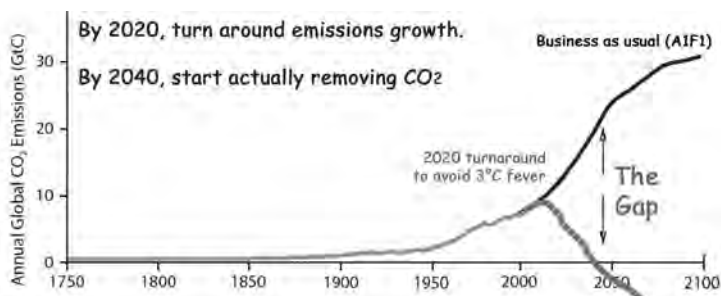


It is becoming clear that we must make a choice. We can resolve to move rapidly to the next phase of the industrial revolution, and in so doing help restore wonders of the natural world, of creation, while maintaining and expanding benefits of advanced technology.

Or we can continue to ignore the problem, creating a different planet, with eventual chaos for much of humanity as well as the other creatures on the planet.

—climate scientist Jim Hansen, 2007



This graph shows the slow growth in fossil-fuel emissions until about 1950, then the five-fold increase in the second half of the twentieth century, and finally the projected path until 2100 under a Business As Usual economic scenario.

The gray line is simply my cocktail-napkin sketch of what is needed to reverse the growth in emissions by 2020 and getting into net removal of CO₂ by 2040. The vertical distance between the two projections, which must be filled by reducing emissions and creating carbon sinks, is called The Gap.

19

Turning Around by 2020

The future ain't what it used to be.

— Yogi Berra, Baseball Hall of Fame philosopher

Time has become so short that we must turn around the annual emissions growth before 2020 to avoid saddling today's students with the world of refugees and genocides that results if we're too slow.

That means not waiting for a better deal on some post-Kyoto treaty. It means immediately scaling up technologies that we know will work, not waiting for something better that could take decades to debug.

The standard green answers (compost, carpool, eat locally grown foods rather than ones that require long-haul transport, become a vegetarian, and so forth) are all important. But, as James Lovelock likes to say, they may prove no more effective than dieting.

What we need are sure-fire solutions that stop the CO₂ pollution from all of those tailpipes and smokestacks. And do it quickly, which means not relying on efficiency

improvements or new rapid transit systems that take decades to implement. Our problem has now become too big and too immediate to rely on reforming people's habits.

Since a quick response is not the timescale of investment capital, the energy changeover is going to require major government leadership to make sure it gets done quickly. The Manhattan Project of 1942 to 1945 shows us how we have quickly turned recent science discoveries into major engineering projects.

Going to the Moon was a major national effort that, while expensive, did not require a wartime economic restructuring. I had lunch with George Mueller, who ran the Apollo Project for NASA in those critical years from 1963 to 1969. I asked him what it would take to stage, on an urgent basis, our energy makeover and climate restoration.

First, he said, simply banning certain energy uses would not work any better than the U.S. experiment with banning alcohol, which simply created a bootlegging industry. (Imagine cheap Chinese incandescent bulbs smuggled into California, Australia and Canada, now that they have decided to ban the old-fashioned bulbs.)

For an Apollo-scale project to create non-carbon energy alternatives, Mueller said that we needed a goal that was easy to understand (something like putting a man on the moon and returning him safely). And the goal needed a time frame (President Kennedy's "this decade") to persuade the public to act now.

We choose to go to the moon
in this decade
and do the other things,
not because they are easy,
but because they are hard,
because that goal will serve
to organize and measure
the best of our energies and skills,
because the challenge is
one that we are willing to accept,
one we are unwilling to postpone,
and one we intend to win . . .

—John F. Kennedy, 1962

I'd propose *Turning around by 2020* as our goal and time frame, followed up by two more.

1. The 2020 target would be stopping the annual growth in emissions to keep the eventual fever below 2°C. But we'd still be growing the CO₂ blanket, year after year, just at a constant rate.
2. The 2040 target would be to stop the annual CO₂ growth altogether. This means that increased sinks would have to balance out any remaining fossil carbon emissions, including the delayed ones. Note that we still haven't reduced CO₂ concentrations, only stopped its growth. Then we begin removing more CO₂ from the air each year than we add. That makes it a matter of adding sinks, not merely controlling emission sources. Call it *Sinking CO₂ by 2040*.

