Chapter 12

Making It Happen

The world is indisputably warming — probably by another 1°C from where we are now. This 1°C rise will be painful, especially for the poor, but it is very survivable. (It is already 6°C warmer than it was 15,000 years ago.) A more dangerous problem is a less likely but not impossible scenario: This modest 1°C rise could set into motion latent forces that have not been seen for millions of years and that could in turn cause far larger further temperature increases. In an even less likely scenario, the domino effects could even extinguish our species.

Fossil fuels are almost surely the primary cause of this 1°C warming (although some scientists are still wondering whether it is the only one), and their harmful health effects even absent their global warming effects are terrible. Getting off fossil fuels as soon as possible is now in the interest of humanity. So we need to end our book with observations about what can realistically be done to speed up the worldwide transition to a cleaner planet?

Although we view ourselves as environmentalists, our recommendations are not quite the same as those promulgated by other well-known environmentalists, such as **Greenpeace** or the **School Strike For Climate** (Greta Thunberg's Organization). We have our reasons.

First, we need to be not just against but also in favor of big policies, occasionally even painful ones. Some environmentalists are simultaneously against everything — fossil fuels, **nuclear power**, **hydroelectric dams**, **lithium mining**, **solar cells** even in the desert, **windmills** that can harm birds, new **electric transmission lines**, and **tree felling**. Such indiscriminate endorsements requiring no environmental harm on any dimension are not going to change the world for the better. They only empower the status quo.

Second, we are more concerned about what policies can maintain large-scale popular support for a long time — not just in rich countries but all over the world. If the transition to clean energy is badly managed, the backlash could delay or even stop the green

transition. Energy outages or "back to nature" are bad plans. Nature cannot sustain 8 billion people without modern industry and agriculture. Even if some environmentalists are prepared to accept the consequences, most people are not. They would revolt and the environmentalists would lose.

Third, we are more concerned about what is feasible. Utopian, high-minded, but unrealistic plans will not *move the needle*, not now and maybe never. Yes, we too would love countries to spend their military budgets on humanitarian causes instead — but it won't happen.

Fourth, we are more concerned about efforts that can begin today than problems that will arise in 50 years. (Those are important, too, but we leave their consideration to others.) Quoting an old Chinese proverb, we need to **start the journey of a thousand miles with the first steps today**. We cannot sit down at the starting line and lament that humanity has not yet gotten far enough or will have to travel a thousand miles (eventually), while billions of people have not even arrived at the stadium yet. Ideally, we would stop talking and develop the trucks that can drive all of us over the thousand miles. Walking may be inspirational, but it won't get us there as fast as the trucks will.

In this, our final chapter, we describe what governments, businesses, activists, and individuals can do here and now. Note the order. Global pollution is a big problem and requires big solutions. Countries are as big as effective human organizational structures get.[1] Business and individuals can play useful roles, but their means are more limited than those of governments. Humanity is in a war that can only be fought by the collective, not by individual heroes — and not just a short but a very long war that will have to be fought for many decades and over many generations

Realistically, all viable prescriptions for moving the needle now involve low-hanging fruit. High-hanging fruit is effectively fruitless. Fortunately, there are so many examples of low-hanging fruit that we don't have the space to list them all. This chapter focuses on our favorite ones. Many of them involve the government acting as a catalyst — overcoming bumps rather than climbing mountains. Environmentalism should push for these changes as soon as possible — ideally, yesterday.

But let's start with where we are today.

[1] However, it is also true that governments, because they are so big, are also often more dysfunctional than many smaller organizations — and sometimes governments are outright malicious. Co-opting government for a purpose is still usually more effective than co-opting just your friends and their friends or even your neighborhood.

1 Going It Alone

Can we go it alone before technological change — our advocated best approach — can transform the world? In October 2021, **climate protesters** held a one-week protest against fossil fuels. Although we share their ultimate goal of decarbonization, we do not believe that most protesters understand what it is that they were **asking** for — or more importantly, what it is that they should be asking for. Thus, for readers that have skipped earlier chapters, let us again briefly reiterate the tradeoffs.

The estimated global temperature is expected to rise by about 2°C relative to preindustrial times, about 1°C more than where it is today. Global climate conferences argue about what has to be done to reduce warming by about **0.5°C**. And make no mistake: 0.5°C would be a big deal with big consequences for the environment.

Let's explore the tradeoffs further. It takes about **200-250** $GtCO_2$ to change earth's temperature by 0.1°C. The United States emits about 6 $GtCO_2$/year. If the United States could completely decarbonize now, it would take about 35 years to influence earth's temperature by 0.1°C— from an expected increase of 2.0°C to an expected increase of 1.9°C. Even an 0.1°C would be a **big deal**. However, the reduced warming effects of complete U.S. decarbonization would not be felt for decades — and, in truth, would be barely noticeable by the average American voter for a decade or two. Increasing earth temperature and heat-waves would largely continue within our lifetimes.

Total OECD emissions are about 13 $GtCO_2$/year. If all the OECD countries would decarbonize, the temperature increase could be 1.8°C instead of 2.0°C. This would be more noticeable. Of course, as we already explained, China currently emits about 10 $GtCO_2$/year, still growing, and unlikely to follow the OECD. The rest of the developing world accounts for another 10 $GtCO_2$/year, also still growing. Climate activist protests are not allowed in China, and unlikely to meet with great success in India, Africa, and beyond. Again, even if the OECD could completely decarbonize, increasing earth temperature and heat-waves would largely continue within our lifetimes.

How painful would our contribution to decarbonization be? Let's assume that the protesters succeeded in the United States. How much would the 0.1°C global temperature reduction cost? If the annual cost of reducing emissions is about $100/tCO2, it would cost $0.6 trillion or about 3% of U.S. GDP. Figures this high are difficult to comprehend. A friendlier figure is that this is about $5,000 per year per tax-payer. This is about the same cost as all U.S. higher education — all colleges and all universities combined. The going-it-alone American choice is about whether to make all college and university education free or to lower earth's temperature from 2.0°C to 1.9°C over 30 years. Assuming that there are resource limits and only one or the other is feasible, what do you think would garner more American votes?

Let's make it even more obvious. The going-it-alone choice for Los Angeles, an area with about $1 trillion in GDP and 50,000 teachers, is roughly doubling every teacher's salary, hiring twice as many teachers, or spending $100,000 per homeless person on

the one hand, vs. reducing earth's warming in 30 years from 2.0°C to 1.995°C on the other hand. What would the average Angelino vote for?

