Vox

How to drive fossil fuels out of the US economy, quickly

The US has everything it needs to decarbonize by 2035.

By David Roberts | @drvox | david@vox.com | Aug 6, 2020, 10:10am EDT

The roof of the 96,000-square-foot "Circa" building on Platte Street in the Lower Highland neighborhood in Denver, Colorado, is covered by solar panels. | Hyoung Chang/The Denver Post via Getty Images

In the runup to World War II, President Franklin Delano Roosevelt enlisted the entire US economy in an effort to scale up production of war material. All of the country's resources were bent to the task. In 1939, the US had 1,700 aircraft; in 1945, it had 300,000 military aircraft and 18,500 B–24 bombers.

By the time the war was won, the economy was up and humming with a massively expanded workforce (drawing in women and African Americans) and turbocharged productive capacity. Investments made during the war mobilization yielded a robust middle class and decades of sustained, broadly shared prosperity.

A similar mobilization will be necessary for the US to decarbonize its economy fast enough to avert the worst of climate change. To do its part in limiting global temperature rise to between **1.5° and 2° Celsius**, the US must reach net-zero carbon emissions by 2050 at

the latest. To achieve this, the full resources of the US economy must be bent toward manufacturing the needed clean-energy technology and infrastructure.

FDR began with two questions. First, he asked not what was politically feasible but *what was necessary* to win the war. He also asked not how much funding was available in the federal budget but how much productive capacity was available in the economy — *what was possible*.

Saul Griffith is trying to answer those same questions on climate change: what is necessary, given the trajectory of global warming, and what is possible, given the resources in the US economy.

Saul Griffith | Courtesy of Saul Griffith

A physicist, engineer, researcher, inventor, serial entrepreneur, and MacArthur "genius" grant winner, Griffith's recent work spans two organizations. First, he is founder and chief scientist at **Otherlab**, an independent research and design lab that has mapped the energy economy.

And alongside Alex Laskey, co-founder of **Opower**, he recently started **Rewiring America**, which will develop and advocate for policies to rapidly decarbonize the US through

electrification. (The organization is going to release a book called — be still my heart — *Electrify Everything*.)

Last week, Rewiring America made its big debut with a **jobs report** showing that rapid decarbonization through electrification would create 15 million to 20 million jobs in the next decade, with 5 million permanent jobs after that. For the most part, the media covered it as just another jobs report, saying basically what other clean-energy jobs reports have said.

But the jobs are, in many; ways, the least interesting part of the work. Much more interesting is Griffith's larger project the model he's built and its implications.

In a nutshell, he has shown that it's possible to eliminate 70 percent to 80 percent of US carbon emissions by 2035 through rapid deployment of existing electrification technologies, with little-to-no carbon capture and sequestration. Doing so would slash US energy demand by around half, save consumers money, and keep the country on a 1.5° pathway without requiring particular behavior changes. Everyone could still have their same cars and houses — they would just need to be electric.

"The report reinforces a key finding," says Leah Stokes, an environmental policy expert at the University of California Santa Barbara. "Cleaning up the electricity system solves the lion's share of the problem. It allows us to electrify our transportation and building sectors and parts of heavy industry, which would address more than 70 percent of total emissions."

Some of Griffith's conclusions run contrary to conventional wisdom in the energy space. And they are oddly optimistic. Despite the titanic effort it would take to decarbonize, the US doesn't need any new technologies and it doesn't require any grand national sacrifice. All it needs, in this view, is a serious commitment to building the necessary machines and creating a regulatory and policy environment that supports their rapid deployment.

The humble heat pump. | Shutterstock

In this post, I will walk through the energy data he's assembled, what the data reveals about the fastest way to decarbonize, how fast that decarbonization could be accomplished, why it's doable, its political challenges, and its political promise.

Griffith's work is among the most interesting contributions to the climate discussion in ages. There's a lot here, but it is worth your time. Let's start with how he built the model.

How energy is used in the US economy, explained

In 2018, after applying for years, Otherlab was finally awarded a contract from the Department of Energy's Advanced Research Projects Agency-Energy to assemble in one place, for the first time, all publicly available data on how energy is used in the US.