3. Restoring CO₂ concentrations to 1939 levels would be my third goal. Call it *Restoration by 2080*.

We may well need to double power production in order to clean up CO₂, double again for worldwide modernization, and with another step up if we are to go to electric cars. This expansion only makes sense with C-free energy—lots of it.

Let me now evaluate the various candidates for accomplishing the 2020 turnaround. I'll later summarize their advantages in a table for easier comparison.

Use less. That's the most obvious solution. There are two versions. The relatively painless one is increasing efficiency. A modern refrigerator uses one-fourth the power of a 1975 model. And so we replace incandescent light bulbs with compact fluorescents or LEDs. Same lumens, less watts. Better gasoline mileage and more carpools also achieve the same end use, but using less power.

The more painful version is the diet that requires shedding the end uses themselves—say, turning off the all-night street lights or hanging the clothes out to dry instead of using the clothes dryer. Such banished end uses tend to creep back on stage within a few years.

Furthermore, both versions are local or regional solutions that won't produce global solutions in time.

Developing countries won't forego modernization just because we say so.

Better for 2020 to assume that those end uses will stay the same and even expand. And so we must focus on substituting C-free power sources and finding ways to create new carbon sinks.



You already know the scene for reducing our use of oil—converting to hybrid vehicles and alternative fuels. If plug-in hybrid electric vehicles (PHEVs) were to replace the 198 million cars, vans, SUVs, and light trucks in the U.S., it would cut oil imports by half.

Though I wouldn't recommend it, 84 percent of the recharging job could be done with excess overnight capacity in America's coal-fired plants. Even though burning coal to replace oil, it would nonetheless reduce overall CO₂

emissions. Such is the wasted energy from using 198 million inefficient internal combustion engines that must be kept idling in congested traffic.

But this has to be done globally. A fleet of PHEVs requires much mining to make the batteries. Poorer countries would have to import them. “Air cars” that run on compressed air would be easier for a developing country to manufacture from local materials.

No, it’s not a rocket. No electric motor, either. It’s an engine where the compressed air runs a piston. Refilling the air tank can be done overnight by plugging in the on-board compressor. So air cars also run on electricity, just one step removed. It’s the same for hydrogen fuel cell cars.

Just as a spray can cools your hand, so the carbon-fiber air tanks will become quite cold during use. The free air conditioning ought to make air cars popular in the tropics—and elsewhere, as global warming increases. I predict that beer will be cooled this way and that attached garages will also become popular, opening widely into the living quarters to cool them down as you unload the groceries.

	Ability to expand	Public view	Down side	Ups & Downs	Enough by 2020?
Hybrids	large	very good	mining battery	—	•••
Compressed air car	large	none yet	air tanks	—	•
Improve efficiency	good	in favor	slow grind	—	•
Dieting	limited	a pain	easy to fail	yo-yo	no

Coal-fired power plants are the big actors on the fossil carbon scene (in the U.S., more than half of the electricity comes from burning dirty coal) and if we don't address them immediately, the long run considerations will be irrelevant.

Coal-fired power plants are large, what with the ash heaps and settling ponds for the parts of coal that aren't carbon. Their footprint also includes those sawed-off mountains and terraformed landscapes left behind.

Though some new coal plants do a better job of capturing the metals which fall out locally, and the sulfuric acid that can travel much farther downwind, capturing the invisible CO₂ and methane is talk rather than action. The so-called "clean coal" (regularly featured in the quarter-page greenwashing ads on the *New York Times* op-ed page) is, at present, just trapping more ash and sulfur from going up the smokestack.

Coal-fired power plants throughout the world are the major source of radioactive materials released to the environment. Thorium and uranium may only be a tiny fraction of the coal but we burn a lot of coal. These trace amounts add up to far more than the entire U.S. consumption of nuclear fuels for electricity. About 10 percent is carried aloft on fly ash, made airborne for us to breathe.

For all the talk of capturing CO₂ and storing it down deep somewhere, it looks like such technology will suck up 40 percent of the power generated. Let's see, retrofitting the 403 existing U.S. coal plants would create a need for

another 269 coal plants. Big Coal's sales would go up 67 percent. (It's odd that no one ever mentions that.)



The Zimmer power plant in Ohio was supposed to be a nuclear power station but, in the middle of construction, they switched to coal, abandoned the expensive containment dome next door, and now truck the ash to what will become the highest hill in southern Ohio. Dumping the finer stuff into the air we breathe is “free.”

