We Have the Power

100% Renewable Energy for a Clean, Thriving America

Environment Washington Research & Policy Center

Frontier Group

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Spring 2016

Acknowledgments

Environment Washington Research & Policy Center sincerely thanks the following individuals for their review of this report: Jennifer Amman and Steve Nadel of the American Council for an Energy-Efficient Economy; Stephan Edel of the Center for Working Families; John Farrell of the Institute for Local Self-Reliance; Felipe Floresca of the Emerald Cities Collaborative; Johanna Goetzel of the Climate Group; Mark Jacobson, professor of civil and environmental engineering at Stanford University; Ingrid Kelley of Architecture 2030; Karl Rabago of the Pace Energy and Climate Center; Gordian Raacke of Renewable Energy Long Island; Wilson Rickerson of Meister Consultants Group; Emily Rochon and David Pomerantz of Greenpeace; Steve Savner of the Center for Community Change; Kevin Taylor of World Wildlife Fund; Jodie Van Horn of the Sierra Club; Philip Warburg, author of Harness the Sun; and Bill Weihl of Facebook for their review of drafts of this document, as well as their insights and suggestions. Thanks also to Jeff Inglis, formerly of Frontier Group, for his contributions to early drafts of this document, and to Elizabeth Ridlington of Frontier Group for editorial support.

Environment Washington Research & Policy Center thanks the Barr Foundation, the John Merck Fund, the Scherman Foundation, and the Arntz Family Foundation for making this report possible.

The authors bear responsibility for any factual errors. The recommendations are those of Environment Washington Research & Policy Center. The views expressed in this report are those of the authors and do not necessarily reflect the views of our funders or those who provided review.

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Executive Summary

America can address our largest environmental challenges by shifting to 100 percent renewable energy. Renewable energy makes us safer and healthier, protecting our communities from global warming and from hazardous air pollution. Renewable energy reduces the need for dangerous and destructive practices like shipping explosive fuels through our cities, fracking for gas near our water supplies, or razing our mountains to dig up dirty coal.

An economy powered by 100 percent renewable energy is within our reach. First, we can reduce the total amount of energy we use through improved efficiency, even as our economy continues to grow. Second, we can tap America's virtually inexhaustible supplies of energy from the wind, the sun, the land and the oceans.

Our transition to a clean energy system has already begun. But, with the need to reduce the pollution that causes global warming growing more urgent every day, we need to step up the pace. To maximize the benefits of moving to 100 percent renewable energy, leaders at all levels must act to accelerate our progress. America's energy policy should facilitate mass deployment of clean energy solutions, support research and development of new clean energy technologies, and keep much of our coal, oil and gas reserves in the ground.

A shift to 100 percent renewable energy can limit the impacts of global warming.

- Clean, renewable energy sources such as wind and solar energy produce little to no global warming pollution. By transitioning to 100 percent renewable energy, we can replace the dirty fuels – including coal, oil and gas – that are causing our planet to heat up.
- Serious impacts of climate change are already underway. The faster we transition away from dangerous fuels, the better able we will be to protect our communities from harm. With rapid action, we can prevent large-scale catastrophes, including permanent flooding of coastal cities, more extreme storms, and widespread food and water shortages.
- In Paris in December 2015, the nations of the world made a historic commitment to protect our climate, pledging efforts "to limit [global] temperature increase to 1.5° C above pre-industrial levels." In order to achieve that goal, America must transition to 100 percent clean energy before mid-century, and leave most of our remaining coal, oil and gas reserves in the ground.

Renewable energy improves our health, increases our safety, and puts our economy on a sound foundation.

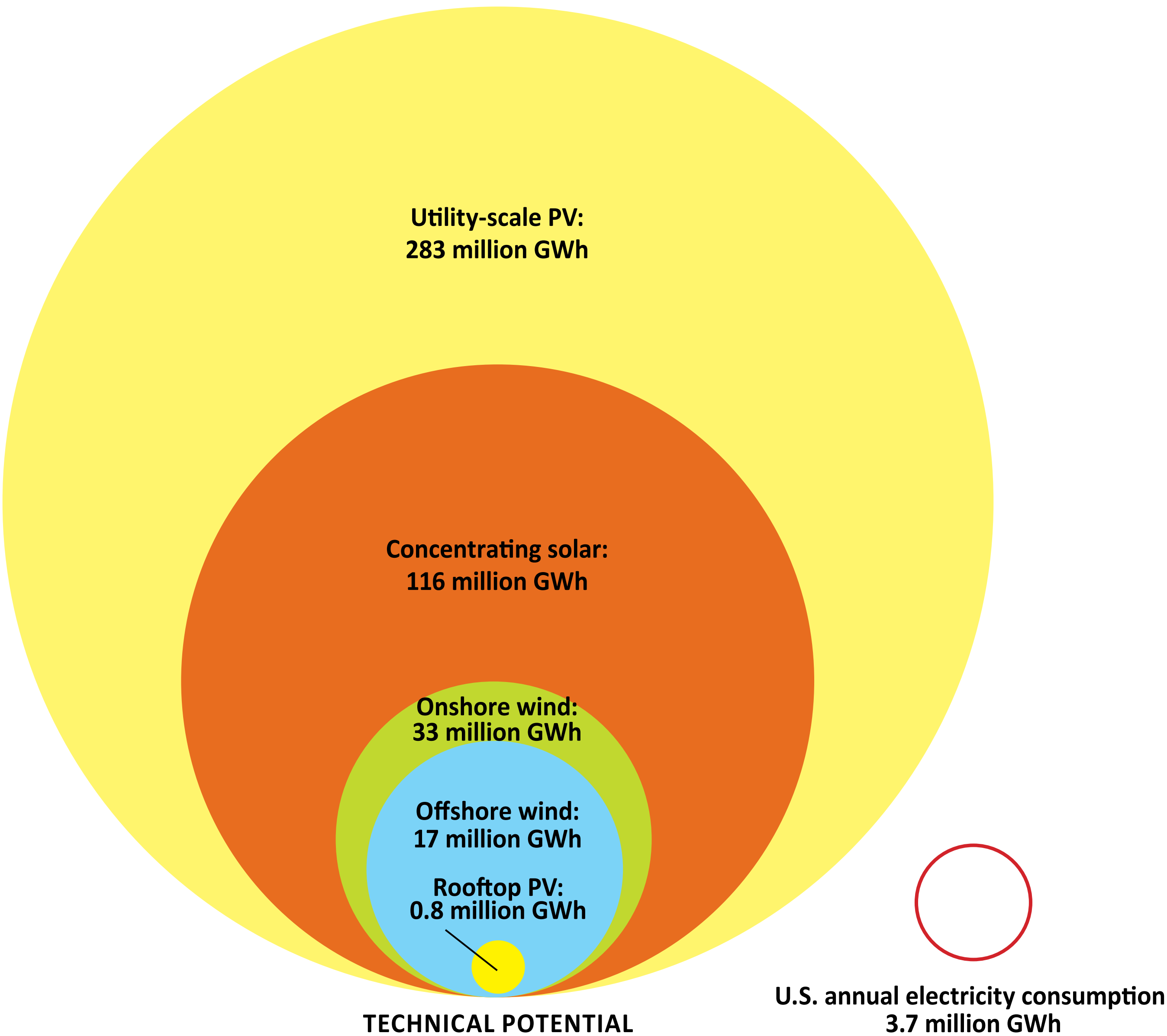
- Moving to 100 percent renewable energy will eliminate air pollution from fossil fuels, making us healthier and longer-lived. Today, air pollution kills about 200,000 Americans a year, reduces our quality of life, and gives our children respiratory diseases like asthma.
- Renewable energy will make us safer. Reaching 100 percent renewable energy will protect our drinking water supplies from hazardous contamination by drilling and fracking. It will also protect our communities by eliminating the need to ship explosive fuels through our neighborhoods on train cars or in leaky pipelines. Generating renewable energy locally (as with rooftop solar panels) can also make our energy system more resilient.

- Dirty energy sources have no inherent economic advantage over renewable energy. On the contrary, expanding renewable energy creates local jobs that cannot be outsourced, reduces the impact of fossil fuel-induced harm to our environment and health, and safeguards the economy from the volatility of fossil fuel prices.

America has vast renewable energy resources – enough to meet our needs many times over.

- America has massive, virtually inexhaustible reserves of renewable energy from the wind, the sun, the earth and the oceans. Just a fraction of these resources could power our entire society. According to the National Renewable Energy Laboratory, the United States has the technical potential to meet its current electricity needs more than 100 times over with solar energy and more than 10 times over with wind energy. America also has massive potential to save energy. The American Council for an Energy-Efficient Economy (ACEEE) estimates that we can reduce our overall energy use by 40 to 60 percent below current levels by mid-century, even as our economy continues to grow.

Figure ES-1: Comparison of Renewable Energy Technical Potential and Current Consumption (Data: NREL)



Affordable 100 percent renewable energy is within our reach.

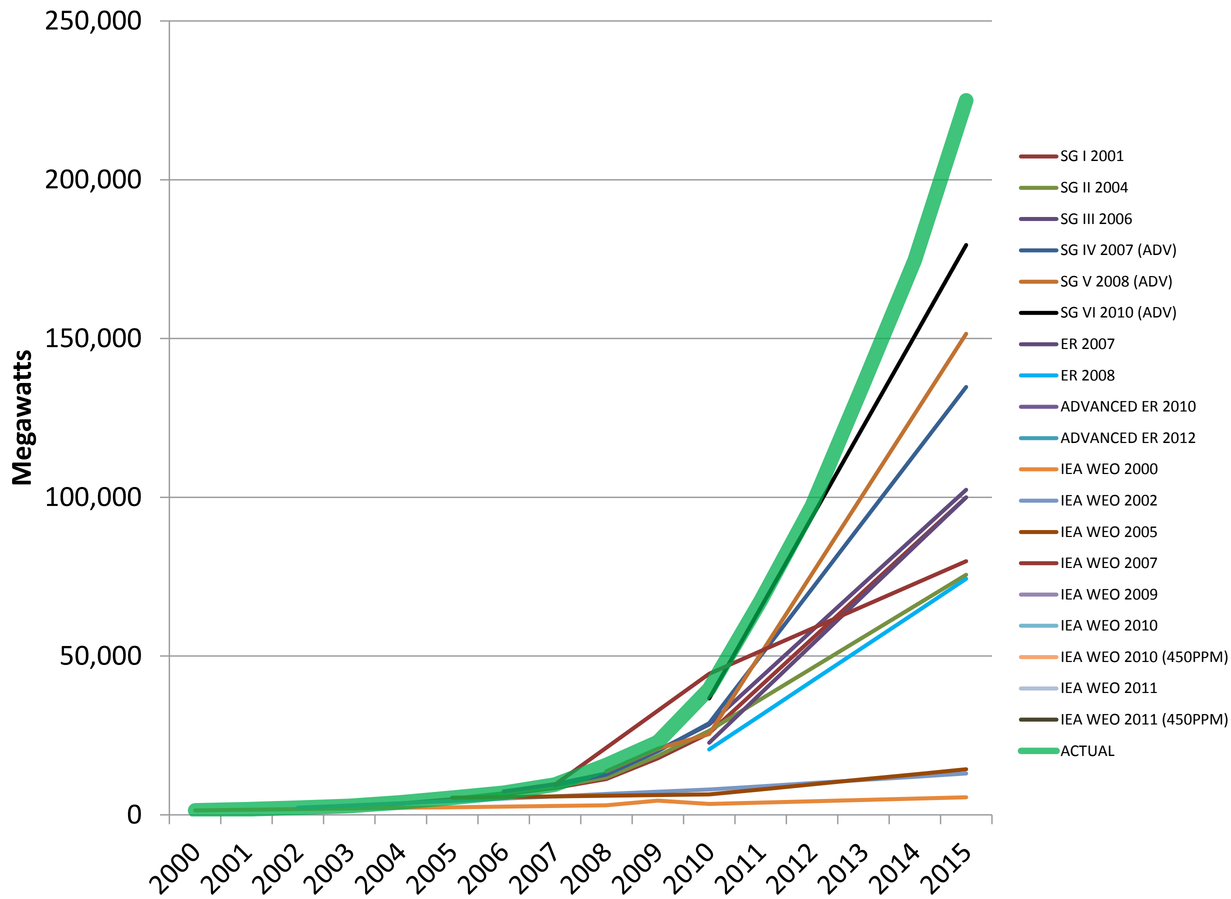
- There are no insurmountable technological or economic barriers to 100 percent renewable energy. At least seven detailed studies of clean energy systems – conducted by academics, government agencies and nonprofit organizations – suggest that we have the tools we need to make the transition. (See Table ES-1.)
- Over the past 15 years, growth in renewable energy worldwide – especially solar energy – has outstripped most forecasts, even those made by environmental advocates such as Greenpeace. (See Figure ES-2.)
- Economists predict that we can build a 100 percent renewable energy system at costs comparable to or less than what we would have to spend to continue our reliance on dirty energy. The International Energy Agency estimates that limiting warming to 2° C would require an additional investment of about 1 percent of global GDP per year. That investment would yield savings of more than $115 trillion on fuel by 2050 – a net savings of more than $70 trillion.[1]
- Including the health and climate costs of dirty energy in the equation makes it even clearer that renewable energy is cost-effective.