As it happens, the US has great energy data. In response to the oil crisis of the 1970s, presidents created the Energy Information Administration, the Department of Energy, and the Environmental Protection Agency. Those agencies began gathering data on how energy is generated, transported, and used in various parts of the economy, and since have accumulated an enormous catalog.

Oddly, all that data has never been gathered, harmonized, and put in a single database. So Griffith and colleagues spent years poring over agency output from the last 50 years — he ruefully cops to being "the only person on the planet who has read every footnote of every DOE report since 1971" — and assembling it in a massive dashboard, which you can view **here**.

It tracks where every unit of energy enters the economy and how it is used as it passes through.

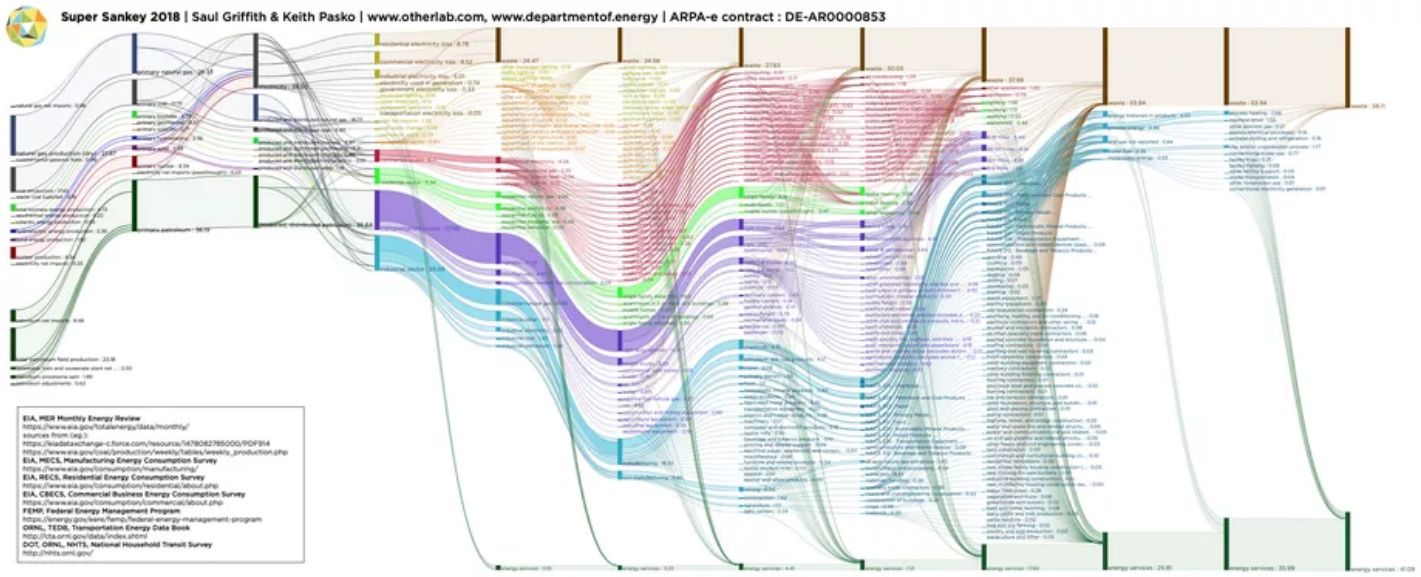


Figure 1: *A high resolution Sankey flow diagram of all US energy flows.*

A zoomed-out image of Griffith's visualization. | Rewiring America/Saul Griffith

This is not a model, per se, it's just lots and lots of data visualized, a close-up "machine-level" view of energy flows in the US economy. But having the data in one place provides the raw material for Rewiring America to build a high-resolution model of what it would actually take to decarbonize — how many machines must be built, what kind, and how fast.

"Where most studies look at decarbonization in specific individual sectors such as transportation, the electricity grid, or buildings — and mostly only on the supply side," the Rewiring America report says, "we build a model of the interactions of all sectors, both supply and demand, in a rapid and total decarbonization."

The fastest way to decarbonize is to electrify everything

Griffith begins with a core assumption: We need to make a plan to solve the problem with the tools available. It is unwise, for instance, to bet on a large amount of carbon capture

and sequestration coming online in time to make a difference. The technologies are still in the early stage and there are **strong arguments** they will never pencil out.