Let's curb our ambitions for the moment. Roughly speaking, if the world could stabilize its fossil fuel consumption and all future energy consumption *growth* henceforth were to come from clean fuels, it would still cost $3 trillion per year, about 5% of global GDP. Who will cover this cost, especially in poorer nations now responsible for about one-third of emissions? In line with our estimates, the developing nations have recently asked for **$1.3 trillion** per year in climate support, or else they plan to ramp up their fossil fuel consumption. We note that many of these countries have notoriously high levels of corruption. Even if the OECD were to volunteer to pay, it is unclear how the donors could appropriately channel the funds in a way that would accomplish their intent.

The key question to us is not even whether it would be appropriate for the OECD to send this much money abroad, but whether it seems plausible to expect it. How realistic would you judge such a transfer? We believe the answer is exceedingly unlikely. There are a lot of things that we think the United States and OECD might do, but "just say no to fossil fuels," pay off poorer countries, and see the earth warm up slower over decades is not plausibly one of them.

The country with the most concern for climate change may well be Germany. In a November 2021 survey, German 14- to 29-year-olds expressed that **climate change** was their number one concern. How much skin are they willing to put into the game? Among those surveyed, 60% regularly travel by car and more than 80% cannot imagine life without one. Only 19% are willing to make the sacrifice of life without a car. Only 27% are willing to forego flying – incidentally, the biggest carbon contribution most of us will rack up within our lifetimes. It's easy to protest. But even when it comes to luxuries, own sacrifices are much more difficult.

Don't shoot the messenger. It's not our fault. We wish it were not so. In Laurence Fishburne's words in **The Matrix**, all we are offering is the **red pill** — the unpleasant truth, nothing more.

Like it or not, we believe that the only promising way forward is cheaper clean energy through technological progress that will make it in the self-interest of countries and individuals to leave fossil fuels. In a sense, that's the point of our book.

2 What Can Countries Do?

We have already discussed remedies that we think are bound to fail and remedies that are promising (especially in Chapter 7). In the current chapter, we are summarizing our favorite approaches in the hope of leaving an impression. They are not listed strictly in order of importance, effectiveness, or cost. But they are limited to those we consider highly important, highly effective, and relatively cheap. And they are not mutually exclusive. Political activists, parties, and governments should work on all of them at the same time.

Increase Innovation

Recall the truck example from the start of this chapter — the one supposed to carry us all to the finish line? The truck is technology. We need to requisition it. Technology does not appear out of the blue. Countries should do everything they can to push new, clean technologies.

We covered relevant technologies in the third part of our book (Chapters 9-11). Ultimately, technologies that make clean energy *cheaper* are the *only* way to reduce emissions to the point where atmospheric CO_2 concentration will decline again. Every other environmental measure will, at best, slow the accelerating increase.

➤ Research, Development, Deployment

New technologies require research, development, and deployment (RDD). Research is the part where scientists are poking around and really do not know whether the results will ever be useful. Development is the part where the scientists know that the concept works, but they do not know whether an invention could work in the real world. Deployment is the part where companies begin commercialization, with a few first pilot tests in the field. (Engineers call this kind of deployment **FOAK**, First Of A Kind. The FOAK cost is typically much higher than the **NOAK**, Next of A Kind, cost.) The borders between the three areas are fluid. For example, the first deployment often uncovers new problems that lead back to new research.

We are not alone. There is near-universal agreement that the best path to green energy adoption worldwide is through innovation. Period. Innovation is likely to provide the most bang for the buck. **Lomborg** estimates that every dollar spent on fundamental green energy research expects to pay off ten dollars. Although this estimate is on the high end, it is not out of line with other research. Even if the expected payoff were only $5, governments should still do a lot more to foster RDD than they do today. This is the easy low-hanging fruit — increasing the funding for clean-energy RDD. Incidentally, it is also the case that even companies that work without government funding still draw heavily on government-funded basic research often started at research universities. The Internet and batteries are just two of many such examples.

With such payoffs, recommending more funding for clean-energy RDD is the easy part. Doing it well is the hard part. We need a conceptual framework. How should governments allocate funding? What role should the market play? What are the problems?

➤ Externalities

There are at least two economic externality problems with private RDD, already explained in Chapter 5. The first is that the private rewards for inventions are only a fraction of the social benefits. If RDD is left to private entrepreneurs, there won't be enough of it from a social perspective. The second is the desire of inventors, once successful, to patent their inventions and prevent others from using them. Of course, this is understandable: no one would invest $1 billion in a new battery technology, with its great risk of failure or of the arrival of a superior competitor, if there were not high profits in case of success. But after the technology works, the world would be better off if it were available to everyone at the lowest cost.

Economists do not have universal solutions to these two problems. They do know that the best solutions in the real world are often imperfect mixes of government subsidies and private markets. (Just because markets are not perfect does not make the government perfect. Governments often respond to short-term political pressures and do not seek out the best long-run alternatives.)

Despite the just-mentioned problems, the benefits of clean-energy RDD are so high that the government should fund more of it. The best choices of which technologies to support should be left to panels of expert scientists and engineers. Some far-out alternatives could pay off big, too, and deserve funding. (However, sometimes it does not take an expert to understand that some research is so relatively cheap and could have such positive effects on humanity that it should be subsidized in any event. A few of our favorites are listed in Appendix Section App. A.)

➤ Public-Private Collaboration

Worldwide research funding already largely operates in a mixed public-private partnership way. Governments fund research, often in universities, and the results, if any, are later commercialized by companies. In exchange for generous government subsidies, governments could demand more knowledge-sharing of inventions with other companies.

University researchers and experts tend to be better in assessing basic research than companies. Companies are better at the technology development and deployment stages. At these later stages, the potential profits and losses align much better with corporate incentives. The government may still want to help with a first "FOAK" plant deployment, but thereafter it becomes high time for governments, researchers, and experts to leave the field to as competitive a market of firms as possible.

➤ Risk and Failure

An important difficulty in funding research is that government employees (and bureaucracies) often have no stomach for embarrassing public failures. Yet the whole purpose of R&D is to venture into the unknown. If we knew a concept worked, we wouldn't need research.

In 2010, the U.S. company **Solyndra** received hundreds of millions of dollars to manufacture and deploy novel solar cells. It ultimately failed because prices of competing Chinese silicon cells dropped too quickly. The resulting fallout made great headlines for the GOP opposition, because Solyndra was funded by the Obama administration. Whether right or wrong, it was Monday-morning quarterbacking. A quarterback who has never thrown an interception on a long pass should probably throw more marginal passes — he has not taken enough risks. If every R&D investment worked out, we would not have made enough of them. We should have aimed higher. And herein lies the problem. Risk-taking is not what politicians and bureaucrats excel in. Ideally, innovation research would be funded by a bipartisan panel.

