

Warheads to Windmills

How to Pay for a Green New Deal

by

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*This is for our children and grandchildren,
and for all those working to ensure a safe and healthy future for us all.*

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Our survival as a planet depends on drastically curbing greenhouse gas emissions in the very near future.

Our survival also depends on completely eliminating the danger of nuclear weapons.

By fortunate coincidence, the resources (federal funding, private funding, scientific and technical expertise, jobs and infrastructure) currently being wasted on nuclear weapons can be shifted to the production of green technologies to address the climate crisis.

A note on terminology used in this report:

- “Carbon” is short-hand for carbon dioxide and equivalent greenhouse gases.
- “CO₂e” stands for carbon dioxide equivalent and is the standard measurement for all greenhouse gases converted to their equivalent amount of carbon dioxide.
- “MMT” is the quantity of carbon or CO₂e emitted in million metric tons.
- “MW” stands for megawatts, or a million watts, or a thousand kilowatts (kW).
- “GW” stands for gigawatts, or a thousand megawatts.
- “kWh” stands for kilowatt hours, and is a measurement of how many kilowatts of electricity is used over a period of time, for instance in a year.
- “Capacity” is the maximum amount of MW or GW an electricity generating source is supposed to be able to deliver at any one time.
- “Capacity factor” is the percentage of time that an electricity generating source is normally operating at full capacity.
- An electricity generating source, such as a power plant or a wind farm, will have a capacity measured in MW or GW and a capacity factor of perhaps 50% for a power plant or 20% for a wind farm (since the wind doesn’t always blow). With 8,760 hours in a year, a 100 MW wind farm with a capacity factor of 20% would produce 175,200 MWh of electricity in a year ($100\text{MW} \times .20 \times 8760 = 175,200$).

A note about the report's images:

If the reader is using Mac's iBooks, you can double click on images to blow them up. This should help make it easier to read many of the charts and tables.

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EXECUTIVE SUMMARY

Three emergencies that threaten our existence

1. Climate

- We have 10 years to make drastic changes. The latest Inter-governmental Panel on Climate Change (IPCC) report gives us until 2030 to make radical cuts in greenhouse gas emissions, and until 2050 to reduce these emissions to zero (net), if we are to avoid the worst effects of climate change.
- Damage from extreme weather events cost the US \$400 billion in 2018, and this cost could easily reach \$3 trillion per year by 2050.
- The cost of air pollution from burning fossil fuels is estimated to be as much as \$176 billion per year, or as much as \$5.2 trillion total by 2050.
- There is currently not enough investment in green technologies.
- Many of the scientists needed for green innovation are tied up in nuclear weapons and other life-damaging businesses.
- Whatever we do in the US will be insufficient if the rest of the world doesn't also make a rapid shift to a green economy, and there is currently too much animosity and competition among nations to come together to solve this problem in the time we have left.

2. Nuclear weapons

- Nuclear weapons are unthinkable dangerous to every living being on earth, whether they are detonated by accident or on purpose, no matter where.
- The Bulletin of Atomic Scientists has its “Doomsday Clock” currently set at 2 minutes to midnight.
- These weapons are now militarily obsolete; using them would be suicidal.
- They are extremely expensive, and Department of Defense figures reveal only a fraction of their full cost.
- Taxpayers are currently paying as much as \$70 billion per year for nuclear weapons-related costs.
- Current plans to “modernize” the nuclear stockpile will cost the US over \$1.7 trillion over the next 30 years (and even this could be an underestimate).
- The Department of Defense budget is now approaching \$750 billion per year.
- Other military-related spending (tucked inside the Department of Energy budget, for example) brings the total to nearly \$1 trillion for FY2020 (money that could be used for medical care, education, housing, food, and programs that sustain life). This is more than the rest of the world combined spends on the military.
- The US has built a reputation of invading and bombing other countries, assassinating opponents in other countries, interfering in other countries' elections, pulling out of treaties, and ignoring global agreements.
- US nuclear weapons are a very explicit threat to utterly destroy any country at will.
- They undermine the very foundation of international cooperation and the goodwill essential for solving global crises like climate.

3. Inequality and injustice

- We have now reached grotesque and unsustainable levels of inequality in the US and in the world.

- The top 0.1% of US households now have the same amount of wealth as the bottom 90%.
- Globally, the richest 1% of the population now owns more than 45% of the world's total wealth.
- This harms everyone, rich and poor alike.
- We need buy-in and participation from all demographics to solve problems that affect everyone.
- Many "solutions" to climate change continue to harm and exploit poor and indigenous communities, while enabling business as usual for wealthy polluters.

We have the solutions

A Green New Deal

- A “Green New Deal” is a mass mobilization of resources to make the changes by 2030 that can lead to a carbon neutral economy by 2050.
- This means moving swiftly to electric cars and heating and 100% clean, renewable energy by 2030, plus completing changes to industry and agriculture by 2050.
- Nothing short of this will achieve the required cuts to greenhouse gas emissions in the timescale we have left.
- A GND will require as much as \$9 trillion of investment over the next 30 years, or as much as \$300 billion per year.
- But that's not a cost as much as a capital investment, since it will be recouped by future sales of electricity, electric vehicles, electric public transport fares, and other income.
- A GND would produce enormous savings, millions of jobs, and other benefits, including healthier air.
- A GND would require many green-collar workers: PV installers, wind turbine construction workers, electric car and bus production line workers, etc.
- A GND must also have a large number of experts in science, technology, engineering, and math (STEM) to solve some highly complex and technical problems like large-scale battery storage, more efficient solar panels, zero emission airplane fuels, etc.

The Nuclear Ban Treaty

- The US has been legally committed to eliminating nuclear weapons since the Non Proliferation Treaty (1970).
- The Nuclear Ban Treaty (2017) now outlaws everything to do with nuclear weapons.
- The Treaty creates a pathway for multilateral, verifiable nuclear disarmament.
- Unlike the climate crisis, getting rid of nuclear weapons does not require a retooling of the entire economy.
- The money saved can be redirected to green technologies essential for solving the climate crisis.
- Scientific talent can be redirected to crucial research needed for a GND.

Jobs, justice and cooperation

- A GND can provide millions of decent, well-paid jobs, lower the cost of basic necessities like heating and electricity, and subsidize the transition to a renewable economy.
- Private investment and charity cannot solve inequality and injustice – a GND must focus on lifting the most

vulnerable out of poverty and providing real opportunities for working and middle class families.

- A GND for the US must include investing considerable support in other countries. • There must be a fundamental change in the way the US treats the rest of the world.
- A GND cannot focus exclusively on what's "best" for Americans.
- We're all in this together, and without a strong commitment to international cooperation and solidarity, we will not survive as a species.

We can pull together as a planet, pay for a Green New Deal, eliminate nuclear weapons, and prioritize justice. This is not optional. Our children are speaking out to demand sensible action to safeguard our future.

“You are not mature enough to tell it like it is. Even that burden you leave for us children... You say you love your children above all else, and yet you are stealing their future in front of their very eyes.”

- Greta Thunberg ¹

INTRODUCTION

Unless we take swift and decisive action to reduce global carbon emissions, the consequences of climate change will be catastrophic. This is a life-threatening emergency that can only be adequately addressed in the timeframe we have available to us through a profound change in our priorities, as in a “Green New Deal.”

The existence of nuclear weapons is also a life-threatening emergency that threatens all life on this planet, and needs to be addressed with equal urgency. The world has now outlawed these weapons through the 2017 Treaty on the Prohibition of Nuclear Weapons (or “Nuclear Ban Treaty”). It is up to the US to lead the way to their total elimination.

Paying for a Green New Deal is going to require money, skills, jobs, technological innovation and infrastructure on an unprecedented scale. It will also require working much more cooperatively with other countries. Eliminating nuclear weapons will release a huge amount of money, skills, jobs, technological innovation and infrastructure needed for a Green New Deal. And it will also help to transform our relationship with the rest of the world.

Nothing we have ever faced in all of human history is as important as what we do now in the face of these global life-threatening emergencies.

And underpinning both of these global emergencies is a third emergency of equal importance: an emergency of spiraling inequality and injustice that makes both nuclear war and uncontrolled climate change both more likely and more dangerous. Unless we simultaneously address the grotesque levels of inequality, both within and between countries, we will not be able to solve the other two global emergencies we face.

That is why the Green New Deal that has been proposed by Massachusetts Senator Markey and New York Representative Ocasio-Cortez is about creating jobs, supporting the poorest and most marginalized communities, and addressing the inequalities and injustices around us as we address climate change.

There are many, many other issues that are also of huge importance right now – and they can be solved, as long as humanity itself survives.

Since the climate and nuclear crises are such profoundly egregious examples of injustice and political corruption, it’s possible that solving them can offer renewed hope, strategies, and energy for solving the epidemic of gun violence; the systemic racism that is not just denying people opportunities but literally killing them; the cycle of terrorism and wars that just breed more terrorism; the injustices suffered because of sexual orientation and gender identification; and the broken systems of health care, immigration, and mass incarceration.

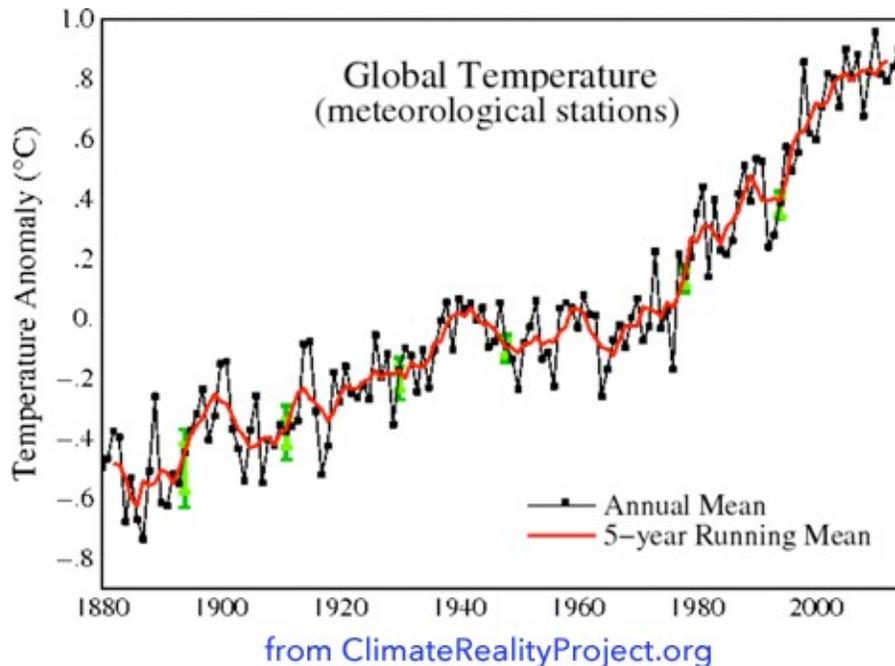
Our survival is not guaranteed. This is the choice before us as we approach the 2020 national election cycle: will the people of this country rise up and demand that we address these three life-threatening emergencies as our absolute top priority?

Nothing we have ever faced in all of human history is as important as what we do now in the face of these global life-threatening emergencies.

FACING UP TO THREE LIFE-THREATENING EMERGENCIES

The climate crisis

Global temperatures have already increased by approximately 1°C (or 1.8° F) since the beginning of the industrial age.² Levels of carbon dioxide in the atmosphere are now higher than they have been for at least one million years.³



Carbon dioxide (along with certain other greenhouse gases, or GHG) absorbs heat from the sun and reflects it back to earth, thus creating the “greenhouse” effect of warming the earth’s surface. Climate scientists have enumerated in great detail the effects this has already had on global ecosystems upon which we all depend for our survival.⁴

We cannot predict exactly what will happen if the earth continues to heat up. We do know, however, that if all 25 billion tons of ice that sit on top of Antarctica were to melt, sea levels would rise by more than 200 feet.⁵ We also know that increased temperatures cause increased drought, so if temperatures continue to rise, this will eventually lead to catastrophic crop failure across all major grain-producing areas of the globe.⁶

Avoiding the most extreme effects of climate change will require a 45% cut in global carbon emissions by 2030.

Other possible effects of uncontrolled climate change include the collapse of ecosystems and the mass extinction of species,⁷ mass migration of people as coastal areas flood and extreme temperatures make areas of the world uninhabitable, and extreme weather events causing even more migration and disruption, as well as physical damage costing trillions of dollars to the global economy.⁸

The Paris Climate Agreement, reached in December 2015, committed every country in the world to do what they could to prevent global warming from reaching 2°C (or 3.6° F) above pre-industrial levels. Many campaigners at the time felt that a limit of 2°C was too high to prevent runaway climate change.

In November 2018, the latest report from the Inter-governmental Panel on Climate Change (IPCC)⁹ confirmed their worst fears. The verdict from the world’s leading climate scientists is that allowing global temperatures to increase to 2°C above pre-industrial levels will create instabilities and extremes in global weather patterns

which could be catastrophic to human civilization as we know it.¹⁰

Avoiding the most extreme effects of climate change will require, according to the IPCC report, a 45% cut in global carbon emissions by 2030, reaching a target of net-zero carbon emissions by 2050. ¹¹ This is required to keep global warming to no more than 1.5°C above pre-industrial levels.

Even 1.5°C of global warming will have serious consequences. Going beyond that is now too dangerous to contemplate.

The nuclear nightmare

By now, most people in this country are aware that climate change is a life-threatening emergency that must be urgently addressed. They may be at least dimly aware that an exchange of nuclear weapons would be the end of human civilization as we know it, and possibly of all life on earth.

The belief that the world can continue to hold onto nuclear weapons indefinitely without ever using them is as dangerous as the belief that we can go on burning fossil fuels indefinitely without causing a climate catastrophe.

The fact that we have not had such a war in over 70 years has lulled many people into thinking that nuclear war cannot happen. Indeed, we have been reassured by those in positions of authority that nuclear weapons keep us safe and will never be used.¹²

The belief that the world can continue to hold onto nuclear weapons indefinitely without ever using them is as dangerous as the belief that we can go on burning fossil fuels indefinitely without causing a climate catastrophe.

It is not just the possibility of nuclear war that poses an existential threat to human civilization. Just one detonation in a city, by accident or on purpose, would kill millions. The immediate casualties would overwhelm the response capacity of the entire global Red Cross/Red Crescent and overflow every burn bed in every hospital on the planet. Women, girls and fetuses would suffer the most from ionizing radiation. Food and water would be toxic for generations. There is no possible military or political agenda worth such a risk.

These weapons are made by human beings and they are managed by human beings. They break down, they have faulty parts, they malfunction, they get lost.

And the people who look after them make mistakes, they fall asleep on the job, they take drugs on the job, they forget how to do their tasks. In 2007, 6 US nuclear weapons went “missing” for several hours because they were loaded onto the wrong plane and sent to the wrong air force base in the wrong state.¹³ In 2013, 17 officers with the authority to launch nuclear weapons were stripped of their duties because of a “pattern of weapons safety rule violations...”¹⁴ And in 2016, 14 airmen responsible for guarding America’s ICBM nuclear missiles were disciplined for drug offenses.¹⁵

If an 82-year old nun can break into the “Fort Knox of uranium,” imagine what terrorists could do.¹⁶

As many as 50 nuclear weapons currently lie at the bottom of the sea.¹⁷ They have sunk with submarines, rolled off ships, or been jettisoned from airplanes. In 1961, two 4-megaton nuclear bombs were dropped on North Carolina after a plane caught fire and broke up in mid-air.¹⁸ One of the bombs was recovered and the other one is still 180 feet underneath a cornfield, cordoned off but still there, more than 50 years later, because it would be too dangerous to try to remove it.¹⁹

Nearly 2,000 out of a stockpile of 7,000 U.S. nuclear weapons are standing by, 24 hours a day, on “hair-trigger” alert, ready to be launched at a moment’s notice with an order from the President, or even through the actions of a rogue military officer with access to the launch mechanisms. This is not a distant, far away threat. This is an immediate, life-threatening emergency.

Nuclear weapons are also a climate issue

Nuclear weapons are designed to destroy entire cities and kill millions of people. We know from nuclear power plant disasters like Chernobyl and Fukushima how fast and how far radioactivity can spread, affecting people many thousands of miles away from a nuclear accident or explosion.

Radioactive particles get into the air we breathe, the water we drink, and the soil we depend on for food. They work their way up the food chain, and people eventually die – years or even decades later – from cancers and other effects of radiation poisoning.

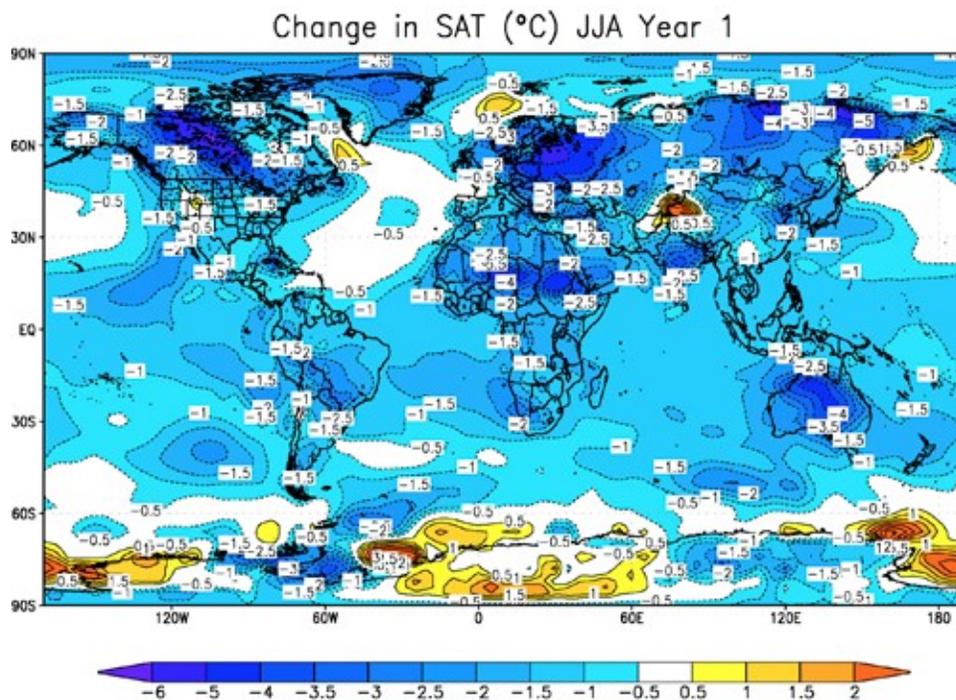
It is now estimated that as many as 2.4 million people worldwide have died or will die from cancers caused by the nuclear weapons testing in the atmosphere during the 1950s and 60s – nearly 10 times as many as died initially from the atomic bombs dropped on Hiroshima and Nagasaki in 1945.²⁰

Radiation is not the only danger that threatens the entire planet no matter where a nuclear explosion might take place. Because of the extensive research on climate change that has been going on in recent years, we also now know much more about the impact of nuclear weapons on climate.²¹

The nuclear weapons testing in the 1950s and 60s was mostly done in deserts or on “deserted” islands in the South Pacific.²² Scientists calculated how much soot would be drawn into the upper atmosphere if these weapons were instead detonated on large modern-day cities, like Moscow, New York, Beijing or London.

Estimates of the likely impact of a full-scale exchange of nuclear weapons between the US and Russia suggest that as much as 150 million tons of soot could be blasted into the upper atmosphere.²³ This would lower global temperatures by as much as 7 degrees C (or 12 degrees F) for an extended period of time, plunging major food-producing regions of the world to below-freezing temperatures for several summers in a row and causing widespread famine.²⁴

Even a so-called “limited” nuclear war, involving a nuclear exchange between India and Pakistan for instance, could result in a sufficient drop in global temperatures to starve up to two billion people as a result of crop failures and worldwide famine.²⁵



The possible use of nuclear weapons is therefore also a climate issue. The risk to human civilization and to the planet is roughly equivalent, whether the earth is suddenly overheated as a result of fossil fuel burning or

suddenly overcooled as a result of nuclear war. In either case, billions of people would die of famine and the underlying ecosystems we all depend on would be at serious risk of collapsing.

Unfortunately, the two potential climate catastrophes do not cancel each other out. A little bit of nuclear winter is not the antidote for a little too much carbon dioxide in the atmosphere. We must work now to prevent both of these climate disasters from ever happening.

Inequality and injustice – The third emergency

The climate crisis and the nuclear nightmare both pose an unacceptable risk to the future of the planet that must be addressed. And there is another time bomb that is ticking away, which, if not addressed, could be just as disastrous.

