Chapter 8

Leaving Fossil Fuels

Even after record years for green energy, the world today still runs approximately 85% on fossil fuels. We shall thus start the technology part of our book with an introduction to the advantages and disadvantages of coal, oil, and natural gas vis-a-vis three important clean alternatives: hydrogen, nuclear power, and batteries (most likely charged by wind and solar farms). We will also caution to keep a cool head when it comes to taking in all the propaganda. This caveat applies both to clean-energy objections from the fossil-fuel side and overly exuberant technology forecasts from the clean-technology side.

1 Ongoing Growth

The scale of the energy transition poses huge challenges. If humanity simply wanted not to increase fossil-fuel consumption further — too modest a goal — then clean energy will "only" have to cover the future increases in energy needs. Nevertheless, as we explained in Chapter 1, where we also mentioned that nameplate power and fossil-fuel inefficiency in the conversion to electricity are roughly similar, this still means that clean energy will need to grow by a factor of 15 *within the next 30 years*. In numerical terms, that translates into an increase from a measly 8 PWh to 117 PWh, with about 110 PWh just to prevent increases in fossil fuel use. If humanity also wants to retire coal, it will require growth of 150 PWh, a factor of 20. If the goal is to retire all oil, gas, and coal, it will require 240 PWh, a factor of 30. The latter two numbers represent real growth rates between 9% and 12% per year. Think about what it would take to increase anything by a factor of 30 — say, your income or bank account.

Right now, clean energy is growing by about 15% per year — but it's easy to grow from a low base. Growing at 12% per year consistently over thirty years is not impossible, but it's a tall order. Doing it **much faster** seems impossible. (And if it is, we should push for it.)

2 Fossil Fuel Advantages

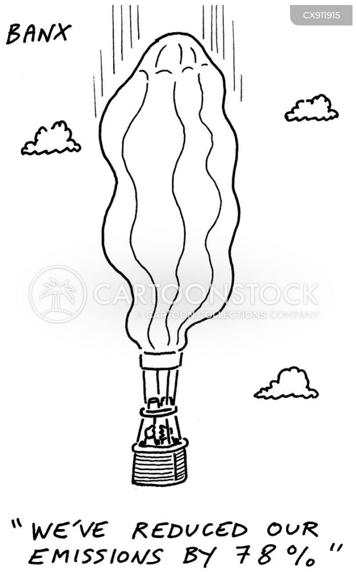
Fossil fuels have taken over the world because they have some important advantages. You should understand them first. Besides the sheer challenge of replacing such large amounts of energy, it is also the case that fossil fuels are different from renewable and clean replacements — their energy is better in some respects, worse in others. The most important advantages of fossil fuels are:

1. An existing infrastructure to collect fossil fuels, send them to the desired destination, and use them efficiently (especially in highly-developed countries). This includes wells, storage facilities, refineries, distribution networks, and devices that run on fossil fuels, such as cars, ships, trucks, planes, heaters, factories, and furnaces.
2. Abundant availability at low cost, even after figuring in logistics costs.
3. Low shipping costs for gas (pipelines) and oil (tankers), but not for coal.
4. A high energy density for oil and gas, both by weight and volume. This is important not only for shipping, but also when used to power engines. Airplanes, cars, and trucks simply perform better when light and small.
5. A good safety record, with limited potential for disasters.
6. Near-perfect efficiency when burned for heat. However, fossil fuels have poor efficiency when converted to electric or kinetic energy.

These characteristics need to be judged relative to those of the clean alternatives available — principally hydrogen, batteries (charged from electricity from wind and solar), and nuclear energy.

We will discuss technologies in more detail in part III, but for now, let's outline how clean energy differs from fossil fuels.