Failure seems to be more (but also not sufficiently) tolerated in academic research grants, if only because the research results often remain more obscure. This is perhaps one of the reasons why government scientific grants to universities are a good solution.

➤ Prizes and Funding

Traditional research grants to universities are important, but we would recommend some more daring supplemental funding mechanisms, too.

The **X-Prize Foundation** has offered highly visible prizes that have proved to be great catalysts for creative research. Winners of X-prizes gain not only funding, but also instant publicity and credibility. **Elon Musk has now offered a $100 million as a prize for carbon capture**. Governments should supplement such prizes. Why can't prizes be $1 billion or $10 billion instead of $100 million?

The government could also offer prizes that consist of guarantees to buy the first product, such as the first 100 GWh of fusion electricity provided for a price point of $300/Mwh or the first 1 $GtCO_2$ removed via accelerated weathering for a price point of $20/MWh. Would it work? We won't find out unless we try. (The same "fail sometimes" approach is needed here.)

➤ Engineering and Public Education

Finally, a more long-run aspect of R&D is education. This ranges from training more engineers to educating voters and consumers. We need science and engineering to become "sexy" again.

➤ Funding

Our immediate and most important recommendations is also the easiest:

1. Expand the budgets earmarked for green technologies at the National Science Foundation and the Department of Energy — perhaps double, perhaps quadruple. Keep politics out of it and keep it science- , research- , and development-based.
2. Establish large prizes and guarantees for milestone achievements for FOAK plants.

Share Technology Globally

Most of the RDD funding, and as a result most new discoveries, will probably come from developed countries. Although breakthroughs are more likely to happen when there are many brilliant scientists working together, this is not all good. U.S. universities have been responsible for the largest brain drain in human history, from poor to rich countries — though immigration antipathy in the United States has recently been slowing it down.

Morally, we owe it to poorer countries to help them with their transitions on so many levels. Pragmatically, CO_2 emissions are a global problem. They are as bad when they occur in India as when they occur in Indiana. It is in the world's interest to share technology and expertise. Is it also in countries' self-interests? This is less clear. If we could wave a magic wand or direct global negotiations, our emphasis would be on ways for the world to collaborate more on clean-energy RDD.

How can clean energy be made more accessible to poorer countries? Despite a lot of general waffling and political lip service, most governments have been defending their own industries and not been advocating for the interest of the world, much less the interests of the poor of the world. Public relations talk of *equity* is one thing. Actual sacrifice and sharing are another. There is also a second complication. The best solutions may not be the same in poor countries. In many politically less stable countries, energy technologies need to be different. It makes little sense to build a nuclear plant or a dam in a war zone. Countries without an electric grid may be better off with roof solar cells. And so on.

Our immediate recommendation is therefore for the West, East Asia, and China to establish a joint program that discounts technology license fees or waives patent fees for countries that meet certain poverty criteria and that want to install clean technology domestically. Barge-based near-shore nuclear power plants could provide subsidized electricity to many countries that want clean power but cannot be trusted with nuclear technology.

Tax Local Fossil-Fuel Pollution

We economists love taxes on negative externalities such as pollution. Prices provide incentives to reduce harmful pollution and to develop and deploy alternative sources of energy. Therefore, we would advocate that countries should impose fossil-fuel taxes (instead of today's fossil-fuel subsidies) to reduce local harm; and in reasonable amounts it will also make them better off themselves. Fossil-fuel taxes reduce co-pollution and adverse health consequences and help develop competitive clean-energy export sectors.

Why are we not advocating a major effort for a global CO_2 tax to combat climate change? Forcing 200 other countries to institute global-targeted taxes would be like **Sisyphus** rolling the proverbial stone up a hill. Even if CO_2 taxes can be passed on behalf of global rather than local interests, they would likely take decades to come into force and not survive some next electoral cycle, recession, or energy crisis in many countries.

In contrast, local CO_2 taxes that provide local benefits are more like putting a wedge under the rolling stone. Such taxes can be catalysts. The government only needs to run the trick one time and get people used to it. Once established, going back to allowing high emissions that make one's own population worse off is going to be more difficult for the fossil-fuel industry — especially, once the public in places like New Delhi and Beijing realizes how much better life can be without asthma and visibility limited to 30 feet.

Nevertheless, let's not kid ourselves: even local CO_2 taxes will be difficult to institute. The biggest hindrances are powerful mining and fossil fuel lobbies, both on behalf of companies and employees. And CO_2 taxes often hurt poorer people more. To institute local CO_2 taxes will require excellent politicians, carrots, and sticks. But locally justified CO_2 taxes and controls stand at least a fighting chance for long-term public support. Globally justified CO_2 taxes do not.

You may disapprove of the modesty of our goal, but we wouldn't be surprised if local CO_2 taxes alone could make a big difference, halving global CO_2 emissions. However, we admit that we have no evidence to back up our assessment. Whereever possible, let's try it out!

potential anecdote

> Most governments have been deficient in basic tasks. Gratuitous methane leaks from oil&gas wells are low-hanging fruit. Burning off leaking methane would be cheap. However, it remains even cheaper for producers to abandon wells than to appropriately plug them at the end of their lives, and few governments have had the attention bandwidth to do much about it. They should impose harsh penalties. Governments worldwide — especially those in the Middle-East and North America — have been dysfunctional in failing to institute such.

Price Electricity By Demand and Supply

Wind and solar are already the cheapest forms of power in history. The problem is electricity storage.

But why do we need so much storage in the first place? Part of the reason is because few of us are used to dirt-cheap electricity from 9am to 5pm and expensive electricity from 5pm to 10pm and 5am to 9am. How many of us would be willing to buy smarter appliances and adjust if we could count on saving half of our electricity bills *and* at the same time do good for the environment? And we could make it twice as expensive for those of us who refuse to adjust. We suspect most of us would learn pretty quickly — and saving money on expensive electricity is something that should appeal even more to countries and people that are poorer.

"We only cut our CO2 emissions to piss off the utilities companies."

Governments can help facilitate the switch to demand-sensitive pricing on many levels. They should help electricity companies sign up as many customers as possible to demand-sensitive pricing plans. They should tax fossil-fuel plants to increase their after-hour prices further. They should help make electricity price information ubiquitous. They should open a frequency in the RF spectrum on which providers could broadcast the current and anticipated prices of electricity (the same way we broadcast atomic clock signals and hurricane warnings). They should standardize power-embedded signals and encourage standardized Internet-based two-way signaling of prices and impending customer electricity demands.

Again, our suggestion is for governments not to fight market forces in order to reflect global CO_2 externalities over decades or centuries. Instead, it is for governments to act as one-time catalysts to bring about the changes that switch consumer habits to consuming when energy is both dirt-cheap and no-dirt-clean — and then to get out of the way as soon as possible.