Levels of inequality, within the United States as well as globally, have reached staggering proportions and continue to increase. Reverend William Barber of the Poor People's Campaign calls the levels of poverty and inequality in this country a "moral emergency."²⁷

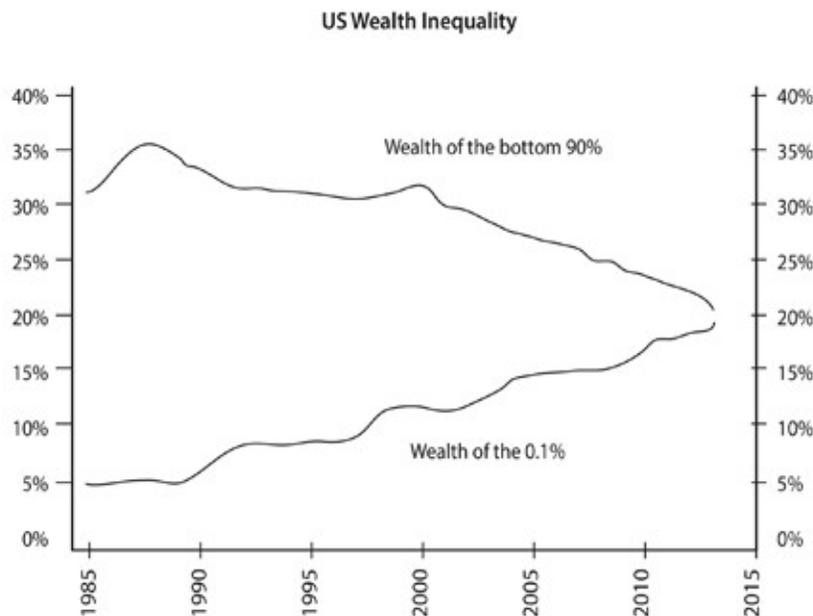
According to a recent survey,²⁸ 78% of all US workers are living "paycheck to paycheck." As many as 100 million people²⁹ are living in "near poverty" – just on the edge of being able to make ends meet. About 40 million US-Americans are living in conditions that the UN would define as "poverty," 18.5 million in "extreme poverty," and 5.3 million in "Third World" conditions of "absolute poverty."³⁰

The top 0.1% of US households now have the same amount of wealth as the bottom 90%.

In the United States, people of color are twice as likely as white people to fall into one of the "poverty" categories.³¹ It was inevitably the poorest who were affected most by flooding in New Orleans and hurricanes in Puerto Rico. And it will be the poor who starve first, whether from global warming or from nuclear winter.

These extremes of poverty are in one of the wealthiest countries in the world, with over 11 million millionaires, 540 billionaires and a national output of over \$20 trillion.³² And the gap just keeps on increasing, to the point where the top 0.1% of US households now have the same amount of wealth as the bottom 90% of households (see chart).³³

Globally, the figures are even more extreme, with 80% of humanity earning less than \$10 a day and 1.3 billion people living in extreme poverty.³⁴ The richest 1% of the world's population now owns more than 45% of the world's wealth.³⁵



Source: Deutschebank

Poor and indigenous people suffer the worst effects of climate change, nuclear mining and testing, war, and pollution. For full global participation in climate solutions, we need everybody's participation, and we must be careful of "solutions" that involve continued exploitation of poor and indigenous people and pollution of their environments.

For example, forms of carbon trading that allow polluters to "offset" their emissions by supporting forest

preservation in poor countries have the potential to benefit national governments and trading companies, while leaving the people who live in those forests without traditional livelihoods, jobs, compensation, or access to their ancestral lands.³⁶

Climate change and nuclear weapons are emergency situations because if we do not address them now, it may soon be too late. We cannot know the consequences of continuing indefinitely to increase the wealth of the richest at the expense of the poorest. History tells us that societies that do not meet the needs of their people do not long survive.³⁷

The global dimension

None of these three emergencies can be solved by the United States alone. Poverty and extreme levels of inequality are drivers of anger, hostility, instability, war and terrorism across the globe. Walls along our borders can no more keep out the rest of the world than they can keep out rising sea levels or drifting clouds of radiation.

We cannot even address the growing inequality within this country without also addressing the bigger picture. As long as the wealthiest people are able to simply move their wealth to other countries to avoid more progressive or fairer tax laws here, the effect of those laws is much reduced. And as long as companies can simply move their factories abroad to avoid giving their workers better pay or conditions here, that affects the pay and conditions of all workers in this country.

No matter what the United States might do to address the climate crisis, it will remain a crisis if other countries do not do likewise. Companies move around to avoid environmental restrictions or tougher regulations, making it impossible to address a problem as serious as the climate crisis unless all countries band together and agree to follow the same course of action.

International agreements like the Paris Climate Accords are essential for addressing problems that face all of us no matter where we live. But they are also essential for building the cooperation and goodwill needed to maintain a functioning planet.

We cannot solve any of these problems *without* working more closely with other countries.

For the past 70 years, nations without nuclear weapons were excluded from having any say about these weapons, even though the devastating impacts of a nuclear war would affect them all.

It took until the 2017 Treaty on the Prohibition of Nuclear Weapons for the vast majority of non-nuclear armed nations to finally stand up to nine nuclear-armed nations³⁸ and say “enough is enough”. Even if two relatively “lightly” armed nuclear countries, like India and Pakistan, were to launch nuclear weapons at each other, the effects would be disastrous for the whole planet. The world is just too small a place for nuclear weapons ever to be used by anyone.

The United States claims that these weapons are “essential” for our security. This is nothing other than an incitement to proliferation. For if these weapons are essential for the survival of the United States, why would they not be equally essential for the survival of every other country on the planet? And if they are essential for every other country on the planet, why does the United States go to such great lengths to try and stop North Korea, Iran or any other country from having them?

The truth is that nuclear weapons are not essential for the survival of the United States. They are obsolete and outdated dinosaurs of the Cold War era and the longer they remain in anyone’s hands, the greater the risk of them being used, on purpose or by accident.

What these weapons do is swallow up vast resources and undermine the cooperation and goodwill essential for solving any global issue. They divide the world yet further into “haves” and “have nots,” then they threaten the “have nots” with obliteration, demanding that we get our way “or else.” We cannot move forward as a planet with such an approach.

SOLUTIONS – A GREEN NEW DEAL

Addressing the climate crisis – why a Green New Deal?

In order to keep global warming to no more than 1.5°C above pre-industrial levels, we need to achieve a 45% cut in global carbon emissions ³⁹(from 2010 levels) by 2030, reaching a target of net-zero carbon emissions by 2050.⁴⁰

There are many possible pathways to reaching the IPCC target of net-zero carbon emissions by 2050. But there is really only one way to cut emissions to the extent required by 2030, and that is by moving swiftly to electric vehicles (EVs), to electric heating, and to clean wind and solar powered electricity.

This simply cannot happen through ‘market forces’ or personal lifestyle choices... Serious government intervention is required.

Other steps are required to reach net-zero emissions over the next 30 years. But unless we take these hugely important steps (and make some initial headway on the others) during the next 10 years, we will have missed our one chance to avert climate catastrophe.

A “Green New Deal” (or GND) would move the US and the rest of the world off of their dependency on fossil fuels and onto a new path in just 10 years. This simply cannot happen through “market forces” or personal lifestyle choices. ⁴¹More energy conservation measures and reductions in the massive amounts of energy we waste as a society are still needed, but to address the scale of the requirement, serious government intervention is required.

The Obama administration committed many tens of billions of dollars to clean energy over several years, and this helped to jump start progress on a number of fronts. ⁴²More investment, stronger legislation and a real commitment from all sectors of society is needed to achieve the goal. The next administration will need to address all this on a scale not seen since the New Deal ⁴³of the 1930s and 40s. But it will also require action at local and state levels, as well as at the level of individuals, organizations and institutions. These do not need to wait for a new government to be elected in Washington.

A GND needs to begin right now, and it needs to address the other two life-threatening global emergencies if it is to achieve the targets needed to address the climate crisis.

Failing to address inequality risks failing on climate because the measures needed to cut carbon require more than government intervention. These measures require the buy-in and participation of a very large number of people.

If the net result of government measures to address the climate crisis is that large numbers of people end up in the same economic condition as they are now, or even worse off, they are unlikely to accept it. And without cooperation from citizens, it is hard to see how these measures can succeed.

Failing to address the nuclear nightmare also risks failing on climate. The money, skills and infrastructure currently wasted on nuclear weapons are urgently needed for addressing the climate crisis. And we need the international cooperation and goodwill that is currently being squandered by the way we treat the rest of the world.

What is meant by a Green New Deal?

The US Green Party has been promoting the concept of a Green New Deal since 2006.⁴⁴ The idea was picked up by Alexandria Occasion- Cortez and others in 2018 and turned into House of Representatives Resolution 109, with 67 original co-sponsors. Senator Ed Markey introduced the identical resolution in the Senate, but it was voted on and defeated almost immediately after it was introduced. The House Resolution, as of June 2019, has 93 co-sponsors and has been referred to 11 committees and 10 sub-committees for consideration.



Alexandria Ocasio-Cortez Photo: Dmitri Rodriquez

Many of the Democratic candidates for president have indicated support for a Green New Deal, although with differing degrees of enthusiasm and with some markedly different ideas of what they mean by it. Jay Inslee, whose singular campaign focus is the climate crisis, has come out with the most detailed proposal so far, but all the major presidential contenders are following suit with proposals that acknowledge the urgency of the issue, to some degree.⁴⁵

In order to be effective, any Green New Deal has the following fundamental features:

1. A Green New Deal must be a bold and sweeping call to tackle the climate crisis head on, with a 10-year “national mobilization” on a similar scale to the original New Deal of the 1930s. The age of fossil fuels is over. A transformation of our entire economy is required in order to adjust to that new reality.
2. While a GND calls for a 10-year mobilization, it also explicitly refers to the IPCC target of keeping global temperatures to 1.5°C above pre-industrial levels by achieving a 45% reduction in global greenhouse gas emissions by 2030 and net-zero emissions by 2050.⁴⁶ That is the timescale required and it can’t happen any slower than that. Although many would like to see it happen faster, in all probability, it cannot.
3. The aim is 100% clean, renewable, zero-emission energy supplies. There is no agreed definition of what this includes, but biomass, which is renewable, is not clean or zero-emission. And nuclear power, which some consider “clean,” relies on uranium supplies, which are highly toxic and not “renewable.”⁴⁷ Continued reliance on fossil fuels is ruled out completely, with or without “carbon capture and storage.”⁴⁸
4. A GND is designed to address the climate crisis without making the poorest and most vulnerable worse off, but instead by providing millions of decent, well-paid jobs, better working conditions and better living conditions for all. This is absolutely core to a GND and cannot be taken away without losing what gives it that name.

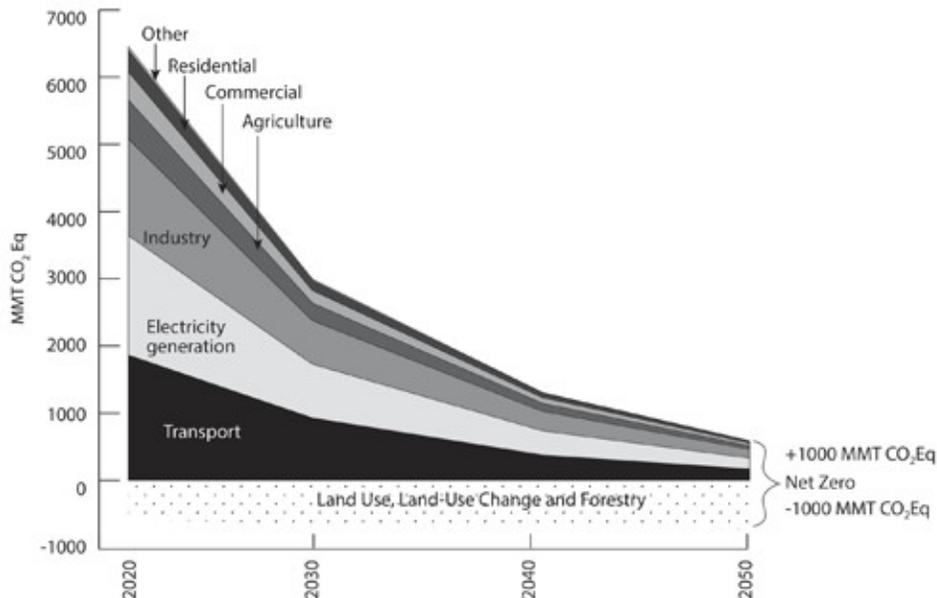
There are many possible pathways to reaching the IPCC target of net-zero carbon emissions by 2050. But there is really only one way to cut emissions to the extent required by 2030, and that is by (1) undertaking a massive shift to wind and solar powered electricity, (2) beginning the transition to electric vehicles and (3) beginning the transition to electric heating for buildings and industry.

No plan for meeting the carbon reduction targets can succeed without major reductions in these three areas. Luckily, these are the three areas where cheap and effective alternatives already exist and can easily be upscaled to meet the targets.

What are the specific targets of a Green New Deal?

In 2017, the US emitted roughly 6,500 million metric tons (MMT) of carbon. The IPCC targets use the figures for 2010 as their starting point, and in 2010, the US emitted nearly 7,000 MMT of carbon.⁴⁹ So we have already achieved an 8% reduction towards our goal of a 45% reduction by 2030. In real terms, this means we need to cut a further 2,650 MMT in carbon emissions to reach a goal of 3,850 MMT of carbon emissions by 2030.

Reduction of US Carbon Emissions 2020-2050



The two largest sources of carbon emissions in this country are transportation (currently pumping out 1,866 MMT of carbon per year) and electricity generation (pumping out 1,778 MMT of carbon). These are also the two easiest sectors of the economy to address in the timescale we have available.

Cutting emissions from the industrial and the agricultural sectors is not impossible and it will have to happen. But it will be costly, complicated and time-consuming. These sectors cannot, therefore, be the top priorities for achieving rapid reductions by 2030.

Cutting emissions from commercial and residential buildings will also have to happen. While this is not complicated,⁵⁰ it will still be costly and time-consuming, and cannot therefore be a top priority for a GND.

Target 2030

What can happen by 2030, with sufficient investment and legislation to back it up, is:

1. A transformation of the car industry so that it is producing only electric vehicles by 2030 (leading to only electric vehicles on the road by 2050). Carbon reduction = 620 MMT by 2030, 1,800 MMT by 2050.
2. A transformation of the electricity industry so that it is producing no electricity from fossil fuels by 2030 (leading to 100% clean, renewable electricity by 2050). Carbon reduction = 1,830 MMT⁵¹ by 2030.
3. A transformation of the building and construction industry so that it is designing, building and retrofitting only 100% fossil-free buildings by 2025, with a program in place to retrofit every building in America to be 100% fossil-free by 2050. Carbon reduction = 50 MMT⁵² by 2030, 610 MMT by 2050.
4. A complete ban on HFCs as a refrigerant. Carbon reduction = 150 MMT by 2030. There are many

other steps that can and must be taken as part of a GND in order to ensure we are on track to achieve net-zero carbon emissions by 2050. But these four steps taken on their own are sufficient to achieve the goal of no more than 3,850 MMT of carbon emissions by 2030.

Target 2050

In order to achieve the 2050 target of net-zero emissions, a further 2,800 MMT of carbon emissions must be cut and 300 MMT of carbon absorption capacity added to the 700 MMT of existing carbon absorption capacity:

5. A transformation of farming techniques to reduce use of nitrogen fertilizers, increase crop rotation, and capture methane from manure. Carbon reduction = 300 MMT by 2050.
6. A transformation of the industrial processes for making steel, cement and other products that currently depend on the use of fossil fuels. Carbon reduction = 725 MMT by 2050.
7. Carbon absorption capacity must also be increased by planting 32.5 million trees per year on existing federal lands to absorb 300 MMT of carbon per year by 2050.

This would mean that by 2050 approximately 1,000 MMT of carbon is going into the atmosphere along with approximately 1,000 MMT of carbon coming out, achieving net-zero carbon emissions for the United States.

Economic sector	2017 emissions	Reductions 2020-2030	2030 targets	Reductions 2030-2050	2050 targets
Transportation	1,866	620	1,246	1,164	82
Electricity generation	1,778	1,778	0	-	0
Industry	1,436	202	1,234	722	512
Agriculture	582	-	582	291	291
Commercial	416	25	391	360	31
Residential	331	25	306	270	36
Other	47	-	47	-	47
TOTAL	6,457	2,650	3,806	2,806	1,000
- Carbon absorption	(714)		(714)	+286	(1,000)
=Net emissions	5,742		3,092		0

2017 US carbon emissions (in MMT) by economic sector with targets for 2030 and 2050.

Source for 2017 emissions: EPA Inventory of US Greenhouse Gas 53

Reaching GND goal #1: Electrifying transportation

Bicycles are the most efficient form of human transportation ever invented. Sadly, they are unlikely to replace cars.

Electric cars

Rapid advances in battery technology and lowering of prices mean that electric cars are fast approaching the same price bracket as gasoline-powered and hybrid cars. 200,000 electric vehicles (EVs) were sold in 2017, and 360,000 in 2018. That was an 80% increase in one year, but it still represents only 2% of the 17 million vehicles sold in the US each year.⁵⁴

Following California's lead, there are now ten states with laws that require automakers to sell a certain percentage of electric cars and trucks in their state.⁵⁵ Other incentives at the city and state level can help speed up this process.

By 2030, all vehicles sold in the United States must be fully electric.

The IRS tax credit of up to \$7,500 for a new electric vehicle brings the cost of an EV closer to that of an equivalent gasoline-powered car, but under current rules, this incentive will be phasing out rather than increasing. A GND will need to prioritize incentives like this to encourage the rapid increase in EV sales and to make it possible for lower-income families to transition to electric vehicles.

But most importantly, there will need to be a clear decision, enacted into federal law, which simply says that by 2030 all vehicles sold in the United States must be fully electric.

That would still leave a large number of gasoline and diesel powered cars and trucks on the road in 2030. But there would be 85 million fewer by then than the 272 million on the road today. And that would mean 620 MMT less carbon emissions going into the atmosphere.

With only electric vehicles to choose from after 2030, virtually every car would be electric by 2050, simply through normal rates of replacement, although this could also be enforced through legislation. By 2050, a further 1,000 MMT less carbon emissions would then be going into the atmosphere.



2-door EV selling new in 2019 for \$17,450 ⁵⁶

To be selling only electric vehicles in the US by 2030 means increasing sales by roughly 40% every year from now to 2030. That is only half the rate of growth quoted above for 2018, but it is still a huge rate of change for any industry. In addition to providing incentives to car buyers, a GND will need to support the automotive industry through this transition, particularly with continuing investments in battery improvements and in

developing clean industrial processes for car production itself.

SUVs, pickup trucks and semis

A number of manufacturers are already producing electric SUVs and pickup trucks, so the transformation in this area will follow only slightly behind that for cars.

Heavy-duty trucks and semis are not that far behind. Tesla announced in 2017 that it was starting production of its first all-electric heavy-duty semi with a 500-mile range. Daimler delivered its first all-electric “eCascadia” Freightliner truck at the tail end of 2018,⁵⁷ and other manufacturers, including Nikola Motors, Volvo, Thor and MAN-VW have recently announced all-electric versions of their leading truck models.



Daimler's eCascadia electric semi unveiled, Dec 2018. PHOTO: Electrek ⁵⁸

Government support will again be needed to speed up the transition to electric trucks and to get diesel powered trucks off the roads by 2050. New regulations requiring all new vehicles sold in the US by 2030 to be electric, including trucks, will be the deciding factor.

Public transportation

Electric buses have been commonplace in Europe for many years, but in the US there are so far only 300 electric buses operating in the whole country. (For comparison, China has more than 400,000 electric buses.) Replacing existing fleets of fossil-fueled buses with electric buses will be comparatively easy and straightforward, with few additional costs to municipalities.

Electric trams, subways and trains, on the other hand, require extensive infrastructure that does not yet exist in most parts of the country. How much a GND should prioritize trains is an important question.

At present, diesel powered trains account for just 42 MMT of carbon emissions. But to eliminate those emissions will require electrifying the entire rail network nationwide. If that has to be done sooner or later anyway, it makes no sense to invest in all that infrastructure without also creating a national high-speed rail network that would serve the needs of the traveling public.

High-Speed Rail

One of the arguments for high-speed rail is that it would cut down on air travel as well as the use of cars. California's high-speed rail project aims to cut the travel time between San Francisco and Los Angeles to 2 hours and 40 minutes, competing with the 1 hour and 40 minutes it takes to fly between the two, not counting the time to and from airports, checking in, collecting bags, etc.

China built 12,000 miles of high-speed rail network across a country similar in size to the United States in just 9 years.⁵⁹ The US High Speed Rail Association believes it can build a similar network in the US, covering 17,000 miles of track, in 20 years.⁶⁰ But it requires a big investment.



Artist impression - the Boeing SUGAR Volt 61

Air travel

Air travel accounts for more than 120 MMT of carbon emissions and it will take some time to eliminate this. Fossil-free air travel requires powerful and very lightweight batteries, but these are coming. Two-seater battery-powered electric airplanes already exist, and the first hybrid electric passenger airliner, the Boeing SUGAR Volt, is currently under development.⁶²

Ships

Ships, of course, have sailed the seven seas for centuries without the use of fossil fuels. However, rather than returning to the era of sailing ships, new developments in marine propulsion are already well underway, with battery-powered cruise ships, ferries and the world's first 2,000-ton electric cargo ship currently under construction in China.⁶³

Reaching GND Goal #2: 100% Clean and renewable electricity

Of course, electric transportation itself is of little help unless the electricity itself is clean. In addition to cutting emissions from the transportation sector, a GND must therefore reduce and eliminate the carbon emissions of electricity generating plants by moving rapidly to clean, renewable sources and phasing out fossil fuels, biomass and nuclear power.⁶⁴

Utility-scale wind and solar power, together with existing hydro-power resources, is already producing nearly 20% of the nation's electricity. With sufficient government support, this can be scaled up to as much as 90% by 2030, reducing carbon emissions by 1,780 MMT CO_{2e}. By 2050, with closure of the remaining nuclear power plants, we would have a fully 100% clean, renewable electricity supply.

Reducing the carbon emissions of the transport sector, as well as a great deal of the industrial, commercial and residential sector, involves moving from fossil fuels to electricity as a source of heat and propulsion. This means in the short to medium term a significant increase in our electricity consumption as we move to electric cars, electric heating of buildings and so on.