3 Hydrogen



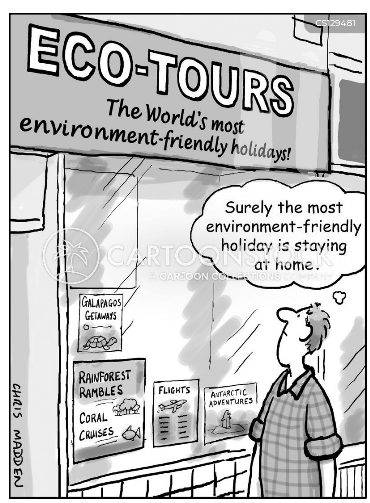
Hydrogen is the closest direct clean substitute to fossil fuels, particularly natural gas (methane). It contains energy in the form of chemical bonds. It is so similar that it can even use most of the existing natural gas pipeline infrastructure (with some alterations to reduce corrosion). And it can be **converted** further into natural gas. But it's not exactly the same.

First, there are differences in energy density. Hydrogen is lighter but requires more space (even in liquid form). It can store almost 40 KWh per kg, which is about three times higher energy density *by weight* than oil and gas (and eight times higher than coal). Great. However, hydrogen can only store 2.8 KWh per liter. This is one quarter the energy density *by volume* of oil and one half the energy density of gasoline. Not so great.

Despite drawbacks, hydrogen (or further derivatives based on it) has an almost assured future: It will likely become the fuel for airplanes, where there is no grid connection and weight matters. However, the necessary increase in fuel tank volume will require airplane and possibly **power train redesigns**.

If you feel queasy about flying in a hydrogen airplane, this is probably because you have watched the 1937 **Hindenburg disaster**, in which a spark ignited leaking hydrogen and caused a massive fire. It has given hydrogen a bad rap that it has never overcome. Yet with modern technology, hydrogen can be just as safe as fossil fuels. The real problem was not even the disaster (airplanes have had many worse disasters) but the spectacular **film record**. Even this footage was misleading. Most casualties on the Hindenburg were from people jumping out of the gondola. Hydrogen burns quickly and upward from its **envelope**. The gondola, where the passengers were located, was below the envelope. Passengers who simply waited until the gondola descended walked away scot-free.

As of 2021, hydrogen has "only" one practical drawback, but it is deadly: for the same amount of energy, when created from clean sources via **electrolysis** (rather than from natural gas), hydrogen energy costs about ten times more than natural gas. Over the next 30 years, the cost differential is likely to decline from this factor of ten to a factor of two.

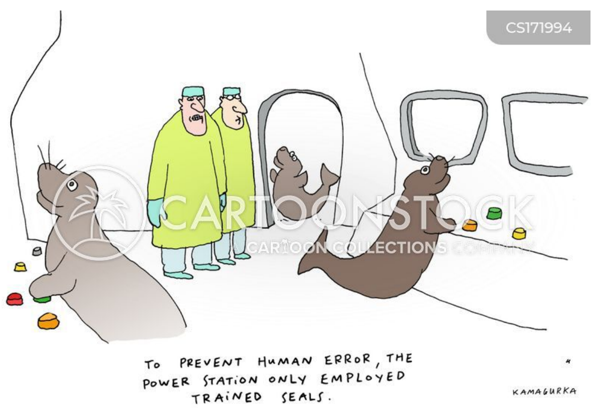


Even if hydrogen becomes economically viable against natural gas, it will still likely not be used in all the same ways. Fossil fuels are a cheap way to store massive amounts of energy that will eventually be turned into electricity. That is, fossil fuels today are mined, then stored and finally burned when needed. Without a breakthrough catalytic technology, the round trip (make hydrogen from electricity, store hydrogen, make electricity from hydrogen) will remain more expensive than using batteries, or storing air pressure or heat.

Therefore, we can predict that hydrogen will be important in transport applications that have no close access to the electric grid (specifically, airplanes and ships), but not in utility-scale electric generation or automotive transportation.

4 Nuclear Power

The next clean alternative is **nuclear power**, the ultimate **Promethean fire**. **Uranium** and **thorium** are powerful and inexpensive energy sources, but they are also extremely dangerous. Society considers nuclear power's biggest problems to be (1) the mixed safety record, and (2) the high plant construction cost. However a third problem may now be even worse: (3) the risk of early obsolescence. All three problems are linked.