Table ES-1. High Renewable Energy Scenarios for United States

Author	Year Published	Scope	Timing	Percentage Renewable	Energy Sources Included
MacDonald, et al.[2]	2016	Electricity, U.S.	2030	~63% (low cost renewables case)	wind, solar, hydropower (plus nuclear and gas)
Jacobson, et al.[3]	2015	All energy, U.S.	2050	100%	efficiency, wind, solar, geothermal, tide, wave, hydropower
Greenpeace[4]	2015	All energy, global	2050	100%	efficiency, wind, solar, geothermal, biomass, ocean, hydropower, hydrogen, synfuels
Williams, et al.[5]	2015	Electricity*	2050	>80% (High Renewables case)	wind, solar, geothermal, hydropower
Budischak, et al.[6]	2013	Part of U.S. electric grid	2030	100%	wind, solar, energy storage
National Renewable Energy Laboratory[7]	2012	Electricity	2050	80%	wind, solar, geothermal, hydropower, biomass
WWF[8]	2011	All energy, global	2050	~100%	efficiency, wind, solar, geothermal, biomass, wave & tidal (small pct. of residual fossil fuels)

* High renewables case also included replacement of 83% of gas fuels with biomass and hydrogen and reduction in solid fossil fuels use.

Figure ES-2. Global Solar Photovoltaic Capacity (Green Line) versus Projections (data: Greenpeace)

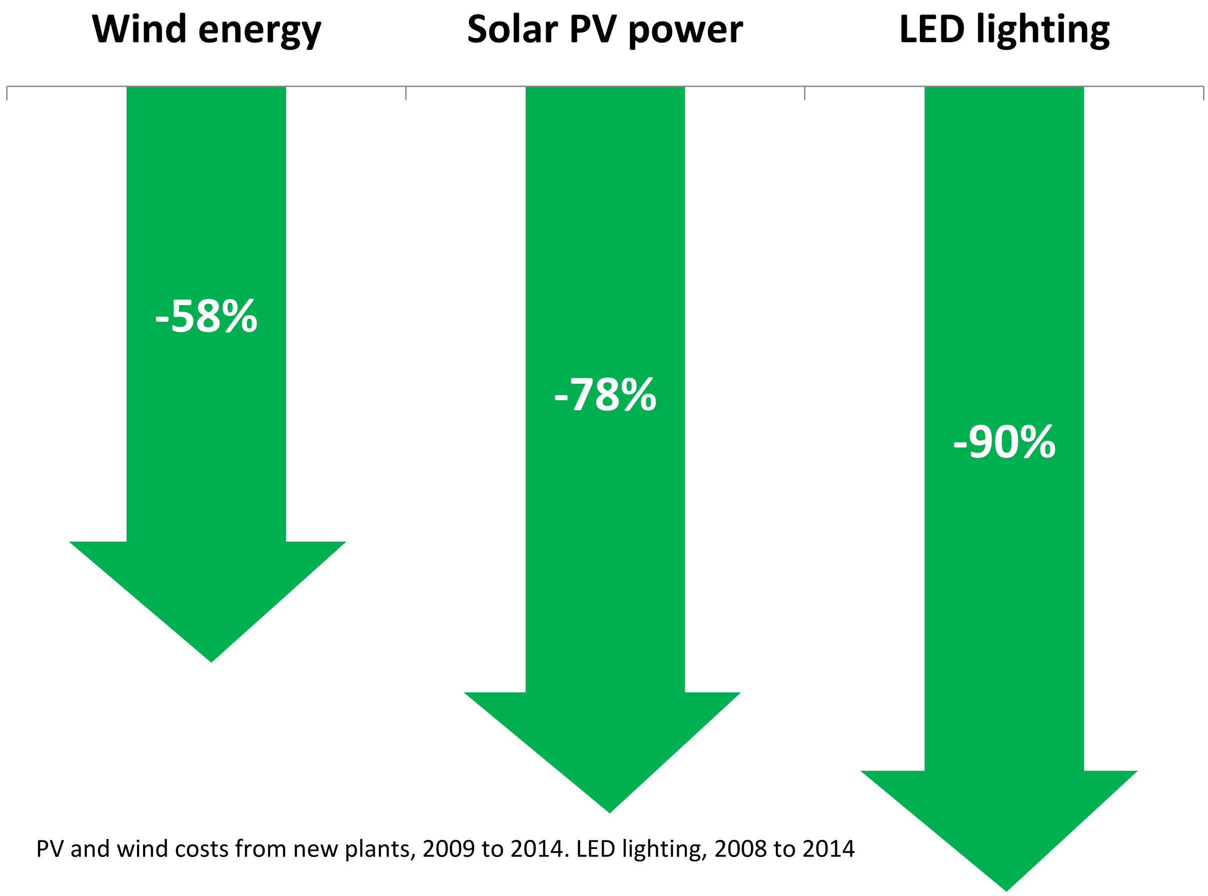


Solar energy installations around the world have grown faster than even the most optimistic forecasts made by Greenpeace (SG, ER, Advanced ER), the solar energy industry (SG) and the International Energy Agency (IEA)

Emerging technologies and new trends are opening the door for an unprecedented transformation of our energy system to 100 percent clean, renewable power.

- Renewable energy and energy efficiency technologies are quickly falling in price. Between 2009 and 2014, the cost of solar electricity in the United States fell by 78 percent and the cost of wind energy fell by 58 percent, according to Lazard. Since 2008, the cost of LED lighting has fallen by 90 percent. In many parts of the United States, wind is now the cheapest source of electricity, and solar power is on track to be the cheapest source of power in many parts of the world in the near future.
- Renewable energy technologies are continually improving in performance. For example, the U.S. Department of Energy estimates that improvement in turbine technology could expand the number of locations that can take advantage of clean wind energy.
- Promising new tools – for heating our homes, powering our factories, and moving people and goods over long distances with renewable energy – are either in development or beginning to make their way into the market. Experience with the current wave of renewable energy technologies suggests that supportive public policies can hasten the arrival of these low-carbon tools.

Figure ES-3. Recent Cost Declines in Clean Energy Technologies[9]



PV and wind costs from new plants, 2009 to 2014. LED lighting, 2008 to 2014

Leaders at all levels of government should act to accelerate our transition to 100 percent renewable energy. Five key principles should guide America's energy policy:

- Prioritize energy savings. Conserving energy and using it more efficiently can ease the transition from dirty fuels to clean, renewable energy.
- Promote steady and swift deployment of clean renewable energy sources. Solar and wind energy are poised to play a major role in every vision of a 100 percent renewable energy system.
- Transition those portions of our economy that rely on direct combustion of fossil fuels to electricity and other zero-carbon energy carriers.
- Provide reliable access to renewable energy by modernizing the electricity grid and enabling community microgrids and grid-connected energy storage.
- To protect the global climate and our health, keep much of our coal, oil and gas reserves in the ground and cease construction of new fossil fuel infrastructure.

Introduction

History is filled with examples of dramatic technological shifts that changed everything, seemingly overnight. In just the last few decades, the rise of the personal computer, the Internet and the iPhone have rearranged daily life and our economy – creating new billionaires, while eliminating industries that had once seemed all-powerful.

When historians look back at our current era, they may say the same thing about America's transition to clean energy. Over the last decade, conditions have aligned to make possible something that previously seemed inconceivable: the rapid transition to an economy powered by 100 percent clean, renewable energy.

It is no secret that the energy in wind and moving water, the heat and light from the sun, and the warmth of the earth are more than sufficient to power our entire economy many times over. But over the last decade, America and the world have begun to learn how to tap that energy cost-effectively and use it to provide for an ever-greater share of our energy needs. Advances in clean energy technologies, new business models, and supportive public policies are poised to unleash a "virtuous cycle" that can accelerate America's clean energy transition – bringing a 100 percent renewable energy system within our reach.

The renewable energy revolution is happening not a moment too soon. With the world facing the urgent imperative to slow global warming, with fossil fuel production and use taking an increasingly grim toll on our environment and health, and with billions of people worldwide seeking an escape from poverty, the potential for a transition to a 100 percent renewable energy system provides a ray of hope that those challenges can be met. Renewable energy can reduce the impact of fossil fuels on the disadvantaged communities that often bear the burden of environmental pollution, create new opportunities in fast-growing industries, and empower people of all walks of life to take control over their own energy future.

The goal of an economy powered by 100 percent renewable energy is drawing new supporters – and not all of them the usual suspects. In 2015, San Diego – the eighth-largest city in the United States, led by a Republican mayor – approved policies requiring a transition to 100 percent electricity by 2035, while Hawaii adopted a state law requiring all electric utilities to supply 100 percent renewable electricity by 2045.[10] Leading U.S. businesses – including Apple, Nike, Walmart, Starbucks and Johnson & Johnson – have pledged to transition to 100 percent clean electricity.[11] Global investment in renewable energy is skyrocketing.[12]

Around the country, communities are envisioning how renewable energy can lay the foundation for a prosperous, sustainable future. From Greensburg, Kansas, which rebuilt itself on a foundation of clean energy following a devastating tornado, to Buffalo, New York, where solar energy manufacturing is seen as a vehicle for economic revitalization, clean, renewable energy is creating new opportunities for people of all backgrounds.

In this report, we lay out the case for moving to 100 percent renewable energy; summarize the growing body of research that shows that the transition is not only possible, but cost-effective; and describe the technological and public policy advances that can help us reach the goal.

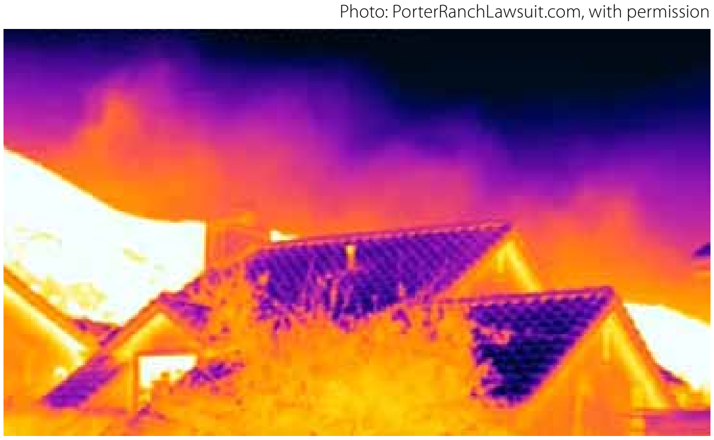
Getting there will not be easy, especially given the entrenched power of fossil fuel interests and utilities. But it is possible. By setting a course for 100 percent renewable energy, America can mobilize the resources needed to make the transition, with benefits for our climate, our environment, our health and our economy that will last for generations.

America Needs 100 Percent Renewable Energy

Switching to 100 percent renewable energy is essential. To preserve the climate conditions on earth in which our species was able to evolve, we must stop using the dirty fuels that are heating our planet, preferably using tools that do not compromise our environment, our economy or our health. The Paris Climate Agreement, supported by practically every country on the earth, sends the clearest signal yet that a full global transition to clean energy is inevitable, and that we must leave most of our coal, oil and gas reserves in the ground. Achieving the promise of the Paris Agreement requires immediate action.

Fortunately, renewable energy comes with widespread benefits for all. Not only will renewable energy help to minimize the impacts of global warming, but it will also clean our air and improve our health. At the same time, it will make our communities safer from the many hazards of fuel extraction and transport.

Photo: PorterRanchLawsuit.com, with permission



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A gas reservoir blowout in 2015 caused 1,200 tons of gas pollution to spew into the skies above communities in Los Angeles, captured here in a still from an infrared video. Increasing our use of renewable energy, like residential rooftop solar power, will reduce the climate and health impacts of extracting and transporting dirty fuels.

Clean, Renewable Energy Protects Us from Global Warming

Clean, renewable energy can power our society without warming our planet. By transitioning to renewable energy, we can limit the impacts of global warming and help protect our families, our communities and our future.

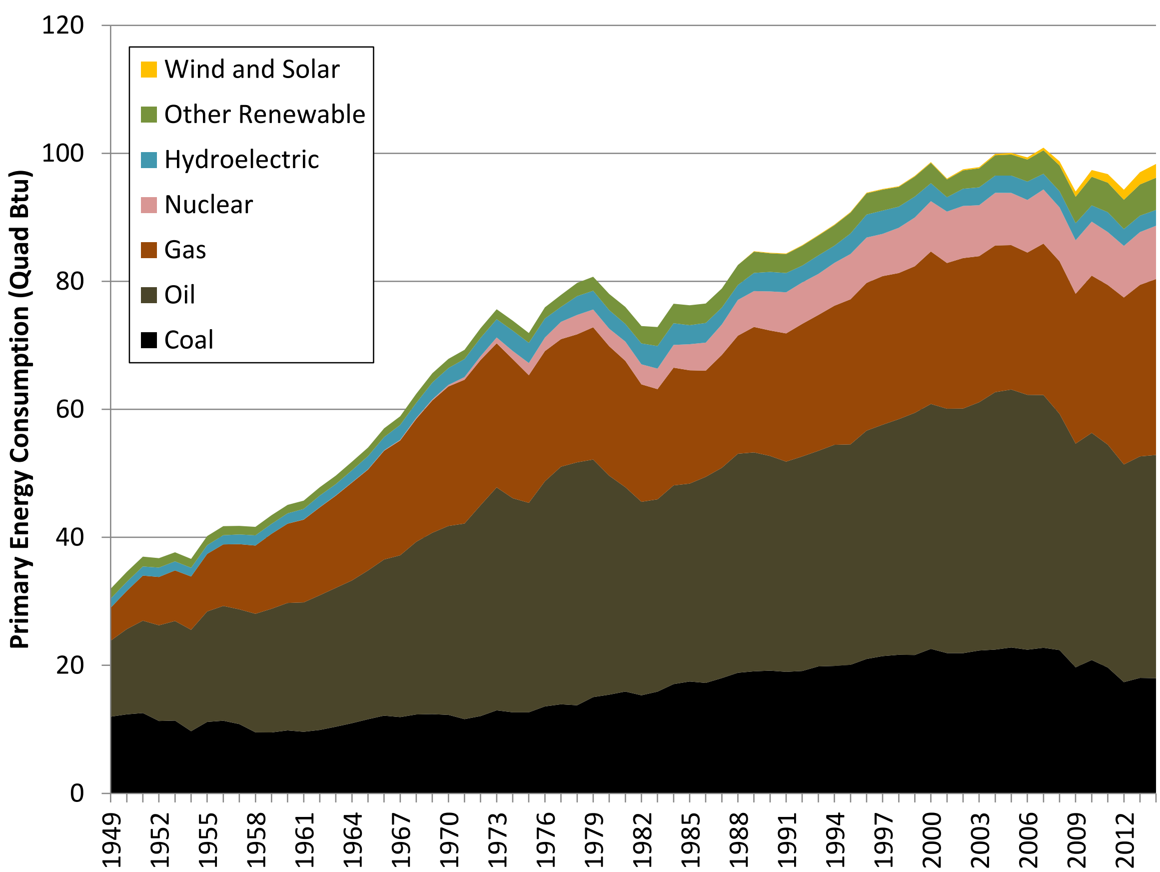
Renewable Energy Can Replace the Fuels that Are Causing Our Planet to Warm

Fossil fuels are the dominant source of energy in America today, heating most of our homes, fueling our cars and trucks, powering industry, and generating much of the electricity we use every day. Our reliance on fossil fuels comes at a heavy cost to the climate, however, with the energy sector accounting for more than 84 percent of the nation's contribution to global warming in 2013.[13]

Renewable energy sources such as solar and wind power do not contribute to global warming. By transitioning to 100 percent renewable energy, we can replace the dirty fuels – including coal, oil and gas – that are causing our planet to heat up.