Electric vehicles currently consume approximately 0.2-0.34 kWh of electricity per mile of travel. Gasoline powered vehicles in the US currently travel approximately three trillion miles per year. So if all those vehicles were powered instead by electricity, that would be an additional 600-900 billion kWh of electricity generation needed on top of the existing load of approximately 4,200 billion kWh per year (by 2050).

Currently, approximately 116 million homes in the US are heated with gas. Homes vary enormously in size and energy efficiency, but assuming it takes, on average, about 10,000 kWh per year to heat a home with electricity, that is an additional 1,160 billion kWh of electricity to be added to the existing load per year for home heating. Adding the extra electricity needed for vehicles and home heating brings the total electricity needs of the United States up from 4,200 to over 6,300 billion kWh per year by 2050, or roughly 50% more than we use at present. This can be reduced with better energy efficiency and a stronger commitment to energy conservation, but to present a viable alternative to fossil fuels, renewable energy sources need to be able to meet the expected future energy needs.

Calculating future US electricity needs

<i>Billions kWh</i>	2018	2030	2050
Existing electricity consumption	4,178	4,200	4,400
Added electricity needed for vehicles	-	234	750
Added electricity needed for heating	-	68	1,160
Total electricity needs	4,178	4,502	6,310

Producing all our future electricity needs from renewable sources is totally doable with the technologies we already have and at a cost that will more than pay for itself with cheaper electricity prices over the long-term.

What is needed to unlock these resources, more than anything, is the unequivocal commitment of the federal government to a fossil-free future. Without that, it is difficult to see how utilities, private investors or even committed individuals will take the steps necessary to make that happen.

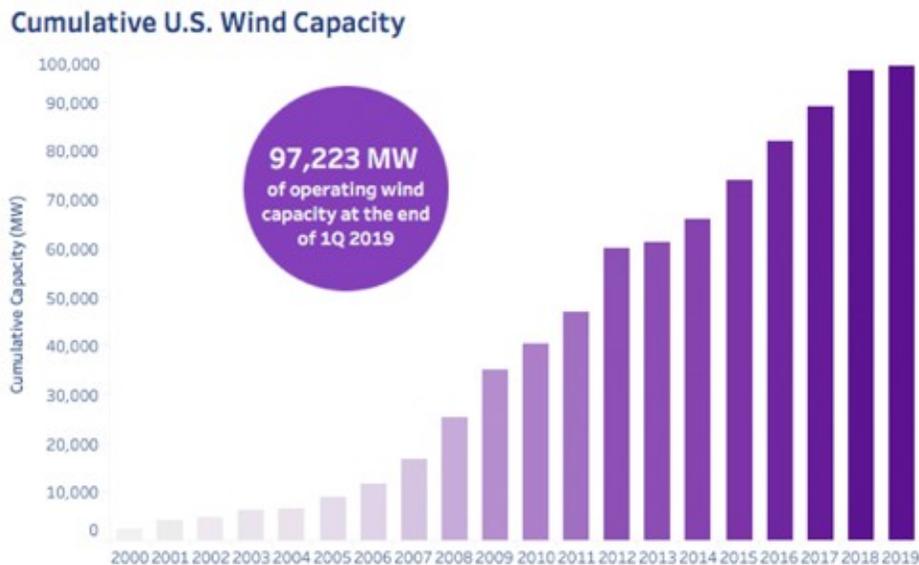
Wind

The technical potential⁶⁵ for generating electricity from wind resources in the US is estimated to be more than 11,000 GW from onshore wind and another 4,200 GW from offshore.⁶⁶ This is vastly greater than the total amount of electricity currently available in the US from all sources (1,200 GW).

The Obama administration produced a detailed study in 2008, updated in 2015, which looked at the prospects for wind power in the United States.⁶⁷ The report concluded that wind power could provide 10% of the nation's electricity by 2020, 20% by 2030 and at least 35% by 2050. That report was based purely on existing market trends and not on any assumption that the federal government might step in to help speed up the process.

When the report first came out in 2008, wind was providing just 1.5% of the nation's electricity. As of 2018, it was already providing about 6.6% of the nation's electricity and 8% of the nation's generating capacity.

Meanwhile, the cheapest wind power (using the levelized cost of electricity, or LCOE) has fallen below \$30/MWh, the report's estimate of what that figure might reach by 2030. With gas currently priced at \$41-\$74/MWh (LCOE), the economics of electricity generation have now shifted decidedly in favor of wind, even without government intervention.



Source: AWEA

Utility-scale wind farms

There are currently over 200 wind farms operating across 30 states, with a total generating capacity of nearly 100 GW (roughly equal to the total generating capacity of all nuclear power plants currently operating in the US). There is another 17 GW of wind power currently under construction and a further 22 GW in advanced stages of development.⁶⁸

Wind energy is not 100% renewable, because it takes steel and cement to make a windmill, and at present, those are very fossil fuel dependent materials. There is growing opposition to wind farms for other environmental and aesthetic reasons. More research is needed to better address these issues and to reduce the harms.

However, if we are to address the climate crisis in the timescale required, we have no choice but to increase the pace of wind development in this country.

At the current pace of adding roughly 20 GW of wind power per year, we would reach a total wind capacity of around 300 GW by 2030. We need to be doubling the current rate of growth to 40 GW per year in order to bring the capacity up to over 500 GW by 2030.

Off-shore wind

Wind blowing over the ocean is generally much stronger and more consistent than wind blowing inland. More than 18 GW of wind is installed off the shores of UK, Denmark and Germany. Currently, the US has only one offshore wind farm, producing 0.03 GW off the coast of Rhode Island. But with a potential for harvesting more than 4,000 GW of US offshore wind, this is a resource which is likely to take off very soon. At least ten offshore wind projects are currently under development in seven states. These will ensure at least 10 GW of offshore wind will be up and running in the near future.⁶⁹

While the costs of installing offshore wind are considerably higher than for onshore wind farms, the reliability and efficiency of the turbines, once installed, should more than offset these costs over the longer term. More financial support will be needed to significantly increase the contribution from offshore wind, but eventually this has the potential to generate nearly as much as is currently projected for onshore wind (perhaps 100 GW by 2030 and 300-400 GW by 2050).

Distributed wind

Smaller-scale wind turbines installed on homes, farms, schools, factories, commercial premises and government buildings are another important source of electricity, especially for rural communities.

The Distributed Wind Energy Association (DWEA) estimates that there are 23 million suitable locations for distributed wind in the US, with the potential for 1,100 GW of generating capacity, or roughly the current total generating capacity from all sources.⁷⁰

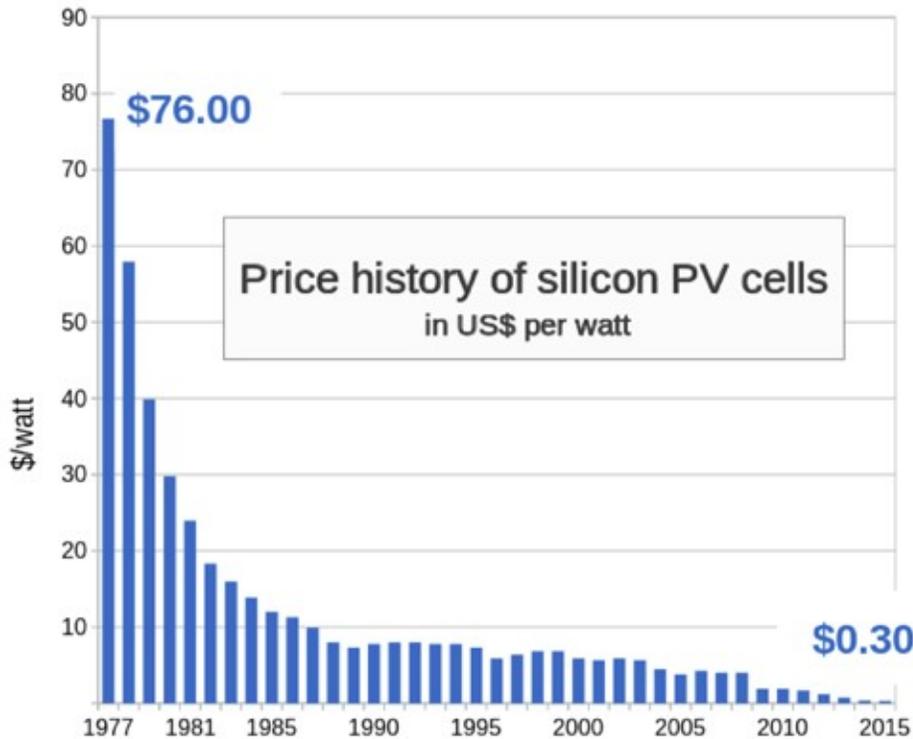
The DWEA launched a strategy in 2014 to achieve 30 GW of distributed wind by 2030. Installed distributed wind capacity as of 2017 stood at around 1 GW of electricity from over 81,000 turbines in all 50 states.⁷¹

Solar

Solar power comes in two main forms: photovoltaic (PV) solar panels that convert sunlight directly into electricity, and various forms of solar thermal (CSP) power that concentrate the heat of the sun to boil water and run turbines similar to any other electricity generating plant.

PV solar panels are made predominantly from quartz, which is the most abundant mineral on the planet. However, other toxic chemicals and materials are involved in the production, as well as large amounts of energy.

Large-scale solar PV farms also take up a lot of open space that could be used for farming or recreation. Once again, it is literally impossible to prevent climate catastrophe without a massive shift to solar power, so it must be a priority to resolve these continuing issues through the setting of high safety and environmental standards.



Source: Bloomberg New Energy Finance & pv.energytrend.com

Utility-scale solar PV farms

There is now 64 GW of Photo-Voltaic (PV) solar capacity in this country, providing just 2% of the nation's electricity.⁷² For solar to be providing somewhere between 30% and 50% of the nation's electricity by 2050 would require installing another 64 GW or so of solar panels each year for the next 30 years.⁷³

Costs per kWh have fallen even faster for solar PV than they have for wind. This makes utility-scale solar PV farms much more attractive as an option, especially in parts of the country where sun and vast open spaces are both plentiful.

Concentrated solar power (CSP) plants

As of 2017, there were 50 CSP (solar thermal) projects worldwide, with nearly 5 GW of electricity generating capacity, mostly in Spain. These involve a field of mirrors pointing the rays of the sun to a central tower where water is boiled to run turbines. So far, only eight of these are in the US, mostly in California. Total CSP capacity of these plants as of 2017 was 1.8 GW.⁷⁴

Although PV technologies are now considerably cheaper, CSP has the advantage of being able to store energy (using molten salt) without the use of batteries and to step up production to meet peak demand. For these reasons, many consider CSP an important part of the mix in terms of future electricity production.

Distributed Solar (Rooftop)

Up to half the total solar contribution will need to come from rooftop installations on homes and commercial buildings.⁷⁵ Unlike small rooftop wind turbines, which are much less efficient than the giant ones, rooftop solar panels can be as efficient as those found on massive solar farms.

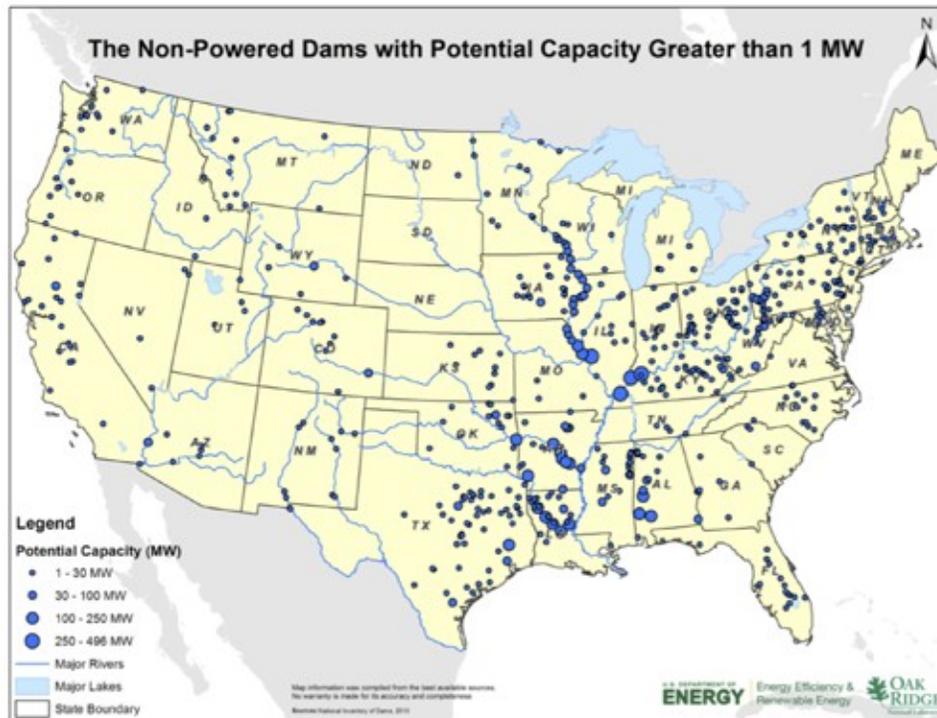
This means potentially providing large numbers of people not just with carbon-free electricity, but with

virtually free electricity.

Hydroelectric

Hydroelectric power from existing dams currently provides about 12% of the nation's electricity, with 80 GW of capacity from conventional dams, plus another 23 GW of pumped storage.

In addition to the 2,500 dams that currently produce hydroelectricity, there are approximately 80,000 “non-powered” dams across the country. A DOE report from 2011 suggested as much as 22 GW of additional electricity could be generated from just 100 of these existing dams, without the need to build any new dams or disrupt environments.⁷⁶

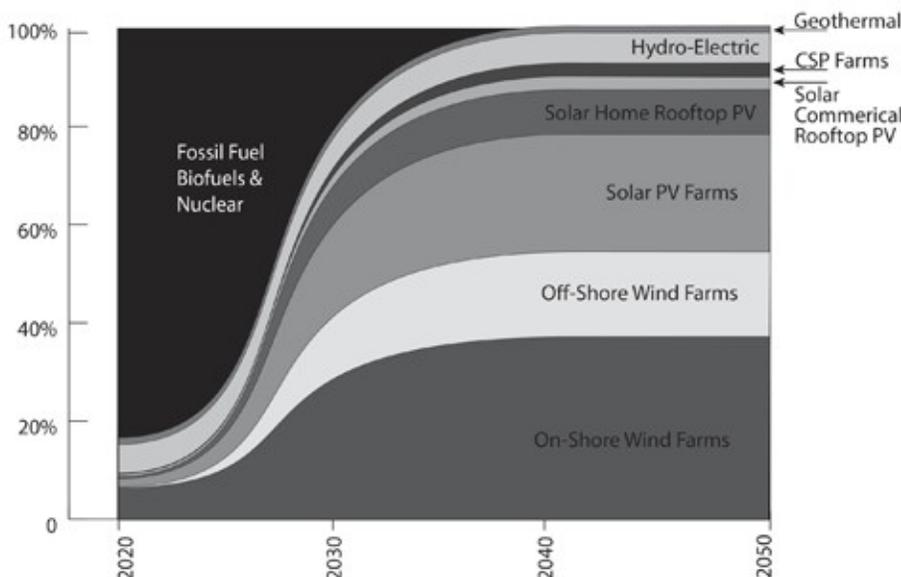


Another study in 2014 by Oak Ridge National Laboratory identified a further 65.5 GW of potential hydroelectric power from areas that would cause the minimum environmental and recreational disruption.⁷⁷

Geothermal

There are currently 32 geothermal energy plants with a total capacity of 3.7 GW of electricity in the US (including one in Hawaii).⁷⁸ A number of new plants are under construction or planned in several states with geothermal potential. Total geothermal potential in the US is estimated at 9 GW out of 200-230 GW worldwide. So the contribution of geothermal to overall electricity demand will remain small.

Sources of Electricity 2020-2050



Wave and tidal power

Wave power is an emerging technology that could contribute substantial grid-connected power, but not yet, and not without substantial investment. The U.S. Department of Energy estimates that wave power could be generating as much as 100 to 150 GW of electricity, although the “practical resource potential,” which factors in the economic, environmental, and regulatory considerations, would likely be somewhat less.⁷⁹

Still, if we captured even a portion of the potential of the wave energy available in the USA’s 12,383 miles of coastline, we might meet up to about a quarter of all US electricity needs. Tidal power has about a quarter of the potential of wave power, or 7.5 to 10% of US consumption. Ocean currents and river currents have less potential, together offering perhaps 5 to 9% of US consumption.⁸⁰

Storage

Electricity demand across the country varies hour by hour as well as seasonally because of peak requirements at certain times of the day or year. Currently, peak demand is met by an over-capacity of generating power that can be turned on and off as needed. Since the sun does not shine at night and the wind does not always blow, renewable energy sources are generally less useful in meeting peak demand as and when it is needed.

Current electricity generating capacity is about double the total demand required in order to meet peak time requirements. Some analysts have suggested that wind and solar capacity would need to be at least double this, or four times to total US electricity demand, in order to meet peak time requirements.⁸¹

Others have suggested even more peak capacity would be needed, but another option for meeting the variable nature of electricity demand is through storage.

Already, a certain amount of peak demand is met through pumped storage at hydroelectric plants. Current plans to turn Hoover Dam into a “giant battery” involve using electricity from the dam to pump water back into the reservoir during off-peak times to allow more water to flow through the turbines at peak times.⁸²

Industrial scale batteries are also being developed, and with the rapid fall in battery prices, this may become a viable option for meeting peak demand. The total energy stored at all utility scale battery storage sites in the US as of the 4th quarter of 2018 was 777 MWh.

But this is small compared to what is coming. A single battery storage system is being built in Florida that will

provide 900 MWh of storage on its own when it becomes operational in 2021. An 800 MWh battery in China is scheduled to be operational in 2020.⁸³



A 1 MW/4MWh vanadium flow battery operating in Pullman, WA PHOTO: Wikimedia Commons

Upgrading the grid

In order to make the shift to 100% renewable electricity, the grid that delivers electricity to where it is needed will need a major overhaul. A so-called “smart power grid” (not to be confused with the 5G “smart grid”) would potentially save on wastage and losses in transmission as well as better optimize and balance the peaks and troughs of demand.⁸⁴

Reaching GND Goal #3: Electrifying commercial and residential buildings

To achieve the targets for 2030, a further 50 MMT CO_{2e} needs to come out of the fossil fuel heating of buildings. One of the first things a Green New Deal will need to establish is new buildings codes that require the incorporation of electric (including heat pumps) rather than fossil fuel heating and cooking systems for all new buildings.

There were approximately 80 million single-family houses, 30 million apartments and 5.6 million commercial buildings in the US in 2015.⁸⁵ These are being added to or replaced by construction of approximately 373,000 apartments, 614,000 single-family houses and 407,000 commercial buildings each year. That is roughly 1.3 million new buildings/units per year, or a bit more than 1% of the total building stock of the country.

As a priority, ensuring that all new buildings meet the highest fossil-free standards would thus reduce CO_{2e} emissions by approximately 5 MMT per year, or 50 MMT by 2030. This is clearly not enough to meet the targets, so a major effort of retrofitting buildings will have to be a central component of a Green New Deal, aiming to replace all fossil fuel-based heating (and cooking) systems with electric ones by 2050, with a further reduction of 630 MMT possible by that point.

This is a major undertaking that will require significant government resources. Because a 45% reduction cannot be achieved by 2030 in all sectors, it is all the more important to make big reductions where it is easiest – in the electricity and transportation sectors.

Reaching GND Goal #4: Banning HFCs

In the 1980s, it was discovered that chloroflourocarbons (CFCs), used mainly for refrigeration, air conditioning and aerosols, were destroying the ozone layer that protects the earth from the sun's ultraviolet radiation. CFCs were banned by the Montreal Protocol, an international agreement that went into effect in 1989.

CFCs were largely replaced by hydroflourocarbons (HFCs), another type of chemical that served the same purposes as CFCs but without affecting the ozone layer.

An immediate ban on the use of HFCs where less harmful alternatives are widely available is the easiest way to reduce carbon emissions and is something the EU has already done.

Unfortunately, HFCs do contribute to climate change. In fact their global warming potential is over 1,000 times that of carbon dioxide.⁸⁶ There are a number of HFC-free technologies already available to replace the role that HFCs and CFCs have played, especially in refrigeration.

In 2016, the Kigali Amendment to the Montreal Protocol was agreed, phasing out the use of most HFCs worldwide by 2050. It entered into force in 2019 after 65 countries had ratified the amendment. But the US is not among them.

The US needs to ratify the Kigali Amendment and phase out all HFCs by 2030 to reduce carbon emissions by 150 MMT and meet the climate goals we need to achieve by then.

Reaching GND Goal #5: Agricultural reforms

Reducing carbon emissions from the agricultural sector will be more difficult and will take time. Luckily, we are not aiming for 100% elimination of carbon emissions by 2050, but only for net-zero emissions. That means aiming to reduce emissions from agriculture by as much as 50% by 2050, leaving the remainder to be offset by the amount of carbon absorbed back out of the atmosphere, mainly from forests and wetlands.

Government support will be key to making the transition to more sustainable farming methods that do not rely so heavily on nitrogen fertilizers, revert to the ancient practice of crop rotation and reduce methane emissions from cattle.⁸⁷ Healing our damaged earth from disruptive agricultural practices and finding better ways to reduce carbon emissions from the agricultural sector will require serious effort and more research.