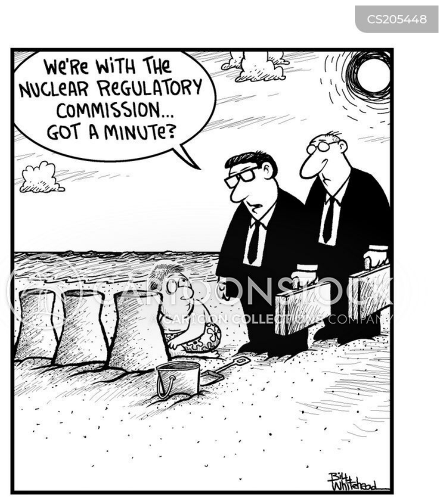
Nuclear plants may be among the safest plants ever designed by engineers, but they have such exceptionally catastrophic potential that safest may not be good enough. Despite extensive safety regulations, there have been major nuclear accidents about every 30 years. (**Chernobyl** was the worst.) The estimated **rate has been 1 core-melt down per 3,704 reactor years**, which is far higher than what engineers designed the plants for. (You can see that this is a problem when you count: there are about **500** nuclear power plants operating in the world today.) Despite excellent engineering arguments about how safe they can be or are, it remains plausible that future unknown unknowns will cause new types of unforeseen nuclear accidents. Each one will be a little different and fixed — but potentially catastrophic at least once.

It is also likely that the wider public (and some experts) will always doubt whether nuclear plants can ever be trusted. Think about the construction incentives when not everything can be triple-checked and inspected. We cannot forget John Glenn's famous quote: "**I felt exactly how you would feel if... you were sitting on top of 2 million parts — all built by the lowest bidder.**" Somewhat ironically, the public has been more forgiving of coal plants, which are much **more harmful**. They kill thousands of people with their relentless pollution every year, but they do so with more consistency, less individual-death attributability, and most importantly, with less of a bang on the evening news.

potential joke

> What's the most terrifying word in nuclear physics? Oops!

Regulation of nuclear plants is a difficult subject. Regulators are on the hook if something goes wrong, as they should be, but they get no reward when the plant runs. No new nuclear plant has been designed and built since the inception of the **Nuclear Regulatory Commission** (NRC) in 1975. It is an excellent **question** whether the current regulatory approach and thicket of regulations have been making plants safer by adding more safeguards, or less safe by making newer designs so expensive that they have not been worth inventing.



But if nuclear energy is to make a comeback, the only way will be one in which the safety can be improved by **two orders of magnitude via new designs**. Such designs must no longer be based on **active pressurized cooling** that can lead to a chemical explosion when it fails.[1] (In turn, chemical explosions and cooling loss can cause a core meltdown.) This is not a pie-in-the-sky possibility — better designs already exist. They just have not been built yet. **First Of a Kind** plants in general and in **nuclear energy specifically** are much more expensive than **Next Of a Kind** plants. Even **Fusion** plants, despite their completely different physics, are economically really just like a fission plant that immediately turns off when disturbed and is thus much safer. (Fuel costs have never been a limiting constraint for fission reactors.) And these very expensive new types of plants may never even need to be built. But what if clean energy storage were to stall? Then what?

The public is also concerned about the **nuclear-waste disposal** problem. However, this problem is solvable. It was created in large part by governments. They promised to take care of the waste, thus giving utility operators little incentive to worry about waste themselves. Much of the waste could even be used as fuel in newer breeder reactors, especially the most dangerous element, **Plutonium**. (Of course, they are not being built,

[1] Contrary to popular perception, nuclear reactors cannot explode like a nuclear bomb. Instead, they can explode when they are not appropriately cooled, because their heat then generates explosive hydrogen as a byproduct. Once the hydrogen explodes, the core becomes like a "dirty bomb" — which is not really a bomb in a conventional explosive sense, but a source of highly toxic pollutants. Moreover, also contrary to public perception, the nuclear waste problem can be solved with a "breeder reactor." Existing nuclear plants consume only a tiny fraction of the energy in their nuclear fuel, but it is not worth it to recycle it because fresh uranium is dirt-cheap (truly!).

either.) It is cheaper for nuclear plant operators just to mine new uranium than to reprocess nuclear waste.