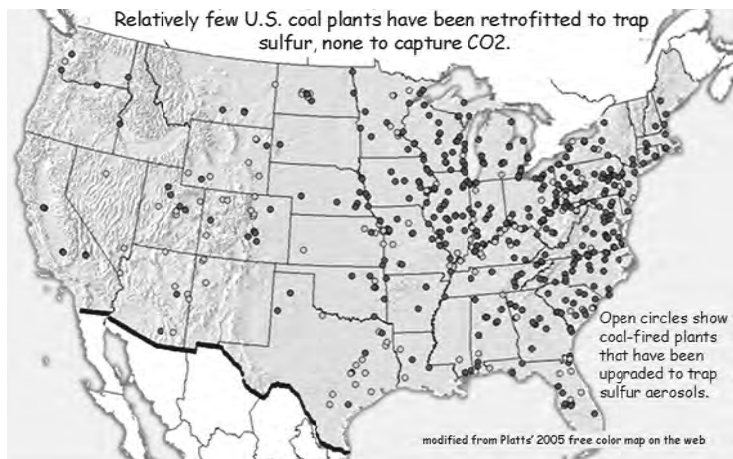
Over a fifty-year lifetime, each retrofitted 500-megawatt coal plant would produce a billion barrels of liquid CO₂ to be stored underground. No one knows how safe such storage would be. An earthquake could fracture the well's casing, allowing the stored CO₂ to escape. Clearly, this is experimental technology, not ready for prime time.

Such capture-and-storage talk may be another example of Big Coal trying to buy time by delaying action while, of course, getting yet another tax break from Congress to increase their record profits. Worst of all, even if practical, carbon capture and storage is not going to help very much

for decades. I can think of better ways to spend our climate makeover money.



In 1992, Zimmer set the world record for the most coal burned by a single generating unit, consuming four million tons of coal that year and venting thirteen million tons of CO₂.



Most U.S. coal plants have not bothered to retrofit acid rain scrubbers. Even using low-sulfur coal, there is the problem of uranium and thorium in the fallout.



It's grossly irresponsible, but U.S. power companies are planning on doubling coal consumption by 2030. The U.S. Department of Energy 2007 report is entitled "Coal's Resurgence in Electric Power Generation." It contains not a single word about the impact on climate change.

Here’s my subjective evaluation of coal.

	Ability to expand	Public view	Down side	Ups & Downs	Foot print	Storage needed	Enough by 2020?
Coal as usual	huge	dirty	huge	no	very large	no	n/a
Coal but capture the CO2	large	caution	storage burp, leaks	no	67% more coal	huge	very little

Hot Rock Energy is the most attractive possibility I know for quickly expanding an alternative energy source. Drill a 5-km-deep well into hot granite, feed it water, harvest the rising steam to spin the usual old-technology steam turbine, and you get electricity.

Though still in the demonstration project stage, it doesn’t suffer from nuclear fears, 15-year permit delays, and 5-year construction times. It is an alternative energy solution that is C-free, doesn’t fade as the sun sets, isn’t fickle like the wind, doesn’t require lots of space like biofuels, and doesn’t require mining heavy metals that are radioactive. It’s nice and steady without needing storage like hydro. It’s immune to droughts.

There’s nothing equivalent to coal trains and super-tankers, not even trade deficits. There are no big questions hanging over it as with carbon capture and sequestration. A Hot Rock plant’s footprint is no bigger than a two-story parking garage, with no runoff or air pollution or trucks hauling stuff—indeed, it would fit atop an old oil platform

offshore or inside a large barn (except when cooling condensers are needed).

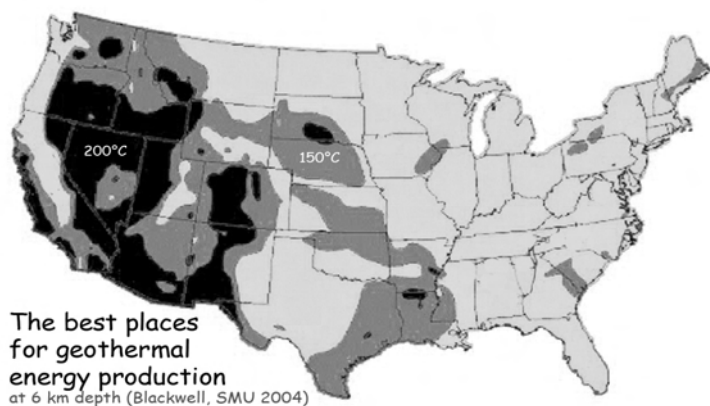
If you haven't heard of Hot Rock Geothermal (and it is typically left off the alternative fuels list, even when *Scientific American* did a special issue on the subject in 2006), it's because "geothermal" has an image problem rather like electric cars once had. It took the success of a 1997 gasoline-electric hybrid called the Prius to help people think ahead to an all-electric car without defaulting to an image of a golf cart of limited utility, not suitable for the freeways.