Reaching GND Goal #6: Industrial reforms

Industry accounts for more than 20% of total carbon emissions. About half of this comes from the burning of fossil fuels for both heating of buildings and the heating of industrial materials. The rest is emitted from the industrial processes themselves, which will require a much longer timescale to address. As with residential and commercial buildings, only a small proportion of industrial heating is renewed in any one year, meaning that carbon reductions will require significant retrofitting efforts and cost.

The only reductions expected in the industrial sector by 2030 are those directly related to the infrastructure required to continue supporting the burning of fossil fuels for transport and electricity. As reductions are made, especially in the electricity sector, these will lead to corresponding reductions in the emissions from oil refineries, gas pipelines, coal mines and other fossil fuel facilities.

There would still be oil refineries, coking plants, steel mills, petrochemical and many other polluting and dangerous facilities making steel, cement, plastics, pharmaceuticals, paints and many other products out of fossil fuels or through the process of burning fossil fuels in 2030.

At least half of these would be expected to be converted by 2050 to facilities that may still use fossil fuels as a natural resource for production of plastics and other products, but not as a fuel for burning.

Reaching GND Goal #7: Reforestation and land restoration

With a major program of re-forestation and restoration of wetlands, the total capacity for GHG absorption could be increased to 1,000 MMT or more, according to some studies.⁸⁸ This would involve planting as many as 32.5 million trees per year on existing federal lands. During the course of the original New Deal in the 1930s, 3 billion trees were planted, putting 3 million unemployed people back to work.⁸⁹ If we did it then, we can do it again. This time, our lives depend on it.



Civilian Conservation Corps planted 3 billion trees in 1930s

How can a Green New Deal address inequality and injustice?

Addressing the grotesque and unsustainable levels of inequality and injustice in this country requires all kinds of policy changes that only the federal government can make. But the single most important way to address inequality is to make sure there are plenty of decent, well-paid jobs available. That is the core of any Green New Deal.

Jobs

No matter how it is done, moving to a low-carbon economy will create millions of jobs. There are already 786,000 people employed in the renewable energy field in this country (compared to 3.8 million in China).⁹⁰ According to the US Department of Labor,⁹¹ solar photovoltaic installers and wind turbine service technicians were the two fastest growing occupations in 2018.

Nevertheless, as many as 1.4 million jobs are also at risk from the closing of coal mines, oil refineries, gas-fired power stations and other fossil-fuel dependent industries.⁹² Ensuring that these people are offered comparable jobs with comparable wages and benefits in the renewable energy field will be crucial to ensuring a fair, and smooth, transition to the new economy.⁹³

When the government creates jobs that pay a living wage sufficient to support a family, this does more than provide a decent job for those who get hired. It also sets a standard which other private employers have to achieve and raises wages and standards of living for many more workers.

A focus on distributed power

The second most important way to address inequality is to make sure federal funding for a GND focuses on those areas that will best support low- and middle-income families in making the transition to electricity and a low-carbon future.

A Green New Deal can also address inequality and injustice by avoiding some of the climate change ‘solutions’ which will not benefit the poor.

Subsidies for distributed (rooftop) solar, especially in urban areas, and distributed wind, especially in rural areas, must be a priority. This could lower electricity costs and provide an unprecedented level of energy independence for large numbers of people. A GND can also help ensure a fair distribution of the benefits of moving to electricity by subsidizing home battery storage.

Providing distributed (rooftop) solar and/or wind turbines for government buildings, schools, libraries and other public buildings should also be a high priority for federal funds.

Transportation priorities

Existing subsidies, in the form of IRS tax credits on the purchase of new electric vehicles, must be extended and increased in order to speed the sales of EVs. Buy-back schemes to dispose of old gas and diesel cars will also be needed because there will be no second-hand market for these vehicles once it becomes impossible to buy fuel for them.

Public transportation is also a key priority for improving the well-being of all citizens. Better bus and train services, connecting people to and from urban centers as well as between more remote rural communities, can save people time and expense, and enable them to work with less commuting time and more time with their families and in their communities.

Home heating and cooking

Those who can afford it should pay for their own conversion to electric heating and cooking in homes. Federal funds need to prioritize low-income housing and apartments to speed up that conversion for those who cannot afford it.

Tax policy

Finally, it is of course the case that the way taxes are collected is the defining feature of a fair society. When the wealthier members of society end up paying less in taxes than the less well off, inequality increases and so does resentment. Reversing tax cuts that benefit the rich and building a more progressive taxation system will be critical for addressing inequality.

Carbon pricing

A GND can also address inequality and injustice by avoiding some of the climate change “solutions” which will not benefit the poor but could actually hit them even harder.

Carbon pricing is an attempt to use the market to achieve the goal of a carbon-neutral economy, by charging people and industries and governments for the carbon they emit. A very quick way to lower carbon emissions would be to charge hefty taxes per ton of emissions. This would hit a lot of industries very hard, but the costs would be passed on, eventually, to the consumer, meaning the price of nearly all goods would rise.

A slower build-up of carbon taxing has worked in some countries to some degree, but the question here is whether carbon pricing can be achieved without increasing inequality and overall levels of poverty. Generally speaking, when people have very little spare cash, a small increase in the price of basic necessities has a very big effect on their ability to make ends meet.

The better carbon pricing schemes actually benefit the poor and plow the proceeds back into green technologies.

Carbon pricing, unless it is handled with extreme care, increases the cost of things that emit carbon – like gasoline for your car, heating for your house, electricity for your TV, not to mention the food you eat. That can have a direct and very negative impact on poor families, unless the revenues are carefully redistributed back to communities to offset those negative effects.

More than 40 governments around the world are already applying carbon pricing, and the more well-designed and well-executed programs redistribute funds to make up for the increased cost. The better carbon pricing schemes actually benefit the poor and plow the proceeds back in to green technologies.

Canada’s and Chile’s carbon tax revenues are used to lower the tax burden for consumers, and Colombia uses its carbon tax revenues to support rural development and environmental projects.⁹⁴ In California, 25% of cap-and-trade funds must be allocated to projects in low-income and polluted communities.⁹⁵

The Regional Greenhouse Gas Initiative covers 10 states in the Northeast and Mid-Atlantic, raising revenues through quarterly auctions of permits for CO₂ emissions. Not only have these investments made the power system cleaner and more efficient, but by design they have also reduced electricity bills for businesses and consumers, including low-income households.

A bill pending in the Massachusetts legislature, H. 1726, builds on the Regional Greenhouse Gas Initiative to ensure that 80% of the revenue from carbon fees is rebated to households and employers, with 20% going to regional transportation projects and energy efficiency upgrades for small businesses.

How much will a Green New Deal cost?

Benefits of a GND

The latest report from the Global Commission on the Economy and Climate ⁹⁶ claims that “bold action” to address the climate crisis could yield direct economic benefits worth \$26 trillion globally over the next 10 years. In any case, there are clearly benefits, as well as costs, to any plan that increases jobs, cuts pollution-related health problems, improves access to jobs and housing, reduces waste, increases productivity and brings in government revenues.

The cost of inaction

There are also costs associated with not adequately re-tooling to a renewable economy and facing the damages of uncontrolled climate disruption. Extreme weather in the US caused more than \$400 billion worth of damage in 2018 alone.⁹⁷ The UN estimates the total cost of climate change globally could reach \$69 trillion by the end of this century.⁹⁸

So in a very real sense, we cannot afford not to invest in a Green New Deal, no matter what it costs. And the cost of implementing a Green New Deal could still end up being less than the cost of not implementing it.

GND is not, however, “free”

Alexandria Ocasio-Cortez has pointed out that nobody asks the question, when launching a war, “how much is this going to cost?” They just go to war and pay for it later.⁹⁹ The same could be asked of trillion dollar tax cuts. Nevertheless we know that those decisions do cost money and we all pay for it later, in the form of interest on the national debt – now standing at a staggering \$22 trillion dollars and set to increase (because of the latest tax cuts) this year by another \$1.2 trillion.¹⁰⁰

So, yes, the government can always just borrow more money to pay for a Green New Deal, like they pay for everything else. We can also weigh up the costs of a Green New Deal against the costs of not doing a Green New Deal.

But there is still a price tag to be put to something that involves research and development, creating infrastructure, and subsidizing the transition to a new economy. The price tag is not going to be anything close to the \$100 trillion that President Trump has quoted. But neither will it be free.

How much will it cost?

The Political Economy Research Institute at the University of Massachusetts, Amherst, together with the Center for American Progress (PERI-CAP) produced a detailed study in 2014¹⁰¹ of what it would take to reduce carbon emissions to 3,200 MMT over a 20-year period rather than 10-year period. Their figure came to \$200 billion per year for 20 years.

Another study, ¹⁰² from Mark Jacobson at Stanford University, calculates that moving to 100% renewable energy (using only wind, water and sunlight) by 2050 would cost around \$9.5 trillion, or \$316 billion per year.

Extrapolating from levels of investment that seem to be working in other countries and the levels of investment that have so far proven to be insufficient in this country, Ed Barbier at Colorado State University¹⁰³ has come up with a figure of \$970 billion of investment over five years, or \$194 billion per year, as a reasonable price tag for a GND.

A number of presidential candidates have now come out with their own figures, and although these are based on different assumptions and involve different amounts of private investment on top of, or included within the figures, there is a surprising degree of agreement that a GND is likely to cost around \$200-\$300 billion per year

for the next 30 years, or between \$2-\$3 trillion by 2030 and \$6-\$9 trillion by 2050. ¹⁰⁴

Costing a Green New Deal (over 10 years)

<i>Estimate</i>	\$billions/yr	\$trillions
AAF ¹⁰⁵	223-270	2.23-2.7
PERI-CAP	200	2.0
Jacobson	316	3.16
Barbier	194	1.94
Rynn ¹⁰⁶	255	2.55
Inslee	300	3.0
O'Rourke	170	1.7
Warren	200	2.0
Biden	170	1.7

Cost vs investment

This figure is not simply a “cost” in the same way that paying for nuclear weapons is a “cost.” Paying for green technologies is an investment, since it is creating jobs, bolstering the economy, and ultimately making the cost of doing business cheaper for everyone. It will also bring a return, not simply in the form of taxes as more people are put to work, but also in the form of payments for the services being delivered.

It might, for example, cost \$680 billion dollars to build a high-speed rail system, but once the system is built, people will be paying fares to use it, and sooner or later, in a purely “free market” system, those fares would be expected to fully recover the cost of building the system (and then with much lower ongoing “marginal” costs, it would start to return a net profit).

Likewise, the sale of solar or wind-generated electricity can be expected to far exceed the cost of building the windmills and putting in solar panels. So in the long run, all that capital investment is recouped by sales.

Rapidly falling prices

The accepted way to compare electricity costs is to look at the levelized cost of electricity (LCOE), which adds up all the costs of building and running a power plant and divides it by the total amount of electricity produced during the lifetime of the plant to get a figure of what it costs per kWh of electricity.

Everything that has ever been written about the cost of renewable electricity has been out of date by the time it was published, as every year, technological developments and the economies of scale are driving these costs further and further down.

Just within the last year, the LCOE for onshore wind farms and utility scale solar farms has fallen below the LCOE for coal, gas or nuclear power.¹⁰⁷

Avg. LCOE by source \$/MWh	low	high
On-shore wind	\$29	\$56
Solar PV utility scale	\$36	\$44
Gas	\$41	\$74
Coal	\$60	\$143
Geothermal	\$71	\$111
Solar thermal with storage	\$98	\$181
Nuclear	\$112	\$189

Source: Lazard 2018¹⁰⁸

This means that it is now more profitable for existing utility companies to invest in renewable electricity sources than it is for them to invest in more fossil fuel plants. That alone could mean the end of fossil fuels for

electricity.

There are still many challenges to overcome, however, in transitioning to a fully renewable electricity grid, let alone addressing the carbon emissions coming from all the other sources listed earlier. A Green New Deal will still require considerable investment.

The need for more investment

One of the biggest obstacles right now to a fully renewable electricity grid is the grid itself, which is out of date and very inefficient for moving electricity around the country to where it is needed at the time it is needed.

One big project of any Green New Deal will be to build a new national “smart grid,” which is likely to cost between \$388-\$476 billion, according to the Electric Power Research Institute, which estimates the benefit of that investment to be \$1-\$2 trillion in efficiency savings over the long term, on top of the reduced carbon footprint that would result.¹⁰⁹

Another important area for investment is battery storage (and other forms of electricity storage), since the biggest drawback to solar and wind power is their intermittency. Batteries have also come down enormously in price, but to keep the price coming down still further will require both economies of scale and further innovation. And that means investment. Already \$620 billion is being invested worldwide in battery technologies.¹¹⁰

Another major project for a Green New Deal will be building a national High-Speed Rail network. Again, costs are difficult to determine, because prices vary from project to project. Japan built its high-speed rail network for \$5 million per mile, while European high-speed rail projects have cost anywhere from \$25-\$40m per mile, and in China the cost has been closer to \$50m per mile.¹¹¹

Estimates for the cost of a US high-speed rail network also vary according to different scenarios and the number of miles involved. For 17,000 miles of track at European prices, the system would cost between \$425-\$680 billion. This might take until 2050 to complete, so roughly a third (\$226 billion) would be needed up to 2030.

Another important piece of any GND will be a massive investment in (electrified) public transportation for inner cities and poorer rural communities. The American Public Transportation Association has identified \$232 billion in investment needed to bring the nation’s public transit up to date.¹¹²

Retrofitting existing homes and commercial buildings across the country to meet reduced carbon goals will cost a lot, but it will also create millions of jobs and reap huge savings in energy costs. A 2012 report from the Rockefeller Foundation suggested that an investment of \$279 billion over 10 years could make a substantial difference, saving as much as \$1 trillion in energy costs during the same period.¹¹³

Finally, a major tree-planting initiative similar in scale to the New Deal of the 1930s would perhaps involve hiring one million people to plant one billion trees over the next decade. At an average liveable wage, that would cost roughly \$30-\$40 billion per year, or \$300-\$400 billion for 10 years.

This brings us to a total of around \$300 billion per year, or \$3 trillion for 10 years, or \$9 trillion for 30 years, as a reasonable estimate for the cost of a Green New Deal.

Approximate investments needed for GND

<i>\$billions</i>	Per year	10 years
EV car subsidies	50	500
Rooftop solar	17	175
Distributed wind	22	225
Smart Grid	45	450
Research program	40	400
High-speed rail	23	226
Public transit	23	232
Reforestation	35	350
Retrofitting buildings	30	279
Farm support	15	150
Overseas climate aid	10	100
Total GND	310	3,087

Public vs private investment

Not all that money needs to come from the federal government, however. In fact, by some estimates, most of it would not. In addition to local and state government investment, particularly in buildings and public transit, most estimates of the investment needed assume that private investors will cover two-thirds to three-quarters, of the total.¹¹⁴

The American Council on Renewable Energy brings together the country's major providers of capital investment in renewable energy projects, and believes that private investors can easily raise as much as \$1 trillion of investment¹¹⁵ for renewable energy projects between now and 2030 if the federal government were to return to its previous commitments to meet the Paris Climate targets.

According to a 2019 Rainforest Action Report,¹¹⁶ 33 banks had invested nearly \$2 trillion dollars in the fossil fuel industry since 2016, and with a shift in priorities, much of this investment would presumably shift to clean, renewable alternatives.

How can a GND ensure emission targets are met globally?

Reducing carbon emissions in the United States is absolutely crucial for addressing the climate crisis. But carbon emissions in the US account for only about 20% of total carbon emissions globally. So no matter what we do here in the US to address the climate crisis, unless other countries are doing the same, we cannot stop a climate catastrophe.

Most other countries are already doing more than we are right now, under the current administration, to address the climate crisis. However, much more still needs to be done.

A lot of China's emissions are actually our emissions, resulting from the production of goods that are sold and used in the United States.

At the global level, priorities are slightly different than for the US itself. Globally, electricity generation is the number one carbon emitter, followed by agriculture and industry, whereas in the US, transportation and buildings are numbers two and three. And for China, the largest carbon polluter in the world, industrial emissions top the charts.

Top carbon emitting countries

<i>Carbon emissions 2013</i>	MMT	%
China	11,735	26.8
USA	6,279	14.4
EU	4,224	9.7
India	2,909	6.7
Russia	2,199	5.0
Japan	1,353	3.0
Canada	738	1.7
South Korea	673	1.5
Australia	580	1.3
Saudi Arabia	546	1.25
Pakistan	326	0.7
All other countries	12,175	27.95
Total	43,737	100.0

Source: World Resources Institute

China is also the world's largest exporter, and much of its manufacturing output goes to the United States. In reality, therefore, at least a portion of China's carbon emissions are because the US has outsourced industrial production to China. A lot of those carbon emissions are actually our carbon emissions, resulting from the production of goods that are sold and used in the United States.

The US as a market

The United States buys goods not only from China but from all over the world. Over half the cars sold in the US, for example, are made in Europe and Japan. Stiff regulations ensuring that by 2030 all cars sold in the US are fully electric would automatically mean that producers in these other countries would also need to shift a large part of their production to all-electric vehicles. That in itself would help speed the use of all-electric cars in those other countries.

The US imports solar PV panels, batteries, steel needed for windmills, and many other products needed for the green economy. As a buyer of these products, the United States is in a position to set emission standards and other requirements as a condition of import, and these too can help ensure that other countries are meeting the necessary emission targets.

The US as a donor

The United States is a major provider of overseas aid, and is certainly capable of directing this money in ways that will help lower carbon emissions around the world. Aid includes goods, funding, technical assistance, educational programming, healthcare, military and security assistance, and support for businesses and charitable groups.

The Congressional Research Service (CRS), which includes military and security assistance in its definition of aid, calculates that the US spends about 1.2% of the federal budget on foreign aid. This amounted to \$49 billion in 2016.¹¹⁷

The US as an investor

As a main contributor to almost all multilateral institutions, including the United Nations, the World Bank, the IMF and many others, the US has significant influence over the investment and granting policies of these institutions. The United States can encourage investment to be directed towards the goals of a Green New Deal globally.

The United States can do much more to mobilize financial resources for use in dealing with the climate crisis internationally. There is a precedent for this: at the end of World War II, the United States invested billions of dollars in re-building Europe through the Marshall Plan. Elizabeth Warren has called for a new “Green Marshall Plan” to complement investments at home with a massive program of investment in green technologies abroad.

The US as a major world player

In addition to being a key financial player in the world, the United States is also, of course, a key player politically, with huge influence over NATO allies in Europe, allies in Asia and the Pacific, and other countries like Israel.

The United States is one of the five permanent members of the UN Security Council. It sits on many other international committees. It can and must take a lead in bringing important issues to the table for international agreement.

The US played a key role in achieving a positive outcome at the Paris Climate Talks in 2015. That commitment needs to be reaffirmed and reinforced. The Paris agreement is already outdated, however, and will need to be superseded with a stronger commitment from the whole world to limit global warming to 1.5°C rather than 2.0°C and to make concrete and specific steps in that direction by 2030.

Improving our relations with the rest of the world

All of these avenues can help ensure that other countries are also addressing the climate crisis with the same urgency as the United States. But these alone are insufficient.

The reality is that there needs to be a change of tone, attitude, and behavior in the way we as a country relate to the rest of the world. By demanding that other countries live up to their climate commitments and threatening them with punitive measures if they do not, we cannot build the cooperation and solidarity required to deal with this crisis.

The climate crisis has brought home the reality of our interdependence perhaps more than any other issue we have ever faced as a species.

This is not about finding a way for the US to “lead the way” in new green technologies or to ensure that US companies “dominate the market.” This is not about safeguarding “American jobs” or protecting US-American “national interests” or ensuring our own “security” at the expense of other countries.

To develop new technologies and build the necessary infrastructure in a very short span of time requires a degree of openness and a level of international cooperation that corporations scrambling for patents and politicians thinking only of national self-interest are not familiar with.

“There is no us and them,” says Pope Francis. “It’s only us!” The climate crisis has brought home the reality of our interdependence perhaps more than any other issue we have ever faced as a species. We simply cannot solve this crisis except by working on it together.

SOLUTIONS – THE NUCLEAR BAN TREATY

Addressing the nuclear nightmare – why abolition?

If we are to survive, we simply cannot risk waiting to make the necessary shift in our climate policies and practices. We cannot wait for others to take the lead or to see whether new solutions will come along to replace the ones we already know about.

Yet there are many voices on the climate front calling for a more incremental and “realistic” approach to the problem. Rather than trying to eliminate our reliance on fossil fuels with a 10- year national mobilization of resources, why not focus on more gradual reductions through market forces, for example?

Taking the President’s ‘finger off the button’ might make us all feel a bit safer at night. But does that move us closer to actually eliminating these weapons or does it just make us feel a bit safer?

When it comes to nuclear weapons, those who insist on more incremental and “realistic” steps have dominated the discussion for many decades. These voices seek ways to reduce nuclear stockpiles and slow the spread of nuclear weapons to other countries, one warhead at a time.

Some have insisted that more reasonable and “realistic” steps towards reducing the nuclear threat might include a policy of “no first use,” or removing nuclear weapons from “hair-trigger alert,” or removing the President’s “sole authority” to launch these weapons.

Others have proposed cutting specific weapons systems or developments such as the “low yield” warhead option that is already in production and soon to be deployed on US nuclear submarines. All of these more incremental and more “realistic” approaches have their congressional backers and organizational supporters around the country. But do they address the problem of nuclear weapons at the scale and with the urgency required?