But ironically, the biggest threat to nuclear power is no longer actual safety, poor public relations, excessive regulations, or radioactive waste disposal though these have greatly contributed to increasing the cost of building new nuclear power plants. Instead, the biggest threat now is economics. The problem is the sheer required scale of building a nuclear power plant given the looming potential of other clean energy waiting in the wings. Who wants to invest their money into a $5-10 billion nuclear plant that will take 5-10 years to build and then needs to earn money over a 30-year lifespan, if the invention of better, clean energy storage could obsolete it before it is even finished? (But, again, what if clean energy stalls?)

The best candidates for purchasing nuclear power that we can think of for the nuclear power solution are governments that are pressed to increase electricity production immediately, or perhaps governments that want to become the go-to source for all things nuclear (i.e., France). If nuclear plants could be mass-produced and shipped on trucks (as indeed some can), they could probably provide a lot of energy on very short notice. But, with a 10-year construction schedule, nuclear power cannot satisfy urgent power needs fast enough, either.

In the meantime, the world's 500 nuclear plants are on average over 30 years old. Most will shut down within our lifetimes. Extending their lifetimes, perhaps with stricter safety inspections and guidelines until clean energy has solved its remaining problem of storage, should be on the menu.

5 Batteries

We will discuss wind and solar power generation (and energy storage) extensively in the next chapter. They are already the cheapest sources of power today. Their Achilles heel is that they generate power not on demand but only when nature cooperates. Fortunately, batteries can be charged by wind and solar power when electricity is cheap and abundant; and discharged on demand when electricity is expensive and scarce.

potential anecdote

> Abraham Lincoln, 1860: Of all the forces of nature, I should think the wind contains the largest amount of motive power ... Take any given space of the earth's surface, for instance, Illinois, and all the power exerted by all the men, beasts, running water and steam over and upon it shall not equal the 100th part of what is exerted by the blowing of the wind over and upon the same place. And yet it has not, so far in the world's history, become properly valued as motive power. It is applied extensively and advantageously to sail vessels in navigation. Add to this a few windmills and pumps and you have about all. As yet the wind is an untamed, unharnessed force, and quite possibly one of the greatest discoveries hereafter to be made will be the taming and harnessing of it.

Batteries are intrinsically completely di erent from chemical and nuclear energy storage. They cannot store energy in every chemical bond. Thus, they have low energy density. Even the best lithium batteries provide only about 0.25 KWh/Kg and 0.5 KWh/L (compared to 12 15 KWh/Kg and 5 11 KWh/L for oil and gas). For transportation, this limitation is partly compensated for by the fact that electric engines have 90% (or more) e ciency compared to 25% for combustion engines. Similarly, for grid-based and near-grid-based electricity storage, the low energy density of batteries is not very important. Their high input-output e ciency makes up for it.

However, for some applications, batteries are as wrong an economic solution as hydrogen is for electricity storage. The least suitable application is heat. Burning fossil fuel for heat is supremely e cient, with almost all the energy coming in the form that is ultimately desired.

However, even if fossil fuels were banned, batteries would still not be the right solution. The alternative to storing electricity in batteries and making heat later is making heat rst and storing the heat in thermally isolated containers. The latter is far cheaper and more easily scaled. This is not only the case for home heating, but also for industrial applications, such as in furnaces.

The second and greater problem with batteries is a central subject of our next chapter: their xed cost structure. More energy storage for batteries means manufacturing more batteries. This is expensive. In contrast, more energy storage of fossil fuels simply means a larger tank. This is why there is only about 100 GWh of battery storage on the U.S. grid. That's enough to power the U.S. electric grid for about 10 minutes. To cover just ordinary days (and without growth of demand) will require at least 50 times as much capacity. If the world were to electrify transport and heat, too, it would probably require

100 to 200 times as much capacity. Currently, batteries are too expensive to take over electricity storage at this scale.

6 How To Read Technology Forecasts

At this point, you are probably as enthusiastic as we were when we started writing this book about wind, solar, and battery technology. (We still are, but a little more cautiously so.) A lot of pundits are describing an exciting energy future ahead. Not a week passes without more great news on some invention. And the progress of clean-energy technology has consistently outperformed even its optimistic predictions . But before you buy into all the clean-energy propaganda, let's take a step back and explain why you should remain excited in general but not in the speci cs.