Uproot Environmentally Bad Habits

Many emissions can be cut **without spending a penny**. But, as Benjamin Franklin noted, old habits die hard. Many people are not only too busy to worry about changing (a **status quo** bias) but intrinsically distrustful of anyone trying to alter what has worked for them for a long time — even if they barely **remember** the reasons why they are doing what they are doing in the first place. The good news is that habits can be altered by governments acting as catalysts. Governments can jump-start changes and then get

out of the way once habits have changed. Governments won't have to fight this battle forever.

Here are a few important bad habits in the environmental context.

First, most people don't know or don't care about electricity pricing. They have busy lives. They still think of electricity as being *more* expensive during the day rather than the night, which is how it was when coal plants supplied factories with electricity mostly during the day-time. How can we get people to notice and change? If we can get consumers onto time-of-day plans *and* make them aware that electricity is cheap during the day and expensive at night, then we, the people, will probably do all the rest voluntarily.

Second, habits influence agricultural tilling and farming practices (Chapter 10). Turning over the soil reduces weeds and increases yields, but releases more CO_2 than **No-Till** farming. Worse, farmers tend to be intrinsically even more conservative and distrustful of government than the average person. How can we nudge farmers to adopt practices that will not cost them much and help improve the environment? We could offer them direct subsidies for better tilling practices and tax them for harmful tilling practices. But the big deal will be to change farming habits. Getting farmers to try out an alternative at least once would be winning more than half the battle.

Third, habits can be based on and reinforce mistrust and myopic consumption patterns. The ***Energy Efficiency Paradox*** is that most people decline to spend more upfront even when the lifetime energy and cost savings are far greater. For example, a majority of people decline to spend more on energy-efficient washing machines, even though they would come out financially better.

Changing habitual behavior patterns is not easy, but it can be done. Here are three possible approaches.

➤ Coercive Mandates

A forceful way to overcome inertia is to mandate the purchase of more efficient devices. The government effectively forced inferior incandescent bulbs, inferior housing insulation (with building codes), and inferior gasoline engines (with MPG standards) off the market. The flip side of this approach would have been to subsidize LED bulbs, insulation material, and more efficient gasoline engines to make them cheaper. (The two could go together, too.)

An important aspect of coercive mandates is that they help the ultimately better solution steal the appropriate economies of scale from the prevailing worse solution. Economists tend to be skeptical of mandates for good reasons. There is a lot of potential for abuse and unintended consequences. Thus, they are probably best used only if the social disadvantages of the current solution are so large that there is little chance that the government could get it wrong.

➤ Nudges

There is often a better, less coercive, and brilliant alternative: **Nudges**, i.e., gentle prods, courtesy of **Richard Thaler** (a Nobel-Prize winning economist) and **Cass Sunstein**.

Nudges are at their most powerful when they can put people's intrinsic inertia to good use by selecting good defaults. In an example, 42,000 households in Germany were asked to choose between a green-energy provider and a fossil-fuel provider for their electricity. The green choice was slightly more expensive. For those households for which the traditional fossil fuel provider was the default, only 7.2% switched to the green alternative. When the green alternative was the default, 69.1% of households chose to stick with it. This was the case even though everyone could choose whatever they wanted.

Thaler and Sunstein also advocate taking advantage of social norms. Many utility companies now include Home Energy Reports in their bills, which tell consumers how their usage compares to that of their neighbors. This tactic has led to remarkably large reductions in energy usage. It can be pushed further in many ways. If someone has switched and saved a lot of money doing so, the government could tell neighbors and friends, or even reward switchers when they themselves tell neighbors and friends. (Some advertisers post rewards for bringing in other customers.)

Nudges can also help overcome an information problem. Why would the government need to tell people that they can save money with better lighting, insulation, and cars? Are they not smart enough to ask themselves? They may be, but it would be difficult for buyers to compare different products when every seller can measure and claim benefits in their own way. Vendor claims would degenerate into a race to the bottom. In such cases, government can promote better products not by forcing everyone to abandon inferior products, but by disclosing standardized cost estimates. The classic example is the standardized **Monroney sticker on cars**, which informs shoppers of fuel efficiency. In many cases, information disclosure is cheap for sellers and salient to consumers. Of course, it does not work everywhere. In some cases, too much good intent can lead to uselessness — as everyone who has ever had to sign 120 disclosure documents when obtaining a mortgage can attest.

Nudges can be brilliant and cost next to nothing. It's just that someone more clever than us has to think of them in the first place and then implement them.

➤ Product Introduction

Governments can also help implement beneficial social changes in the same ways that companies try to increase their sales:

Advertising is the most common way to make the public aware of changes.

Price discounts for early adopters of better climate practices make it easier to try out different practices. For a time, governments should subsidize electricity consump-

tion during the day and tax it at night, *beyond* what is otherwise optimal, making cheap daytime electricity even cheaper. It's the same strategy by which **Uber** weaned us from taxis and alerted us to its presence. Uber rides started out cheap but they **no longer are**.

Guarantees for those who are willing to adopt new practices can reduce the fear of the unknown unknowns. For instance, there should be strong one-time "no-worse-off" guarantees for all farmers who are willing to try out more environmentally friendly tilling practices.

Reverse Bad Technological Lock-In

There are many cases in which economies suffer from **Technological Lock-in**. These are situations in which the economy is too committed to an existing technology to allow it to change to a better one. At some point, when the social benefits of a switch become much higher than the one-time transition costs, then governments should step in to make us better off. Here are two examples: lighting and cars.

Just one decade ago, LED light bulbs cost about three to five times as much as incandescent light bulbs. However, their lifetime cost was only one-fifth as high. LED bulbs last longer and consume less energy. Nonetheless, the aforementioned energy efficiency paradox kept most consumers using incandescent bulbs. In turn, this buying pattern maintained economies of scale in incandescent production and reduced economies of scale in LED production.

In 2007, the Bush government banned the manufacture of particularly inefficient household light bulbs.[2] After some detours,[3] the end result is that today's LED bulbs have become cheaper to purchase than incandescent bulbs ever were! Competitive incentives and mass production have worked wonders for per-unit production costs. When incandescent bulbs ruled the market, they had the existing economies of scale on their side. Now LED bulbs have them. Who could argue with the result? Cheaper, better, less polluting!

Take another example. For the longest time, gasoline cars were thought to be irreplaceable. Their production had economies of scale. Yet it has become increasingly clear that electric cars are superior. Combustion cars have served civilization well for a century, but their time has passed. The problem is: How can electric cars overcome the advantages of gasoline cars in terms of mass production, available infrastructure (especially gas stations), and consumer familiarity?