Just as with the climate crisis, proposing more limited steps and solutions which do not get at the root of the problem can actually help to legitimize the continued existence of the problem. Some forms of carbon pricing, for example, which allow companies to “buy” someone’s cleaner emissions in exchange for their dirty ones, do not fundamentally address the need to eliminate our reliance on fossil fuels once and for all.

Similarly, carbon capture and storage, if it is merely a means of making it “cleaner” to continue burning fossil fuels, does not get to the heart of the problem, which is the burning of fossil fuels itself. ¹¹⁸

Demanding that the US renounce the idea of using nuclear weapons “first” sounds like a positive step forward, but if it is merely reinforcing the idea that the US will still retain the right to use nuclear weapons “second,” how does that move us away from nuclear weapons altogether?

Taking the President’s “finger off the button” and handing that job to Congress might make us all feel a bit safer at night. But does that move us closer to actually eliminating these weapons or does it just make us feel a bit safer?

What is the Nuclear Ban Treaty?

Just as the world is rising up to demand action on climate change, so has the world been rising up to demand the elimination of nuclear weapons.¹¹⁹ Since the end of the Cold War, people in this country have largely forgotten about this issue. But not so in the rest of the world.

These weapons are in the hands of just nine countries, but the whole world would be affected if any were ever used. So, after 72 years of waiting for the nuclear-armed nations to get rid of these weapons, the rest of the world decided to take the matter into their own hands. On July 7, 2017, 122 countries at the United Nations adopted the Treaty on the Prohibition of Nuclear Weapons, or “Nuclear Ban Treaty.” This treaty outlaws everything to do with these weapons for all time.¹²⁰

Hard as it is for many Americans to imagine, this is the beginning of the end, not only for fossil fuels, but also for nuclear weapons.

The United States did not participate in the treaty negotiations and so far refuses to sign it. But sooner or later, pressure from the rest of the world (and from within the US) will force this country to address this lingering relic of the Cold War and eliminate its nuclear weapons. A Green New Deal makes this even more urgent.

As of April 2019, the Nuclear Ban Treaty has been signed by 70 countries and ratified by 23. The Treaty will enter into force once 50 countries have ratified it. Those countries are then expected to pass national legislation to enforce the provisions of the Treaty.

Article 1(e) of the Treaty makes it illegal to “assist, encourage, or induce anyone to engage in any activity prohibited under the Treaty.” As with other weapons prohibition treaties (like Chemical Weapons or landmines), this has been interpreted to also include a prohibition against financing the companies involved in producing the prohibited weapons, as well as a prohibition on taking part in activities that support the continued existence of these weapons.

The impact of this new Treaty will be felt most immediately by the two dozen or so private companies that make and maintain nuclear weapons for the United States and other nuclear-armed states. Already, Deutsche Bank, Resona Holdings in Japan, and two of the largest pension funds in the world have moved to divest their funds from these companies.¹²¹

Many other financial institutions have taken, or are now considering, similar action. Here in the United States, divestment campaigns are already underway¹²² to add to the pressures being put on these companies globally.

Companies like Boeing, Honeywell, General Dynamics, Northrop Grumman, and Jacobs Engineering have offices, subsidiaries, suppliers, plants, projects and investors in dozens of countries around the world. They cannot ignore what goes on in those other countries, especially when laws are passed which could affect their global operations.

Hard as it is for many US-Americans to imagine, this is the beginning of the end, not only for fossil fuels, but also for nuclear weapons. Just as the fossil fuel companies continue to resist the inevitable, so will the nuclear weapons companies.

But just as with climate change, the world is waking up to the existential threat of nuclear weapons. This opens up a unique opportunity for finally addressing both of these issues here in the US.

What does signing the Nuclear Ban Treaty mean for the US?

Signing the Nuclear Ban Treaty would commit the United States to work towards the complete elimination of its nuclear weapons. Since this is something the US is already legally committed to under the Non-Proliferation Treaty (1970), it would have no immediate significance in terms of US nuclear weapons policy. Signing the Treaty does not mean that the US must immediately or “unilaterally” give up its nuclear weapons. This is just the first and initial step.

The US is not legally bound to implement the terms of this Treaty until the Treaty has been ratified by consent of the Senate. It is only after the ratification and subsequent entry into force of the treaty (90 days after the ratification has been deposited with the UN) that the specific legal obligations outlined in the Treaty begin to take effect.

Before ratifying the Treaty, the US will have ample time to reach some kind of agreement with the other nuclear-armed nations to ensure that they all give up their nuclear weapons together.

The Treaty requires each country to come up with its own legally-binding, time-bound plan for the verifiable and irreversible elimination of its nuclear arsenal. Before ratifying the Treaty and submitting its plan to the other parties, the US will have ample time to reach some kind of agreement with the other nuclear-armed nations to ensure that they all give up their nuclear weapons together.

There are many ways they could do this, but how these countries work something out between them is secondary to the fact that, sooner or later, the total elimination of nuclear weapons will require them to sign an agreement prohibiting nuclear weapons for all countries and for all time. If another country cheats, and does not give up all their nuclear weapons when the US does, that does not suddenly put the US in any more danger than we are in right now. Nuclear weapons can kill and maim hundreds of thousands of people and destroy whole cities. But they cannot stop a single nuclear weapon from landing on our country. Only the total elimination of all nuclear weapons worldwide can do that.

Therefore, giving up “our” nuclear weapons does not mean we are suddenly vulnerable to other countries who still have them. Nor does it make it more likely that one of those other countries is suddenly going to decide to launch, or threaten to launch, a nuclear attack against us.

The US has been at the forefront of every development in nuclear weapons since it first tested and then used nuclear weapons in 1945. Other countries have followed the US example and copied not only the technological developments as they have come along, but also the political rationale the US has used to justify having these weapons.

Will North Korea give up its nuclear weapons if the US does? There is no guarantee that they will, but they are certainly more likely to do so if the US does. And even if they don't, the US still has the most powerful military on the planet, even without nuclear weapons. Russia, on the other hand, is unlikely ever to give up its nuclear weapons unless the US does. The US must now take a lead on disarmament if we want to see any of the other nuclear-armed nations disarm.

Eliminating nuclear weapons – how can it be done?

Fulfilling existing commitments

Signing the Nuclear Ban Treaty and inviting the other nuclear-armed nations to do likewise is the first step to getting the United States back on track with its existing commitments. How quickly the other nuclear-armed nations join the Treaty will depend on many other factors.

Confidence-building measures

The US can and must lead the way to improving international relations with Russia and China. This means, first of all, treating these countries as partners rather than as adversaries. If NATO is to be perceived by Russians as a purely defensive alliance and not as a potential threat, the removal of offensive nuclear weapons that are aimed at Russian cities and military facilities is an important first step. Other offensive weaponry should also be withdrawn and new agreements reached that would de-militarize and de-escalate the potential for military conflict.

The role of the United Nations

In order to rebuild the trust and confidence needed for a world without nuclear weapons, the United States must renew its commitment to the United Nations and to its agreed procedures for resolving international disputes.

No country can be allowed to simply ignore treaties and agreements it has made with other countries, and that includes the United States. No country can be allowed to invade another country, to overthrow the government of another country, to assassinate the leaders of another country or to interfere in the elections of another country, and that includes the United States.

Negotiations

Before ratifying the Nuclear Ban Treaty, the US and the other nuclear-armed nations will need to agree on the detailed mechanisms for actually eliminating their nuclear arsenals, including the means they will use to monitor and verify that each party has done what it promised to do. The INF and START treaties have already established an extensive precedent that does not need to be reinvented.

Verification

Dismantling and destroying nuclear weapons according to an agreed timetable is a well-established procedure by now, as are the mechanisms for verification. These include regularly scheduled on-site inspections as well as “surprise” inspections at short notice. They include satellite and seismographic monitoring of test sites and missile launches. They include following nuclear safeguards agreements with the International Atomic Energy Agency (IAEA). Literally everything that is required for the complete, verified and irreversible elimination of all nuclear weapons worldwide has already been tried and tested through the implementation of previous treaties.

National implementation plans

When the agreements are in place, and the legislatures of the nine nuclear nations have ratified the Nuclear Ban Treaty, it will be time to make "warheads into windmills." Each of the nine will enact a national plan to convert all nuclear weapons facilities to other uses.

This is where a Green New Deal comes into the picture again. Rather than simply closing down research

facilities and production plants and putting all those people out of work, this report proposes converting all those jobs and facilities to helping solve the climate crisis. In particular, nuclear weapons jobs and facilities are needed for research and development of new forms of battery storage, new clean energy technologies, electric-powered air travel, and other cutting edge technologies.

Steps to zero

Proposals from organizations like Global Zero describe the steps necessary to get from the current levels of nuclear weapons down to “zero” through gradual reductions of the number of warheads on all sides.¹²³ The START treaty process followed that kind of logic, but we are now well beyond the point of merely reducing stockpiles. If the goal is the total elimination of these weapons in line with the Nuclear Ban Treaty, then the steps needed to get there must address all nuclear weapons and not just a certain portion of them at each stage.

The draft Nuclear Weapons Convention,¹²⁴ first deposited with the UN in 1997 and then updated in 2007, sets out five phases for implementation. These follow similar patterns to the INF Treaty and START Treaties and are the basis for the process now envisaged by the

Nuclear Ban Treaty:

1. All nuclear weapons to be removed from operational status:
 - a. Remove targeting coordinates and navigational information
 - b. Disable and de-alert all delivery vehicles
 - c. Cease all further production of components and equipment
 - d. Cease all further funding and research on nuclear weapons, except as may be necessary for their elimination
 - e. Cease production of fissile material
2. Declare all nuclear weapons and related materials held:
 - a. Submit a complete inventory of all nuclear weapons held, including locations and quantities
 - b. Submit an inventory of all fissile nuclear materials capable of making a nuclear weapon
 - c. Submit a report on any missing data regarding nuclear material that has gone missing and plans for recovery of the data
 - d. Submit a complete inventory of nuclear weapons facilities
 - e. Submit a complete inventory of all nuclear-capable delivery systems
3. Submit a legally-binding, time-bound plan for the verifiable and irreversible elimination of all nuclear weapons
 - a. Make a plan for the dismantling and destruction of the weapons and delivery systems
 - b. Make a plan for the decommissioning or conversion of testing facilities, research and production facilities
 - c. Make a plan for the safe disposal of all fissile material under IAEA control
4. Negotiate agreement with the IAEA for the safeguarding of all fissile material
 - a. Allow IAEA access to all stages of the nuclear fuel cycle
 - b. Provide full information to the IAEA on quantities and locations of fissile material
 - c. Arrange for inspections and testing by IAEA experts
 - d. Agree on final disposal and safe storage of remaining fissile material

5. Scheduled process to dismantle and destroy all nuclear weapons
 - a. Separate warheads from delivery vehicles
 - b. Destroy delivery vehicles
 - c. Remove fissile material from warheads
 - d. Destroy warheads
 - e. Decommission or convert all remaining facilities
 - f. Implement safeguards agreement with IAEA, including final disposal of fissile material

The total process of eliminating nuclear weapons will take several years, not including the final disposal of the fissile material, for which no agreed plan yet exists. There will continue to be costs involved throughout that period of time, especially for the security of nuclear materials prior to final disposal.

Out of the trillions of dollars budgeted for nuclear weapons over the coming decades, as much as \$500 billion, or \$10 billion per year, will need to be set aside for their elimination and final disposal. Nevertheless, the savings will begin immediately and will be substantial.

What do we currently spend on nuclear weapons?

It is notoriously difficult to determine exactly how much the US actually spends on nuclear weapons. The government itself does not provide an overall figure. The annual budget of the Department of Defense (DOD) includes a figure for “Strategic Forces,” but this includes programs that are not nuclear-related and leaves out many that are.¹²⁵

A number of other government departments are also involved in nuclear weapons activities, most notably the Department of Energy (DOE), which is responsible for most of the research and development of nuclear warheads in this country. The Congressional Budget Office (CBO) provides useful figures that include both DOD and DOE expenses, but these are also incomplete.¹²⁶

Independent analysts have looked at the figures in more detail over the years, but they all use different methodologies to come up with different figures and none of these are sufficiently recent to provide up-to-date numbers.¹²⁷

Atomic audit

The most comprehensive analysis of the true cost of nuclear weapons was conducted by the Brookings Institution in 1996. The 722-page report detailed every aspect of the nuclear program, from the first beginnings of the Manhattan Project through to the dismantling of more than 25,000 obsolete nuclear weapons by that point.

The Atomic Audit¹²⁸ calculated that the US had spent more than \$5.5 trillion (in 1996 dollars) on its nuclear weapons program between 1940 and 1996. This amounted to 29% of total military spending during that period.¹²⁹ They calculated that another \$365 billion would still be needed for final disposal of the plutonium and other highly radioactive waste produced during that period. Atomic Audit From Atomic Audit (1998)

<i>Constant</i> <i>\$billions</i>	<i>1996</i>	<i>56 yrs.</i>	<i>Av. per yr.</i>
Building the bomb		409.4	7.0
Deploying the bomb		3,241.0	55.9
Targeting the bomb		831.1	14.3
Defending the bomb		937.2	16.2
Dismantling the bomb		31.1	0.5
Supporting the victims		2.1	0.03
The cost of secrecy		3.1	0.03
Oversight of the bomb		0.9	0.01
TOTAL 1940-1998		5,455.9	94.0
Final disposal ¹³⁰		365.1	6.3

From Atomic Audit (1998)

Averaging a total cost of \$5.5 trillion dollars over a period of 56 years comes to nearly \$100 billion per year (see table above). Since the end of the Cold War, one would assume nuclear spending is much less than that now. But one would be wrong.

Nuclear spending today

In order to try to figure out what the US currently spends on nuclear weapons, we need to start with some figures from the government as a baseline. According to the CBO,¹³¹ the US will have spent \$33.6 billion on nuclear weapons in 2019.

Baseline nuclear spending figures

<i>In current \$billions</i>	DOD	DOE	TOTAL
Submarines	8.5	1.3	9.8
ICBMs	2.6	0.2	2.8
Bombers B-2, B-52	3.2	1.2	4.4
Other nuclear	1.4		1.4
Tactical nuclear	0.2	0.4	0.7
Stockpiles	n.a.	2.1	2.1
Infrastructure	n.a.	3.0	3.0
Support	n.a.	3.6	3.6
Comm'd & Control	1.4	n.a.	1.4
Communications	2.3	n.a.	2.3
Early warning	2.2	n.a.	2.2
Nuclear forces	21.8	11.8	33.6

Source: CBO (2019)¹³²

This figure includes the cost of managing all the bombs and missiles in silos and on bombers and submarines, the cost of redesigning and developing all the warheads, and the cost of running all the command and control, communications, and early warning systems that support these weapons.

What it does not include, according to the CBO itself,¹³³ are the costs associated with dismantling nuclear weapons no longer in use, disposing of the highly radioactive waste or cleaning up the mess left behind from previous manufacture and testing of nuclear weapons. It also does not include the cost of implementing arms control agreements or programs aimed at reducing the threat of nuclear weapons disappearing or falling into the hands of terrorists. And it does not include the costs of defending our own missiles from possible attack.¹³⁴

These three categories were estimated to cost an additional \$20.8 billion in 2014,¹³⁵ which was the last time the CBO counted those figures. Adding those costs (plus inflation=\$21.2 billion) to the CBO's 2019 figures would bring the 2019 nuclear weapons budget up to \$54.8 billion (see table below).

Overhead

The CBO figures also do not include any of the overhead or support costs that the deployment of nuclear weapons incurs out of the total military budget.¹³⁶ For every 332 sailors on a ballistic missile submarine, for example, there are another 78 service personnel directly employed to provide them with all the things they need, plus another 264 in administrative and other supporting roles.¹³⁷

According to the CBO's own calculations elsewhere,¹³⁸ these additional indirect and overhead costs amount to about \$7.1 billion on top of the direct costs.¹³⁹ Given the total Pentagon budget, which is now over \$750 billion per year, this is almost certainly an underestimate.

This would bring the figure up to \$61.9 billion so far, or almost double the baseline figure of \$33.6 billion in the preceding chart.

Final disposal

On top of this is the cost, sooner or later, of finally disposing of the high-level waste that remains once all the bombs and submarines and nuclear weapons facilities are dismantled and cleaned up. The Atomic Audit calculated in 1996 that this would come to a total cost of \$365 billion.¹⁴⁰ That is close to the amount of money the government had set aside by 2017 to cover this eventual expense.

As of 2019, this figure is now \$494 billion. That is the estimate for final disposal of the nation's high-level radioactive waste over the next 50 years.¹⁴¹ If these future costs were to be accounted for on an annual basis, that would add another \$10 billion per year to the \$60 billion figure we have so far, meaning that nuclear weapons

are costing roughly \$70 billion per year as of 2019.

<i>In current \$billions</i>	2014	2019 est.
Legacy costs	7.0	7.2
Threat reduction	3.2	3.3
Missile defense	10.6	10.7
Total nuclear-related	20.8	21.2
Added to baseline		33.6
Total direct costs		54.8
Overhead		7.1
Total with overhead		61.9
Liability for disposal		10.0
Total with liabilities		71.4

The cost of “modernization”

So far, we have estimated the true cost of the nuclear weapons program to be more than double the most quoted figure provided by the CBO. But the cost of nuclear weapons is set to rise steeply over the coming decades as a massive nuclear “modernization” program gets underway.¹⁴² This involves upgrading every single nuclear weapon and delivery system currently in the US arsenal, plus adding some new capabilities.

Once again, the CBO provides some baseline figures as to what this program is likely to cost over the next 10 years, including the anticipated cost overruns that characterize all military spending.

Ten-year nuclear program costs

<i>Const 2019 \$billions</i>	cost	w. overruns
B-21 bomber	49	56
F-35A	15	17
LRSO	16	18
Columbia subs	107	122
GBSD	61	70
B-61-12	15	17
Life Extension Prog	24	27
Command&Control	77	87
Infrastructure	41	47
Other support	41	47
TOTAL 2019-28	432	494

CBO (2019)

As with the yearly figures above, these new figures do not include all the extra costs identified by the CBO itself. If we add in the \$21.2 billion per year for nuclear weapons “related” activities, \$7.1 billion per year for overheads and \$10 billion for clean-up, that adds another \$38.3 billion per year, or \$383 billion over 10 years.

Instead of spending \$494 billion over the next 10 years, it seems more likely that we will therefore be spending \$877 billion. Extrapolating their original figures to 2050, for a total of 30 years, the CBO in 2017 came up with the figure of \$1.2 trillion in constant dollars, or \$1.7 trillion in unadjusted dollars.¹⁴³

A more likely figure for what we will pay for 30 more years of nuclear weapons, including these additional costs, is closer to \$2.7 trillion in constant 2019 dollars, or potentially as much as \$3.8 trillion in unadjusted dollars.

Trump’s additional requests

Already, since the CBO produced these figures, the Trump administration has begun adding to them. The 2018

Nuclear Posture Review proposed a number of additional programs¹⁴⁴ that increase the total figure just given.

These include a new submarine-launched nuclear cruise missile (\$9 billion), expanded production of plutonium pits (\$9 billion), a new “low-yield” warhead for the Trident submarines (\$0.1 billion),¹⁴⁵ a new gravity bomb for the air force (unknown), a new ground-launched nuclear missile (unknown) and additional ballistic submarines on top of the 12 already on order (unknown).

The CBO estimates that these additions will cost an additional \$17 billion over the next 10 years, not counting two additional submarines (\$18 billion?) and two additional missile programs (\$18 billion?).¹⁴⁶ Our estimate is therefore \$53 billion up to 2030.

However, there would be considerable increases beyond that time period, since many of these programs will just be in the developmental stages by 2030. A conservative estimate is that all together, these additional programs, if implemented, would add an additional \$90 billion between now and 2050.¹⁴⁷

Unlike the money spent on renewable energy, this is not a capital investment in things that will bring a return of income at a later date. This money is simply spent and then it is gone. It is turned into weapons that can never even be used except in an end-of-the-world scenario.

Were it not for the enormously powerful vested interests that benefit from making and maintaining these weapons, it is doubtful that any government would have continued paying for them this long.

<i>\$billions 2020-2050</i>	<i>av/yr</i>	<i>30 yrs</i>	<i>adjusted</i>
Nuclear forces - baseline	43.2	1,296	1,827
Estimated cost over-runs	6.2	186	262
Nuclear -related costs	21.2	636	896
Overheads	7.1	213	232
Nuclear clean-up costs	10.0	300	432
New weapon systems	3.0	90	127
TOTAL	90.7	2,721	3,776

IT'S NOT JUST ABOUT THE MONEY

What jobs will be required to implement a Green New Deal?

Funding a GND is going to take a massive investment amounting to trillions of dollars of taxpayer money. A lot of that money is already sitting on the government's books, ready to be spent on nuclear weapons. We need that money for addressing climate change. But a GND needs more than just money to succeed.

There are already 786,000 people employed in the renewable energy field in this country (compared to 3.8 million in China).¹⁴⁸ And according to the US Department of Labor,¹⁴⁹ solar photovoltaic installers and wind turbine service technicians were the two fastest growing occupations in 2018.

Many of the new jobs that will be needed to implement a GND are in manufacturing, construction, operations and maintenance, forestry and other "green collar" jobs. But there is also a need for scientists, engineers, researchers, designers, technicians, managers and other professional positions.

We already know how to generate electricity from the sun and wind. We know how to build a high-speed rail system. We know how to make buildings more energy efficient. Many of the technologies needed to solve climate change have been invented, but not all.