For decades, America's consumption of fossil fuels increased nearly every year. But, over the last decade, the grip of fossil fuels on our energy system has begun to slip, with fossil fuels providing a smaller share of America's energy in 2014 than in any year since at least the late 1940s. Over the last decade, America's total consumption of energy has declined – thanks in part to improvements in the energy efficiency of our cars, appliances and homes – while once-marginal sources of energy such as wind and solar power have begun to make a meaningful contribution to the nation's energy needs.[14] (See Figure 1.)

Figure 1. U.S. Primary Energy Consumption by Source[15]



Renewable energy can be used for most – if not all – of the purposes for which we currently use fossil fuels. Even when counting pollution that results from manufacturing and decommissioning photovoltaic panels and wind turbines, solar and wind power produce only a tiny fraction of the greenhouse gas pollution created by electricity generated from coal and gas.[16]

In 2014 alone, wind power in the United States averted 143 million metric tons of carbon pollution, the equivalent of removing more than 30 million passenger vehicles from the road or shutting down 37 coal-fired power plants.[17] The same year, solar energy offset 27.5 million metric tons of carbon dioxide pollution, equivalent to taking nearly 6 million vehicles off the road.[18]

Increasing our use of renewable energy will also reduce the climate impact of extracting and transporting dirty fuels. For example, the methane that leaks from gas or oil wells or gas pipelines is a potent greenhouse gas, 80 times more powerful than carbon dioxide.[19] As much as 25 percent of the global warming that has happened to date is because of methane pollution.[20]

In 2015, the disastrous gas reservoir blowout at Porter Ranch in California offered a powerful reminder that dirty fuels have climate impacts well before they reach a power plant or factory. After the gas industry failed to replace a broken safety valve, an underground gas storage reservoir began to vent 1,200 tons of gas pollution per day into the skies above California. State officials estimate that this one source accounts for a quarter of California's current contribution to global warming.[21]

Moving to 100 Percent Renewable Energy Will Limit the Impacts of Global Warming

Global warming is already underway. The world is about 1° Celsius (1.8° F) warmer now that it was in the late 1800s.[22] 2015 was the hottest year on record.[23]

People across the country are feeling the effects, including more heat waves, rising sea level, more frequent coastal flooding, more extreme storms, and more severe wildfires and droughts.[24]

Some additional future warming is inevitable because of pollution we have already emitted. Significant impacts of that warming – like sea level rise – will take hundreds of years to be fully realized. However, the severity of future impacts of global warming largely depends on the choices we make today.

If the world continues to emit unchecked amounts of global warming pollution, average temperatures across most of the United States could be as much as 10° F hotter by the end of this century.[25] Warming on that scale would have terrible consequences for Americans – including making it harder to grow the food we need, causing drought and water shortages in the Southwest, increasing the frequency and devastation caused by coastal flooding (with seas rising as much as 4-6 feet), and making damaging events like Hurricane Sandy more likely. Unchecked warming is also likely to disrupt ecosystems and accelerate species extinctions. Many of these impacts would be irreversible over hundreds to thousands of years.[26]

By accelerating our transition to pollution-free energy sources, we can prevent the worst impacts of global warming. The faster we transition away from dangerous fuels, the better able we will be to preserve our climate and protect our communities from harm. Every pound of global warming pollution we prevent means less warming in our future. It also increases the odds that we will avoid climate "tipping points" – thresholds beyond which uncontrollable, irreversible and civilization-threatening changes may occur.

Renewable Energy Is Key to America's Global Leadership

In December 2015, leaders of nearly every nation in the world gathered in Paris and agreed to hold "the increase in the global average temperature to well below 2° C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5° C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change."[27]

To limit global warming to 1.5° Celsius, yearly global pollution levels must peak very soon and start rapidly declining, with global emission reductions of 80 percent or greater below 1990 levels by 2050.[28] The faster and more vigorously we act, the better able we will be to limit the impacts of global warming.

No matter the long-term temperature target, science tells us that halting the increase in global temperatures will require reducing climate pollution to zero.[29] The actions needed to limit warming to 1.5 degrees Celsius are similar to those necessary to stop warming at 2 degrees, or 2.5 degrees, only faster.

To reach zero emissions, we must replace all polluting fuels with clean energy, and leave most of the world's dirty fuel reserves in the ground. That includes more than 90 percent of the remaining coal in the United States.[30]

Since the Industrial Revolution, the United States has emitted more climate pollution than any other nation.[31] As a result, America has a special responsibility to lead the world in the transition to 100 percent renewable energy – and a special opportunity to enable U.S. inventors, engineers and companies to develop the technologies that will power the world in the 21st century.

Renewable Energy Improves Our Health and Increases Our Safety

Protecting our climate is not the only reason to switch to 100 percent renewable energy. Renewable energy also improves our health by preventing hazardous air pollution, and increases our safety by protecting us from the hazards of extracting, transporting and processing dangerous fuels.

The health and safety benefits of shifting to renewable energy will be greatest for residents of the often-disadvantaged communities in the shadow of fossil fuel infrastructure – from towns where fracking is prevalent to neighborhoods adjacent to busy highways.

Photo: Alan Graham McQuillan PhD ARPS via Flickr, CC BY-NC-ND 2.0

Photo: Drenaline via Wikipedia, CC BY-SA 3.0

Switching to renewable sources, like wind energy on farms in Kansas, will eliminate hazards in our communities associated with extracting and delivering dangerous fuels. On left, trucks sit by new housing development in the Bakken shale region of North Dakota.

Fossil fuel production and use creates hazardous air pollution, including smog, seen here blanketing Salt Lake City. By replacing dirty fuels with renewable energy, we can reduce air pollution and make our families and communities healthier. At right, solar panels on the roofs of a Massachusetts shopping center supply 30 percent of the complex's power.

Moving to 100 Percent Renewable Energy Will Reduce Air Pollution

By replacing dirty fuels with renewable energy, we can reduce air pollution and make our families and communities healthier.

Burning dirty fuels in power plants and vehicles causes soot and smog pollution. Traffic pollution from fossil fuel-powered vehicles on our roadways puts toxic chemicals into the air where we live and work. That air pollution interferes with the normal development and function of our lungs, causes cancer and heart attacks, and cuts lives short.

Reducing air pollution will increase life expectancy for people across the country – and particularly those who live in urban areas.[32] Air pollution kills on the order of 200,000 people a year in the United States. Pollution from on-road vehicle traffic is responsible for about 50,000 of those deaths, and power plant pollution is responsible for another 50,000.[33] Exposure to hazardous airborne soot has been shown to be higher in urban, minority and poor communities, suggesting that residents of those communities bear a disproportionately high toll from fossil fuel-related pollution.[34]

Reducing air pollution will also help us breathe better and increase our quality of life. For example, on days with high pollution levels, hospitals admit more patients for respiratory and cardiovascular disease, children and adults suffer more asthma attacks, and more children and adults are absent from school or work due to illness.[35] Long-term exposure to air pollution harms the growth and development of our children's lungs, and even leads to chronic diseases like asthma.[36]

Actions to clean up the air under the Clean Air Act are already saving hundreds of thousands of lives every year and providing more than $2 trillion in health and productivity benefits.[37] By switching to 100 percent renewable energy, we can accomplish much more.

Renewable Energy Can Mean Cleaner Drinking Water

Reaching 100 percent renewable energy will protect our drinking water supplies from contamination caused by mining, drilling and fracking, ensuring that the homes and business in our communities have access to safe water.

Ending our use of oil and gas for energy means that we will no longer drill fracking wells near our water supplies. That will protect underground aquifers from contamination with toxic chemicals and protect surface waters from spills.

Fracking fluids and wastewater contain toxic chemicals linked to cancer, endocrine disruption and neurological and immune system problems.[38] There have been several recent incidents in which fracking fluids have spilled into water supplies, threatening the health of local communities, including:

- In January 2015, 3 million gallons of fracking wastewater leaked out of a pipe in western North Dakota. The toxic brine contaminated two creeks that feed into the Missouri River, a source of drinking water for nearby towns.[39]
- In April 2015, an equipment malfunction spilled 42,800 tons of fracking fluid into the streets and storm sewers of a residential area of Arlington, Texas.[40]
- After equipment failed during the drilling of an Ohio well in 2014, about 16,000 gallons of oil-based lubricant leaked out into a tributary of the Ohio River, which supplies drinking water to millions of residents.[41]

Fracking may be the most recent threat posed by fossil fuel production to our water, but it is not the only one. Coal mining has a long history of fouling rivers and streams with acid mine drainage, while the storage of toxic coal ash at power plants has been linked to groundwater contamination and has been the cause of several catastrophic spills that fouled major waterways.[42]

Photo: U.S. Geological Survey via usgs.gov

Photo: Steve Janosik via Flickr, CC BY-NC-ND 2.0

Reaching 100 percent renewable energy will protect our drinking water supplies from contamination caused by mining, drilling and fracking. North Dakota's rivers are among those threatened by fracking spills, left. But the state is also host to vast wind energy resources.

Switching to renewable energy can also reduce water consumption by power plants. Nearly half of all water taken from waterways in the United States is used in a power plant.[43] Fossil fuel and nuclear power plants are large users of water, contributing to water availability problems in areas suffering from drought. Many renewable energy technologies – especially wind and solar photovoltaic power – use little to no water in the production of electricity, leaving more water available for homes, businesses and the preservation of healthy aquatic ecosystems.

Moving to 100 Percent Renewable Energy Will Make Our Communities Safer

In addition to reducing air pollution, switching to 100 percent renewable energy will eliminate hazards in our communities associated with extracting and delivering dangerous fuels, including the need to ship explosive fuels through our neighborhoods, and earthquakes triggered by fracking activities.

Oil train derailments can result in spills of toxic, flammable materials on land and in water, with devastating consequences. In July 2013, a 72-car oil train derailed in Lac-Mégantic, Quebec (just miles from the Maine border), rolled downhill and exploded. The incident killed 47 people, forced thousands from their homes and destroyed most of the town.[44] In 2014, American oil trains spilled flammable crude oil 141 times.[45] Trains hauling oil from the Bakken region of North Dakota have recently derailed in Alabama, Illinois, North Dakota, Montana, Oklahoma, Pennsylvania and Virginia.[46] In February 2015, a 109-car oil train in West Virginia derailed, causing a massive fire and spilling crude oil into a river that supplies water to about 1,000 people.[47]

Transporting oil and gas via pipeline can be just as dangerous. Since 1986, pipeline accidents have killed more than 500 people, injured more than 4,000, and cost nearly $7 billion in property damages.[48] For example, a natural gas pipeline explosion in 2010 in San Bruno, California, killed eight people and destroyed 38 homes.[49]

Credit: La Sûreté du Québec via Wikipedia, CC BY-SA 1.0

Photo: Brookhaven National Laboratory via Flickr, CC BY-NC-ND 2.0

Shipping explosive fuels through our neighborhoods is hazardous at best, catastrophic at worst. In 2013, an oil train exploded in Quebec, killing 47 people and forcing thousands from their homes. Pictured at right, a utility scale solar farm on Long Island provides energy to power 4,500 homes.

More than 2.5 million miles of gas pipelines exist in the United States, and more than half of that infrastructure has been in use for more than 50 years.[50] When we switch to 100 percent renewable energy, we will no longer face the risk of that infrastructure leaking or exploding.

Moving to 100 percent renewable energy will also eliminate earthquakes caused by injecting drilling wastewater from fracking operations into seismically active ground.

Injecting fracking wastewater into underground storage can trigger earthquakes.[51] According to the U.S. Geological Survey, the annual number of earthquakes larger than magnitude 3 in central and eastern states has more than quadrupled since 2009 – coinciding with increased use of underground injection wells for drilling wastewater disposal.[52] The number of earthquakes big enough for people to feel in Oklahoma, for example, increased from two a year in 2008 to more than two a day in 2015.[53]

Finally, generating power from local renewable energy sources, such as rooftop solar panels, can support the development of a more resilient electricity grid better able to withstand failures resulting from natural disasters, geopolitical crises, and terrorist attacks.