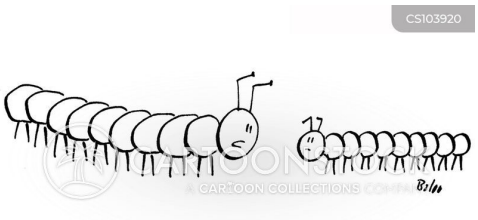
[2] We would not have advocated for an outright ban, analogous to an infinite tax, but merely for a much higher tax instead.

[3] In hindsight, the mandate may have been three years too early, because LED needed a few more years to overcome the advantages of fluorescent bulbs, another technology. However, without the mandate, the development incentives would have been lower and it could have taken a decade.

Governments helped. They did not invent electric cars, but they did support relevant fundamental R&D for many years. They also offered generous subsidies to car makers for early zero-emission cars. We all know what happened next. Tesla showed the world that electric cars are not only more efficient and pollution-free but also no more expensive than gasoline cars, courtesy of the economics of mass production and falling battery costs. Soon, electric cars will be cheaper. Every car maker on the planet is now planning to phase out combustion engine cars by the end of this decade.

With the exception of the fossil-fuel industry and combustion-engine makers, everyone has won. Perhaps best of all, having acted as the catalyst that drove the switch from a worse equilibrium to a better one, government is now no longer needed. Its job is done. It can now get out of the business of deciding winners and losers and let market forces take over.

Coordinate Transitions



"Strength and speed are useful, son, but coordination is *crucial!*"

Technological lockin is especially severe when it comes to problems that require many simultaneous changes. Selling electric cars requires public charging stations. Tesla not only had to invent practical electric cars, but it also had to install a charging network, because there were no electric gas stations. Other car makers are still working on the problem. To build profitable charging stations requires widespread adoption of electric vehicles. A classic chicken-and-egg problem!

Let's zoom out to a wider perspective. There are two coordination problems that are so paramount that they could make or break the transition to a clean energy economy, and only government is in a position to move them along.

The first is the capacity of the electric grid. It has served us well in the past, but it has grown into a messy tangle of poor interconnections dominated by local regulations and interests. Without the ability to connect to a grid that can make good use of clean electricity, it makes little sense to generate more clean electricity. Making it cheap for clean-electricity providers to sell electricity into the grid is of first-order importance and requires national involvement.

The second is the coordination of electricity supply and demand. We need a universal open bidirectional communications protocol for generators, end-consumers, and storage on the electric grid. Establishing a protocol is harder than it appears. It requires addressing issues such as geography (which price matters to what house?), time (what is the price now and what will it likely be?), and cyber-security (how can the grid mitigate wrong and/or malicious signals?).

Our governments need to tackle both problems.

Reduce Green Red Tape

Real-world governments enact not only useful regulations, but also many bad ones. Many start out good but turn bad over time. Economists consider this examples of **unintended consequences**.

Most of us (especially our lawyers) like the ability to sue parties that harm us, but the law can also become our own worst enemy. Most environmentalists want wind power, just **not in their own backyards**. The typical wind project in the United States already takes over a decade (!) to get lease approvals and permits. This is one reason why American offshore wind capacity is less than 5% of Europe's.

"I kind of regret objecting so strongly to the wind farm they originally had planned."

Yet even in Europe, neighbors don't like rumbling from windmills. Farmers and fishermen often **don't like** windmills, either. In America, offshore wind opponents are often the **wealthy and powerful** who live the near the shorelines. But what is the alternative? Yes, someone may deserve consideration even in the case of clean wind power, but year-long lawsuits are not the ideal way to handle the problem.

Most of us environmentalists like clean cars and clean grids. As we explained in Chapter 9, the necessary batteries are made out of cobalt, nickel, and lithium today. Without a lot more of these elements, there will be no clean-energy transition. Yet, few of us environmentalists like mining — but civilization's choice now is between more mining and no energy transition. We can't have our cake and eat it, too. Of course, we should not want unregulated mining—that would also be a terrible idea. However, it now takes **16(!) years to approve the average global mining project** (*before* it can start breaking ground). We must make green-related mining decisions better and faster.

potential anecdote

Nevada has some of the richest Lithium sources in the world. The environmental harm of lithium mines are modest (unlike, say, for lead, gold, or coal mines). Alas, standing in mid 2021, new Lithium mines in Nevada have hit some "minor" snags:

Ioneer Corp wants to build a mine halfway between Reno and Las Vegas. Unfortunately, three years into the process, the U.S. Fish and Wildlife Services discovered a rare plant named **Tiehm's buckwheat**, and later named it an endangered species.

Lithium Nevada Corp wants to build a 20,000 acre mine in the Thacker Pass. Unfortunately, the Reno-Sparks Indian colony, about 300 miles southeast of the project, has filed a lawsuit based on the **National Historic Preservation Act** (plus some process violations about environmental approvals). It is where Native Americans in the late 1800s hid and were **slaughtered** by U.S. soldiers. The relevant area is only half an acre.

The environmental harms may be modest and plausibly resolvable. The economic harms of the law suits are not. They could take years to resolve.

We like safety, fairness, and competitive regulations, but these regulations also prevent new competitors from entering. For example, today only utilities are allowed to buy energy from the grid. You cannot build a wind farm to power a data center if it also needs occasional backup from the grid. Don't ask how difficult it would be for a data center to obtain utility status. (And don't ask how many different agencies and bodies have to approve anything that wants to be connected to the grid or wants to extend the grid.)

We like *extremely* stringent safety regulations for nuclear power, but it seems as if the NRC considers reactors safest when they are not built. It has become impossible in many countries to design and build better and safer plants. The time, effort, and uncertainty to get regulatory approvals have killed off most of the nuclear construction industry over the last five decades. We are keeping our fingers crossed that **Terrapower**'s new Wyoming plant will be able to overcome the hurdles and build the safest nuclear power plant in the world.

Good regulations are not easy. They require constant struggling. Unfortunately, once in place, even bad rules are difficult to overturn. How many unnecessary stop signs have ever been taken down when traffic patterns changed later? Business as usual has become too slow to deal with the world's climate crisis. The rate of regulatory evaluation and change has to be accelerated when it comes to environmentally better solutions.