Hearing geothermal, we often pop up a mental image of a sulfurous hot spring and wrinkle our nose. Too many people think that geothermal is just piping near-surface hot water around to heat some buildings—say, Idaho's State Capitol buildings in Boise. This in turn makes you think that geothermal electrical power is a special case, nice for Iceland but not more generally. That, however, is your grandfather's notion of geothermal.

And a heat pump might be your father's. That's a different principle, the one that has long led people to build underground cellars to store food. A few feet down, the soil doesn't change temperature very much between winter and summer—and so by running a pipe through it, a heat pump can get it to cool water (which then cools air) in the summer and to provide some heat in the winter. Just think of burying a sprinkler system without the sprinklers.

Many countries have good traditional geothermal resources that have yet to be exploited for generating

electricity. Shallow wells are the most common. That's the "geothermal" implied in most mentions of alternative fuels.



The deep version now coming on stage is Hot Rock Energy with two or three adjacent wells. The idea is *not* to find hot water but rather hot rock that is dry. Then apply water to make steam. Though the U.S. has been lagging behind, the Hot Dry Rock concept was invented by scientists working at the Los Alamos National Laboratory in 1972.

Below the sedimentary layers is usually granite that's hot and dry. The farther down you drill into granite, the hotter it gets. Drilling 6 km below the surface is often sufficient to get 200°C (about 400°F, oven temperature) in the western U.S. The 100°C you'd get elsewhere works too, though it produces lesser amounts of electricity. (So you drill twice as many wells.) It usually takes the deep

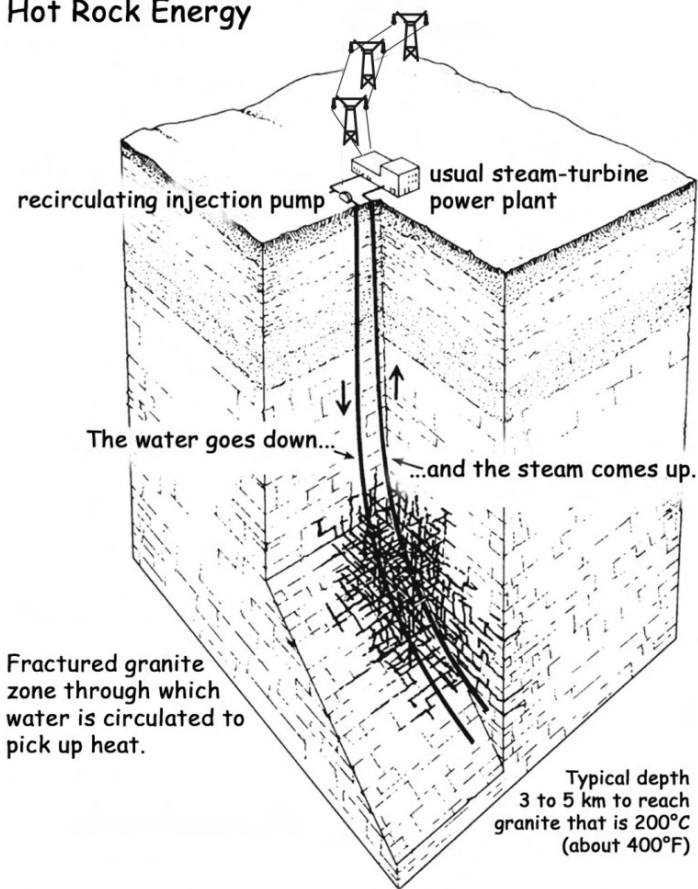
drilling technique used by the oil industry which can go 7 km down.