Moving to 100 Percent Renewable Energy Will Protect Treasured Places

Renewable energy will also protect treasured landscapes and ocean expanses that are critical for preservation of natural beauty and also for economic activities like tourism and recreation.

The Deepwater Horizon oil well blowout of 2010 is perhaps the most dramatic symbol of just how damaging dirty energy can be. That disaster killed 11 people in a fiery explosion

Photo: Dr. Oscar Garcia, via John Amos on Flickr, CC BY-NC-SA 2.0

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The Deepwater Horizon oil well disaster of 2010 is a dramatic symbol of the long-lasting damage to the environment that can be caused by fossil fuel extraction. Recovery from the disaster, which included burning off oil on the ocean's surface, created its own environmental damage. Offshore wind energy, where properly sited, is a symbol of the promise of renewable energy to power our economy.

Photo: James Holloway via Flickr, CC BY-NC 2.0

Photo: Duke Energy via Flickr, CC BY-NC-ND 2.0

Dirty fuel extraction is irreparably destroying mountains and forests in Appalachia, where mining companies are tearing up natural areas to extract coal. Renewable energy has the potential to create jobs and economic benefits in communities with declining fossil fuel economies.

on a drilling rig and started the largest marine oil spill in U.S. history. Oil flowed from the wellhead into the ocean for 87 days, releasing 4.9 million barrels of oil across 68,000 square miles, an area about the size of the state of Oklahoma.[54] More than 8,000 birds, sea turtles, and marine mammals were found injured or dead in the six months after the spill.[55] Five years later, wildlife continues to suffer from the impact of the spill.[56] In 2015, scientists identified lasting damage to coral reefs as far as 67 miles from the site of the leak.[57]

Spills damage treasured landscapes as well. For example, in the past decade, ruptured pipelines spilled over a million gallons of crude oil into the Kalamazoo River in Michigan and another 63,000 gallons into the Yellowstone River in Montana, poisoning water for miles and killing wildlife.

Dirty fuel extraction is also destroying mountains and forests in the Appalachians and in the Rockies, where mining companies are tearing up natural areas to extract coal. In Pennsylvania, Texas and North Dakota, drilling companies are turning natural areas (and even open spaces near our homes and schools) into industrial zones to drill fracking wells and pump out gas.

Switching to renewable energy can reduce the dangers of energy production to our environment – particularly if renewable energy development is done thoughtfully, and in ways that protect critical natural areas and resources. Shifting to renewable energy will eliminate the need to drill more wells in the Gulf of Mexico, and eliminate pressure to open the Atlantic Coast, additional parts of the Pacific Coast, or pristine areas in Alaska and the Arctic to oil drilling. At the same time, switching to 100 percent renewable energy will stop fracking and coal mining – protecting our communities and mountain landscapes from industrialization.

What Is Clean, Renewable Energy?

Every form of energy has an impact on our environment. But the impact of some forms of energy is much greater than others. Truly clean, renewable energy is:

- **Virtually pollution-free** – It produces little to no global warming pollution or health-threatening pollution.
- **Inexhaustible** – It comes from natural sources that are regenerative or practically unlimited. No matter how much we use, there will always be more.
- **Safe** – It has minimal impacts on the environment, community safety and public health, and those impacts that do occur are temporary, not permanent.
- **Efficient** – It is a wise use of resources.

Some forms of renewable energy are truly "clean," provided that they are sited in appropriate locations with minimal impacts on ecosystems and wildlife. Solar and wind energy fit into this category, as do many types of ocean, tidal, river current and geothermal energy. Energy efficiency technologies nearly always count as "clean energy" – delivering continuous environmental benefit at limited to no environmental cost.

Other forms of renewable energy carry much more significant environmental trade-offs. Hydroelectric and biomass energy are two forms of renewable energy that often fail to meet the definition of "clean." New hydroelectric dams are often destructive to natural landscapes and divert water from communities that need it. They also produce significant emissions of greenhouse gases – especially in the first few years after a dam is closed and the reservoir is created.[58] Biomass energy is often touted as a low-carbon alternative – despite the carbon dioxide emissions produced when it is burned – because the organic material once absorbed carbon dioxide from the atmosphere at the time it was grown. Biomass energy production can, however, damage important natural landscapes and ecosystems – including ecosystems that play an important role in carbon storage. Both hydroelectric and biomass power can play a role in the transition to a 100 percent renewable energy system, but that role is limited.

In addition to renewable energy sources, some non-renewable sources – such as nuclear energy – are sometimes considered "clean" on the basis of their low emissions of greenhouse gases. However, nuclear power plants produce hazardous radioactive waste for which no safe, long-term storage solution has been found, while the process of mining uranium has severe environmental impacts. The risk of accidents at nuclear power plants – such as the Fukushima disaster in Japan in 2011 – must also be considered. Lastly, unlike renewable energy technologies such as wind and solar power, which can be installed quickly and in small increments, nuclear power plants have proven to be extremely capital intensive and very slow to build, limiting their usefulness as a climate solution.

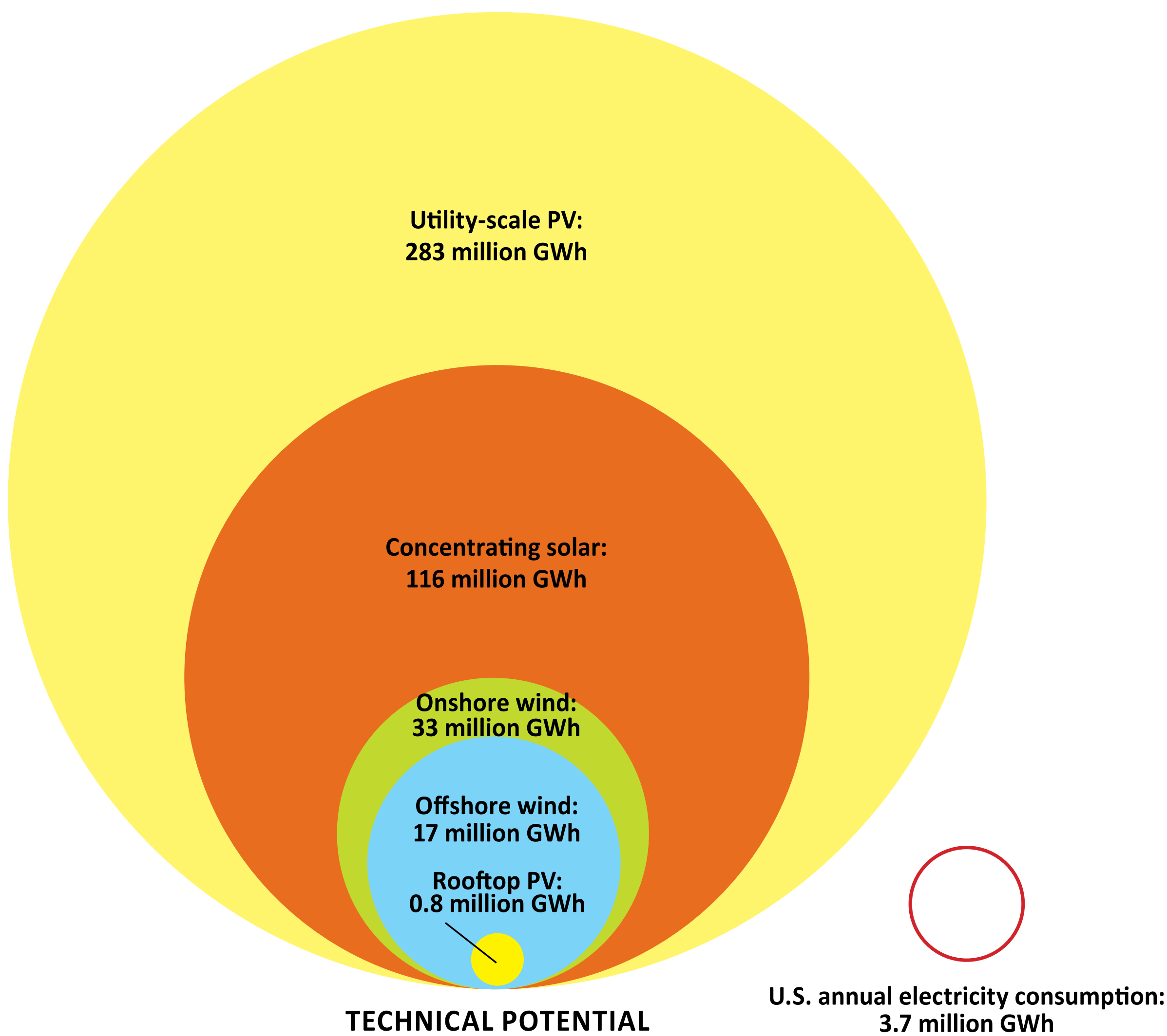
Prioritizing truly "clean" renewable energy sources within America's efforts to eliminate carbon pollution from our economy can expedite the development and deployment of those sources at minimal cost and with the greatest benefit for our environment and society over time.

100 Percent Renewable Energy Is Within Our Reach

America can power itself entirely with clean, renewable energy. America has nearly limitless technical potential to generate energy from the wind, the sun and other renewable energy sources. These resources can be used not just for powering America's electric grid, but for all of our energy needs.

There are many possible ways we could assemble a 100 percent renewable energy system that is affordable and costs less than continuing to depend on dirty energy (especially when the costs of dirty energy to our environment and health are factored into the calculation). At the same time, there are many

Figure 2: Comparison of Renewable Energy Technical Potential and Current Consumption[59]



tools at our disposal that can ensure that a renewable energy system is at least as reliable and dependable as the system we currently have.

Just a Fraction of America's Vast Renewable Energy Resources Could Power Our Entire Society

America has massive reserves of renewable energy from the wind, the sun, the land and the oceans – and vast potential to increase our energy efficiency. Just a tiny fraction of these resources could power our entire society.

Energy Efficiency

America has vast potential to do more with less energy. Eliminating waste saves money, making energy efficiency measures the cheapest way to meet many energy needs. Many energy efficiency solutions are available today and can be deployed quickly. For these reasons, experts often call efficiency the "first resource."[60]

Energy efficiency has been a critical part of the U.S. economy for decades. Since the 1970s, efficiency improvements have supplied more than three-quarters of the increased U.S. demand for energy, even as our economy tripled in size.[61] Americans today use less energy in total than we did a decade ago, despite recent growth in population and economic productivity.[62] As a result, we were able skip unnecessary infrastructure projects and avoid their cost. Through energy efficiency standards and programs, our appliances deliver better performance while using less energy, our buildings waste less energy through leaky windows and poorly insulated walls, and our cars and trucks go further on a gallon of gas.

Still, massive energy efficiency potential remains untapped. More than 60 percent of the energy we currently consume in the United States is wasted.[63] This is particularly the case in the transportation sector, where only 20 percent of the energy in gasoline and diesel fuel actually moves our vehicles forward, with much of the rest wasted as heat.[64]

The American Council for an Energy-Efficient Economy (ACEEE) estimates that we can reduce our overall energy use by 40 to 60 percent below current levels

Photo: Walter Siegmund via Wikipedia, CC BY 2.5

Photo: J. N. Stuart via Flickr, CC BY-NC-ND 2.0

Utilizing just a tiny fraction of America's renewable energy resources could power our entire society and render polluting fossil fuel facilities like this Washington oil refinery (left) obsolete.

by mid-century, even as our economy continues to grow, simply by using better technologies and eliminating waste across our economy.[65]

The Sun

Sunlight is clean, safe and available in virtually limitless abundance all across the country. According to the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), the United States could generate more than 100 times as much electricity from solar power installations as the nation currently consumes each year.[66] Each of the 50 states has the potential to generate far more electricity from the sun than its residents, businesses and industries consume.[67]

There are many land areas – both in urban and rural areas – that would be appropriate for building utility-scale solar farms or concentrating solar thermal power plants. Even better, the rooftops of existing homes and commercial buildings can host solar panels – a recent NREL study found that rooftop solar alone has the technical potential to produce 39 percent of the electricity the nation currently consumes each year.[68] Putting solar panels on top of land we've already developed can minimize the amount of new land we will need to use for electricity generation. At the same time, building-mounted solar energy systems are efficient, because much of the power is consumed locally, minimizing energy losses that occur when power is shipped over long distances.

Photovoltaic panels are not the only way we can put solar energy to work. Solar thermal technology directly captures the energy of the sun in the form of heat, either at a utility-scale power plant or on top of a building. Collected heat can be used to provide hot water, space heating, air conditioning and electricity.[69]

The Wind

Just as our ancestors used the power of the wind to sail across the oceans and pump water from the ground, we can use energy in the air to power our economy with modern wind turbines.

With vast stretches of windswept plains and thousands of miles of open coastline, much of America is well-suited for modern wind energy production. According to NREL, wind energy could produce more than 10 times as much electricity as America currently consumes every year.[70] Onshore and offshore wind power in Texas alone could technically generate nearly twice as much electricity as the entire United States uses each year.[71] America's Atlantic Coast is particularly well-suited for power generation from offshore wind as its relatively shallow waters and strong offshore breezes are in close proximity to metropolitan areas with large power demands.

Air also contains heat energy. Using high-efficiency electric-powered air-source heat pumps, we can extract that heat and use it to heat water and keep buildings warm in the winter or cool in the summer.

The Land

We can capture energy from the ground beneath our feet, both in the form of geothermal heat, and from organic materials that come from crop or animal waste.

Geothermal Heat

The temperature of the earth just beneath our feet is constant at around 50 to 55 degrees Fahrenheit, year round. Geothermal heat pumps use this heat to warm homes when it is cold and cool them when it is warm, or to heat water. This technology works anywhere in the United States.