➤ Concierge Services

Many regulations make sense by themselves but not when considered in conjunction with hundreds of others. Figuring out how to start a new clean-energy project is only slightly less painful than a root canal. If we want clean energy, we have to try to entice more competition by making it easier. Governments should:

- Guarantee regulatory "concierge" service, an assigned shepherd with expertise in the regulatory and permission processes and good connections to the relevant agencies, who can facilitate much faster reviews by agencies ideally with firm short deadlines and without undue compromises on safety and environmental standards.
- Guarantee and pay for the interconnection of a new entrants' first plant into the electricity grid.
- Guarantee a stated price for a fixed amount of *clean* dispatchable electric energy over the first decade. The specific terms (e.g., time-related pricing) can be revised every five years. They could even be auctioned off.

This model contrasts with the current *modus operandi*, in which the government funds plants, mostly by incumbents who know how to navigate the process and who have placed past and future employees into the key government posts.

Lease Out Land for Solar and Wind

The Federal government owns over a **quarter** of all the land in the United States, much in sparsely populated states in the West. In Nevada, the government owns 80% of all the land — prime locations for wind and solar farms without great alternative uses. This is also the case in many other countries: governments typically own their countries' deserts and mountains.

An immediate step would be to make it easy for clean-energy developers to lease such land cheaply for 30-50 years if it is for the purpose of building wind and solar farms, with penalties for non-use.

Good News Update in August 2021: **More Federal land leasing for clean energy projects has just been made policy in the U.S.!**

Kill the Worst Emitters

Among the lowest hanging fruit is shutting down the worst polluters. They are also remarkable easy to identify.

➤ Methane

Natural gas is worse than suggested by its plant emissions. Indeed, it may be no **cleaner than coal**! This is because too many wells and some pipelines are leaking methane. It is a world-wide problem. Fortunately, the majority of emissions comes from a **minority** of locations. Even better, satellites make large emitters easy to detect. Governments should immediately send crews to flame off or close the leaks. It can be decided later who has to pay for the cost. If need be, allow private-party lawyers to sue for recovery and retain some of the settlement.

➤ Coal

New coal plants are bad, because they release a lot of CO_2. However, old coal plants are worse. They release not only CO_2 but also many other harmful pollutants. Many of these old coal plants are barely economical to run even without fossil fuel taxes. Thus, governments should push them over the edge and immediately close them. With appropriate one-time subsidies and special waivers for many regulatory delays, cleaner plants could substitute for the lost power relatively quickly in many countries. If the subsidies are based on, say, 2015 emissions, they would also not create perverse incentives to build more polluting plants. Yes, such programs cost money — but they are worth it even for local citizens (and, of course, for the world at large).

(We wish we had good ideas how to stop the imminent construction of coal plants in China, India, and beyond. We do not. What a missed opportunity for the world.)

Negotiate Some International Agreements

Most international treaties are not low-hanging fruit. Negotiating over CO_2 emissions seems largely futile to us.

However, there are situations in which international negotiations could work. Our favorite one is methane emissions control that would make it in the interest of countries to eliminate **super-emitters**. The cost of plugging or flaming off leaks for the worst emitters is low (relative to the worldwide harm) and their actions can be easily verified by satellites. An international treaty, in which rich countries could share some of the cost, could speed this along.

Adapt?

Adaptation to climate change will greatly reduce its harmful effects. It is why hurricanes (Chapter 3) kill far fewer people today than they did 100 years ago. It is why most earthquakes in California have become nuisances rather than catastrophes. It is why Venice and the Netherlands are still above water. The **Global Commission on Adaptation 2019 Report** estimates that investing $1.8 trillion globally from 2020 to 2030 could generate $3.5 trillion in total benefits – a hefty return on investment when considered from a social perspective!

Yet our book has barely touched on adaptation. There is a reason to this madness. Most of the time, it is in the interest of the involved parties to adapt. It is (or at least should be[4]) in the interest of people not to build houses on the ocean shore at zero elevation or next to dry forests that will burn sooner or later. It is in the interest of countries to build warning systems, dykes, and fire control systems. Adaptation is not really a global problem plagued by a global externality, like climate change, which is the subject of our book.

Could adaptation be dangerous by substituting for the necessary global fossil fuel detox? Maybe. But we cannot steer the boat (i.e., earth) back so quickly that we won't need adaptation. And we wouldn't want people not to protect themselves.

With a nod to the Buddha, as far as global adaptation goes, "it is what it is" (or "it will be what it will be"). And as far as our book goes, it is already too long, so we have to punt on this important subject.

[4]Some well-meant government insurance schemes have created a **moral hazard** that will make the matter worse in the future.

Crises Beyond Climate Change?

Bjorn Lomborg has a whole **list of global problems** that are worth tackling. For the most part, he concludes that fighting climate change through ordinary means today gives too little bang for the buck. (At least, it used to be too expensive. With improvements in technology, which he also predicted, the tradeoffs are shifting.) Other environmental issues brought about largely but not only by our global population explosion — like eradicating global hunger or **malaria** — are comparably much cheaper. They could be accomplished for a tiny fraction of the cost of premature decarbonization..

It is difficult to choose among worthy causes for humanity and beyond. **habitat destruction**, **species extinction**, and **overfishing** are examples of impacts that extend beyond the human species. How can we weigh the misery of **3 to 6 million children starving to death** or **half a million children dying from malaria** every year today against the misery of a potentially looming climate catastrophe?

Of course, we should tackle them all. As economists, we are schooled in the science of scarcity and tradeoffs. As humans, we find it difficult to judge which miseries are more important than others. These are questions of ethics, and the moral dilemmas posed by these questions weigh heavily on us.

3 What Can Individuals Do?

We now shift to considering voluntary choices made by individuals — good choices and bad choices; choices that could make a disproportionate difference and choices that will not.

Change Your Behavior?!

There have been many bestsellers that have held forth about how to reduce your **carbon footprint**. They sell many copies to the faithful, but they are misguided. They would be amusing distractions if only the issues were not so serious, if only the beliefs were not so widely held, and if only the diversions would not delay what really needs to be done.

Why haven't most people voluntarily changed their behavior? Is the problem that they just don't realize how they can reduce their personal carbon footprints or how much it would help the environment?

We would love people to change their ways selflessly, but it's unrealistic. Economics suggests that not enough people will do so if it is not in their self-interest. This implies also that clean energy must not be much more expensive than dirty energy to achieve widespread adoption. It is a fallacy to think that voluntary changes against personal self-interests could transform the world. It won't happen. Don't shoot the messenger. It's not our fault. We did not design the world this way.

Part of our skepticism stems from the fact that behavioral changes significant enough to affect climate would not only have to be widespread but also long-lived. Otherwise, changes have little impact — in fact, almost surely only an immeasurably small impact. Even large changes in response to a crisis lasting only a few years would barely move the needle.