Unlike the hot springs version of geothermal, you have to provide your own water. But after you prime the well, you just re-circulate. What comes up as dry steam is pumped right back down again as water, via a second well nearby. It forces through cracks in the granite, heats back up, flashes into steam, shoots up the other well to the steam turbine, which spins the electrical generator, which feeds the great electrical grid, which keeps your domestic climate comfortable and your car recharged.

And how do these two wells connect? Such deep rock is already fractured along onion-like sheets, ancient planes of stress from bending. Mineralization has filled those cracks—but high-pressure injection can force water into them, opening up passages. When the high pressure is released, many do not reseal. Sometimes the layers shift a little, and the noise from such little earthquakes serves to locate the newly-opened crack. A map of the enhanced fracture zone is built up and, when it is several km across, the second (and sometimes a third) well is drilled into it to harvest the steam.

Gushers and mud eruptions don't come up out of the granite layers. If a sizeable earthquake fractures the well shaft, nothing happens—you just drill a new well nearby. That makes it much safer than drilling for oil or natural gas—or for storing CO₂.

Hot Rock Energy



adapted from 2006 MIT panel report

Hot Fractured Rock is drought-proof and does not involve a perpetual stream of truck traffic as biofuels and fossil fuels do. It is perhaps the least demanding on industry, except for manufacturing enough tall drill rigs and training enough crews. What's above ground is mostly modern steam plant gear, manufactured in many

countries and quite reliable. Operating it is well within the competence of all developing countries.

How extensive a resource is deep geothermal? For the U.S., the experts said it could yield a thousand times more than our present overall energy use. How polluting? Close to zero.

Geothermal energy from EGS [enhanced geothermal systems = Hot Rock Energy with engineered fracturing] represents a large, indigenous resource that can provide base-load electric power and heat at a level that can have a major impact on the United States, while incurring minimal environmental impacts. With a reasonable investment in R&D, EGS could provide 100 GWe or more of cost-competitive generating capacity in the next fifty years. Further, EGS provides a secure source of power for the long term that would help protect America against economic instabilities resulting from fuel price fluctuations or supply disruptions. Most of the key technical requirements to make EGS work economically over a wide area of the country are in effect, with remaining goals easily within reach.

—The MIT panel's 2006 report, entitled "The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century."

Hot Rock Energy, unfortunately, has been on the back burner for decades, along with most other alternative energy sources, kept there by cheap-and-dirty coal and the small budgets for government R&D. Nonetheless there have been various research projects around the world that have demonstrated the deep heat mining techniques over the last three decades.

Serious power production, however, is only getting started. In northern France, they are getting near-

commercial-sized yields at depths of 4 to 5 km. There are some projects in southern Germany, northern Switzerland, and Japan. Australia has quite a few proof-of-concept projects limping along on private money.



A modern two-well geothermal plant, though using shallow wells and a heat exchanger (thus requiring 178 condensers) not needed for dry steam. Nothing is more than two stories high. It was operating 15 months after the ground-breaking ceremony in Lyete.

The only hesitation that I have about Hot Rock Energy for 2020 is that there is simply not enough experience with it yet, compared with the experience of running hundreds of nuclear plants over fifty years time. Even though merely combining two tested techniques, steam power plant and deep drilling/stimulation, there will be beginners' errors to discover.

The capital costs per megawatt-hour are similar to those of a new coal plant. They are mostly drilling costs. Indeed, until opening up those fractured rocks in the depths with

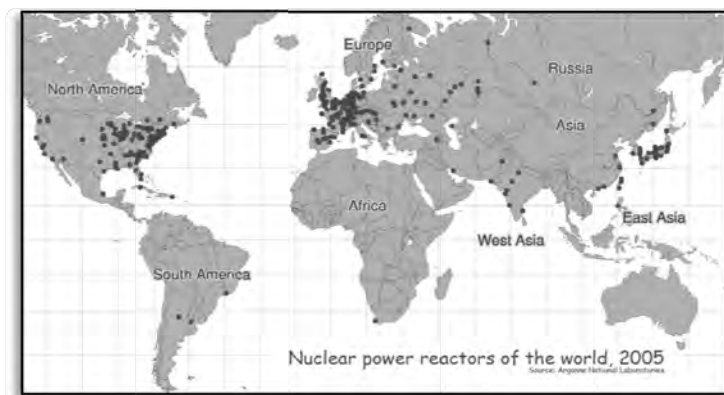
the initial high-pressure injection, you don't know what size power plant to order for the well head. That might cause private capital to hesitate, suggesting a proper role for government money to do the initial steam farms.