For example, Agora is one of our favorite battery technology candidates. It already has a prototype for a CO2 consuming redox ow battery, whose emissions are primarily bicarbonates. These are costly chemicals used widely in industry. Agora could revolutionize the world. What could possibly go wrong? Plenty! The devils are in the details, and there are many details before the technology can be mass-deployed if ever. Foreseen or unforeseen problems could throw a wrench into the gears (though batteries have no gears). Agora may not be able to solve the toxic bromine byproduct problem. The owning partners could fall out among themselves and litigate rather than develop. Or the founders or CEO could be incompetent. Or their sales department may be incompetent. Or the money could run out in the height of a nancial crisis. Or another battery technology could obsolete them before they can even start. Or government regulation and red tape could kill them. Or an accident, possibly with great publicity, could set them back. Or electricity demand may stagnate. Or lithium car batteries could last virtually forever and simultaneously back up the grid. Or some other countries may wait for the rst Agora product, disassemble it, reverse-engineer it, and produce it more cheaply in mass. (Litigation over property could well take decades to resolve, by which time Agora could be bankrupt.) More concerning, Agora is a technology rm, and they will need global manufacturing partners and chemical commodity partners. And so on.

The right way to think about Agora and other battery technologies is that even the most promising truly new technology (i.e., that is not just a small improvement on existing lithium batteries) has perhaps a 1-in-10 chance. (A 1-in-10 chance of revolutionizing the world is no small feat!)

However, the future for humanity is far more promising than just Agora. There is not just Agora, but maybe two dozen battery developers with innovations of various kinds. Any one of them has only a small chance of success. But one or two of them will almost surely hatch.

Put di erently, we would not put all our eggs into Agora's baskets. But we would take a bet that within 10 20 years, today's conventional Lithium batteries will no longer be the dominant form of utility electricity storage. Of it they are, they will be orders of magnitude cheaper.

7 The Politics of Defending Fossil Fuels

We just advised caution about clean-energy propaganda. We would advice twice the caution about better-funded fossil-fuel propaganda. The fossil-fuel industry and its employees are not taking the clean-energy transition in magnanimous resignation. Instead, they are ghting for their livelihoods to delay the transition as long as possible the American way.

Their most prominent approach has been to support surrogates who sow FUD (fear, uncertainty, doubt). The goal of their campaigns is to discourage customers from buying into newer and better alternatives. Historically, the fossil-fuel industry has not just been proli c in providing energy, but also in spreading misinformation the subject of Michael Mann's book The New Climate War.

Today's fossil-fuel proponents are delighted when they can raise environmental objections to wind, solar, and nuclear power. Although their objections are typically correct and indeed require consideration, they are mostly red herrings. There are no intrinsic show-stoppers preventing eventual large-scale deployment of clean energy. Let's go over a few of them.

Energy Density

Their most important objection to wind and solar is their low intrinsic energy density. It is true that physics limits the area density of wind turbines to about 3 Watts per square-meter and the equivalent area density for solar cells to about 10 Watts per square-meter. (There is room to improve this solar number. Moreover, there is plenty of space. O shore wind alone could probably provide enough power for the entire electric grid of the United States, though at a higher price.) Because of the low energy density of renewables, critics note that to provide 4 PWh of energy (the current annual electric energy demand of the United States) would require an area twice the size of Massachusetts about 20,000 square miles. This observation is largely true.[2]

[2] Actually, fossil fuels only provide about 2.5 PWh of these 4PWh, and even the area for 4 PWh is overstated, given newer and more e cient solar cells.

Figure 8.1. Solar Area

Source: Bill Nussey, 2018, at freeingenergy.com .

However, keep the size of the problem in mind. This area would supply the entire electric energy demand for the entire country. Figure 8.1 shows the required area in a more appropriate perspective, courtesy ofBill Nussey . The Mojave desert alone could meet the entire electricity generation demand of the United States.[3] Comparing the required 20,000 needed square miles, Nussey also points out that the oil & gas industry leases about 40,000 square miles from the Federal Government, that about 13,000 square miles are impacted by surface mining, and that about 30,000 square miles are used to grow corn for ethanol. Agricultural land in the United States covers about 900,000 square miles, about 45 times the 20,000 square mile area. Furthermore, wind farms can be built on land that can still be used for agriculture, and solar farms are optimally located in desert areas where there is little agriculture.

