frontiersin.org/article/10.3389/fmars.2020.00548

38. Hamilton, L. C., & Stampone, M. D. (2013). Blowin' in the Wind: Short-Term Weather and Belief in Anthropogenic Climate Change. Weather, Climate, and Society, 5(2), 112–119. https://doi.org/10.1175/WCAS-D-12-00048.1

39. Heat Pump Magic. (2020, April 13). Zero Energy Project. https://zeroenergyproject.org/2020/04/13/heat-pump-magic/

40. Hickey, H. (2018, December 6). What caused Earth's biggest mass extinction? Stanford Earth. https://earth.stanford.edu/news/what-caused-earths-biggest-mass-extinction

41. How do we know humans are causing climate change? (2019, Februrary 1). Retrieved from The Climate Reality Project: https://www.climaterealityproject.org/blog/how-do-we-know-humans-are-causing-climate-change-0

42. How Does a Heat Pump Work? (2017, July 21). Evergreen Energy. http://www.evergreenenergy.co.uk/heat-pumps/how-does-a-heat-pump-work/

43. How Does a Lithium-ion Battery Work? (2017, September 14). Energy.Gov. https://www.energy.gov/eere/articles/how-does-lithium-ion-battery-work

44. How Solar Energy Works. (2009, December 16). Union of Concerned Scientists. https://www.ucsusa.org/resources/how-solar-energy-works

45. Howe, P., Mildenberger, M., Marlon, J., Leiserowitz, A. (2015) Geographic variation in opinions on climate change at state and local scales in the USA, Nature Climate Change. https://climatecommunication.yale.edu/visualizations-data/ycom-us/

46. IEA. (2021). The Role of Critical Minerals in Clean Energy Transitions. IEA. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

47. Insulation. (n.d.). Energy.Gov. Retrieved July 15, 2022, from https://www.energy.gov/energysaver/insulation

48. Jina, A. (2021, February 2). Climate Change and the U.S. Economic Future. EPIC. https://epic.uchicago.edu/area-of-focus/climate-change-and-the-us-economic-future/

49. Jorgenson, J.A., Frazier, W., Denholm, P., Blair, N., (2022). Grid Operational Impacts of Widespread Storage Deployment. National Renewable Energy Laboratory. (NREL/TP-6A40-80688). https://doi.org/10.2172/1840718

50. Kane, J. W., & Pelton, T. (2021, April 22). Weatherizing homes could be one of the most vital legacies of Biden's infrastructure plan. Brookings. https://www.brookings.edu/blog/the-avenue/2021/04/22/weatherizing-homes-could-be-one-of-the-most-vital-legacies-of-bidens-infrastructure-plan/

51. Kemp, J. (January 13, 2022). Column: U.S. energy-related emissions likely to rise in 2022 and 2023: Kemp. Reuters. Retrieved from https://www.reuters.com/business/energy/us-energy-related-emissions-likely-rise-2022-2023-kemp-2022-01-12/

52. Kline, T. (2018, May 4). The keys to solving renewable intermittency. New Energy Solar. https://www.newenergysolar.com.au/renewable-insights/renewable-energy/the-keys-to-solving-renewable-intermittency

53. Knier, G. (n.d.). How do Photovoltaics Work? NASA Science. Retrieved July 15, 2022, from https://science.nasa.gov/science-news/science-at-nasa/2002/solarcells

54. Koerth, M. (2019, October 30). Why Carbon Capture Hasn't Saved Us From Climate Change Yet. FiveThirtyEight. https://fivethirtyeight.com/features/why-carbon-capture-hasnt-saved-us-from-climate-change-yet/

55. Kornei, K. (2021, November 22). Ocean terrain and the engineering challenges for offshore wind farms. Eos, 102. https://doi.org/10.1029/2021EO210598

56. Lawson, A., & Rhee, J. (2020, June 3). Usage of the Defense Production Act throughout history and to combat COVID-19. Yale School of Management. https://som.yale.edu/blog/usage-of-the-defense-production-act-throughout-history-and-to-combat-covid-19

57. Locke, S. (2008, October 20). How does solar power work? Scientific American. https://www.scientificamerican.com/article/how-does-solar-power-work/