STEM experts are needed to rapidly advance the science of sustainability.

Science, Technology, Engineering, and Mathematics (STEM) experts are needed to rapidly advance the science of sustainability. Innovation is needed in order to improve efficiency and increase capacity of energy storage, energy transport, solar panels, wind turbines, hydropower, geothermal power, and the various forms of marine energy.

The national STEM shortage

However, there is a serious shortage of STEM graduates in this country. One recent study¹⁵⁰ suggests that by 2025, there will be over 2 million unfilled jobs in STEM fields.

As of 2016, China was granting almost eight times as many STEM degrees as the United States each year, in order to address their energy and industrial needs. India is graduating almost five times as many STEM majors.¹⁵¹ According to the Smithsonian Science Education Center, "STEM-related jobs in the U.S. grew at three times the rate of non-STEM jobs between 2000 and 2010. By 2018, it [was] projected that 2.4 million STEM jobs will go unfilled."¹⁵²

In the US, where do most of the current STEM graduates go? In 2016, 5 out of the 10 companies with the most STEM job openings were nuclear weapons companies: General Dynamics, with 2,996 STEM openings, Lockheed Martin with 2,742, Northrop Grumman with 2,004, Leidos with 1,421, and Raytheon with 1,261.¹⁵³ In many areas of the country right now, the only jobs available to blue-collar workers as well as to newly qualified scientists and engineers are in the booming business of building nuclear submarines and ballistic missiles.¹⁵⁴

We need these people to help solve the problems of climate change. And we need many more of them to build and implement the new renewable energy systems that are going to be needed as we transition away from fossil fuels.

Research agenda for a Green New Deal

Research and innovation can help drive down the costs of implementing a Green New Deal. But they are also needed to solve many of the technical problems which still beset the move away from fossil fuels. And given the timescale required to solve these problems, the role of research and innovation becomes hugely important.

Transportation

Electric cars are already with us, but more research is needed to improve battery storage times, battery charging times and battery capacity to weight ratios. More research is also needed to develop suitable electric alternatives for heavier duty trucks traveling longer distances, and for other more specialized vehicles, like tractors, fire engines, ambulances, bulldozers, excavators, dump-trucks, etc.

More work is needed to advance hydrogen fuel cells as another alternative to battery-powered vehicles, especially for long distances.

Nowhere is research more needed than in the area of electric-driven and battery-powered air travel. While hydrogen may turn out to be the fuel of choice for future air travel, improvements in battery efficiency and density could be a deciding factor. Other issues have to do with improved aerodynamics of planes, including improved ways to fold or otherwise handle the much longer wingspans required.

Renewable electricity

While the basics of solar and wind power are now well-established, more research is needed to improve the capacity factors and efficiency of both, as well as to connect them more effectively to utility-scale storage options.

If we improve the efficiency of small-scale micro wind turbines, it could make a significant difference to their use as a distributed power source for buildings, especially in built-up areas. More work is still needed to develop off-shore wind, including work on floating turbines, and better ways to store and/or connect off-shore turbines to the on-shore grid.

Research on harnessing the power of waves and tides is still at a fairly early stage of development. Other possible sources of clean and renewable electricity also need further development, including turbines installed in flowing water that do not require dams or other potentially damaging infrastructure.

Heat for buildings

Further research is needed on geothermal heat pumps and the use of underground temperatures for both heating and cooling of buildings. Research is needed on other energy efficiency measures for existing buildings and on better ways to convert existing gas-fired furnaces and boilers to run on electric power.

Industry

Research is especially needed to convert fossil fuel intensive industrial processes to electric alternatives, including for the production of steel and cement, petrochemicals, pharmaceuticals, plastics and many other products. More research is also needed to replace HFCs with safe alternatives.

Agriculture

Although there may be some areas for further research and innovation in agriculture, we already know what is needed to reduce carbon emissions. We need to return to farming and cattle rearing methods that do not rely so heavily on nitrogen fertilizers, the storage of wet manure, overly intensive crop production and cattle

concentration. New ways to protect and restore wetlands and replenish our forests are other possible areas for research.

What skills are being wasted on nuclear weapons?

Apart from the military personnel who are connected directly or indirectly with the deployment of nuclear weapons, there are approximately 27,000 civilian employees and contractors working directly with nuclear weapons at two nuclear submarine bases, two air force bases and three ballistic missile bases.¹⁵⁵

There are a further 42,000 people working at the eight sites across the country where nuclear weapons are developed, tested, assembled and dismantled.¹⁵⁶ These are Sandia Labs and Los Alamos National Lab in New Mexico, Lawrence Livermore Lab in California, Savannah River Site in South Carolina, Pantex Plant in Texas, Kansas City Plant in Missouri, Nevada Test Site in Nevada and the Y-12 complex in Tennessee.

And finally, there are approximately 70,000 people working for the 20 or so private companies¹⁵⁷ who make the warheads, missiles and components for US nuclear weapons and oversee most of the labs and complexes listed above. Most of these companies make other products and services, so it is difficult to determine how many are engaged specifically in nuclear weapons work.

The Air Force has a robust supply of personnel with STEM degrees to meet its recruiting goals...

As with the renewable energy field, there is a wide range of jobs associated with nuclear weapons, from production line workers to security officers to subject matter experts to safety instructors. Many of these positions are generic, requiring few if any academic qualifications.

But by far the most common job qualification for nuclear weapons-related work is some kind of engineering degree and/or experience. Some of these jobs require nuclear engineering in particular, but many do not. These are science, technology, engineering and math (STEM) jobs, and despite the national shortage of graduates to fill STEM positions in general, there appears to be no shortage when it comes to military, and especially nuclear weapons, positions.

“The Air Force [has] a robust supply of personnel with STEM degrees to meet its recruiting goals for STEM positions, with a few exceptions,” says the National Research Council.¹⁵⁸ A sampling of the kinds of jobs and job qualifications being sought in the nuclear weapons field include:

- Entry-Level Nuclear Weapon Surety Network Implementation Engineer (B.A. in Computer Engineering, Systems Engineering, or Electrical Engineering)
- Nuclear Weapons Subject Matter Expert (B.S. degree and 10+ years experience in Nuclear Weapons and Computer Engineering)
- Senior Nuclear Weapons Technical Writer (B.A. degree in a scientific, engineering or technical field with a minor in English, Technical Writing, or similar)
- Nuclear Scientist/Nuclear Weapons Analyst (M.S. in Nuclear Engineering, Physics or a related discipline, plus at least five years of relevant experience, or three years experience with Ph.D.)
- Associate Program Leader for Nuclear Weapon Enterprise (Ph.D. in Science or Engineering or equivalent combination of education and related experience; expert knowledge of simulation and optimization computational methodologies)
- Nuclear Weapons Logistics Management Specialist (B.A. degree in “relevant discipline,” 12-15 years of prior relevant experience, or Masters with 10-13 years experience.)

Mapping nuclear weapon jobs to a Green New Deal

A Green New Deal will provide millions of people with decent well-paid jobs in construction, forestry, operations, production, maintenance and other fields. But to meet GND targets in the timescale required, and to make it all affordable, workers are also needed in research, engineering, design and other fields.

As noted above, many of these skills are in short supply and many of the people who will be needed to fill these roles are currently working for the nuclear weapons industry and in other military-related positions.

Job requirements for design and development positions in the nuclear weapons complex overlap extensively with the requirements for positions in green energy.

The nuclear weapons industry is employing workers with technical skills that are in high demand in the green economy.

Both require advanced degrees and industrial experience in the fields of engineering, nuclear engineering, computer science, systems architecture, mathematics, physics or chemistry. The skills required overlap in information technology and computer science, modelling and simulation, risk analysis and systems assessment.

¹⁵⁹

A 2014 study in the UK ¹⁶⁰ looked at the workforce requirements, job descriptions, transferable skills and locations of 170,000 people currently employed in the UK making weapons and their delivery systems. It mapped these against the 300,000 or more jobs that would be needed to build and maintain enough offshore wind farms and marine energy projects to put the UK on the path to net-zero carbon emissions.

The results were astounding. The study found a direct correlation between many of the existing skills used to build nuclear submarines, for example, and those that would be needed to build wave and tidal energy projects. Even more surprising was the direct correlation between locations of where these jobs would be based.

The study found, for example, that marine engineers and naval architects currently building a new generation of nuclear ballistic missile submarines for the UK at the Naval Shipyard in Burrow-on-Furness could switch over to designing and building the Morecambe Bay Tidal Barrage without even having to move house.

Similar studies in the US have looked at the massive potential for jobs in different parts of the country that could result from the tapping of offshore wind, dammed up rivers and solar energy. ¹⁶¹ These have not as yet been mapped to the equivalent jobs or infrastructure currently absorbed by the military-industrial complex, but this report offers a preview of what more comprehensive mapping might reveal. There already seem to be similar correlations to those in the UK.

Mapping nuclear weapons jobs to a Green New Deal

The two maps on the last page ([click here](#)) of this report show very roughly where and how many jobs there are currently in the nuclear weapons industry, along with where and how many jobs there could be by implementing a Green New Deal. The data for these maps are provided in the tables in Appendix 7 & 8.

Building the global consensus needed to solve these problems

US nuclear weapons are currently targeting the very countries we need to work with to solve the climate crisis. By threatening to annihilate these countries at a moment's notice with our nuclear weapons, we have simply encouraged them to develop nuclear weapons of their own. And by spending enormous amounts of money and resources to constantly improve and refine these weapons, we are forcing these other countries to do the same.¹⁶²

The United States, China, Russia and India account for more than half of the world's total carbon emissions between them. Together with the other five nuclear-armed nations and their nuclear allies, these countries cause nearly three-quarters of all the world's carbon emissions. It is the nuclear-armed nations who are also the major carbon emitting nations of the world.

These other countries need the money, skills and other resources going into their nuclear weapons programs in order to adequately address the climate crisis in their respective countries.

The Cold War

Nuclear weapons were developed in the context of a global battle to the death between two opposing and mutually exclusive ideologies that divided the world into two blocs at the end of World War II. We are all very, very lucky that the Cold War never went "hot," because that would have been the end of all of us.

We came very close to all-out nuclear war, not only during the Cuban Missile Crisis of 1962 but at least 12 other times during the Cold War.¹⁶³ We also came close to an accidental nuclear detonation that could have caused unparalleled humanitarian catastrophe many more times than that. But it was luck, not the "magical" power of nuclear weapons that saved us from these potential disasters.

US nuclear weapons are currently targeting the very countries we need to work with in order to solve the climate crisis.

We no longer live in a world that is divided so sharply into two incompatible ideologies. There are many variations of the economic system that all countries now share and all take part in. Even countries like North Korea, Cuba and Vietnam buy and sell goods to and from the rest of the world and take part in the global economy. Apart from our closest neighbors, Canada and Mexico, China is America's largest trading partner, selling more than half a trillion dollars worth of goods to the US each year.

China and Russia are in many respects more "capitalist" than the United States itself by now. Neither country is trying to push its ideology on the rest of the world, trying to topple other governments or trying to take over the world. To be sure, there are human rights concerns that need to be addressed in both Russia and China. There are concerns about the mass media being used as mere mouthpieces for government propaganda. There are concerns about mass incarceration, about authoritarian leaders, and about bullying and military interference in other countries.

All of these concerns can also be applied to the United States. The US is not the perfect beacon of democracy it claims to be. It has a long history of propping up dictators and authoritarian regimes around the world. It has its own shameful record of mass incarceration, use of torture, voter suppression, "fake news" and human rights violations. The US has interfered in more elections than Russia and China put together. It has invaded far more countries and overthrown far more regimes than either of those countries ever have.¹⁶⁴

Russian interference in elections

Did the Russian government interfere in the 2016 presidential election? If they did, what is the proper response – to denounce them as uniquely evil, suspend diplomatic relations and impose sanctions on them? Or would it be more productive to work with the Russians to come up with some new international standards to prevent this

kind of interference in the future? Since it is an undisputed fact that the US interfered in the 2012 Russian elections, ¹⁶⁵ both countries need to agree that this must stop.

We need to acknowledge that the US is not perfect and that other countries, however unpalatable their regimes may be, are not our enemies, or our adversaries, or even our competitors.

It is now well past time for Americans to acknowledge that our country is not perfect and that other countries, however unpalatable their regimes may be, are not our “enemies” or “adversaries” or even “competitors.” We all have challenges to overcome and we can only overcome these by working on them together.

But most importantly, we will only survive as a species if we work together to solve the greatest problems facing us right now, and those include the climate crisis, the nuclear nightmare and the time-bomb of global inequality.

North Korea

Do North Korea’s nuclear weapons represent an unacceptable threat to the United States and the world? Of course they do, as do the nuclear weapons of the United States and the other nuclear-armed nations. Every single nuclear weapon in the world, no matter whose it is or where it is aimed, is a threat to all of us.

Does that mean that Kim Jong-un intends to launch his nuclear weapons at the United States at the first available opportunity? That is very unlikely. Kim Jong-un has one overriding priority, and that is the survival of his country. He believes, for perfectly rational, if nonetheless incorrect, reasons, that nuclear weapons are the key to ensuring that survival.

It would be surprising for him not to be convinced that the possession of nuclear weapons is an effective deterrent against attack or invasion of his country, given all the claims that the US and other nuclear weapon states continue to make on a regular basis about how effective and essential their so-called nuclear “deterrent” is.

It would also be surprising for him not to be convinced, given all the claims that the US and other nuclear weapon states continue to make on a regular basis, that the possession of nuclear weapons gives the people of his country a certain status in the world.

There is only one way to eliminate the nuclear threat from North Korea, and that is to negotiate the elimination of all nuclear weapons, including those of North Korea but also those of the United States. That means a commitment from South Korea not to allow US nuclear weapons on its soil or in its waters.

Other confidence-building measures, including an agreed “end” to the Korean War and a massive scaling back of conventional forces on both sides could bring peace to the Korean peninsula and an end to the threat posed by North Korea’s nuclear weapons.

As with all the other issues that currently divide the world and create international tensions, the only solution is to engage in dialogue and to build relations based on mutual respect and a commitment to the principles of the United Nations.

CONCLUSIONS

Climate change is a life-threatening emergency on a global scale. It requires an immediate and comprehensive response commensurate with the threat it poses to human civilization and to the planet. The same is no less true of the global, life-threatening emergency posed by the continued existence of nuclear weapons. Inequality is also a life-threatening global emergency that must be addressed as we address these other two emergencies.

A Green New Deal would set in motion a national mobilization in the United States to completely turn an economy based on fossil fuels into one based on renewable forms of energy.

The future of this planet depends on eliminating our addiction to both fossil fuels and nuclear weapons.

That means a massive effort to transform things in the next 10 years, followed by steady progress towards the end goal of net-zero carbon emissions globally by 2050.

The United States can and should move swiftly toward this very ambitious but necessary target. This will require:

1. Major investment from the federal government on the order of \$3 trillion over the next 30 years, or \$100 billion per year.
2. Massive transfer of skills, expertise, technologies and infrastructure from the nuclear weapons industry to green technologies.
3. A complete shift in our relations with the rest of the world and in the way we treat other countries.

The obvious places to find the money and the skills needed for a GND are in the military industrial complex, and especially in the nuclear weapons industry. Eliminating nuclear weapons would also radically change our relationship with the rest of the world.

The future of this planet depends on eliminating our addiction to both fossil fuels and nuclear weapons. Eliminating the latter frees up what we need to eliminate the former. And working in partnership with the rest of the world to address all three global emergencies is the only way we can solve any of them.

All of this is totally doable, so long as there is a President and a Congress committed to making the changes that are required, and brave enough to take on the corporations who want to continue with business as usual. It will take a politically activated public to elect these people in November, 2020, and to make sure they follow through on those commitments.

In the meantime, there are numerous and crucially important steps that individuals, organizations, cities and states can take right now to begin moving this country in the right direction and to make sure that the political will is there to take bold and decisive action starting on January 20th, 2021. This means:

1. Purchasing only electric vehicles.
2. Installing rooftop solar and distributed wind turbines wherever possible.
3. Planting trees and protecting existing forests and wetlands.
4. Using only 100% clean, renewable electricity.
5. Providing incentives to encourage the purchase of electric vehicles, electric heating for buildings and the use of 100% clean, renewable electricity.
6. Using and improving public transportation systems.
7. Divesting from fossil fuels and nuclear weapons.

What you can do now

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If you are running for President,

- Commit to signing the Nuclear Ban Treaty when you get elected, by signing the Presidential Candidates' Pledge.*
- Commit to implementing a Green New Deal when you get elected.
- Initiate negotiations to dismantle every single nuclear weapon.
- Initiate discussions on a stronger international agreement to replace the Paris Accords.
- Create and empower a Department of Peace and Disarmament.
- Restore the Environmental Protection Agency to its scientific and political authority.

If you are a member of Congress,

- LEAD more boldly than you ever have before.
- Protect your country and your world from misinformation and corporate greed.
- Support the Norton Bill (HR 2419) to shift resources from nuclear weapons to green technologies.
- Sign the ICAN Legislative Pledge to support the Nuclear Ban Treaty.*

If you are a state legislator,

- LEAD more boldly than you ever have before.
- Support resolutions and bills in your state legislature that call for the US to sign the Nuclear Ban Treaty and eliminate all nuclear weapons.
- Sign the ICAN State Legislator's Pledge to support the Nuclear Ban Treaty.*

If you are a citizen,

- VOTE.
- Make sure everyone you know is registered to vote and has access to the polls.
- Set aside divisive issues, just for 2020. Choose candidates who care about our survival.

If you can,

- Purchase or rent an electric vehicle.
- Install rooftop solar or wind power wherever possible.
- Convert your home to electric heating and cooking.
- Look into how you can be using 100% clean, renewable electricity.

If you are an investor,

- You can divest from both the nuclear weapons industry and the fossil fuels industry.*
- So can your friends, business, school, college, faith community, hospital, financial institution.*
- So can your town, city and state.*

If you want to do more,

- Join, volunteer or donate to disarmament, environmental, and justice organizations.*
- Run for office.
- Never, ever give up.

* See www.NuclearBan.US

Appendix 1: Nuclear power is not the answer

When the last gas-fired power plant is closed in 2030, there will still be a number of nuclear power plants in operation across the United States and many more in operation across the world. Nuclear power can help smooth the transition to 100% renewable electricity and will probably remain with us until 2050.

However, if there is one overriding lesson to be learned from the climate crisis, it is that we cannot produce things of value to society without also paying attention to the waste products we create in the process. The irony is that carbon dioxide is one of the least harmful of all waste products created by modern industry, and yet it is this seemingly innocuous waste product that now threatens our entire civilization.

The problem of nuclear waste

Generating electricity from the heat produced by radioactive fuels is a “clean” process from a climate perspective. It produces no carbon dioxide or other greenhouse gases in the process. That much is good news.

However, what nuclear power does produce as well as electricity is a wide array of highly radioactive waste products, many of which remain radioactive and harmful to humans for tens of thousands or even hundreds of thousands of years. We still have not solved the problem of what to do with this waste so that it cannot cause harm for considerably longer than the whole of recorded human history.

The US decided in 1987 to store its most high-level radioactive waste (HLW) in tunnels 1,000 feet below Yucca Mountain in Nevada, but as of 2019, some 32 years and \$15 billion later, there are still doubts as to whether this site will be used. Current estimates put back the date for finding a solution to the permanent storage of this waste until 2040 at the earliest. Other countries have explored similar sites for permanent storage, but as of 2019, none of the 90,000 metric tons of HLW already produced by the world’s nuclear power plants has yet been put into long-term safe storage.

Bill Gates believes he has a solution to the nuclear waste conundrum and has offered \$1 billion of his own money to get it going. Instead of running on fresh nuclear fuel, the new nuclear reactor design would use the nuclear waste products themselves as fuel – generating electricity and getting rid of the nuclear waste at the same time. However, this remains an unproven design and efforts to build a pilot plant in China were cancelled earlier this year due to the current trade war. ¹⁶⁶ Existing “fast breeder” reactors in Europe, which burn up some of the waste products of conventional reactors, have actually turned out to produce even more radioactive waste than the conventional reactors.¹⁶⁷

The problem of timescales

Perhaps at some point in the future, a safe way will be found to store and/or use up the thousands of tons of highly radioactive waste already produced by nuclear power plants around the world.¹⁶⁸ But we do not have very much time available to us if we are going to solve the climate crisis before it becomes a climate catastrophe. And that is the second reason why nuclear power is simply not an option worth pursuing at this point.

It takes many years to develop new nuclear power technologies and many more years to actually build the nuclear power plants. As of 2019, there are just two nuclear power plants under construction in the United States, both at the Vogtle site in Georgia. These are for a newer, supposedly safer, reactor design, the AP2000.

The AP2000 was designed in the 1990s and the design was submitted to the Nuclear Regulatory Commission (NRC) for approval in 2002. Approval was granted in 2005, so that was at least three years in the design phase, before even thinking about actual construction of a power plant.

The initial construction permit was applied for in 2006 and various contracts were agreed by 2008. In 2009, the permit was granted to begin construction, and construction began on March 12, 2013. It thus took another seven years from the application to start constructing a power plant to the point of actually pouring the first cement.

These two power plants were originally scheduled for completion by 2016 and 2017 for a total cost of \$14 billion. By 2017 they were both hopelessly behind schedule and over budget. Westinghouse, the company which designed the AP2000, then went bankrupt as a result of losses on two other nuclear power plants under construction in South Carolina, which were subsequently cancelled.¹⁶⁹ As of 2019, the new scheduled completion dates for the Vogtle reactors are 2021 and 2022, at a revised cost of \$25 billion.