Nevertheless, although doubling or tripling the 20,000 square mile area to cover 4 PWh of electricity would still not be a problem, the United States consumes a whopping 30 PWh in primary energy (i.e., all energy, not just in electricity). Electricity is a higher-quality source than fossil fuel if it has to be converted to kinetic energy, but it would still require an area more like 100,000 square miles (ve times the square in the area),

[3] Of course, environmentalists will object that lizards' and turtles' habitats will be adversely a ected, but until the environmentalists can present a better constructive electricity alternative, these concerns should not be enough to stop construction, merely enough to modify speci c plans. It is also not clear whether the extra shade won't be of natural bene t to many species.

plus a requisite area for energy storage, to transition all power to clean electricity. This is a taller order than just transitioning electricity generation, but it is not impossible. [4]

Many similar objections are variations on the theme that the required scale is just too large for example, a recent variation on this theme claims that the United States would have to build one new renewable solar/wind installation every other day. This assertion seems frightening until the reader realizes that 7 new power plants per U.S. state per year sum up to 350 power plants. It's one new plant per year for every 1 million people. The United States is a big country.

Fortunately, all of this is a tall order that we do not even need to contemplate for at least another decade or two area density and growth will not be limiting constraints for decades. Instead of focusing on the debate how much we could ultimately cover, we should instead focus on starting to plaster large areas with solar cells soon in order to move that needle now.

Resources, Recycling, and Waste

Another objection from the fossil-fuel lobby is that wind and solar farms require resources and energy to build and install.[5] Another version of this argument is that many renewable technologies need more rare earth elements such as lithium or cobalt than the world is producing now. This objection is, in fact, correct. This why mining companies are exploring actively for new mines. Rare earths are not at all rare. They have just not been needed. When demand for them goes up, miners will produce rare earths in abundance. Moreover, for almost every needed ingredient for batteries, there are already many alternative materials on the horizon manufacturers are simply using the ones that are cheapest at the moment.

Still another version is that turbines and panels will have to be retired at the end of their lives. These claims are again true. The green industry has not yet worked out how to recycle its devices the industry has been busy and has not yet built enough wind, solar, and battery devices even to worry about large-scale recycling.

Although it is true that mining materials to build renewables will have adverse environmental consequences, a lot more mining is required to keep fossil-fuel plants going. The desolation and pollution spawned by many coal, oil, and natural gas elds are comparably devastating. In comparison, if worse comes to worst, at the end of their lifespans in 30 years, we can just bury turbines and solar panels in shallow graves or land lls. Unlike coal, oil, and gas infrastructure, obsolete turbines and panels are not hazardous waste. Even lithium batteries are comparably harmless.

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[4] Deserts can similarly provide most of China and Africa (and to a lesser degree India) with power, although with high transmission costs. China has the potential to meet 13 times its electricity demand with solar power.

[5] Ars Technica (2021) has a wonderful rebuttal of a typical set of fossil-fuel shill claims trying to knock clean technology.

But it probably won't come to this. When there are enough end-of-life installations, someone will probably find a new use for them. In 1990, there were three billion car tires in disposal sites (over 1 billion in the United States). There are no more tire mountains today, not because the environmentalists raised the alarm, but because used tires are now a valuable raw material for the construction of cement, flexible surfaces, etc. In fact, used tires are expensive now.

More likely, industry will be able to reuse some and discard other parts. And in any case, there are no externalities that could not be priced into the construction and disposal of clean energy especially if the United States were to institute a fossil-fuel tax and sensible environmental regulations.

In a cosmic view, objections to renewables should even be welcome. Thinking about these issues early on is a good idea. For example, there will indeed be environmental impacts associated with the transition. How else could the world provide the energy for 8 billion people? (Both the agriculture and the energy sectors evolved naturally and never managed their much larger environmental impacts. This has made them more problematic than necessary.) Companies could build solar cells, windmills, and batteries designed for easier recycling, especially if the government forced them to take back the residuals at the end of their lifespans. (The race is already on.) The government could also plan better in terms of where and how to foster specific clean-energy solutions.