58. Loomis, R., Kershaw, F. (2021, May 19). Floating Offshore Wind Brings Challenges and Opportunities. NRDC. https://www.nrdc.org/experts/rebecca-loomis/floating-offshore-wind-brings-challenges-and-opportunities

59. Loucks, D. P. (2021). Chapter 2 - Impacts of climate change on economies, ecosystems, energy, environments, and human equity: A systems perspective. In T. M. Letcher (Ed.), The Impacts of Climate Change (pp. 19–50). Elsevier. https://doi.org/10.1016/B978-0-12-822373-4.00016-1

60. McBride, J., & Siripurapu, A. (2022, July 5). How Does the U.S. Power Grid Work? Council on Foreign Relations. https://www.cfr.org/backgrounder/how-does-us-power-grid-work

61. McLaren, D., Nils, M. (2020). The co-evolution of technological promises, modelling, policies and climate change targets. Nature Climate Change, 10(5), 392-397. https://doi.org/10.1038/s41558-020-0740-1

62. Milman, O. (2022, April 28). Global heating risks most cataclysmic extinction of marine life in 250m years. https://www.theguardian.com/environment/2022/apr/28/global-warming-risks-cataclysmic-mass-extinction-marine-life

63. Morningstar Consult. (2022). Climate Innovation Perceptions.Morningstar Consult. https://www.edf.org/sites/default/files/documents/EDF_Climate%20Innovation%20Perceptions_Jan2022.pdf

64. Moseman, A. (2021, February 23). How Efficient is carbon capture and storage? MIT Climate Portal. https://climate.mit.edu/ask-mit/how-efficient-carbon-capture-and-storage

65. Municipal Climate Change Action Center. (January 15, 2020). How greenhouse gas emissions are measured. Municipal Climate Change Action Center. Retrieved from https://mccac.ca/2020/01/15/how-greenhouse-gas-emissions-are-measured

66. New York State. (n.d.). Weatherization Assistance Program. Retrieved July 8, 2022, from https://hcr.ny.gov/weatherization

67. NRDC. (2022, June 1). Fossil Fuels: The Dirty Facts. Retrieved from NRDC: https://www.nrdc.org/stories/fossil-fuels-dirty-facts

68. O'Brien, P., Kral-O'Brien, K., & Hatfield, J. L. (2021). Agronomic approach to understanding climate change and food security. Agronomy Journal, 113(6), 4616–4626. https://doi.org/10.1002/agj2.20693

69. Office of Energy Efficiency & Renewable Energy. (2017). Wind Vision Detailed Roadmap Actions: 2017 Update. U.S. Department of Energy. https://www.energy.gov/eere/wind/downloads/wind-vision-new-era-wind-power-united-states

70. Office of Energy Efficiency & Renewable Energy. (2020, March 13). Top Reasons to ♥ Solar Energy. EERE. https://www.energy.gov/eere/articles/top-reasons-solar-energy

REFERENCES

71. Office of Energy Efficiency & Renewable Energy. (n.d.) Weatherization Assistance Program. Energy.gov. Retrieved from https://www.energy.gov/eere/wap/weatherization-assistance-program

72. Office of Energy Efficiency & Renewable Energy. (n.d.). Advantages and Challenges of Wind Energy. EERE. https://www.energy.gov/eere/wind/advantages-and-challenges-wind-energy

73. Office of Energy Efficiency & Renewable Energy. (n.d.). End-of-Life Management for Solar Photovoltaics. U.S. Department of Energy. https://www.energy.gov/eere/solar/end-life-management-solar-photovoltaics

74. Office of Energy Efficiency and Renewable Energy. (n.d.). Heat Pump Systems. Energy.gov. Retrieved July 12, 2022, from https://www.energy.gov/energysaver/heat-pump-systems

75. Office of Nuclear Energy. (May 1, 2020). What is Generation Capacity? Energy.gov. Retrieved from https://www.energy.gov/ne/articles/what-generation-capacity

76. P.R. Shukla, J., Skea, R. Slade, A., Al Khourdajie, R., van Diemen, D., McCollum, M. Pathak, S., Some, P., Vyas, R. Fradera, M., Balkacemi, A., Hasija, G., Lisboa, S., Luz, J., Malley. (2022). Summary for Policymakers. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC. doi:10.1017/9781009157926.001