➤ A Historic Carbon Footprint List

Still don't believe us? In his classic and still prescient book **Sustainable Energy Without the Hot Air** published more than a decade ago and which inspired us greatly, David MacKay recommended that individuals adopt the following good practices:

- Put on a woolly sweater in winter and turn down your heating's thermostat (to 15°C or 17°C, say). Put individual thermostats on all radiators. Make sure the heating's off when no one's at home. Do the same at work.
- Read all your meters (gas, electricity, water) every week, and identify easy changes to reduce consumption (e.g., switching things off). Compare the results competitively with a friend. Read the meters at your place of work, too, thereby creating a perpetual live-energy audit.
- Stop flying.[5]
- Drive less, drive more slowly, drive more gently, carpool, use an electric car, join a car club, cycle, walk, use trains and buses.
- Keep using old gadgets (e.g., cell phones); don't replace them early.
- Change lights to fluorescent or LED.
- Don't buy clutter. Avoid packaging.
- Eat vegetarian six days out of seven.

None of these recommendations should come as a surprise. They are about as widely known as "eat less sugar and exercise more — it's good for you."

The sad fact is that all these suggestions read a lot like New Year's Resolutions or diet plans. They begin with great excitement and commitment but then fade quickly. Unfortunately, evanescence won't work for climate change. The necessary behavioral modification must last multiple lifetimes, because even future generations will have to adopt them; and they must occur not just in the West but all over the world.

Reading through the list today, we note that the only one that has had widespread and lasting impact is switching lights — and it is not due to environmental aspirations. It is due to technological improvements and mass production that have made LEDs both

[5] Recall Chapter 1. Flying is probably the fastest way for an individual to rapidly increase her carbon footprint. Cutting airplane travel is more important than everything else on this list — even for environmentalists.

cheaper and better than incandescent lights. Electric cars are about to become a second example of a technological transition. Of the entire list, only the ones due to technological change will have worked. Even the more modest "sweater" recommendation is a no-go. Comfort and self-interest come first when it comes to large populations.

➤ Setting an Example

What about setting an example? Of course, if you are the Pope, the Archbishop of Canterbury, or the Orthodox Ecumenical Patriarch, your example and **joint appeal** may matter. However, if you are like the rest of us, don't overestimate your importance. Frankly, the world does not care what your thermometer reads or whether you eat vegetarian or not. Of course, none of MacKay's recommendations are bad — most of them are outright healthy for you, and we encourage you to follow them. (And please exercise more, too.) Just don't think that your actions and those of your friends will make a difference to the CO_2 concentration in the atmosphere. The statement "if everyone did it" is a fallacy. (If everyone does it, it will have nothing to do with you; your eating steak won't change everyone.)

➤ Carbon-Shaming

What about carbon-shaming others? Fat chance. It may make you feel morally superior, but it is more a sign of ignorance about what really matters than it is an effective climate-change strategy. And even if you are the world's greatest carbon-shamer, convincing everyone you will ever meet, *it doesn't matter*. The world only cares what hundreds of millions of people eat, not what you and your friends eat. The world does not care whether you fly across continents, sail across oceans, or stay home altogether. The world only cares if hundreds of millions of people do so. Realistically, you can't shame even a significant fraction of so many people.

So What Can You Do?

We are all little cogs in a big machine of eight-thousand million people. By far, the best contribution you can make is to play a small part in moving the large collective — not playing a large part in moving a small collective.

Thus, you can do more to combat climate change by working on inventing and deploying new, clean technologies than you could ever possibly do by decarbonizing your local neighborhood. Only better technology can move the needle. Your neighborhood deployment cannot.

The best advice we can give to climate activists is to bicycle to work not for the sake of the planet but for the sake of fun and exercise. The best advice for the sake of the planet is to get involved in clean-energy research, development, and implementation.

Business and economics are not the enemy. They are part of the solution. Often the most difficult aspect of new technologies is cost-effective implementation. Elon Musk is not an inventor. He is, however, the greatest technological innovator of our time. His entrepreneurial talents have almost single-handedly pushed the United States back into a leadership position in both cars and rockets. Inventors are a dime-a-dozen. Visit the laboratories of your local university, and you will find hundreds of fascinating inventions. Elon Musk's brilliance has been his ability to jump start the deployment of important large-scale generation-leaping inventions.

There are also other ways to help. Politicians can help convince the public to make better choices and occasionally even sacrifices. Journalists can help capture the attention of readers. Academics and authors can help educate the next generation about what is important. Climate activists and environmentalists can help prick our conscience and help maintain public support. Religious leaders can help foster the common good and appeal to our less-selfish instincts. Philanthropists can help, at least a little, where government has failed—this includes Bill Gates, whose initiatives in the third world and in the energy sector are a blessing for humanity.

In our minds, the best way to help humanity now remains researching, developing, and implementing scalable clean-energy technologies. Getting **rich** in the process is merely a nice bonus for those who end up making a contribution.

What would we recommend to our own children? What can they do? What can you do?

- Build your career in science and technology related to climate change. One path would be studying climate change directly. Another would be doing research related to green energy provision. Yet another would be research on improving agricultural processes.
- Become an entrepreneur or work in the clean energy space. Elon Musk has moved the needle far more than the entire United Nations — with all its Rio, Kyoto, Copenhagen, Cancun, and Paris conferences. So have **Lewis Urry** and Sony with their Lithium battery work. So has our colleague, **Lesley Marincola**, who is trying to bring small-scale solar energy to the poorest of the poor. There is room for thousands of start-up firms exploring new ways to accelerate the transition for millions. Don't feel guilty if you get rich off it, too.
- Lead others. As much as you may dislike politics, government is the only institution capable of significantly accelerating the transition to a clean economy. For those who have the stomach and the talent, government service is a route to consider. If you do so and when you get there, don't fall for futile showy green policies that won't accomplish much in the end. Instead, expand your country's research, development, and initial deployments of green technology.
- Pursue a relevant teaching career. There is so much misinformation out there — some intentional, some ignorant — that helping educate the public about

the science and economics behind climate change is an important undertaking. Educate people about what really matters. Inspire them.

- Write a book. Remain honest. Tell people what the problem is, what can be done about it, and what truly matters. That is what we have tried to do here. It is why we wrote this book. We would welcome better solutions, regardless of whether you agree or disagree with us,

4 Conclusion

Why did we think the world needed another book about climate change?

First, we thought we could explain the issues better and do so in a way that had no partisan agenda. Second, we wanted to contribute to pushing our readers towards more realistic approaches and away from unrealistic ones. Little of what we have written has not already been stated somewhere else. If you already knew it all, we apologize for having wasted your time. If you did not, we hope we helped focus your thinkinh.