Ingredient Costs

It is also true that there can be battery price fluctuations related to shortages of ingredients for today's battery chemistries. It won't be lithium, which is actually the cheapest part of the battery, but cobalt and nickel used for anode and cathode. But this is temporary. The world has just not needed these materials in large quantities for a long time, and it will take a while to find and open new mines. Here, the free market and profit motive will work wonders. In the long run, ample natural availability of ingredient elements, mass production, and competition will almost surely continue to drive down battery prices. Furthermore, there are also plenty of other materials suitable for stationary utility-scale batteries that can be developed over time. From an economic perspective, cobalt (and nickel) just happen to be the best materials at the moment.

Unfair Competition

An even sillier claim is the complaint about unfair competition and subsidies to clean energy. Although it is true that clean energy is now subsidized in many locales, the sum-total does not remotely come close to the subsidies that the fossil-fuel industry has enjoyed for over a century and is continuing to enjoy. As already mentioned, the IMF (itself no anti-capitalist green institution) has assessed the worldwide externalities and subsidies to the fossil fuel industry at more than $5 trillion per year.

The Inevitable Delayed

Perhaps the most e ective impediment to clean energy are variants of NIMBY (not in my back yard) litigation. They can e ectively delay and sometimes outright stop the transition. We will come back to how to handle this concern appropriately in our nal chapter. In any case, ultimately, the transition is unavoidable. At current rates of usage, fossil fuels other than coal could be depleted in a century or two .

8 The War on Climate-Change

Given news coverage of public concern about climate change, is it the case that the world is now at war with climate change? Allow us to be cynical for a moment. Who exactly views climate change as a coming apocalypse? Climate change seems to be primarily a niche concern of middle- and upper-income people living in richer countries. By and large, most people go on with their lives instead of thinking about future generations. For most, the national soccer team or personal relationships seem more important. Some journalists try to push climate change as an important issue, but the press has become largely an echo chamber. It writes what its audiences want to hear and audiences self-select. Most of the audiences of climate-change websites are the people who are already concerned. And even most of them have other more immediate problems to worry about.

Table 8.1 shows where government spending actually goes. As a whole, Western countries are not putting their money where the media's mouths are with regard to climate change.

Take the United States, for example. We emit about 5 GtCO_2 per year. There are plenty of opportunities to remediate or switch technologies to remove at least the rst tonne of CO_2 at $50-100/t$CO_2$ or less. (For example, we could start o by planting trees and harvesting wood, as we will explain in Chapter 11.) Multiply 5 GtCO_2 by $50/t$CO_2$ and you get a total cost of about $250 billion per year, or about $750 per U.S. citizen.

Yes, $750 per person per year (or $3,000 for a family of four) is a lot of money, especially considering that the median income is only about $35,000/year per capita and $63,000/year per household. But $750/year is also $2 a day. And it is only about one-quarter of our military budget. If we rst subtract out enough from our budget to match the sum of Russia's and China's spending on military expenditures, it is still only about half of our additional military expenditures. Double it, if you wish to account for our optimism about the cost of CO_2 removal at scale. The

Table 8.1. Annual GDP, Spending, and CO_2 Removal Costs, 2020

		In Trillion-$	Per Person
Global	GDP	$ 84.71	$10,870
	Health Spending (9.9%)	$ 8.40*	$1,078
	Defense Spending (1.5%)	$ 1.98	$254
US	GDP	$ 20.94	$63,480
	Health Spending (17%)	$ 4.00*	$12,200
	Defense Spending (5%)	$ 0.78	$2,380
	... minus RU ($0.062) and CH ($0.252)	$ 0.46	$1.400
5 $GtCO_2$ (US) Removal Cost @ $50/$tCO_2$		$ 0.25	
15 $GtCO_2$ Removal Cost @ $100/$tCO_2$		$ 1.50	
30 $GtCO_2$ (World) Removal Cost @ $200/$tCO_2$		$ 6.00	

Explanations: The gures are approximate. Per-person numbers are based on a global population of 7.8 billion and a U.S. population of 328 million. For perspective, the per-person per-year emissions of India are 1.5 tCO_2, of China 7.5 tCO_2, and of the US 15 tCO_2. The global average is about 5 tCO_2. Key Sources: OECD, SIPRI, and OECD.

fact is that countries are not at war with emissions. They are at (a low- ame) war with one another.