Griffith takes a "yes, and" approach. If carbon capture sequestration works out, great. If next-gen nuclear reactors work out, great. If hydrogen-based fuels work out, great. But we shouldn't rely on any of them until they are real. We need to figure out how to do the job with the technology available.

On that score, Griffith's modeling reaches two key conclusions.

First, it is still possible to reduce US greenhouse gas emissions in line with a 1.5°C pathway. Specifically, it is possible to reduce US emissions 70 percent to 80 percent by 2035 (and to zero by 2050) through rapid electrification, relying on five already well-developed technologies: wind and solar power plants, rooftop solar, electric vehicles, heat pumps, and batteries.

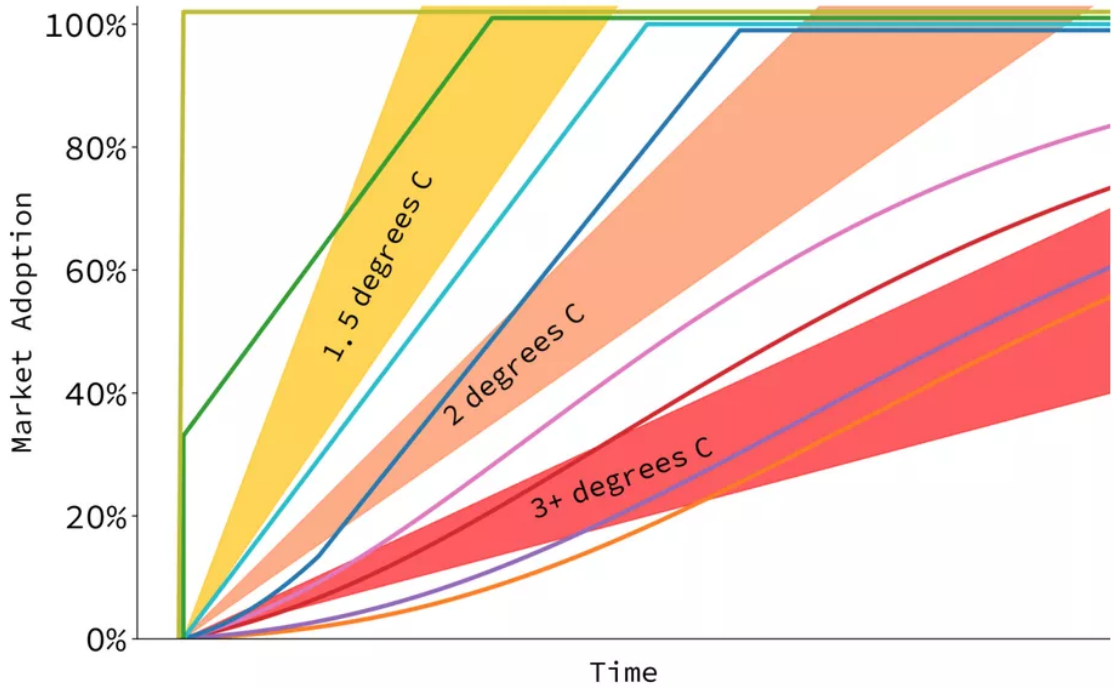
Think of those technologies as the infrastructure of 21st century life. If everyone uses carbon-free energy to heat their homes and get around, the bulk of the problem will be solved.

Second, to decarbonize in time, substitution of clean-energy technologies for their fossil-fuel counterparts must ramp up to 100 percent as fast as possible, after a brief period of industrial mobilization. Every time a gas or diesel car is replaced, it must be replaced with an EV; every time an oil or gas furnace is replaced, it must be replaced with a heat pump; every time a coal or gas power plant goes offline, it must be replaced with renewable energy.

Rewiring America/Saul Griffith

There is no room left in a 1.5° or 2° scenario for more fossil fuel infrastructure or machines.

We need to radically ramp up production of electrification technologies and implement the policy and financing tools that will enable 100 percent substitution.