A geothermal heat pump system in a typical building could reduce local consumption of electricity and natural gas by 40 percent or more.[72] That means less need for far-off power plants or drilling for natural gas. Equipping 2 million homes with geothermal heat pump systems would provide about the same amount of useful energy as a large (1 gigawatt) nuclear reactor.[73]

Geothermal Electricity

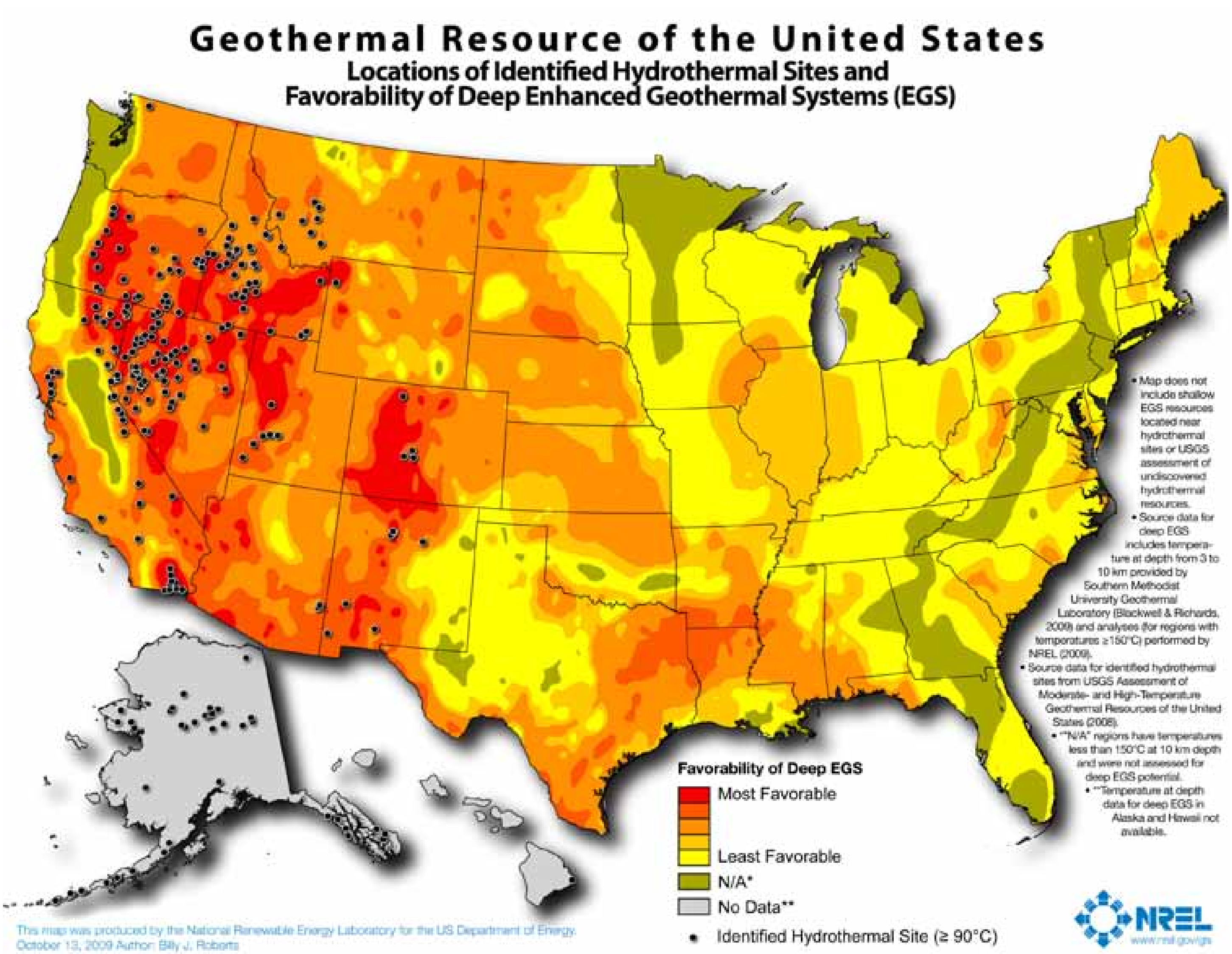
The earth contains heat that we can use to generate electricity. The Union of Concerned Scientists estimates that the first 33,000 feet of Earth's surface contains 50,000 times more heat energy than all of the world's oil and natural gas reserves combined.[74]

Traditional geothermal power plants tap underground reservoirs of hot water, mostly found in the western United States. Enhanced geothermal power technology can access heat reservoirs in many more locations, even when there are no natural deposits of water. (See Figure 3.)

A panel of scientists at MIT estimated that the technical potential for enhanced geothermal energy is at least 2,000 times bigger than all of the energy the United States currently uses for all purposes.[76] Looking only at the best resources and optimum well depths, NREL estimates that enhanced geothermal energy resources in the United Sates could produce as much energy as we currently use for all purposes.[77]

Geothermal electricity is not always clean or safe – risks include groundwater contamination and potential seismic impacts. Proper siting and regulation of geothermal energy production can reduce these risks.

Figure 3. Geothermal Resources in the United States[75]



Biomass Energy

Plant matter and animal waste can be used to produce energy or chemical feedstocks. Biofuels may come to be an important component of a 100 percent renewable energy system, as they can replicate the energy density and ease of transportation of oil. Not all biomass energy, however, is clean or sustainable. The practice of thinning forests for biomass production, for example, can harm local ecosystems. Burning biomass creates unhealthy air pollution. Growing crops specifically for energy can create conflicts with the need to use agricultural land for the production of food. Some types of biomass energy production – like corn ethanol – do not necessarily deliver global warming benefits on a life-cycle basis.

Because of the many potential climate, ecological and food-related impacts of biomass energy production, expansion of biomass use should be limited, undertaken with caution, and focused on serving energy needs that are more difficult to address with other forms of renewable energy.

The Water

Our oceans and rivers contain vast stores of energy – in the form of waves, tides, currents and heat. Capturing a fraction of this energy could generate large amounts of electricity to power our lives, particularly near coastal cities. According to the U.S. Department of Energy, ocean and river energy resources could technically produce 50 percent as much electricity as the United States currently uses each year.[78]

Every part of our coast has access to good energy resources. Waves hold the largest energy generation potential, particularly along the West Coast and along the shores of Alaska. Hawaii and the U.S. Southeast have particularly good resources for ocean thermal energy production, which takes advantage of the temperature contrast between warm surface waters and colder deep water to power an engine and produce electricity. All of the West Coast and much of the East Coast have sites with good tidal energy potential. Southern Florida has access to a particularly strong ocean current as the Gulf Stream wraps around Miami, flowing north. Almost half of the total energy potential for river currents – which can be harnessed without the construction of damaging hydroelectric dams – is in the lower Mississippi River basin.[79]

We Can Make a 100 Percent Renewable Energy System Work for All of Our Energy Needs

There are many possible ways that we could assemble our renewable energy resources into a fully functional, cost-effective and reliable system to meet all of our energy needs. All indications are that going 100 percent renewable is not just feasible, but that it also will be better for our economy than continuing business as usual.

At least seven recent studies have proposed various pathways for replacing all or much of America's demand for fossil fuels with clean, renewable energy. (See Table 1, next page.)

Possible Pathways to 100 Percent Renewable Energy

There are many possible ways that we could harness our clean energy resources to assemble a cost-effective, reliable energy system, largely using existing technologies. Researchers at Stanford University, the World Wildlife Fund (WWF), Greenpeace, the U.S. Earth System Research Laboratory and NREL, among others, have sketched out visions for what such a system might look like.

Stanford University Professor Mark Jacobson has developed plans for every state in the United States, as well as for 139 countries around the

Table 1. High Renewable Energy Scenarios for United States

Author	Year Published	Scope	Timing	Percentage Renewable	Energy Sources Included
MacDonald, et al.[80]	2016	Electricity, U.S.	2030	~63% (low cost renewables case)	wind, solar, hydropower (plus nuclear and gas)
Jacobson, et al.[81]	2015	All energy, U.S.	2050	100%	efficiency, wind, solar, geothermal, tide, wave, hydropower
Greenpeace[82]	2015	All energy, global	2050	100%	efficiency, wind, solar, geothermal, biomass, ocean, hydropower, hydrogen, synfuels
Williams, et al.[83]	2015	Electricity*	2050	>80% (High Renewables case)	wind, solar, geothermal, hydropower
Budischak, et al.[84]	2013	Part of U.S. electric grid	2030	100%	wind, solar, energy storage
National Renewable Energy Laboratory[85]	2012	Electricity	2050	80%	wind, solar, geothermal, hydropower, biomass
WWF[86]	2011	All energy, global	2050	~100%	efficiency, wind, solar, geothermal, biomass, wave & tidal (small pct. of residual fossil fuels)

* High renewables case also included replacement of 83% of gas fuels with biomass and hydrogen and reduction in solid fossil fuels use.

world, to meet 100 percent of their energy needs using energy from the wind, water and sunlight.[87] He concludes that there are no technological or economic barriers to reaching 100 percent clean energy for the United States and the world as a whole. The only obstacles are social and political.[88]

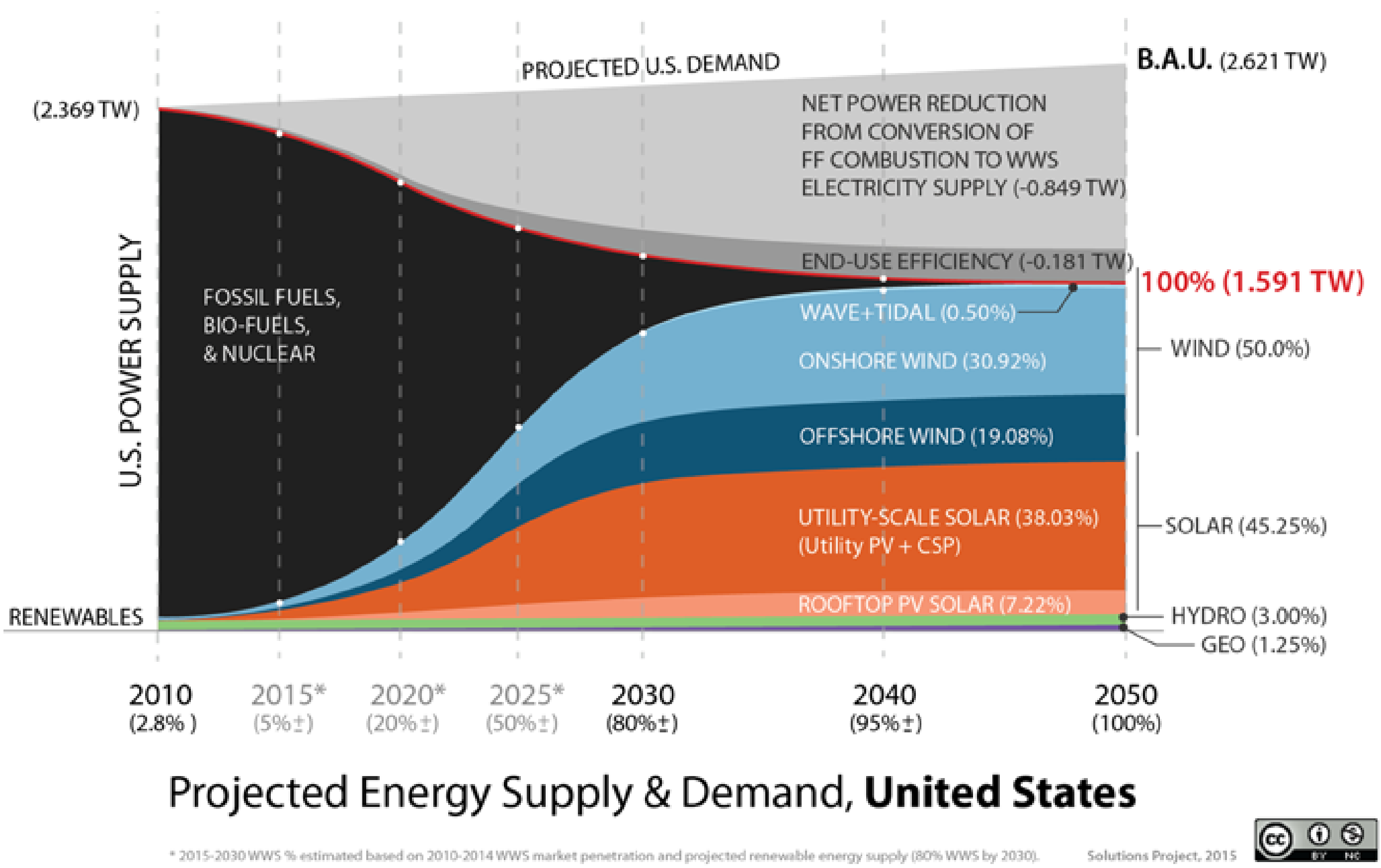
Dr. Jacobson's plan replaces 80 to 85 percent of our dirty energy use with clean resources by 2030, reaching 100 percent by mid-century. (See Figure 4.) In 2050, the U.S. energy mix would consist of 50 percent wind energy, 38 percent photovoltaic solar power, 7 percent concentrated solar power with energy storage, and 5 percent geothermal, wave, tidal, and hydroelectric power.[89] For heavy shipping and airplanes, the plan proposes using electricity stored in the form of hydrogen fuel. The plan avoids biofuels and nuclear power altogether because of concerns about their environmental impacts and safety.