We share the obvious wish to redirect the world's military spending to better causes. But, for better or worse, as we explained in the previous chapter, the world is not a decision-maker. Thinking in terms of global welfare is a conceptual error. Countries are the decision makers. And realistically, they will not redirect their military spending towards environmental spending.

As of 2021, American energy-related spending remains small and almost incidental. Not surprisingly, the U.S. Armed Forces spend more on nuclear weapons than on clean-energy technology. But the same is true even for the so-called Department of Energy ! The National Science Foundation did o er modest support, but much of that spending funds university overhead rather than speci c energy projects. Clean-energy R&D needs more funding administered in a better fashion.

But our voters and politicians have spoken, and they do not view climate change as the apocalypse. They prefer to support their militaries rather than the war on climate-change. And even if the current U.S. or any foreign administration is willing to direct more funding to environmental issues, the next administration may not be. And, at the rate that our voters' views can be changed, we may get around to committed large-scale pollution ghting in, say, 100 years. This is not good enough.

The United States is by no means alone, either. Take Germany, among the most environmentally conscious countries on earth. (The European Union in general is the world exception.) With the Green Party in government and without any enemies on its borders, Germany's typical green spending is approximately **$12** billion, about 25% of its spending of **$50 billion** on its military. (However, Germany's recovery stimulus program is far more aggressive in its green spending.)

Go beyond Europe and the rich West, and there is almost no spending on green initiatives and lots of spending on militaries. And as we explained in Chapter 2, the world's most urgent task now is to convince China, India, and Sub-Saharan Africa to curtail their growth in emissions. The United States and Europe are no longer enough.

Thus, our recommendation for realistic environmentalists is this: Let's advocate moving on actions that we can engage in *in our own countries here and now*, that have a good chance of winning and maintaining political support *in our own countries here and now*, and that are likely to have staying power *in our own countries and beyond here and now*. Let's leave the Utopian proposals to later.

Realistic solutions should be such that, once implemented, it will be cheaper and more convenient to continue with them and not to return to the old fossil-fuel way of life in the next electoral cycle. Again, this means focusing on low-hanging fruit. And the sweetest fruits are those that require only getting a process started, without having to pay forever to keep it going — in other words, let's convince our governments to view themselves as **catalysts** rather than cops.

9 Conclusion

Don't believe everything you read. Clean technology is exciting but not yet fully ready to take over the world from fossil-fuel technology completely. Activists need to keep pushing in the most intelligent and effective ways possible. Let's try to nudge government efforts towards accelerating the transition at realistic costs.

The current steps are really all that activists should care about right now — *moving the needle now*. Let's worry about the grander proposals for full decarbonization only after we have made good progress on the first task.

Further Readings

Books

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Shorter Newspaper and Magazine Articles and Clippings

- **Timmer, John**, 2021, **Pure nonsense: Debunking the latest attack on renewable energy**, Ars Technica.
- **Your Batteries Are Due for Disruption**, New York Times, Sep 12, 2021. (Sila for silicon-based anodes.)
- **Laville, Sandra**, 2021, **G7 nations committing billions more to fossil fuel than green energy**.
- **Mills, Mark P.**, 2019/08/05, **If you want renewable energy, get ready to dig**, Wall Street Journal. (The substance is correct, but Mr. Mills does not compare how toxic it is to dig up and process fossil fuels into electricity.)
- Bousso, Ron, 2021/09/20, **Special Report: BP gambles big on fast transition from oil to renewables**, Reuters.
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- Ghosal, Aniruddha, 2021, **'Nothing Else Here': Why it is so hard for the world to quit coal.** Associated Press News.

Excess Cartoons

batteries-footprint

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