Clocking the maximum feasible transition to clean energy

Griffith and his colleagues set out to model a "maximum feasible transition" to carbon-free energy, limited only by the country's production capacity. They describe it like this:

> The maximum feasible transition (MFT) involves two primary stages: (i) an aggressive WWII–style production ramp–up of 3–5 years, followed by (ii) an intensive deployment of decarbonized infrastructure and technology up to 2035. This includes supply–side generation technologies as well as demand–side technologies such as electric vehicles and building heat electrification.

When it says production ramp-up, it's no joke. Within three to five years, production of electric vehicles would have to increase four-fold, batteries 16-fold, wind turbines 12-fold, and solar modules 10-fold.

Accommodating all those new electricity loads would also mean expanding the size of the grid by three- or four-fold. "Today, we deliver about 450 gigawatts constantly," says Griffith. "In the model of the future — where everyone's house is the same size, everyone's car is the same size, but it's all electrified — you need to deliver 1,500 to 2,000 gigawatts."

(To be clear, Griffith doesn't necessarily think Americans *should* keep driving giant cars and living in giant houses. He supports urbanism and cycling and downsizing generally. He spent many years running **a radical downsizing experiment on his own life**. But he wants the public to know that changing their lifestyle is not *necessary* for decarbonization.)

Almost all the heavy lifting in the maximum feasible transition is done by electrification, "the exception being 5-10 Quads of non–electrical energy sources coming from [biofuels]" the Rewiring America report says. "Hydrogen or other synthetic fuels (which are generated from electricity) are deployed for a few high–temperature applications. The scenario does not rely on any deployment of carbon capture and storage, and all primary energy sources are net zero."

In terms of generation, wind and solar do the bulk of the work, "along with a doubling of the current nuclear electricity fleet from 100GW to 200GW." In particular, distributed energy (rooftop and community solar and batteries) plays a huge role, "accounting for around 25% of energy supply and a high degree of the storage capacity" would reduce the amount of energy the US needs by half.

One key aspect of electrification makes this transformation possible, and it represents perhaps the most astonishing finding in Griffith's modeling: Large-scale electrification would slash total US primary energy demand in half, from around 100 quads to about 45-50. This a huge deal — it means America only needs to produce about half the energy with renewables that it is currently producing with fossil fuels.

And that massive drop in demand assumes no behavior change, no insulated buildings or double-glazed windows, no traditional "efficiency" measures of any kind. The transition from fossil fuel combustion to electricity, in and of itself, is the largest demand-side climate policy available.

How is that possible? The simple answer comes down to the fact that electric motors are more efficient than fossil fueled motors at converting primary energy into useful work.

The somewhat more complicated answer is this. You cut almost 10 percent off of energy demand right off the bat, says Griffith, because the Energy Information Administration has been overestimating, due to the way it accounts for nuclear and hydroelectric energy. (It's too complicated to get into here.)

Another 10 percent of energy used in today's economy goes toward "finding, mining, refining, and transporting fossil fuels," Griffith says, and that demand goes away in an electrified economy. So it's down to 80 percent left to replace.

Shifting from fossil fuel power plants to renewable energy saves another 15 percent, because carbon-free, non-thermal power sources rely on fewer energy conversions than thermoelectric sources. Electrifying transportation gets another 15 percent, because electric vehicles (EVs) are more efficient than internal combustion engine (ICE) vehicles. Electrifying buildings gets another 6 percent to 9 percent.

To be clear, the US could reduce demand even more if it continued to better insulate buildings and other efficiency measures, if it downsized homes, drove less, and relied more on walking and electric cycling to get around.

But it is worth emphasizing, again: The biggest demand-side policy by far is electrification, which could slash US energy demand by half.

"You can't efficiency your way to zero," Griffith says. "You have to transform."

EVs are more efficient than ICE vehicles. | Shutterstock

Industry is not as big a carbon problem as it appears

The alleged difficulty of decarbonizing heavy industry has been a major topic in carbon circles lately. (I have **written about it myself**.) It is one of the reasons often offered for why **large-scale negative emissions** will be needed.

Griffith disagrees. He points out that a big chunk of the carbon emissions attributed to industry are devoted to fossil fuels and will disappear as they do. For instance, 4 percent to 5 percent of US energy is used to turn oil into gasoline, a subcategory of industry that will decline along with ICE vehicles.