Greenpeace teamed up with the German Aerospace Centre in 2015 to map a pathway to reach 100 percent clean energy across the entire globe by 2050.[91] Under this approach, the world reaches 85 percent renewable power by 2030, then eliminates the remainder of dirty fuel use by 2050. World total energy demand declines by 12 to 15 percent through increased efficiency and by replacing many uses of oil with electricity. The leading sources of electricity generation are wind, solar, hydroelectric, geothermal and ocean energy. The plan puts particular emphasis on decentralized sources of energy, such as photovoltaic panels on building rooftops and geothermal heat pumps. At high levels of renewable energy penetration, the plan relies on "smart grid" demand management plus some energy storage, as well as integration of resources across a wide geography through long-distance power lines.

Researchers at the U.S. Earth System Research Laboratory and the University of Colorado found that it is possible to cut carbon pollution from U.S. power generation by almost 80 percent by 2030 at costs similar to what we pay today. All of the technology we need is already commercially available.[92] The least-cost clean energy system involved a large increase in wind and solar power capacity, plus better power transmission lines. "The surprise was how dominant wind and solar power could be," said Alexander MacDonald, an author of the research, in a NOAA publication.[93]

Scientists at the University of Delaware found that a well-designed electricity system composed solely of wind and solar energy, plus a small amount of energy storage in batteries and fuel cells, could reliably meet America's electricity needs in 2030, at costs comparable to what we pay today.[94] The scientists modeled 28 billion different combinations of renewable energy sources and storage mechanisms over four years of historical weather data for the eastern United States, covering one-fifth of the United States electricity grid. They found that the most cost-effective way to meet our electricity needs was by building extra solar and wind capacity, across a wider region, to minimize the amount of energy storage needed to cover periods of low renewable energy production to only 9 to 72 hours (depending on whether the storage technology used was hydrogen or batteries). Using extra electricity to offset heating uses of natural gas makes the system even more economical.[95]

Figure 4: One Path to 100 Percent Renewable Energy for the United States[90]



Another detailed vision for near-100 percent clean energy comes from the Deep Decarbonization Pathways Project, which has brought together experts from 16 countries to craft country-specific plans for limiting global warming to less than 2° Celsius. [96] Under the "high renewables" vision for the United States, national electricity generation is nearly carbon-free by 2050, and electricity replaces many uses of petroleum.[97] The plan envisions a 30-fold increase in national wind and solar energy capacity, while national energy use decreases 18 to 22 percent thanks to fuel switching and energy efficiency measures in buildings.

World Wildlife Fund teamed up with consulting firm Ecofys in 2010 to map out a pathway to 100 percent clean energy for the world by 2050, using only existing technology.[98] Under this approach, the world reduces overall energy demand by 15 percent through electrification and energy efficiency. The major sources of electrical power are wind, sunlight, biomass and hydropower. Most of the heat necessary for buildings and industry comes from solar thermal collectors or geothermal or air-based heat pumps. Where electrification is impractical, the plan uses biofuels – mainly for airplanes, ships, freight trucks, and high-temperature industrial processes. "Smart-grid" technology helps to manage demand and supply to maintain the reliability of the system.

NREL has created its own study analyzing the viability of a near-carbon-free electricity system, with a focus on the grid impacts and energy supply challenges of 80 percent renewable energy penetration in the United States. The *Renewable Electricity Futures Study* concluded that "renewable energy resources, accessed with commercially available generation technologies, could adequately supply 80 percent of total U.S. electricity generation in 2050 while balancing supply and demand at the hourly level."[99] The study also found "no insurmountable long-term constraints to renewable electricity technology manufacturing capacity, materials supply, or labor availability." [100] In addition, NREL identified solutions to the technical challenges of integrating large amounts of renewable energy into the electric grid, including the addition of transmission infrastructure to deliver energy from remote renewable resources to load centers in order to smooth the generation variability of renewable resources.[101]

Principles for How to Get to 100 Percent Renewable Energy

Although there are many possible ways to achieve a 100 percent renewable energy system, every vision follows the same basic template.

Maximize Energy Efficiency

Repowering America with 100 percent renewable energy will be easier if we reduce the amount of energy we use in the first place. The more efficient we are in our energy use, the easier and the more cost-effective it will be to transition away from dirty fuels. Every path to 100 percent renewable energy includes continuing progress toward the eradication of energy waste in our homes, our businesses and our transportation systems.

Build New Renewable Energy Facilities

Electrifying most of our economy and eliminating coal- and gas-fired power plants will require a dramatic, rapid increase in energy production from wind farms, solar panels, geothermal power facilities, and other renewable energy installations.

For example, under Mark Jacobson's plan for 100 percent renewable energy in the United States, we would need to build:[102]

- More than 300,000 new onshore wind turbines, on top of the 48,000 we already have;
- More than 150,000 offshore wind turbines;
- More than 40,000 new utility-scale solar power plants;

- More than 75 million new residential rooftop solar photovoltaic systems;
- More than 200 geothermal power plants;
- 36,000 wave energy capture devices;
- 9,000 tidal energy turbines;
- 3 new hydroelectric power plants in Alaska; and
- 10,000 solar thermal and concentrating solar thermal power plants with storage, to provide peaking energy services.

Building this infrastructure would require the use of just a fraction of available renewable energy resources, and require a tiny fraction of the land area of the United States. Under the plan described above, new infrastructure would occupy less than 0.5 percent of the land area of the United States, with an additional 1.5 percent of land to space out onshore wind turbines – land that could be used for other purposes like grazing or crops. To put that into context, about 18 percent of U.S. land is currently used for growing crops, and cities and other urban areas occupy 5 percent of all land.[103]

Electrify as Much as Possible

Most of our renewable energy resources are best captured in the form of electricity. That means achieving a 100 percent clean energy system will likely require switching most direct uses of petroleum or gas – like the use of gasoline in cars and trucks and fossil fuel combustion for heating – over to electricity.

Electrification will bring with it dramatic improvements in energy efficiency. For example, electric vehicles are about three times as efficient as conventional gasoline cars.[104] In the Jacobson renewable energy plan, electrification cuts the overall energy we need to run our economy by a third.[105]

Improved technologies, such as air-source heat pumps, are a far cry from the inefficient electric resistance heaters of old and can provide heat and hot water for homes and businesses efficiently and affordably.

Photo: National Wildlife Federation blogs via Flickr, CC BY-NC-ND 2.0

Photo: Tuey via Flickr, CC BY 2.0

Environmental disasters such as the Deepwater Horizon oil spill require vast amounts of paid and volunteer labor to clean up. Switching to 100 percent renewable energy will lead to different kinds of jobs, such as positions in a North Dakota factory that manufactures wind turbines.

While electricity can serve most of our energy needs, there may be some uses of energy – such as for airplanes or certain forms of manufacturing – for which it is less practical. In these cases, other forms of low- or zero-carbon clean energy – such as renewably generated hydrogen fuel or biofuels – may play an important role in facilitating the transition to 100 percent renewable energy.

Ensure Reliability through Grid Improvements and Energy Storage

A 100 percent renewable energy system can be made even more reliable than today's electricity grid.[106] Ensuring reliability will require some combination of grid modernization, transmission upgrades, energy storage capacity, and energy management technology that can help match demand to available supply.

Three factors contribute to the reliability of a renewable energy system:

- Some renewable energy power plants are always available – meaning that they can produce power constantly, or ramp power production up and down as needed. That includes geothermal power, concentrating solar power with thermal storage, and hydroelectric power.
- Integrating wind and solar energy resources across a large geography reduces the variability of the resource. If the wind stops blowing or cloud cover dims the sunshine at one location, wind and solar energy are likely to be available at a different place at the same time.[107]
- Making the grid more intelligent and more flexible can enable us to manage our energy needs and keep electricity supply and demand properly balanced. A more intelligent grid can also minimize energy losses and increase efficiency. The Rocky Mountain Institute has shown that scaling up demand flexibility in the power grid can save customers up to 40 percent on their electricity bills and reduce grid costs by $13 billion per year. Companies are already integrating software into appliances like electric vehicle chargers and thermostats that can make this flexibility possible.[108]

Storing excess energy as heat (in soil or liquids), as kinetic energy (for example, in a pumped water system), or as chemical energy (for example, in hydrogen that can be re-converted to electricity in a fuel cell, or in a grid-connected battery) can provide an additional source of flexibility and maximize the efficiency with which we make use of our renewable energy resources.

Dirty Fuels Have No Inherent Economic Advantage over Renewable Energy

We can switch to 100 percent renewable energy without breaking the bank – and while delivering significant and valuable environmental and health benefits to society. The transition to 100 percent renewable energy will require a significant up-front investment to build the necessary solar panels, wind turbines, electric cars and other infrastructure. But, simply maintaining our current access to dirty energy sources will require massive capital expenditures as well, while investing in access to energy sources with no fuel costs will result in price stability and cumulative savings on fuel. Investment in renewable energy will also create local jobs that cannot be outsourced.

Renewable Energy Is Cost-Competitive

Multiple analyses project that we can build a renewable energy system at comparable costs to what we would have to spend on perpetuating our current system of dirty energy. The main difference is that a renewable energy system will require greater capital expenditure in the near term to build the turbines, solar panels and grid upgrades. That expenditure will be balanced out over time by savings on gas, oil and coal that we would otherwise have to extract and transport to power plants and gas stations. For example:

Photo: KOMUnews via Flickr, CC BY 2.0.

Photo: Paul Cooper via Flickr, CC BY-NC 2.0

Gas prices are a common worry for Americans. Electric vehicles offer consumer savings over the lifetime of the car and produce nearly no emissions when powered by a clean electrical grid. Here, a woman in Missouri fills her car's gas tank and electric vehicles charge in a Massachusetts parking lot.

- The International Energy Agency estimates that limiting warming to 2° Celsius – a plan involving 90 percent renewable electricity – would require an additional $40 trillion investment above a business-as-usual course, or about 1 percent of global GDP per year. That investment would yield savings of more than $115 trillion on fuel by 2050, a net savings of more than $70 trillion.[109]
- Greenpeace estimates that switching to 100 percent clean energy globally would require investment of $1 trillion per year through 2050, which would be more than paid back by an average of $1.07 trillion per year in savings on fuel costs alone.[110]
- WWF finds that going to 100 percent clean energy worldwide would require an initial investment of $1 trillion per year, increasing to more than $3 trillion over the next several decades. The investment would be paid back by 2040 due to savings on dirty fuel, with net savings increasing to more than $4 trillion per year by 2050.[111]
- The ACEEE concludes that increasing overall U.S. energy efficiency by 40 to 60 percent by 2050 would save consumers a net of $400 billion per year (or about $2,600 per household).[112] That savings can help reduce the capital expenditure necessary to switch to 100 percent renewables.
- Stanford professor Mark Jacobson estimates that making the transition to 100 percent clean energy in the United States would save the typical American on the order of $250 per year in energy costs (in 2013 dollars) by mid-century.[113]

None of these cost estimates include an accounting of the additional benefits of a 100 percent renewable energy strategy for the environment and public health. When those benefits are included in the equation, there can be no question that renewable energy is the cost-effective choice.

Renewable Energy Can Eliminate the Social Costs of Dirty Fuels

Dirty fuels have harmful social costs. For example, a recent report by the International Monetary Fund estimated that the economic, social and environmental costs of fossil fuel consumption add up to nearly $5 trillion a year globally.[114] This figure includes damage from global warming, health damage from air pollution, and the more than $200 billion in tax breaks offered to oil, gas and coal companies in 2015.[115]

Switching to 100 percent renewable energy will eliminate much of the social costs of dirty energy. For example, Mark Jacobson's 100 percent renewable energy vision would save on the order of 60,000 to 65,000 U.S. lives per year and improve quality of life and productivity by reducing air pollution-induced respiratory disease. Jacobson estimates that those health benefits would be worth on the order of $1,500 per year per person in 2050 (in 2013 dollars).

Renewable Energy Creates Local Jobs

Switching to 100 percent renewable energy will also lead to a net gain in jobs – and many jobs created in renewable energy industries will be local and impossible to outsource.

Photo: Community Environmental Center via Flickr, CC BY-NC 2.0

A worker installs a thermal solar system in New York City.