Actual construction of nuclear power plants, which is supposed to be possible in 4-5 years, in this case is taking 8-9 years (2013- 2021/22). This is on top of the 7 years it took to get an application approved to begin construction (2006-2012) and at least 3 more years from initial designs to an approved reactor design (2002-2005). All together, these two reactors will have taken more than 20 years from the initial designs to the point of producing electricity.

As of 2019, there were 12 other new US nuclear power plant construction projects with approval already granted by the NRC. All 12 have been cancelled or indefinitely postponed,¹⁷⁰ which means that any new nuclear power plant construction at this point will have to start with the lengthy process of getting approval before construction can even begin.

And if a new reactor design is involved, that will add additional years to the timeline. Altogether, it can take up to 20 years from initial designs to a nuclear power plant that is finally producing electricity. We only have 10 years to end this country's dependence on fossil fuels.

Uranium is not renewable

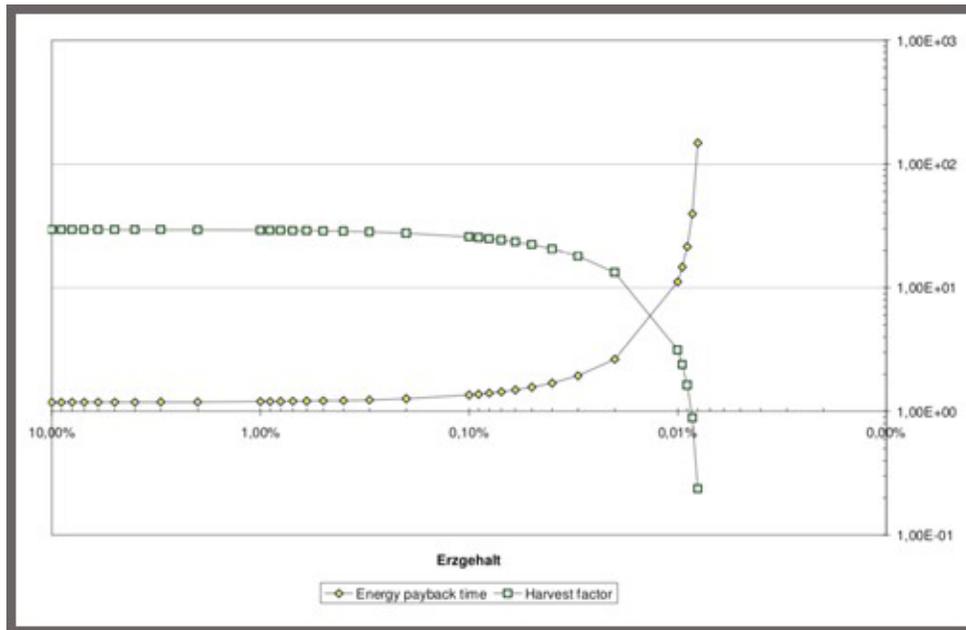
Although some proponents of nuclear power try to describe it as a “renewable” form of energy, it most certainly is not, at least in its current form. It is possible to run nuclear reactors on thorium and other mixed fuels, but all nuclear power plants currently generating electricity in the United States rely on uranium as a fuel. Uranium is a finite resource with “known” reserves of approximately 6 million tons worldwide.¹⁷¹ At the current rate of global uranium fuel consumption (around 65,000 tons per year) these reserves should be able to keep the nuclear power industry going for around 100 years.

But uranium is not mined in its pure form, but in ores that range enormously in their levels of uranium concentration. Some uranium mines in Canada recover ores containing as much as 20% uranium, while ores in Namibia, for example, average only 0.01% uranium.¹⁷² The industrial average for mined uranium concentration levels has been between 0.05% – 0.15%, but the more uranium that gets mined, the lower the average remaining concentration becomes.¹⁷³

According to at least one study, uranium reserves beyond 2050 could have average concentrations as low as 0.013%.¹⁷⁴ At this concentration, the amount of energy required to make the uranium sufficiently concentrated to use as nuclear fuel is potentially greater than the amount of energy that the fuel would produce in a nuclear reactor. This is known as the “energy cliff.” There are different views as to exactly where the threshold grade of uranium ore may lie before it hits the energy cliff, but there is no disagreement that at some point, this threshold is reached.¹⁷⁵

Energy required vs. energy produced by nuclear power

According to the data on this graph, at uranium ore concentrations of 0.1% and above, the amount of energy used to produce the uranium for nuclear fuel is “paid back” after just a few months of producing electricity, but below that concentration, the payback time starts increasing dramatically, so that at an ore concentration of just less than 0.01%, it takes 10 years of producing electricity to “pay” for the amount of energy required to make the fuel. At a concentration of 0.007%, the payback time increases to over 100 years.



source: Austrian Energy Agency (2011), pg. 5.

Nuclear power is not as “clean” as it looks

The mining and enrichment of uranium for use in nuclear power plants is hugely energy intensive. The Olympic Dam mine, for example, which is the largest uranium mine in Australia, is also the single largest consumer of electricity in Australia.¹⁷⁶

Then, the enrichment of the uranium to the grade necessary for use as nuclear fuel is the most energy-intensive part of the process. Even though the current gas centrifuge method of enrichment requires 10 times less energy than the previous gaseous diffusion method, it still requires huge amounts of electricity to generate very small amounts of nuclear fuel.

To produce enough nuclear fuel for a 1GW nuclear reactor for one year requires about 10 GWh of electricity.¹⁷⁷ On top of the mining and enrichment processes, the construction of nuclear power plants over many years requires additional inputs of energy, mostly in the form of fossil fuels at this point.

The total life cycle of nuclear power includes all the following stages:

1. construction of the plant and machinery used
2. operation and maintenance of the plant
3. fuel production, including
 - a. mining
 - b. milling
 - c. enrichment
 - d. fabrication
 - e. transportation
4. dismantling and decommissioning of the plant
5. waste disposal, including final safe storage in a geological repository

When all these stages are taken into consideration, the carbon footprint of nuclear power is anything but “clean.” At the moment, of course, almost all the energy inputs, machinery, transportation, steel and cement production, etc. are produced with fossil fuels, making nuclear power a seriously “dirty” option.

The final nail in the nuclear coffin - cost

Nuclear power is already prohibitively expensive compared to the latest costs for wind and solar. The only reason nuclear power has remained a viable option for many decades is because it has been heavily subsidized by the government. This was originally because nuclear power plants produced the plutonium needed for nuclear weapons. Many of the costs for producing the nuclear fuel for commercial power plants have been kept hidden from view because they were considered nuclear weapons expenses.¹⁷⁸

Through the Price-Anderson Act of 1957, the government limits the liability of nuclear plant operators in the event of a major accident and undertakes to use taxpayer money to cover any shortfall. This has enabled nuclear plant operators to pay for insurance premiums which would otherwise be prohibitively expensive.¹⁷⁹ The Fukushima accident, for example, is now expected to cost as much as \$180 billion just for the clean-up operation.¹⁸⁰

On top of this, more than two million people have sued TEPCO, the owners of the Fukushima plant, for destruction of their property, loss of jobs, health costs, forced evacuation and many other effects of the disaster, including “mental anguish.” As of 2014, TEPCO has paid out over \$50 billion in compensation claims, and by 2018 they had paid out \$76 billion, with more claims still coming in.¹⁸¹

Rather than continuing to promote and subsidize nuclear power, we need to cut our losses and accept that it is simply not the answer to the climate crisis.

Even if the risk of a similar accident and subsequent damages on this scale in the US were considered vanishingly low (which, of course, they are not), the insurance for nuclear power plants would need to be astronomically high to enable insurance companies to cover themselves for that possibility.

But potentially the biggest cost associated with nuclear power is the cost of eventual long-term disposal of the waste. This is currently expected to cost US taxpayers nearly \$500 billion over the next 50 years, including civilian and military waste.¹⁸²

Even without factoring in all these subsidized costs of nuclear power, the construction and maintenance costs continue to rise, putting the comparative levelized cost of electricity generated by nuclear power now higher than coal, gas, wind or solar powered electricity. For this reason alone, nuclear power is unlikely to be the electricity source of choice for any utility company in the near future. Rather than continuing to promote and subsidize nuclear power, we need to cut our losses and accept that nuclear power is simply not the answer to the climate crisis.

As existing nuclear power plants reach the end of their expected life spans, it would be expected that they are each shut down and decommissioned accordingly. That would leave the country with approximately 70 out of 99 nuclear reactors by 2030, with the remainder gradually shut down over the subsequent 20-30 years.

Appendix 2: Biomass and biofuels are not the answer

Biomass is a fancy term for burning wood and/or agricultural waste or other forms of waste, including municipal solid waste that is incinerated instead of going into a landfill.

Biomass plants produce as much as 150% more carbon dioxide per MW of electricity than coal-fired plants.

As of 2018, there were 178 biomass plants in the US, with a capacity to generate 20.2 GW of electricity.¹⁸³ Worldwide, there are more than 3,000 power plants burning biomass, with 122 GW of electricity capacity.¹⁸⁴

Biomass is defined as a “renewable” resource because forests and crops that are cut down can grow back again. There is nothing “clean” about biomass, however. According to Partnership for Policy Integrity, biomass plants produce as much as 150% more carbon dioxide per MW of electricity than coal-fired plants.¹⁸⁵

For decades now, the carbon footprint of biomass has been obscured by a little accounting trick that has allowed the carbon emitted from biomass to be considered “neutralized” by the equivalent amount of carbon that will eventually grow again as new trees.¹⁸⁶

The burning of wood and waste products to generate electricity is a disaster for the climate on two fronts. First, it involves carbon emissions that are not being counted and therefore are not even identified as part of the problem. Second, it involves the cutting down of forests which are the world’s most important protection against the climate crisis.

Trees act as a carbon “sink,” taking carbon out of the atmosphere and thus reducing the overall effect of carbon emissions. By cutting down trees and burning them in power plants, we are doubly increasing the carbon concentration in the atmosphere and worsening the climate crisis. Biomass is not a solution to the climate crisis, not remotely.

What about biofuels?

Biofuels include ethanol, made from corn, biodiesel made from vegetable oils and animal fat, green diesel made from algae and methane made from manure. All biofuels emit carbon when used for fuel, just as fossil fuels do. Again, an accounting trick has been used to hide the emissions of biofuels by claiming that the carbon emissions are “neutralized” by the fact that the plants from which the fuel was produced can be regenerated to absorb the equivalent amount of carbon emitted.¹⁸⁷

One of the most important changes that need to be made at the international level is a re-categorizing of biomass and biofuels as carbon emitting activities which need to be monitored just like all other carbon emitting activities of each country. Plans to reduce carbon emissions would then need to include cuts to biomass and biofuel use as well as cuts to fossil fuel and other greenhouse gases.

There has been surprisingly little interest in tackling the problem of biomass and biofuels among climate campaigners, partly because they are so hidden from view. But to save the planet, the accounting loophole that allows biomass and biofuels to be considered “carbon-neutral” must be closed.

Appendix 3: Carbon capture and storage

Carbon Capture and Storage, or CCS,¹⁸⁸ is an attempt to remove the carbon from the emissions of existing fossil fuel power plants (and other industrial facilities) and then store it underground where it can't contribute to climate change. Some argue that no other solution will reduce the carbon in the atmosphere to a sufficient extent to meet the targets, and others argue that even after the world achieves net-zero emissions, there will still be a need to pump as much of the existing CO₂ out of the atmosphere as we can, using CCS technologies.¹⁸⁹

Technical and economic challenges to the large-scale use of CCS technologies have prevented more widespread application thus far, although as many as 43 CCS projects are already in operation or underway in 17 countries.¹⁹⁰ At least \$20 billion has been invested globally in CCS so far.¹⁹¹ The question is whether more investment should be devoted to CCS or whether it would be better spent on solving other challenges that do not involve the continued use of fossil fuels.

The promotion of CCS is based on an assumption that fossil fuels will continue to be part of the “energy mix” of the future and that removing as much carbon as possible from the burning of fossil fuels is therefore a reasonable ambition. It could be argued, however, that focusing political and financial attention on CCS merely legitimizes the continued reliance on fossil fuels at a time when the world needs to move swiftly and decisively away from fossil fuels.¹⁹²

Coal power with CCS

Although CCS has been used successfully at a number of industrial plants around the world, so far there are only two electricity generating plants using CCS. The Petra Nova coal plant near Houston, Texas, went live in 2017 with a CCS system that they claim removes 90% of the CO₂ emissions from the flue gases emitted by the plant. The captured carbon is then pumped into the ground to help push more oil out of a nearby oil field, boosting oil production from 500 barrels a day to 5,000 barrels a day.¹⁹³

The aim is that the CO₂ captured from the Petra Nova plant will remain permanently underground in a nearby sandstone formation. In the meantime, it is rather ironic that the CO₂ is being used to pump yet more fossil fuels out of the ground at a time when the world needs to stop burning fossil fuels.

At the Boundary Dam Coal Power Station in Saskatchewan, Canada, up to 90% of the CO₂ from one of its 8 chimneys is similarly captured and pumped underground, again to aid in the recovery of more oil from a nearby oil field.¹⁹⁴ In total, 16 out of the 22 CCS schemes in operation as of 2014 used the captured CO₂ to extract more oil out of the ground.¹⁹⁵

Extracting CO₂ from natural gas

A total of 10 CCS projects in 2014 were using CCS technology to extract CO₂ from natural gas fields where the concentration of natural gas is insufficient to use as a fuel unless the CO₂ is removed from it.¹⁹⁶ In other words, CO₂ capture and removal in these cases is an essential and integral part of the process of refining natural gas for use as a fuel.

The capture part of CCS is thus being used to generate yet more carbon emissions, while the storage part remains problematic. None of the CCS projects described above have yet to demonstrate the viability of actually storing the carbon permanently underground.

Most CCS storage plans to date involve injection of the carbon into sandstone rock formations.¹⁹⁷ While this could be an effective solution, scientists are still researching the long-term implications and possible side-effects of doing this on a large scale.¹⁹⁸

Appendix 4: Sample of job opportunities for engineering graduates

Engineering Discipline	Examples of nuclear weapons applications	Examples of renewable energy applications
B.A. Electrical or Electronic Engineering	<ul style="list-style-type: none"> • Nuclear Weapons Surety Network Implementation Engineer • R&D Electrical Engineer • Boilers and Pressure Safety Engineer • Nuclear Hardness Electrical Engineer 	<ul style="list-style-type: none"> • Wind Turbine Generator Engineers • Offshore Wind Engineering Analyst • Wind Fleet Engineer • Electrical Engineer (Solar)
B.A. Marine Engineering/Naval Architecture	<ul style="list-style-type: none"> • Nuclear Propulsion Engineer • Nuclear Engineer, Navy • Navy Nuclear Officer 	<ul style="list-style-type: none"> • Project Manager (Wind) • Marine System Engineer (Wind) • Wave and Tidal Power Systems Design • Coastal Engineer (Tidal) • Program Manager (Tidal)
M.S. in Mechanical Engineering or Aerospace Engineering	<ul style="list-style-type: none"> • R&D Mechanical Engineer • Systems Engineer, Nuclear Safety • Process Controls Engineer • Architectural Systems Project Engineer • Senior Project Leader, Nuclear 	<ul style="list-style-type: none"> • Blade Design Loads Controls Engineer • Mechanical Design Engineer (Thermal Power) • Renewable Energy Innovation Engineer (Wind) • Project Development Engineer (Wind Efficiency) • Deep Geothermal Systems Design
M.S. in Civil or Structural Engineering	<ul style="list-style-type: none"> • Nuclear Weapon Program Analyst • Technology Program Principle Analyst • Nuclear Facilities Engineer 	<ul style="list-style-type: none"> • Offshore Wind Structural Engineer • Civil/Geotechnical Engineer (Wind and Solar) • Solar CAD Technician • Lead Project Engineer (Solar)

Appendix 5: Calculating the overhead cost of nuclear weapons

Figures from CBO Interactive Force Structure Tool at [<https://www.cbo.gov/publication/54351>]

US Military Force Structure - Overhead calculations

Direct Cost of Nuclear Forces as calculated by CBO					
Military Unit	Number of units 2019	Direct Military Personnel per unit	Direct Military Personnel Numbers	Annual direct/Unit \$millions	Direct Military Personnel \$millions
Ballistic Missile Submarines	14	332	4,648	72	1,008
B-52 Bomber Aircraft Squadron	4	1,302	5,208	278	1,112
B-2 Bomber Aircraft Squadron	1	1,990	1,990	535	535
Minuteman III Missile Squadron	8	770	6,160	169	1,352
Totals			18,006		4,007

Indirect Cost of Nuclear Forces as calculated by CBO					
Military Unit	Number of units 2019	Indirect Military Personnel per unit	Indirect Military Personnel Numbers	Annual Indirect cost/Unit \$millions	Indirect Military Personnel \$millions
Ballistic Missile Submarines	14	78	1,092	42	588
B-52 Bomber Aircraft Squadron	4	1,206	4,824	178	712
B-2 Bomber Aircraft Squadron	1	3,560	3,560	527	527
Minuteman III Missile Squadron	8	646	5,168	95	760
Totals			14,644	842	2,587

Overhead Cost of Nuclear Forces as calculated by CBO					
Military Unit	Number of units 2019	Overheads as Military Personnel per unit	Overhead as Personnel Numbers	Annual overhead/Unit \$millions	Overhead as Personnel \$millions
Ballistic Missile Submarines	14	264	3,696	57	798
B-52 Bomber Aircraft Squadron	4	1,517	6,068	350	1,400
B-2 Bomber Aircraft Squadron	1	3,356	3,356	774	774
Minuteman III Missile Squadron	8	856	6,848	197	1,576
Totals			19,968		4,548

Appendix 6: Calculating the estimated cost of building 100% renewable electricity

US Totals	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2020-2030
Falling construction costs in \$/kW expected												
Onshore wind	1350	1300	1275	1250	1235	1215	1200	1180	1160	1140	1130	N.A.
Offshore wind	3782	3700	3500	3350	3250	3179	3100	3075	3050	3025	3000	N.A.
Geothermal	2800	2750	2700	2675	2650	2625	2610	2590	2580	2570	2560	N.A.
Solar PV	800	700	650	600	555	510	485	475	465	455	450	N.A.
Concentrated solar	5100	4800	4450	4150	3900	3700	3450	3350	3250	3200	3150	N.A.
Added capacity in GW												
Onshore wind	18	35	35	35	35	35	35	35	35	35	35	368
Offshore wind	1	3	5	8	11	13	13	13	13	13	13	106
Geothermal	1	1	1	1	1	1	1	1	1	1	1	11
Solar PV	15	30	35	35	35	35	35	35	35	35	35	360
Concentrated solar	2	5	5	5	5	5	5	5	5	5		47
TOTAL ADDED CAPACITY	37	74	81	84	87	89	89	89	89	89	84	1,028
Total cost/yr in \$billions												
Onshore wind	24.3	45.5	44.63	43.75	43.23	42.53	42	41.3	40.6	39.9	39.55	447
Offshore wind	3.78	11.1	17.5	26.8	35.75	41.33	40.3	39.98	39.65	39.33	39	335
Geothermal	2.8	2.75	2.7	2.68	2.65	2.63	2.61	2.59	2.58	2.57	2.56	29
Solar PV	12	21	22.75	21.0	19.43	17.85	16.97	16.63	16.27	15.92	15.75	196
Concentrated solar	10.2	24	22.25	20.75	19.5	18.5	17.25	16.75	16.25	16	0	181
TOTAL BUILDING COST	53.08	104.35	109.82	114.97	120.55	122.83	119.14	117.24	115.35	113.72	96.86	1,188

Appendix 7: Estimated Renewable Energy and Related GND Jobs (2020-2030)

State	renewal energy capacity (MW) ¹⁹⁷	Solar jobs ²⁰⁰	Onshore wind jobs ²⁰¹	Offshore wind jobs ²⁰²	Hydro (including R&D) jobs ²⁰³	Reforestation Jobs ²⁰⁴	Tidal and wave jobs ²⁰⁵	Geo-thermal jobs ²⁰⁶	Electric vehicle jobs ¹⁹⁷	Other renewable jobs	Total renewable energy jobs
Alabama	35.3	142,063							82,000		224,063
Alaska	14.5		45,312		13,562	500,000	625				559,499
Arizona	21.9	41,062									41,062
Arkansas	20.3	67,954									67,954
California	127.8	211,831	199,687			100,000			16,369		527,887
Colorado	27.9	71,075									71,075
Connecticut	11.4	34,513									34,513
Delaware	3.5			14,219							14,219
Florida	61.2	191,173							16,500		207,673
Georgia	47.2	169,181									169,181
Hawaii	3.8						238	114,750			114,988
Idaho	9.5					120,000		14,063			134,063
Illinois	57.9	95,625	217,125						43,000		355,750
Indiana	40.4								70,600		70,600
Iowa	30.6		130,050								130,050
Kansas	18.8		82,250								82,250
Kentucky	28.5	142,062							95,000		237,062
Louisiana	92.7	181,562		347,625							529,187
Maine	9.1						561				561
Maryland	20.1			75,375							75,375
Massachusetts	21.4	29,875									29,875
Michigan	39.9								453,779		453,779
Minnesota	31.5		118,125								118,125
Mississippi	21.0						1,313				1,313

Warheads to Windmills: How to pay for a Green New Deal

State	renewal energy capacity (MW)	Solar jobs	Onshore wind jobs	Offshore wind jobs	Hydro (including R&D) jobs	Reforestation Jobs	Tidal and wave jobs	Geo-thermal jobs	Electric vehicle jobs	Other renewable jobs	Total renewable energy jobs
Missouri	25.5		95,625						196,363		291,988
Montana	7.4				8,857	80,000					88,857
Nebraska	15.5		62,969								62,969
Nevada	11.0	37,813				80,000		20,000	8,000		108,000
New Hampshire	3.9		19,032								19,032
New Jersey	32.9	56,063									56,063
New Mexico	12.8							8,000			8,000
New York	54.9	122,701		137,250							259,951
North Carolina	37.9	62,844									62,844
North Dakota	9.0		60,390								60,390
Ohio	53.5	118,125	150,469						107,400		375,994
Oklahoma	29.1	31,756									31,756
Oregon	16.3	64,630			27,761						92,391
Pennsylvania	59.1	253,982									253,982
Rhode Island	3.2			36,893							36,893
South Carolina	24.2								7,343		7,343
South Dakota	7.5		28,594								28,594
Tennessee	32.2	151,019			4,400				117,900		273,319
Texas	225.3	223,050	704,062						5,369		932,481
Utah	13.8							6,900			6,900
Vermont	2.1				8,446						8,446
Virginia	35.1	55,875									55,875
Washington	31.7				69,830				69,830		140,005
West Virginia	13.0	50,100									50,100
Wisconsin	26.8	26,531	147,132								173,663
Wyoming	11.2		45,500			80,000					125,500
Totals	1,591.0	2,632,974	2,106,325	611,302	133,202	960,000	2,745	164,338	1,289,453		7,900,339

See footnotes at top of columns on previous page for sources of data in each column.