As for the rest, “steel is tiny, and we can use hydrogen to make steel,” he says. “Aluminum traditionally makes a lot of CO2 because we use carbon electrodes for the smelting process; Alcoa and Rio Tinto already have carbonless electrodes for aluminum. Cement is still hard, but that’s only 1 percent. And the rest of industrial heat can mostly be done with induction for high-temperature heat or heat pumps for low-temperature heat.”

In short, industry is a problem, but a relatively small one. “It’s the last 5 percent of emissions,” Griffith says. “It’s hardly the thing that should stop us.”

There’s no way to accomplish a rapid energy transition with market-based policies

In his decarbonization “**field manual**” (written with colleagues, also on the Rewiring America site), Griffith is frank about what will be necessary to drive the MFT:

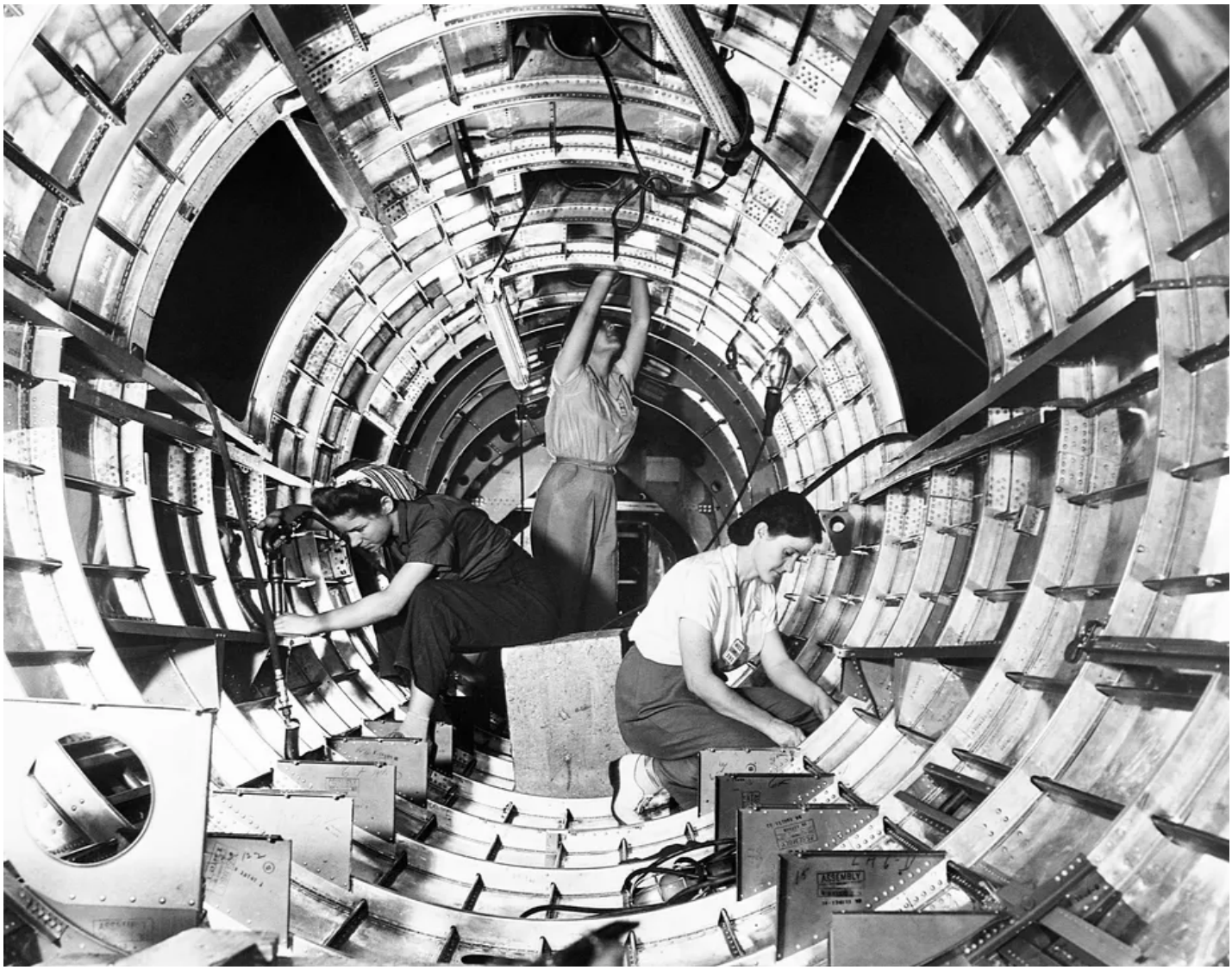
> A 100% adoption rate is only achieved by mandate. The invisible hand of markets is definitely not fast enough; it typically takes decades for a new technology to become dominant by market forces alone as it slowly increases its market share each year. A carbon tax isn’t fast enough, either. Market subsidies are not fast enough.