77. Patel, S. (2021, September 2). Drought-Crippled Hoover Dam, Glen Canyon Hydropower Plants Operating at Substantially Decreased Capacity. https://www.powermag.com/drought-crippled-hoover-dam-glen-canyon-hydropower-plants-operating-at-substantially-decreased-capacity/

78. Peach, S. (2021, June 30). What's the carbon footprint of a wind turbine? Yale Climate Connections.https://yaleclimateconnections.org/2021/06/whats-the-carbon-footprint-of-a-wind-turbine/

79. PM 2.5 polluters disproportionately and systemically affect people of color in the United States https://www.science.org/doi/10.1126/sciadv.abf4491

80. Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies. https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/

81. Poppie, T. (2022, January 11). Why We Need Birds and How to Protect Them From Extinction—One Green Planet. https://www.onegreenplanet.org/environment/why-we-need-birds-and-how-to-protect-them-from-extinction/

82. Recommendations of the Global Commission on People-Centred Clean Energy Transitions, IEA 2021 https://www.iea.org/reports/recommendations-of-the-global-commission-on-people-centred-clean-energy-transitions/recommendation-2#abstract

83. Rhodes, J.D. (January 27, 2018). The state of the U.S. solar industry: 5 questions answered. PBS News Hour. Retrieved from https://www.pbs.org/newshour/science/the-state-of-the-u-s-solar-industry-5-questions-answered

84. Rott, N. (2022, January 7). The Western mega drought is revealing America's "lost national park." NPR. https://www.npr.org/2022/01/07/1067716380/western-megadrought-climate-lake-powell-glen-canyon-reservoir

85. Scanlon, B., Reedy, R., & Nicot, J.-P. (2014). Will water scarcity in semiarid regions limit hydraulic fracturing of shale plays? Environmental Research Letters, 9. https://doi.org/10.1088/1748-9326/9/12/124011

86. Shao, W. (2017). Weather, climate, politics, or God? Determinants of American public opinions toward global warming. Environmental Politics, 26(1), 71-96, DOI: 10.1080/09644016.2016.1223190

87. Shifting U.S. to 100 Percent Renewables Would Cost $4.5 Trillion, Analysis Finds. (n.d.). Yale E360. Retrieved June 13, 2022, from https://e360.yale.edu/digest/shifting-u-s-to-100-percent-renewables-would-cost-4-5-trillion-analysis-finds

88. Skyrocketing Inflation Underscores Importance of Stopping "Build Back Better" https://americansforprosperity.org/skyrocketing-inflation-underscores-importance-of-stopping-build-back-better/

89. Sovine, T. (n.d.). 2022 sustainable energy in america factbook. BCSE. Retrieved July 8, 2022, from https://bcse.org/factbook/

90. State of Global Air Organization. (n.d.). Health Impacts of PM2.5 | State of Global Air. Retrieved June 11, 2022, from https://www.stateofglobalair.org/health/pm

91. Tan, S. H. (2011, November 1). Solar Intermittency: How Big is the Problem? Renewable Energy World. https://www.renewableenergyworld.com/storage/solar-intermittency-how-big-is-the-problem/

92. The Climate and Security Advisory Group. (2022). Challenge Accepted: A Progress Report on the Climate Security Plan for America and Recommendations for the Way Ahead. The Center for Climate and Security. https://climateandsecurity.org/wp-content/uploads/2022/03/Challenge-Accepted_A-Progress-Report-on-the-Climate-Security-Plan-for-America_2022_3_31-1.pdf

93. The Effects of Historical Housing Policies on Resident Exposure to Intra-Urban Heat: A Study of 108 US Urban Areas. https://www.mdpi.com/2225-1154/8/1/12

94. The Science of Insulation Explained. (n.d.). Knauf Insulation Australia. Retrieved July 15, 2022, from https://www.knaufinsulation.com.au/science-of-insulation-explained

95. Tol, R. S. J. (2016). Comment on 'Quantifying the consensus on anthropogenic global warming in the scientific literature.' Environmental Research Letters, 11(4), 048001. https://doi.org/10.1088/1748-9326/11/4/048001