Our book claimed that there are really only two red aces when it comes to reducing CO_2 in the atmosphere: technology and local taxes on fossil fuels for the sake of reducing co-pollution. Although many other approaches can and will help, no others will come close in importance. Many proposed solutions are too limited, unrealistic, too expensive, suited only to rich countries, or all of the above. If the 2 billion people living in the richer economies cannot find solutions that will induce the poorer 6-8 billion people to leapfrog over fossil fuels, the world's CO_2 emissions will not decrease for decades or centuries.

Humanity has been luckier than it could have hoped. Technology has been improving at a rapid rate despite far less government support than optimal. As economists, we believe that real-world governments' best role is to support the transition, not to rule by decree. In this case, self-interest and competition can work wonders. We are optimistic that human creativity can then quickly reduce greenhouse gas emissions. But we must not be complacent. It is in the self-interest of virtually all countries and especially rich countries to work on accelerating progress.

From our small selves to the governments of the world: Please subsidize green research, development, and first deployments far more than you have in the past.

This is the best way to "move the needle now."

Further Reading

Books

- Bill Gates, 2021, **How to Avoid a Climate Disaster**, Knopf, New York. A guide to reducing emissions from the leading philanthropist of our times.
- Richard H. Thaler and Cass R. Sunstein, 2021, **Nudge: The Final Edition**, Penguin Books, New York. Steps that government can take to overcome human inertia.
- William Nordhaus, 2018, **Climate Change: The Ultimate Challenge for Economics**, Nobel Prize Lecture.
- Bjorn Lomborg, 2020, **False Alarm**, Hachette Book Group, New York, 2021. An alternative view of the costs of coping with climate change and the benefits of so doing.
- Global Commission on Adaptation, 2019, **Adapt Now: A Global Call for Leadership on Climate Resilience**. A comprehensive analysis of the costs and benefits of adapting to climate change.
- Joseph E. Aldy and Richard Zeckhauser, 2020, **Three Prongs for Prudent Climate Policy**, Resources for the Future Working Paper.
- We share many views with **Ken Caldera**, who now works as an advisor to Bill Gates — from geoengineering merely being a mask, to exploring many different technologies, to keeping a skeptical but hopeful perspective on nuclear power.

Reports and Academic Articles

- **Borenstein, Severin**, 2005, **The long-run efficiency of real-time electricity pricing**, The Energy Journal.
- H. Damon Matthews, et al., 2021, **An integrated approach to quantifying uncertainties in the remaining carbon budget**, Communications Earth & Environment. (About 0.44°C per 1,000 $GtCO_2$.)

Shorter Newspaper and Magazine Articles and Clippings

- **Adapting our rich cities**.
- **Climate Appeal by Medical Journal Editors**.
- **DOE Signs Up 125+ Local Governments to Fast-Track Solar Permits**
- Taylor, Adam, et al., Nov 10, 2021, **2C or 1.5C? How global climate targets are set and what they mean**, Washington Post.

Websites

To Do

hyperlink authors to wikipedia pages, too. Name the journalists in the “shorter newspaper.”

Ken Caldera helped fact-check Gates’ book. We should beg him for feedback, too.

App. A Some Exciting Green Technologies

We are not engineers, but we want to share our own interest and excitement about some technologies that could potentially change the world.

- Safe nuclear fission power plants with minimal waste. Once built, their power could be so cheap that even natural gas would be more expensive. There are no scientific reasons why it should not be possible to design fission reactors that can intrinsically no longer explode and that can reuse their fuel **a thousand times more often** than they do today. However, for decades, the world has not deployed many new reactors, and nuclear technologyy learning has crawled along way too slowly. Regulation (with good intent but perhaps not good reason) has made any plant changes almost impossible, leading companies to prefer to work with known but ancient, intrinsically dangerous technologies (pressurized water reactors, where cooling failure can lead to meltdowns) rather than with unknown but potentially safer technologies (where cooling is passive and not dependent on a backup power source, so that even if the operators make stupid mistakes, as they did in the **Chernobyl disaster**, the plant cannot blow up). The goal should be to build a reactor in which even the most malicious black-hat operators and hackers could no longer make the plant release radioactivity.
- Nuclear **fusion**: The **National Academies of Sciences' target** for a prototype plant should be 2040. There are still many technical challenges to overcome, but fusion promises virtually limitless safe energy without waste products *if* it could be made to work. It may not work, but it's worth a shot.

  Note that from an economic perspective fusion is often misunderstood. Fusion plants will be more akin to super-safe nuclear fission plants with no waste fuel than like something entirely different. Both fission and fusion plants have extremely high fixed costs and negligible fuel costs. The fact that fusion uses a different, infinitely available fuel is unimportant. There is more than enough dirt-cheap uranium and thorium to run traditional nuclear power plants at almost zero fuel cost for a thousand years.
- Geothermal power could potentially tap more heat from our planet. All it really requires seems to be a very deep hole (and some water). Could the cost be reduced by an order of magnitude?
- Energy storage technologies of all kinds. In addition to different battery chemistries (and we are most interested in tank-like easily scalable batteries than fidgety cell architectures), where can exhausted gas wells and other underground caverns serve as compressed-air storage at large scale?
- Industrial high heat. Could small thorium-based nuclear reactors be used not only for electricity production but for industrial heat?[6]
- Though we are generally skeptical of carbon sequestration because there are few private incentives here, tree planting and advanced olivine weathering for accelerated carbon removal are potentially cheap and deserve further RDD.
- Solar radiation management (SRM). This could involve injecting reflective sulfur particles into the upper atmosphere to reduce the amount of radiation that is absorbed by the Earth. The cost is remarkably low. Can we try this in very small scale and learn what it does?

[6] Nuclear reactors may not be what you think they are. Even a 14-year-old managed to build a basic **reactor** by himself.

App. B SPECIFIC LISTS

There are many good ideas as to how climate-change could be fought. Many of them come in lists. Here are some of our favorites.

EPA has a list.

* Great **summary article** including opportunities to reduce methane emissions.

Brad, please URL link a few of them. I would do it this way:

Nice list of stupid ideas that we should stop (and then some we should do): **clean technica**

Project Drawdown

Perhaps also:

- See exciting technologies below
- Methane leak penalties.
- Offer financing to poorer people (and countries) for the higher upfront cost of clean energy.
- Buy out worst coal plants not just domestically but internationally, and retrain their workers — a position now endorsed by **Coal Miners' Unions**).
- Seasonal Roof color.
- Heat storage. Heat pumps are almost magical devices. They produce heat at far cheaper cost than the very inefficient electric heater ovens.
- Building codes: California is **leading the switchover**.

Cartoons

where do we have government should not interfere with people's lives?

footprint2

"I'm here to check your carbon footprint."

Compiled: November 25, 2021