Renewable energy is already a major employer in the United States. The wind energy industry now employs more than 73,000 people, with a manufacturing supply chain of more than 500 factories across 43 states.[116] The Department of Energy estimates that by 2050, the wind power industry could support over 600,000 jobs in manufacturing, installation, maintenance and supporting services, with $70 billion per year invested in new capacity additions, repowered capacity, operations and maintenance.[117]

The solar power industry is one of the fastest-growing sectors in the American economy. In 2014, the solar power industry employed 173,000 Americans, and saw investments of nearly $18 billion.[118] The industry added jobs nearly 20 times faster than the overall U.S. economy.[119] The Department of Energy has estimated that the solar energy workforce could grow to 340,000 by 2030 and reach 440,000 by 2050.[120] A transition to 100 percent renewable energy would build on those gains:

- A 2015 analysis of the economic implications of the "Deep Carbonization Pathways" analysis (see page 28) estimated that a "high renewables" case for decarbonizing the nation's electricity system would create a net 2 million additional jobs by 2050, representing a 0.9 percent increase in national employment.[121] Most of the new jobs would be potentially high-quality jobs in the construction, utility and manufacturing industries.
- ACEEE estimates that reducing U.S. energy consumption by 40 to 60 percent through efficiency measures would create a net gain of almost 2 million jobs across the country by 2050.[122]
- Greenpeace estimates that a global switch to clean energy would create 20 million jobs by 2030 and provide energy access to the one third of people globally without it. That is far more jobs than coal, gas and oil currently provide.[123]

Opportunities on the Road to 100 Percent Renewable Energy

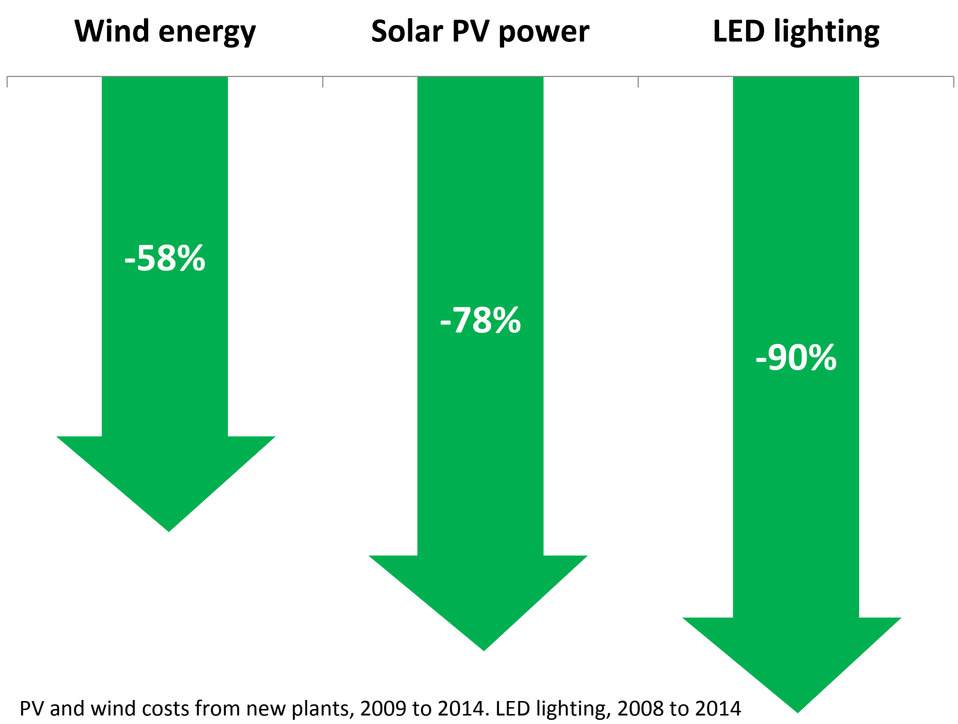
New economic conditions, improving technologies and new social trends are opening the door for an unprecedented transformation of our energy system. Developments that will help bring us to the next level include the rapidly declining cost of renewable energy, continued improvement in renewable energy technologies, promising new tools poised for commercial deployment, and the large and growing base of public support for cleaning up our energy system.

Clean Energy Costs Are Falling Rapidly

Renewable energy is falling in price, transforming the playing field. The cost of key renewable energy solutions has plummeted to levels that would have been hard to imagine even five to ten years ago.[124] And this trend shows no signs of stopping.

Between 2009 and 2014, the cost of wind energy from new plants dropped by 58 percent and the cost of solar photovoltaic power declined by 78 percent in the U.S.[125] In many parts of the United States, wind is now the cheapest source of electricity.[126] Solar energy is also quickly reaching cost parity with natural gas and coal, with utility-scale projects in regions with strong solar resources recently coming in with bids at 4 to 5 cents per kWh – prices that were unthinkable even a few years ago.[127] Industry analysts have found that solar price declines have already outpaced many forecasts for the next decade.[128]

Figure 5. Recent Cost Declines in Clean Energy Technologies[129]



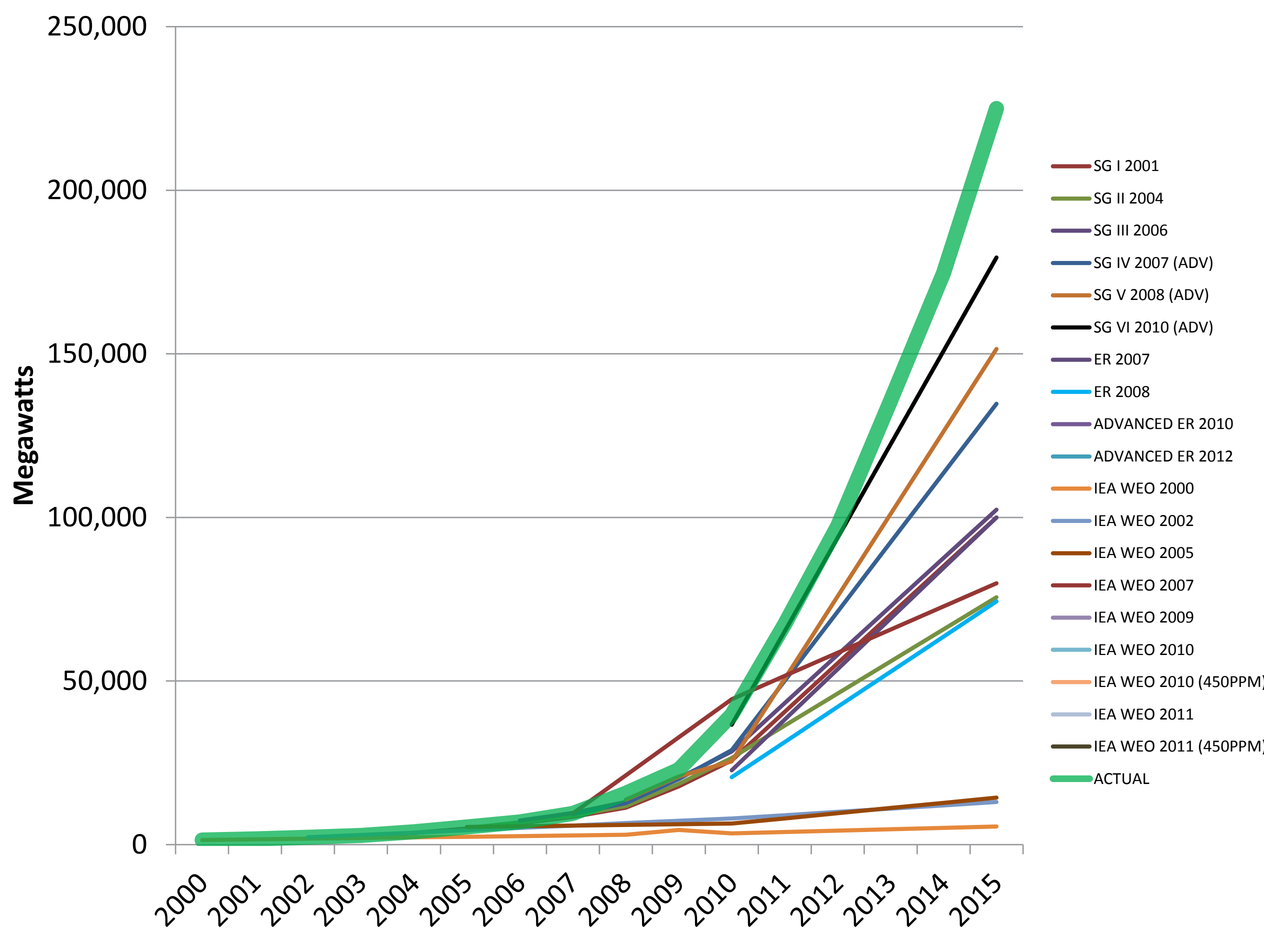
PV and wind costs from new plants, 2009 to 2014. LED lighting, 2008 to 2014

Other clean energy technologies are coming down in price as well.

- The cost of energy-efficient LED lighting technology has fallen by nearly 90 percent since 2008.[130]
- The cost of high-volume battery manufacturing for electric vehicles has fallen by 70 percent.[131] Analysts estimate that the cost of lithium-ion batteries could fall by as much as an additional 50 percent by 2020, bringing the upfront cost of a plug-in vehicle within range of that of gasoline vehicles.[132]
- Since 2006, automotive fuel cells have dropped in cost by more than 50 percent, and doubled in durability.[133]

As costs have come down, an increasing amount of new power supplies have come from renewable energy. In 2015, wind and solar accounted for more than 60 percent of all new power capacity added to the U.S. grid.[134] Over the past 15 years, growth in renewable energy worldwide – especially solar energy – has outpaced most forecasts, even those by environmental advocacy organizations such as Greenpeace.[135] (See Figure 6.)

Figure 6. Global Solar Photovoltaic Capacity (Green Line) versus Projections[136]



Solar energy installations around the world have grown faster than even the most optimistic forecasts made by Greenpeace (SG, ER, Advanced ER), the solar energy industry (SG) and the International Energy Agency (IEA).

Renewable energy costs are likely to continue to drop, because renewable energy is a technology, not a fuel. With every doubling of capacity, solar cell manufacturing costs have gone down about 20 percent, wind turbines by about 7 percent, and electric vehicle batteries by 6 to 9 percent.[137] According to a 2015 analysis by the Fraunhofer Institute for Solar Energy Systems (ISE) in Germany, "solar power will soon be the cheapest form of electricity in many regions of the world" and costs are projected to continue to drop through 2050 – even assuming no new technological breakthroughs.[138]

Further savings can be achieved by implementing strategies to reduce the "soft costs" of solar energy installations, including costs related to customer acquisition, labor, permitting, taxes, and interconnection to the grid. A 2013 study found that the soft costs of solar installations were significantly lower in Germany than in the U.S. and were falling faster with the growth of solar energy.[139]

Additionally, adding more renewable energy to the power grid will tend to undermine the competitiveness of gas- and coal-fired power plants and make renewable energy more attractive. The reason: wind and solar have no fuel costs. As more wind and solar energy is added to the grid, fossil plants operate less – and thus earn less revenue.[140]

Technology Is Improving

With every passing year, industry is making existing clean energy technologies better and more widespread. Technologies that were go-to clean energy solutions a decade ago – such as compact fluorescent light bulbs – are already being supplanted by newer, even more efficient technologies, such as LEDs. Improving clean energy technologies can make them more cost-effective, expand opportunities to move towards 100 percent renewable energy, and empower individuals by giving them a wider range of options to integrate clean, renewable energy into their lives.

Wind and Solar Power

Clean power technology has come a long way in the last decade, and companies are continuing to make meaningful improvements in the performance of wind turbines and solar energy systems. For example:

- Modern wind turbines are almost 50 percent taller and have blades that are more than double the length of turbines made 15 years ago.[141] The U.S. Department of Energy estimates that continued development of taller wind towers, coupled with larger rotors and advanced turbine designs, could increase the power output of wind turbines by two-thirds, making wind power a viable alternative in many areas of the United States where it is currently not an option.[142]
- New technologies are currently being developed to enable the siting of offshore wind turbines in locations with deeper water, including for turbines with floating foundations.[143] As a result of improving technology, the Department of Energy expects that in 2020, the average offshore wind turbine will be able to generate more than 50 percent more power than current designs.[144]
- Commercial solar cells have increased in efficiency by 4 percentage points in the last decade, and there is much room for further improvement. For example, new layered solar cell designs capture multiple wavelengths of light and could deliver twice the power per unit of area of current designs. [145]

Energy Efficiency and Power Management

Information and networking technologies are enabling massive changes in how we communicate with one another, conduct business, and travel. These technologies are also poised to unleash major shifts in how we manage energy use. At the same time, energy efficiency technologies continue to improve. These innovations can both dramatically reduce the amount of energy we use and help regulate the functioning of the electricity grid to ensure reliable service.

A 2015 report by the American Council for an Energy-Efficient Economy (ACEEE) identified 18 technologies not currently in widespread use that each have the potential to reduce electricity consumption by 1 percent or more by 2030.[146] Among them are technologies that fall under the banner of what ACEEE calls "intelligent efficiency" – a new category of energy-saving strategies that harness the power of information technology.[147]

Improving energy efficiency has traditionally meant making technical changes to the design of buildings or specific pieces of equipment – for example, improving the aerodynamics of a car or installing insulation in an old house. Today, however, new technologies make it possible to improve the performance of entire energy *systems* – to see sources of energy waste that had once been invisible, to understand the impacts of changes in our behavior on energy use, and to enable our machines to respond instantly and intelligently to feedback they receive from users or the grid.

In the home, for example, intelligent efficiency measures might:

- Track your energy use in near-real time, enabling you to identify sources of energy waste and take action.
- Enable you to control your furnace or appliances remotely and provide you with information on how to use your household equipment more efficiently.
- Enable "smart power strips" to automatically turn off electronics that are no longer in use or "smart windows" to shade windows on sunny days to keep rooms cool.
- Have your home's energy consumption patterns assessed remotely by an efficiency expert, allowing for quick, inexpensive recommendations for improvements in home energy efficiency.
- Allow equipment to respond to signals from the grid – for example, delaying a wash cycle during times when electricity demand and prices are high – saving money, allowing for more efficient use of the grid, and giving grid operators new options for balancing supply and demand in order to keep the lights on reliably.

These and other measures have tremendous potential for reducing energy use in homes, businesses and industry. An ACEEE study estimates that intelligent efficiency measures in the commercial and industrial sectors alone could save $55 billion in energy costs annually by 2035, with energy consumption reductions of 28 percent in the commercial sector and more than 20 percent in the industrial sector.[148] Economy-wide, ACEEE estimates that intelligent efficiency measures could reduce energy use by 12 to 22 percent.[149]

The potential for efficiency improvements also extends to building better products. For example, the Department of Energy anticipates that the efficiency of LED lighting can be doubled with further technology development.[150] By 2030, LEDs could drive a 40 percent reduction in energy consumption for lighting relative to baseline forecasts.[151]

By putting energy efficiency and renewable energy technologies together, we can make buildings and factories that generate as much energy as they use.[152] As of 2015, there are more than 190 examples of net-zero energy schools, businesses and institutions all across the country, in every type of climate.[153] These buildings – such as the TD Bank offices in Fort Lauderdale, Florida, and a Walgreen's retail store in Evanston, Illinois – include both new construction and retrofits.[154] California has established a goal of having all new residential buildings be net-zero energy by 2020, with all new commercial buildings achieving that standard by 2030.[155]

Industrial facilities have the potential to be net-zero energy as well. The Tesla battery "Gigafactory" under construction in Nevada will be the world's largest net-zero energy building when it is complete in 2017. It will run on 100 percent clean energy generated on site.[156] It will also produce batteries for home energy storage that will support the development of net-zero energy homes.