96. Tyson, A., Kennedy, B., Funk, C. (2021, May 26). Gen Z, Millennials Stand Out for Climate Change Activism, Social Media Engagement With Issue. 100. Pew Research Center. https://www.pewresearch.org/science/2021/05/26/gen-z-millennials-stand-out-for-climate-change-activism-social-media-engagement-with-issue/

97. U.S. Energy Information Administration. (2021, May 21). Energy and the environment explained. Where greenhouse gases come from. https://www.eia.gov/energyexplained/energy-and-the-environment/where-greenhouse-gases-come-from.php

98. U.S. Energy Information Administration. (2022, February 25). Solar Explained. Solar energy and the environment. EIA. https://www.eia.gov/energyexplained/solar/solar-energy-and-the-environment.php

99. U.S. Energy Information Administration. (July 15, 2022). Electricity explained: Electricity generation, capacity, and sales in the United States. U.S. Energy Information Administration. Retrieved from https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php

100. U.S. Energy Information Administration. (June 10, 2022). U.S. energy facts explained. U.S. Energy Information Administration. Retrieved from https://www.eia.gov/energyexplained/us-energy-facts/

101. Understanding Climate Change. (n.d.). Retrieved from Australian Government Department of Agriculture, Water and the Environment: https://www.awe.gov.au/science-research/climate-change/climate-science/understanding-climate-change

102. Union of Concerned Scientists. (2015). The Solar Resource. Union of Concerned Scientists. https://www.ucsusa.org/resources/solar-resource

REFERENCES

103. United Nations Department of Economic and Social Affairs. (n.d.). 7: Ensure access to affordable, reliable, sustainable, and modern energy for all. United Nations. Retrieved from https://sdgs.un.org/goals/goal7

104. United States Environmental Protection Agency. (2017, February 8). Inventory of U.S. Greenhouse Gas Emissions and Sinks [Reports and Assessments]. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

105. US Department of Energy. (2022, June 6). President Biden Invokes Defense Production Act to Accelerate Domestic Manufacturing of Clean Energy. Energy.Gov. https://www.energy.gov/articles/president-biden-invokes-defense-production-act-accelerate-domestic-manufacturing-clean

106. US EPA, O. (2013, February 26). EPA's Study of Hydraulic Fracturing for Oil and Gas and Its Potential Impact on Drinking Water Resources [Overviews and Factsheets]. https://www.epa.gov/hfstudy

107. US EPA, O. (2016, July 1). Climate Change Indicators: Coastal Flooding [Reports and Assessments]. https://www.epa.gov/climate-indicators/climate-change-indicators-coastal-flooding

108. US EPA, O. (2016, July 1). Climate Change Indicators: Wildfires [Reports and Assessments]. https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires

109. US EPA. (n.d.). Climate Impacts in the Great Plains. Retrieved June 11, 2022, from https://climatechange.chicago.gov/climate-impacts/climate-impacts-great-plains

110. Volcanoes can Affect Climate. (n.d.). Retrieved from USGS: https://www.usgs.gov/programs/VHP/volcanoes-can-affect-climate

111. Watkins, K. (2021, June 27). Mining holds the key to a green future - no wonder human rights activists are worried. The Guardian. https://www.theguardian.com/business/2021/jun/27/mining-holds-the-key-to-a-green-future-no-wonder-human-rights-activists-are-worried

112. Weisman, J., Ulloa, J. (2022, July 18). As the Planet Cooks, Climate Stalls as a Political Issue. The New York Times. https://www.nytimes.com/2022/07/17/us/politics/climate-change-manchin-biden.html

113. What is the Carbon Cycle? (n.d.). Retrieved from The National Ocean Service: https://oceanservice.noaa.gov/facts/carbon-cycle.html

114. What is the Greenhouse Effect? (n.d.). Retrieved from NASA: https://climate.nasa.gov/faq/19/what-is-the-greenhouse-effect

115. Predicting the Future of Greenhouse Gas Emissions. (2022, August 15). State of the Planet. https://news.climate.columbia.edu/2022/08/15/predicting-the-future-of-greenhouse-gas-emissions/

116,USA Climate Action Tracker. (n.d.). Retrieved August 17, 2022, from https://climateactiontracker.org/countries/usa/