Businesses and the market can and will help, he says, but “when Mother Nature arm–wrestles with the invisible hand, she will always win.”

A MFT cannot be accomplished through the usual incremental tax tweaks. A three- to five-year industrial ramp-up, followed by a sustained period of 100 percent substitution, would require wartime mobilization, which entails government taking a direct hand in industry, working with it to hit specific production targets through some mix of incentives, penalties, and mandates. For the first three to five years, it would be something more like a command economy than Americans are used to.

It is difficult to imagine such unity of purpose in today’s political circumstances (to say the least), but America has met big challenges with decisive government action before.

And Griffith emphasizes that, in proportional terms, today’s task is less substantial than FDR’s. It took the equivalent of 1.8 US GDPs to win World War II, whereas “the total cost of decarbonizing America is more like 1.2 to 1.5 GDPs,” he says. “Proportionally, it’s a significantly smaller interruption to the economy.”



Workers assemble the tail fuselage of a B-17F bomber at the Douglas Aircraft Company in Long Beach, California, circa 1942. | Corbis/Getty Images

FDR's interventions did not spoil America's market economy, they strengthened it. The enormous investments the US made in its productive capacity yielded an expanded and more egalitarian workforce and decades of prosperity.

Unlike Sen. Bernie Sanders (I-VT), Griffith and his colleagues do not envision government picking up the bulk of the tab for the energy transition. The Rewiring America report says that "the total government share of the expense is likely only $250-350 billion per year, with the total public and private spending over 20 years at about 20-25 trillion dollars." Three trillion in direct government spending over 10 years is well within the range proposed by most Democratic presidential candidates, including former Vice President Joe Biden.

Rather than direct public funding, the MFT leans heavily into the idea that government capital will attract private capital through the establishment of new financing mechanisms.

(Contrary to popular imagination, much of the original New Deal **worked this way as well**.)

The best way to ensure universal access to clean energy is clever financing

Energy infrastructure used to be comprised exclusively of big public projects like dams and high-voltage transmission lines. But in an age of distributed energy, much of what can reasonably be thought of as infrastructure is small and distributed, located "behind the meter," on the customer's property. Solar panels on the roof, a heat pump and a battery in the basement, and an electric vehicle in the garage are 21st century infrastructure — they are all connected to, and interacting with, the grid.

To accomplish the MFT, the US needs to stop financing those behind-the-meter technologies like consumer items and start financing them like infrastructure, with low-cost, government-backed loans.

America has done this before, too. The US invented auto financing in the 1920s, radically democratizing car ownership, and the 30-year, government-guaranteed mortgage in the 1930s, radically democratizing home ownership. During the New Deal, the US invented electric co-ops that could access cheap government loans, radically democratizing access to electricity.

Consumers need access to cheap loans for electrification. How cheap? Griffith writes:

> If we have to pay for it on a credit card, solving climate change will be very expensive — credit card interest rates hover at 15–19%. If we use the common financing options available for [rooftop] solar today, we'll be paying around 8%. If we can pay for it with a government–backed, low–interest rate loan at something like mortgage interest rates of 3.5–4%, it will be affordable for nearly everyone.