Transmission Infrastructure and Service Reliability

Connecting the entire U.S. electricity grid with high voltage direct current (HVDC) power lines could enable increasing penetration of renewable energy without the need for backup power or energy storage.[157] These types of power lines are good for transmitting power over long distances with high efficiency, and they are now in use at many locations around the world.

Scientists at the U.S. Earth System Research Laboratory and the University of Colorado found that building the equivalent of an interstate highway system for electricity would enable clean electricity to be delivered anywhere in the country. Because the wind is usually blowing somewhere – and because clouds don't cover up the sun everywhere all the time – this network of transmission lines could enable wind and solar energy to replace most dirty electricity, and do so within 15 years.[158]

Energy Storage

Grid-connected energy storage can also help to guarantee reliability of electricity service, especially during periods when the sun isn't shining or the wind isn't blowing.

Many technologies can be used to store energy, including pumped water, flywheels, thermal storage and compressed air storage.[159] But perhaps the most exciting prospects for energy storage are in the realm of batteries. Driven by advances in consumer electronics, research for electric vehicles, and growing economies of scale, battery storage is becoming an increasingly feasible and cost-effective option. Battery solutions are being deployed at scales appropriate for distributed, in-home use; and for utility-scale grid backup.[160]

As production increases, prices will continue to drop.[161] One recent analysis predicted that the lithium-ion battery market would quadruple from 2013 to 2020, and Tesla Motors expects its "Gigafactory" alone will produce more lithium-ion battery capacity in 2020 than the entire global market produced in 2013.[162] A 2015 analysis by IHS estimates that the cost of lithium-ion batteries for electricity storage fell by half between 2012 and 2015 and can be expected to fall by a similar percentage between 2015 and 2019.[163]

California has adopted an energy storage requirement for utilities, requiring the installation of an additional 1.325 GW of storage capacity by 2020, or 3 percent of California's statewide peak electric load.[164] But energy storage is proving to be economically competitive even without the mandate; in 2014, energy storage technologies won bids to provide a share of the electricity currently provided by the retiring San Onofre nuclear power plant. Winning technologies included batteries as well as units that make ice during nighttime, off-peak hours and provide cooling to buildings during the daytime.[165]

Outside of California, Texas utility Oncor has proposed a $5 billion investment in energy storage beginning in 2018.[166] Utility giant NextEra Energy announced in September 2015 plans to invest at least $100 million in U.S. storage projects during 2016 alone.[167]

All of these projects will help the grid reliably incorporate increasingly large amounts of renewable energy.

Zero-Emission Transportation

Transportation technology is also undergoing a revolution. Electrification of vehicles is beginning to occur, with new technologies enabling electricity to power many different kinds of vehicles, from motorcycles to trains. Consider:

- Just five years ago, there were only a handful of plug-in vehicle models available. Today there are more than 70 types of plug-in vehicles made by nearly every major vehicle manufacturer – from sedans to city buses.[168] Plug-in cars are entering the market twice as quickly as hybrids did.[169]

- North American electric bus manufacturer Proterra is building a manufacturing facility in California that is anticipated to go online in early 2016. The company estimates that the total lifetime cost of one of its electric buses is already about 25 percent less than a conventional diesel bus. The company has taken hundreds of orders from transit agencies around the United States. CEO Ryan Popple told *Charged* magazine: "Right now, there is a quiet EV revolution occurring across North American transit agencies, and we believe that the transit vehicle market will be the first transportation market to eliminate petroleum."[170] The same revolution is happening in Europe. For example, the Amsterdam transit agency plans to electrify its entire fleet by 2025.[171]

- Trucks mainly used for short trips, such as hauling freight from rail depots or warehouses to stores, could be electrified relatively easily because they drive short routes and park overnight in places with available power supplies.[172] Several U.S. companies are already replacing trucks' diesel-fueled powertrains with electric ones.[173] The Port of Los Angeles has tested 14 zero-emission trucks and tractors since 2008, and plans to deploy another 200 zero-emission trucks by 2020.[174]

- Companies are deploying "fast charging" technology to extend the useful range of electric vehicles. For example, a Tesla "supercharger" can deliver 170 miles of electricity to a Model S car in as little as 30 minutes.[175] Other companies, such as Foton in China, are deploying buses and other heavy duty trucks that can be recharged wirelessly in 10 to 15 seconds, or buses with longer range than can be recharged at a station in 10 to 15 minutes.[176]

- Electrified, high-speed rail systems around the world compete effectively with air travel over short to moderate distances, reducing demand for jet fuel and increasing the use of local transit networks.[177] America's sole high-speed rail line – Amtrak's Acela, which runs in the Northeast Corridor – has proven to be very popular, while plans for new high speed rail lines are moving forward in California and Texas.[178] Electrification can also replace fossil fuels on intercity and commuter rail systems.[179]

Promising New Tools Are On the Way

While we already have all of the basic technology we need to go to 100 percent renewable energy, there are some areas of the economy where a switch to renewable energy is easier than others. The energy density and storage potential of fossil fuels is particularly valuable when it comes to long-distance transportation and industry. In addition, emerging technologies can help America to achieve 100 percent renewable energy more efficiently and at lower cost.

Storing Excess Electricity as Hydrogen Fuel

Currently, when wind farms or solar energy systems generate more power than the electrical grid needs, that power is wasted. While this doesn't happen much today, given the limited penetration of solar and wind power on the grid, it may occur more frequently in the future as renewable energy is added to the grid. In theory, that extra electricity could be used to make hydrogen fuel. Hydrogen fuel could be stored in tanks for later use – either to put power back onto the grid when it is needed, or to power long-haul freight trucks, trains, ocean liners or other types of energy-intensive transportation that may be difficult to electrify.[180]

Air Travel with Biofuel or Hydrogen

Air travel is perhaps the most challenging transportation mode to decarbonize, because of the energy density needed to get an airplane off the ground.[181] The main options for powering air travel without contributing to global warming are:

- Hydrogen jet engines,[182]
- Biofuels,[183]
- Synthentically produced hydrocarbons, and[184]
- Batteries.

Biofuels could also provide an alternative energy source for aviation. Manufacturers have made jet fuel from a variety of different kinds of non-food plant matter – fuel that can be dropped into existing infrastructure and burned in existing jet engines without complications. Airlines have completed test flights, and since 2011, some commercial passenger flights have included partial biofuel energy.[185] The main challenges going forward with biofuels lie in scaling up the best technologies, reducing costs, and ensuring sustainable land and ocean use.

Public Support for Renewable Energy Is Large and Growing

Widespread public support for renewable energy sets the stage for achieving a transition to 100 percent renewable energy. In a March 2015 poll, for example:[191]

- 79 percent of Americans wanted the nation to use more solar energy, and
- 70 percent wanted the nation to use more wind energy.

A July 2015 poll of voters in eight key swing states revealed strongly positive reactions to the idea of going to 100 percent clean and renewable energy. More than two-thirds of respondents supported 50 percent clean energy by 2030 and 100 percent by 2050.[192] Support for the goal spanned party lines. A majority of voters were also very supportive of specific policies to accelerate clean energy development, including job training, efficiency requirements and programs, modernization of the electricity grid, incentives for clean energy, and renewable electricity standards.[193]

Increasingly, public officials are realizing that we are at a point where the politics, the economics and the technology are all there to support bold action. Cities and states that have adopted 100 percent renewable energy goals or policies include:

- San Diego, the eighth-largest city in the country, governed by Republican Mayor Kevin Faulconer, recently adopted a policy to reach 100 percent clean and renewable energy by 2035.
- The state of Hawaii passed a law requiring 100 percent clean and renewable electricity by 2045.
- Fourteen other U.S. cities, including San Francisco, CA, Georgetown, TX, and Fort Collins, CO, have made similar commitments.[194] Burlington, VT, and Aspen, CO, have already achieved 100 percent clean and renewable electricity.

America is ready for 100 percent renewable energy. Now it is time to push the transition into high gear with smart policies that can accelerate our progress and maximize the benefits.

It is also possible to make jet fuel using electricity and carbon dioxide from the air, yielding synthetic hydrocarbon fuels almost identical to jet fuel.[186] The main challenge is how to get the carbon dioxide out of the air at scale, for reasonable cost. More research and development could yield advances that could make synthetic jet fuel more accessible.[187]

Finally, battery technology remains decades away from carrying sufficient energy per unit of weight to power long-distance, commercial air travel, but may develop to the point of providing travel on smaller or short-haul planes.[188] Airbus has developed a two-seater prototype electric plane, the E-Fan 2.0. Building on this technology, the company believes that it will be able to market an 80- to 90-seat regional airliner with zero emissions by 2030.[189]

Industry

Manufacturing facilities have unique and specialized energy needs. Various technologies – including biofuels, solar thermal and geothermal energy, and heat pumps can produce heat sufficient to meet a variety of industrial needs.[190] Continued advances in technologies such as high-temperature solar thermal installations and heat pumps can expand the share of industrial energy use that can be met with renewable energy in the near future.

Accelerating the Transition to 100 Percent Renewable Energy

Our transition to a renewable energy system has already begun. But to meet the challenge of addressing global warming and fulfilling our commitments under the Paris Climate Agreement, we need to step up the pace.

Leaders in government, business and civil society should embrace the idea that 100 percent renewable energy is feasible and necessary – and act to accelerate our progress. We need to reform America's energy policy to facilitate mass deployment of clean energy solutions, support research and development of essential new technologies, and keep much of our coal, oil and gas reserves in the ground.

Set Ambitious Goals

Towns, cities, states and the nation should establish public goals to achieve 100 percent renewable energy and develop plans and policy roadmaps sufficient to achieve the goals.

Maximize Energy Efficiency

Governments should maximize our use of energy efficiency opportunities. The more efficient we are, the less infrastructure we will need to reach 100 percent clean, renewable energy. Every state and every city should adopt a suite of policies to eliminate energy waste by creating or continuing energy efficiency programs, adopting net-zero energy building codes, and implementing building energy retrofit standards, among other measures.

Accelerate Renewable Energy Deployment

Leaders should act to make developing clean energy resources more attractive and easier to accomplish. A broad range of policies – including incentives, renewable energy standards, and provisions to eliminate hurdles to renewable energy deployment – can accelerate the pace at which the energy industry develops America's solar, wind, geothermal and ocean energy resources. Accelerating deployment doesn't just get more renewable energy onto the grid today, but it also spurs innovation in business models and technology that expand access to clean energy over time.

At the same time, we need to act to accelerate the penetration of clean electricity into new sectors of our economy, including transportation. Public policy can help facilitate the transition by providing financial incentives for emerging technologies, making appropriate investments in infrastructure to encourage their use, and requiring manufacturers to include clean energy technologies in vehicles.

Modernize the Electricity Grid

America should bring our electricity grid into the modern age, enabling us to balance demand for electricity with growing supply of clean, renewable power. The nation should take steps to upgrade transmission lines to integrate wind and solar across a much wider geography; facilitate the incorporation of demand flexibility tools into our appliances and buildings and into grid-management plans; and add grid-connected storage for renewable energy where necessary and economical.

Keep Dirty Fuels in the Ground

America cannot afford to continue to build infrastructure for the extraction, processing and combustion of fossil fuels – especially since that infrastructure will need to become obsolete within a generation if the nation is to meet its obligation to address climate change. The nation should immediately move to reverse policies that incentivize the extraction or use of fossil fuels, remove government subsidies for fossil fuel production or use, keep important and ecologically sensitive areas of the country off-limits to fossil fuel production, oppose the opening of new areas such as the Atlantic Coast to oil production, and stop the construction of major new pieces of fossil fuel infrastructure such as the Keystone XL pipeline. Limits on global warming pollution should be strengthened where they exist – and established where they do not – covering every corner of our economy.

By taking these bold steps, the United States can achieve the promise of an economy powered entirely with clean, renewable energy – clearing our air, fueling economic growth, keeping our communities safe and secure, and, perhaps most importantly, striking a decisive blow against global warming and for a habitable climate for future generations.

Opportunities Afforded by the Clean Power Plan

In early 2016, the U.S. Supreme Court issued a stay on the implementation of the Clean Power Plan (CPP). The CPP is the single largest step taken to date to limit global warming pollution in the United States and, if and when it is implemented, will create a golden opportunity for states to lay the groundwork for a transition to an energy system powered with 100 percent renewable energy.

To meet that promise, state plans for compliance with the CPP should:

1. Maximize energy efficiency first.
2. Reduce pollution more than required by the EPA. Clean Power Plan targets are a floor, not a ceiling, for action.
3. Focus on clean, renewable energy resources – including wind and solar power – to meet any new needs for electricity.
4. Avoid investment in dirty fuels. Building new natural gas-fired power plants comes with the risk that that investment would be stranded and unusable as the nation ratchets up its climate action pledge under the Paris Climate Agreement.
5. Structure the Clean Power Plan compliance approach to provide funding for clean energy programs, including energy efficiency.
6. Take advantage of the Clean Energy Incentive Program which rewards the early use of solar, wind and energy efficiency in low-income communities and communities of color.

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