Appendix 8: Nuclear weapons jobs

<i>Name of facility</i>	<i>what goes on there</i>	<i>city</i>	<i>state</i>	<i>employees</i>
A. Military Bases				<i>(civilian)</i>
1. Malmstrom AFB	150 ICBM silos	Great Falls	MT	1,419
2. Minot AFB	150 ICBM silos	Minot	ND	1,419
3. Warren AFB,	150 ICBM silos	Cheyenne	WY	1,419
4. Kitsap Naval Base	8 SSBN submarines based	Bangor	WA	5,000
5. King's Bay Naval Base	6 SSBN submarines based	King's Bay	GE	2,000
6. Nellis AFB	15 B-52H bombers	Las Vegas	NV	600
7. Whiteman AFB	15 B-2 bombers	Knob Noster	MO	1,000
8. Barksdale AFB	15 B-52H bombers	Bossier City	LS	600
9. Pentagon	Command and control	Washington	DC	900
At other military bases	Communications, logistics, etc			13,000
Sub-total - military				27,357
B. US Nuclear Weapon Facilities				
1. Pantex Plant (Bechtel, Leidos, Northrop Grumman)	Warhead assembly	Panhandle	TX	3,300
2. Lawrence Livermore Lab-LLNL (AECOM, Battelle, Texas A&M)	Research and development	Livermore	CA	6,500
3. NNSS (formerly Nevada Test) (Honeywell, Jacobs, Huntington)	Resting and warhead development	Nye County	NV	2,400
4. Los Alamos National Lab-LANL (Battelle, U Cal, Texas A&M)	Design and warhead engineering	Los Alamos	NM	10,000
5. Sandia National Labs (Honeywell, Jacobs, Huntington)	Design and warhead engineering	Albuquerque	NM	10,600
6. Kansas City Plant-NSC (Honeywell)	Warhead components production	Kansas City	MO	4,500
7. Y-12 National Security Complex (Bechtel, Leidos, Northrop Grumman)	Uranium processing	Oak Ridge	TN	4,700
8. Savannah River National Lab (Fluor, Honeywell, Huntington)	Plutonium and tritium production	Jackson	SC	825
Sub-total facilities				42,825
C. Private Contractor Operations				
AECOM	Research and development	Fort Belvoir	VA	?
<i>(Total employees - 87,000)</i>		Albuquerque	NM	?
Aerojet Rocketdyne	Solid fuel rocket motor plant	Camden	AR	900
<i>(Total employees - 4,965)</i>				
BAE Systems	Missile development	Hill AFB	UT	500
<i>(Total employees - 30,000)</i>				
Bechtel	<i>See LLNL, Y-12 and Pantex</i>			
<i>(Total employees - 55,000)</i>				
BWX Technology	Sub missile tubes	Lynchburg	VA	4,500
<i>(Total employees - 4,500)</i>				

Boeing	MIII and GBS development	Huntsville	AL	2,700
<i>(Total employees - 153,027)</i>	repair center	Heath	OH	750
	Test facility	Little Mountain	UT	250
Charles Stark Draper Lab	Missile guidance systems	Boston	MA	1,700
Fluor <i>(Total employees - 53,349)</i>	<i>See Savannah River Lab</i>			
General Dynamics	Submarine missile systems	Groton	CT	16,500
<i>(Total employees - 98,600)</i>	Mission Systems	Pittsfield	MA	900
		Silverdale	WA	?
		Kings Bay	GA	?
Honeywell International	ICBM missile systems	Albuquerque	NM	200
<i>(Total employees - 116,500)</i>				
Huntington Ingalls Industries	Warhead development	Newport News	VA	2,500
<i>(Total employees - 38,000)</i>		Aiken	SC	?
		Ballston Spa	NY	?
		Los Alamos	NM	?
Jacobs Engineering	<i>See NNSS, Nevada</i>			
<i>(Total employees - 80,000)</i>				
Leidos	Warhead development	Albuquerque	NM	100
<i>(Total employees - 32,000)</i>				
Lockheed Martin	F35 nuclear capability	Fort Worth	TX	?
<i>(Total employees - 105,000)</i>		Palmdale	CA	?
	ICBM re-entry vehicles	Littleton	CO	4,000
		King of Prussia	PA	?
		Cape Canaveral	FL	720
		Orlando	FL	1,800
Moog - <i>(Total employees - 10,976)</i>	Missile rocket motors	Niagara Falls	NY	150
	B-2 and B-21 bomber construction	Palmdale	CA	3,000
Northrop Grumman		Albuquerque	NM	13,000
<i>(Total employees - 85,000)</i>				
Raytheon	Warhead and missile development	Tucson	AZ	9,800
<i>(Total employees - 67,000)</i>	Communications systems	Arlington	VA	?
Textron	Aviation and Aerospace	Providence	RI	3,341
<i>(Total employees - 35,000)</i>	AAI subsidiary: Missile and space systems	Hunt Valley	MD	2,000
United Technologies Corp (UTC)	Launch control systems	Cedar Rapids	IO	
<i>(Total employees - 240,000)</i>				
Sub-total contractors				69,311
Total civilian jobs				139,493

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[\[https://www.cbo.gov/publication/54914\]](https://www.cbo.gov/publication/54914)

127) See, for instance, Harrison, CSBA (2015) *op.cit.*, Schwartz, Stephen, *Nuclear Security Spending: Assessing Costs, Examining Priorities*, Carnegie Endowment for International Peace, 2008.

[\[https://carnegieendowment.org/files/nuclear_security_spending.pdf\]](https://carnegieendowment.org/files/nuclear_security_spending.pdf), Rumbaugh, Russell, *Resolving Ambiguity: Costing Nuclear Weapons*, Stimpson Center, 2012, Ploughshares Fund, “What Nuclear Weapons Cost Us” *Ploughshares Working Paper*, Dec 20, 2011, and Wolfstal, Jon et al, *The Trillion Dollar Nuclear Triad*, Center for Nonproliferation Studies, 2014.

128) Brookings Institute, *Atomic Audit*. 1996.

129) *Ibid*,

130) Finding a way to safely dispose of the high-level waste that will remain radioactive and dangerous to humans for many thousands of years is of a different order of magnitude than the dismantling, decommissioning and ‘disposal’ of the nuclear weapons and delivery systems themselves. All the high-level waste is still accumulating in depots around the country awaiting a final solution that is not expected, at this point, for many decades.

131) *Ibid*.

132) CBO (2019), p.3.

133) “Besides the costs directly attributable to fielding nuclear forces, some published estimates of the total costs of nuclear weapons account for the costs of several related activities. Examples include the costs of addressing the nuclear legacy of the Cold War (such as dismantling retired nuclear weapons and cleaning up environmental contamination from past activities at nuclear facilities); the costs of reducing the threat from other countries’ nuclear weapons (including U.S. efforts to halt proliferation, comply with arms control treaties, and verify other countries’ compliance with treaties); and the costs of developing and maintaining active defenses against other countries’ nuclear weapons (primarily ballistic missiles). CBO has not updated its estimate of those costs, which was published in 2013, and such costs are not included in this report.” CBO (2019), p. 5.

134) *Ibid.*

135) CBO, *Projected Costs of US Nuclear Forces, 2014-2023*, Dec 2013.

[<https://www.cbo.gov/publication/54914>]

136) “Unlike estimates by some other analysts, CBO’s estimate does not include a prorated share of the military services’ and DoD’s overhead and support costs that are not specific to the nuclear mission.” CBO (2019), pg. 5.

137) These figures are compiled from Table B-1 in the CBO’s 2019 supplementary data to its July 2016 report *The U.S. Military’s Force Structure: A Primer*. The tables provide detailed figures for the number and cost of military personnel in each ‘unit’ of the armed forces, including the support personnel and ‘overheads’ that are allocated to that unit. They are accessible at: <https://www.cbo.gov/publication/54136>.

138) *Ibid.*, from Tables A-1, B-1 and B-2.

139) See Appendix 5: Calculation of nuclear weapon overhead costs. CBO counts only ‘direct’ costs, not ‘indirect’ or ‘overhead’ costs associated with nuclear weapons. See CBO (2019) p. 5.

140) Brookings Institution (1996), *op.cit.*

141) “Program-Wide Strategy and Better Reporting Needed to Address Growing Environmental Cleanup Liability.” U.S. Government Accountability Office Report to the Chairman of the Subcommittee on Strategic Forces. January 2019.

[<https://www.gao.gov/assets/700/696632.pdf>]

142) <https://www.cbo.gov/publication/54136>

143) The government uses ‘constant dollars’ pegged to a particular year to be able to compare costs of different programs over multiple years. But that also distorts the ‘actual’ cost as it will be felt by the taxpayer in years to come, since inflation generally keeps pushing costs up.

144) US Department of Defense, *Nuclear Posture Review, 2018*.

<https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF>

145) This program is “cheap” in comparison to other nuclear programs because it just involves removing a section of the existing warhead to give it a lower yield.

146) CBO (2019), *op. cit.*

147) \$53 billion over 10 years could translate to as much as \$159 billion over 30 years, plus inflation. Some of the programs being planned may last that long, but others will peak sometime in the next decade and then taper off, so we are using the conservative estimate of \$100 billion to cover all those programs.

148) DOE, *US Energy and Employment Report*, January 2017.

https://www.energy.gov/sites/prod/files/2017/01/f34/2017%20US%20Energy%20and%20Jobs%20Report_0.pdf

149) “Fastest Growing Occupations: Occupational Outlook Handbook,” *U.S. Bureau of Labor Statistics*, April 12, 2019. [www.bls.gov/ooh/fastest-growing.htm.]

150) 2018 Deloitte and The Manufacturing Institute skills gap and future of work study.

[<https://documents.deloitte.com/insights/2018DeloitteSkillsGapFoWManufacturing>]

151) <https://www.forbes.com/sites/niallmccarthy/2017/02/02/the-countries-with-the-most-stem-graduates-infographic/#1f467104268a>. Accessed May 10, 2019.

152) <https://ssec.si.edu/stem-imperative>, Accessed May 10, 2019.

153) See [<https://www.forbes.com/sites/kathryndill/2016/07/13/the-companies-with-the-most-stem-job-openings-right-now-3/#4ac204b37f82>].

154) *Ibid.* Data compiled by *Forbes* magazine.

155) See Appendix 8.

156) Data from websites of the different nuclear weapon facilities and wikipedia pages.

157) See Appendix 8 for a list of the companies involved.

158) National Research Council. *Examination of the U.S. Air Force's science, technology, engineering, and mathematics (STEM) workforce needs in the future and its strategy to meet those needs* (Washington, DC: National Academies Press, 2010).

159) <https://orise.orau.gov/stem/workforce-studies/nuclear-engineering-enrollments.html>. Accessed May 10, 2019.

160) Campaign Against Arms Trade, *Arms to Renewables: Work for the Future*, London, 2014.

161) See, for example, Pollin et al (2014), *op.cit.* and also International Trade Union Confederation (ITUC), *Growing Green and Decent Jobs*, 2012, Mahan, Simon et al, *Untapped Wealth: Offshore Wind can Deliver Cleaner and More Affordable Energy and More Jobs*, Oceana, 2010.

162) Many historians believe that it was the cost of trying to keep up with US nuclear weapons technologies that eventually bankrupted the Soviet Union and led to its collapse.

163) See Patricia Lewis et al, *Too Close for Comfort: Cases of Near Nuclear Use and Options for Policy*, Chatham House, London, 2014.

164) See, for example,

<http://rozenbergquarterly.com/noam-chomsky-on-the-long-history-of-us-meddling-in-foreign-elections/>

165) See, for instance,

<https://www.nytimes.com/2018/02/17/sunday-review/russia-isnt-the-only-one-meddling-in-elections-we-do-it-too.html> and <https://www.thenation.com/article/the-long-history-of-us-russian-meddling/>

166) <https://www.popularmechanics.com/science/energy/a25728221/terrapower-china-bill-gates-trump/>

167) <https://www.ucsusa.org/nuclear-weapons/nuclear-terrorism/reprocessing-nuclear-waste>

168) <https://www.technologyreview.com/s/612940/the-new-safer-nuclear-reactors-that-might-help-stop-climate-change/>

169) https://en.wikipedia.org/wiki/Virgil_C._Summer_Nuclear_Generating_Station

170) See <https://www.nrc.gov/reactors/new-reactors/col-holder.html>, <https://www.power-eng.com/articles/2017/09/dominion-energy-suspends-north-anna-nuclear-expansion.html>, <https://cleanenergy.org/blog/turkey-point-reactors-negligence-litigation-and-a-pause/>, https://nuclearstreet.com/nuclear_power_industry_news/b/nuclear_power_news/archive/2017/08/25/duke-seeks-to-cancel-william-states-lee-nuclear-power-project-082502#.XPQbJS2ZNTY, and <https://www.toledoblade.com/local/2018/02/28/Anti-nuclear-group-seeks-to-halt-Fermi-3-plant.html>

171) <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx#ECSArticleLink4>

172) *ibid*

173) Wallmer, Andrea, and Wenisch, Anthony, *Energy Balance of Nuclear Power Generation*, Austrian Energy Agency, 2011.

[https://www.energyagency.at/fileadmin/dam/pdf/publikationen/berichteBroschueren/Endbericht_LCA_Nuklearindustrie-engl.pdf]

174) <https://www.stormsmith.nl/i38.html>

175) See <https://theecologist.org/2015/feb/05/false-solution-nuclear-power-not-low-carbon>

176) https://en.wikipedia.org/wiki/Olympic_Dam_mine

177) The units used for enrichment of uranium are called SWUs, and it takes approximately 100,000 SWUs to enrich enough uranium for a 1 GW reactor for one year. The gas centrifuge process uses 100 kWh of electricity for each SWU, which adds up to 10GWh for 100,000 SWUs. A 1 GW reactor operating 24 hours a day for 365 days a year would produce 8,760 GWh per year. Refueling, maintenance and unscheduled shut-downs put the average capacity for nuclear power plants at 90%, so a typical 1 GW reactor will produce around 7, 880 GWh per year.

[<https://www.globalsecurity.org/wmd/intro/u-centrifuge.htm>]

178) For instance, the research and development for commercial reactor designs was originally paid for by the Navy for use in submarines and aircraft carriers. Uranium enrichment at Oak Ridge, Tennessee was paid for by the Atomic Energy Commission, and many other related expenses for nuclear weapons development was of direct benefit to the nuclear power industry. See *Atomic Audit* and <https://www.taxpayer.net/energy-natural-resources/nuclear-power-subsidies/>

179) <https://www.hoover.org/research/high-and-hidden-costs-nuclear-power>

180) <https://www.bbc.com/news/world-asia-38131248>

181) <https://www.courthousenews.com/attorneys-implore-judge-to-keep-sailors-fukushima-case-in-u-s/>

182) Strickler, Laura, "Cost to Taxpayers to Clean up Nuke Waste Jumps \$100 Billion in a Year." *NBCNews.com*. January 29, 2019.

[<https://www.nbcnews.com/news/all/cost-taxpayers-clean-nuclear-waste-jumps-100-billion-year-n963586>]

183) <https://www.ecoprog.com/publications/energy-management/biomass-to-power.htm>

184) <https://www.ecoprog.com/publications/energy-management/biomass-to-power.htm>

185) https://www.pfpi.net/wp-content/uploads/2011/04/PFPI-biomass-carbon-accounting-overview_April.pdf

186) See also

<http://www.carbontradewatch.org/downloads/publications/NothingNeutralHere.pdf>

187) See EIA notes at:

https://www.eia.gov/totalenergy/data/monthly/pdf/sec12_n.pdf

188) Carbon capture is also known as carbon sequestration or carbon removal. There are numerous other terms and acronyms related to this concept, including Carbon Capture, Utilization and Storage (CCUS) and Bioenergy with Carbon Capture and Storage (BECCS).

189) Global CCS Institute, *The Global Status of CCS – 2018*,

[https://adobeindd.com/view/publications/2dab1be7-edd0-447d-b020-06242ea2cf3b/z3m9/publication-web-resources/pdf/CCS_Global_Status_Report_2018_Interactive_update.pdf]

190) *ibid.*

191) <https://www.reuters.com/article/us-coal-global-ccs/carbon-capture-projects-worldwide-rise-to-15-report-idUSKCN0SU0GE20151105>

192) For alternative perspectives on CCS, see for instance <https://www.greenpeace.org.uk/the-problem-with-carbon-capture-and-storage-ccs-20080103/>

193) <https://www.worldcoal.org/petra-nova-demonstrates-technical-potential-thats-just-one-side-coin>

194) https://en.wikipedia.org/wiki/Boundary_Dam_Power_Station

195) <https://www.carbonbrief.org/around-the-world-in-22-carbon-capture-projects>

196) This total includes several projects which then used the CO₂ to also extract more oil from nearby oil fields, as described (and counted) in the previous section.

197) <https://www.sciencedaily.com/releases/2013/05/130514085304.htm>

198) <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3888976/>

199) Jobs figures based on the total assumed capacity in each state for utilizing different types of renewable energy. From Jacobson et al, "100% Clean and Renewable Wind, Water and Sunlight All-Sector Energy Roadmaps for the 50 United States," in *Energy & Environmental Science*, Royal Society of Chemistry, 2015, Vol 8, no. 2093.

200) Solar PV jobs based on conservative figure of 6.25 jobs per MW of PV installed. This does not include construction jobs or other ancillary jobs associated with each MW of installed PV. The International Renewable Energy Agency uses the figure of 20.2 total jobs created in the US per MW of solar PV. Many of these jobs are currently in China, however. See International Renewable Energy Agency, *Renewable Energy and Jobs*, IRENA, 2013. Pg. 42.

201) Onshore wind jobs based on conservative figure of 6.25 jobs per MW of installed wind. The IRENA figure for the US is double that, at 12.2 jobs per MW. See IRENA, *op.cit.*

202) Jobs in off-shore wind are more difficult to calculate as the US has only one off-shore wind farm so far. The OECD average is nearly 20 jobs per MW according to IRENA, *op.cit.*

203) Hydro-electric jobs include continuing research and development of environmentally sound hydro projects and pumped storage as well as jobs expected due to increasing hydro capacity from existing dams.

204) Reforestation jobs are based on size of federal land available for tree planting and a ratio of 1 job per 1,000 trees per year, as during the original New Deal. Data derived from Sonja N. Oswalt, W. Brad Smith, eds., "U.S. Forest Resource Facts and Historical Trends," United States Department of Agriculture, August 2014.

https://www.fia.fs.fed.us/library/brochures/docs/2012/ForestFacts_1952-2012_English.pdf and Joshua Knoll, "Seven Largest National Forests," National Forest Foundation, July 22, 2016.
<https://www.nationalforests.org/blog/seven-largest-national-forests>.

205) Tidal and wave projects currently in research and development phases employ small numbers of people and these are estimates of modest growth. The Ocean Renewable Energy Coalition suggests marine and hydrokinetic energy could support 36,000 positions by 2030 in direct and indirect jobs in the United States, if its goal of installing 15 gigawatts of power is met.

<https://www.eesi.org/papers/view/fact-sheet-jobs-in-renewable-energy-and-energy-efficiency-2017>

206) Geothermal job figures from United States Department of Labor, "Careers in Geothermal Energy," Bureau of Labor Statistics, accessed June 9, 2019, which uses existing US figures of 14-17 jobs per MW of geothermal..

https://www.bls.gov/green/geothermal_energy/geothermal_energy.htm

207) Electric vehicle jobs include EV car manufacturing, high speed rail construction, electric plane development and production and EV battery manufacturing. It is assumed here that most existing automotive and airplane construction workers would simply switch from making cars and planes with fossil fuel engines to ones with electric engines, so those jobs remain the same. High speed rail jobs are derived from the AHSRA for the first phase of construction by state. AHSRA, "US Rail High Speed Network Map," US HSR, accessed June 9, 2019.

<http://ushsr.com/ushsrmap.html>.