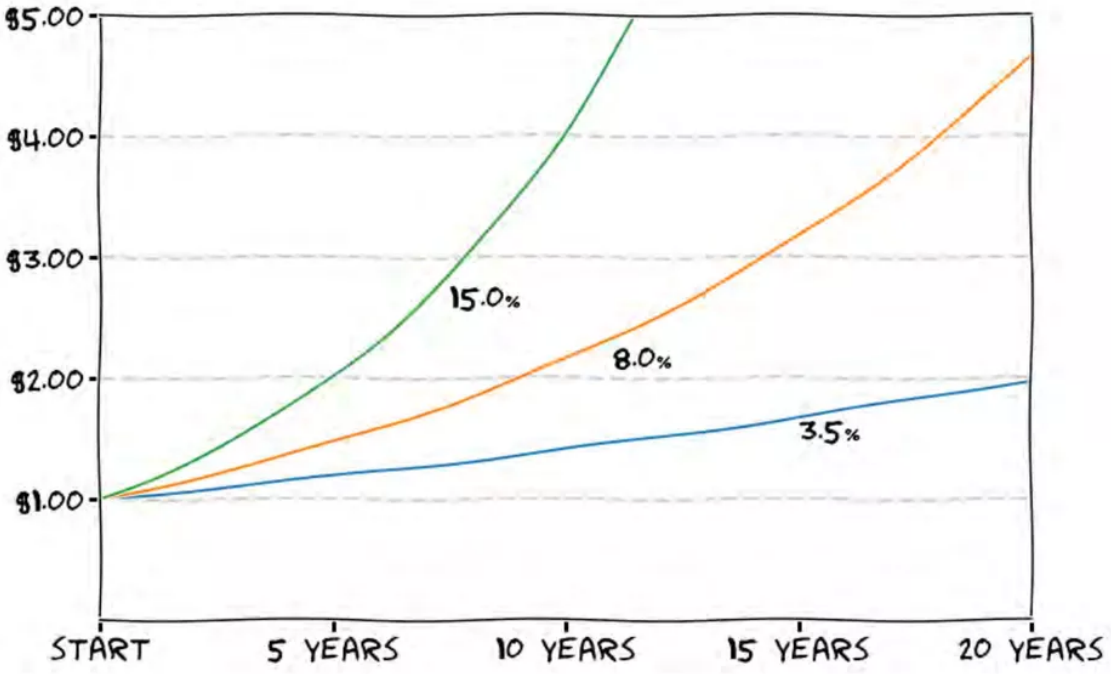


Figure 8.3: *effects of varying interest rates*

Rewiring America/Saul Griffith

For the average American household, going fully electric (rooftop power, heat pump, battery, EV) requires about $40,000. Obviously, most people can't pay that up front, but 4 percent financing could bring it in reach for almost everyone.

So the question is how to extend low-cost, government-backed loans to every homeowner and building owner such that electrification becomes the default choice any time a piece of equipment or roof is replaced.

The Rewiring America team has been thinking about this and will release some formal policy proposals soon. Adam Zurofsky, a constitutional lawyer who helped oversee New York Gov. Andrew Cuomo's climate and energy portfolio and has been consulting with the group, says the first step is determining a "qualifying list of machines," which is no simple matter. Second is determining a target, a state-by-state interest rate that is low enough to make electrification a money-saver for everyone.

Third is extending loans to consumers. Zurofsky mentions several models. One is securitization and "wrapping" of loans, i.e. bundling them and having the federal government guarantee them up to a certain amount.

Another is along the lines of the **Electric Home and Farm Authority** (EHFA), created in 1935 in connection with the Tennessee Valley Authority. The TVA's dams were generating

too much electricity and the government needed consumers to buy more electric appliances, so the EHFA, backed by the Treasury, bought loans directly from businesses that extended low-interest credit to consumers for approved products. Zurofsky imagines something like the same model, only drawing on private capital.

A third is “on bill financing” by utilities, which are already “a long way ahead on customer acquisition and relationships,” Zurofsky says. Local utilities are one of the few entities most Americans trust with energy decisions.

All these models are being batted around as the team thinks over financing. It will be worth revisiting the subject, because as Griffith writes, “if done right, innovative low–cost financing will be the most effective way to ensure equity and universal access to cheap, reliable energy in the 21st century.”

Full electrification will bring all kinds of political benefits

For ages, the climate community has been accused of being too gloomy and doomy, lacking a positive vision for what decarbonization could mean for ordinary folks around the proverbial kitchen table. Climate is said to be too big and abstract to motivate most people, especially if they are being asked to give up things and use less.

Griffith’s model undercuts all that. Its benefits are extremely tangible at a kitchen-table level.

First, obviously a massive industrial mobilization would create jobs. Specifically, the MFT would create “as many as 25 million net new jobs at peak,” with 5 million ongoing new jobs after the initial surge. These jobs would be distributed over every zip code in the US, in a wide variety of well-paying trades and professions. What’s more, the jobs involved in installing solar panels and smart appliances, retrofitting buildings, and constructing high-voltage electricity lines cannot be outsourced. (If you want more on this, the report gets into extreme detail on the types of jobs that will be both destroyed and created, and how they will be distributed.)

A roofer installs a solar panel on a home in Falmouth, Maine. | Ben McCanna/Portland Portland Press Herald via Getty Images

Second, full electrification would practically eliminate most major sources of air pollution, which would bring transformative social and health benefits in the form of fewer respiratory and cardiac illnesses, lower health costs, fewer missed work and school days, and better work and school performance. The benefits would be especially concentrated in low-income and communities of color, which **suffer disproportionately from air pollution**. Electrification of transportation would also eliminate an enormous amount of urban noise pollution (buses would hum rather than roar).

Third, the report concludes that "with appropriate regulatory policies and implementation, energy costs will be lower and the average [US] household will save $1,000–2,000 per year." Even including the cost of building and deploying all those new solar panels, wind turbines, batteries, EVs, and heat pumps, electricity beats fossil fuels on efficiency such that the costs still pencil out in consumers' favor, even in the short term.

Fourth, from the consumer's perspective, electrified life will just be cooler. Electric vehicles are better than ICE vehicles. They have better torque and handling. They can be continuously updated with new features and capabilities over wifi. They have much lower fuel and maintenance costs.

Well-insulated homes and apartments with heat pumps and radiant floor heating are more comfortable than fossil-heated buildings, with far better **indoor air quality**.

Solar panels on the roof coupled with batteries in the garage provide cheap, guilt-free power, a potential income stream, and resilience in the case of grid outages.

You might not notice that your water heater is communicating with your refrigerator, or that they are coordinating with your solar panels and batteries, or that the whole system is coordinating with the larger grid, but you will notice that your power is quietly, invisibly reliable.

All these benefits make perfect sense at the kitchen table, and with the right policy and financing, they can be available to every American.

This is the Green New Deal technical manual

The **Green New Deal** made some lofty demands for rapid industrial mobilization and decarbonization. The response of its critics was often that it lacked a detailed roadmap to accomplish its goals. Griffith has provided that roadmap, with detail down to the machine level. It is possible to substantially decarbonize the US economy by 2035 — we know what to build, how fast to build it, and where to put it.

This is the plan. | Nelson Klein, Sunrise Movement

Where governments have implemented clear standards and invested in electrification technology, it has grown quickly and gotten cheaper. Griffith cites Australian rooftop solar policy, German heat pump policy, and California EV policy as examples.

"The report is clear that our old policy approaches will not cut it," Stokes says. "A carbon tax will not result in sufficient infrastructure turnover at the pace and scale necessary. We need to take a **standards and investment approach** to transform the economy."

American households could have great things: solar on every roof, powering heat pumps in every building, and EVs in every garage, all communicating and coordinating, bringing stability to the grid. Homes could be more comfortable, cities could be quieter, the air could be cleaner, power could be more reliable, energy costs could be lower, and front-line communities could be free of the burden of living next to and suffering disproportionately from fossil fuel infrastructure.

The US could be a more prosperous, healthier, and pleasant place to live.

"For so long we've been sold the lie that we have to choose between a livable planet and a thriving, equitable economy," says Varshini Prakash, executive director of the Sunrise Movement. "The Rewiring America Plan puts that lie to rest once and for all. We can achieve a just transition to a better world out of the wreckage of this economic crisis."

That's the story that needs to be told about tackling climate change. Not a story of privation or giving things up. Not a story of economic decline or inexorable ecological doom. A story about a better electrified future that is already on the way.

We can muster the effort and investment over the next 10 to 15 years to accelerate it, to reach it in time to avert the worst of climate change. We can have clean air, clean energy, a prosperous economy, and a stable climate, all the things we want, if we're just willing to do the work.