As demand increases, improvements will likely drive down drilling costs. Hot Rock power plants could be rather simple compared to shallow geothermal plants today, where the well's output contains a lot of things that you wouldn't want to inflict on a steam turbine sensitive to corrosion. Protecting it means a heat exchanger and that requires a hundred condensers to cool the secondary fluid before it re-circulates through the steam turbine.

So a lot of customizing attends most geothermal today. But continuing further down to 150°C dry granite would allow mass production techniques for simplified power plants. Each installation can tie up a deep drilling rig for the better part of a year, so we are going to need to clone those tall rigs.

If I were the 2020 czar, I'd place an order for twenty deep drilling rigs and fund fifty small heat farms in order to find the beginner's errors and the efficient combinations. We urgently need to know if Hot Rock Energy can be ramped up worldwide to thousands of units.

	Ability to expand	Public view	Down side	Ups & Downs	Foot print	Storage needed	Enough by 2020?
Hot Rock Energy	huge	Just another well?	Month of small EQs?	very stable	very small	none	●●●● to ●●



Nuclear power generation is currently the major C-free energy source. It is over fifty years old, with an excellent safety record. It took three decades before the efficiency doubled. Unlike the other expandable C-free sources, the beginner's mistakes have already been made.

As I mentioned, France has nearly quadrupled electricity production using 78 percent nuclear. It sounds as if nuclear power is cheap in such quantities. So much for arguments that nuclear power is expensive and that reform of our dependence on fossil fuels is impractical, can't be done, will damage the economy, and other excuses heard for maintaining the status quo (and current fossil-fuel profits). Why are many so countries denying themselves this C-free power source, while allowing growth in the hazardous fossil fuels?

Let me briefly discuss the downside of nuclear power. Our view of it—including my own view, until recently—tends to focus on fuel diversion into nuclear weapons or

dirty bombs, reactor accidents, and the long-term management of nuclear waste.

Some things have changed since the heyday of the anti-nuclear-power movement in the 1970s (though not Ralph Nader). Since the Soviet Union's political meltdown, the cat may already be out of the bag for illicit nuclear fuel, so that avoiding additional reactors may not gain us much.

New issues have also emerged. There is now the problem of suicide aircraft attacks with a full fuel load, which might scatter radioactivity downwind. There may be undergrounding solutions to this if the containment walls cannot be strengthened enough, but again pause and note that additional reactors do not really increase this problem; there are sufficient targets already. Indeed, chemical plants of many types are vulnerable. In Bhopal, India, all it took was a gas leak at a pesticide plant to kill 8,000, injure a half-million people, and contaminate an entire city.

There is much data on the safety and environmental problems of all the power sources. Nuclear electricity generation has proven far safer than fossil fuels of all sorts, and even safer than hydro. Dams fail. Per megawatt generated, the hydro fatality rate around the world is a hundred times higher than for nuclear electricity.

That is startling enough. The production and storage of the fossil fuels is far more deadly. Counting only the major disasters (each big enough to kill 300 or more) between 1979 and 2006, there were more than 2,400 deaths from oil and 1,800 from natural gas. For coal—well, China alone

has 6,000 miner deaths *each year*. Coal mining in the Ukraine is even more deadly.

The worldwide fatalities from nuclear power generation average out to one per year. For commercial nuclear power in all countries except one, there has never been a fatality. (An experimental military reactor accident killed three operators in 1961. There have also been on-site fatalities from bursting steam pipes not directly connected to the reactor, a problem with old steam pipes in general and one that high-tech inspection techniques ought to eliminate.)

Two workers at a small, badly designed nuclear reprocessing plant in Japan were killed in 1999 in a flash of radioactivity. No radiation was released into the environment. It was not at a reactor site. The plant was a small specialty operation, not part of the commercial fuel cycle for electricity. They were processing a batch of fuel that had been enriched about four times more than allowed in any commercial nuclear power plant and—the fatal error—they didn't dilute it properly.

The Chernobyl reactor meltdown in 1986 is the only major meltdown accident with fatalities. The operators had violated the rules by disabling major safety features and, when the power surged and popped the lid, it had—incredible as it now seems—no containment to trap the radioactive gases. In the first few weeks, thirty-two Ukrainian staff and firefighters died.

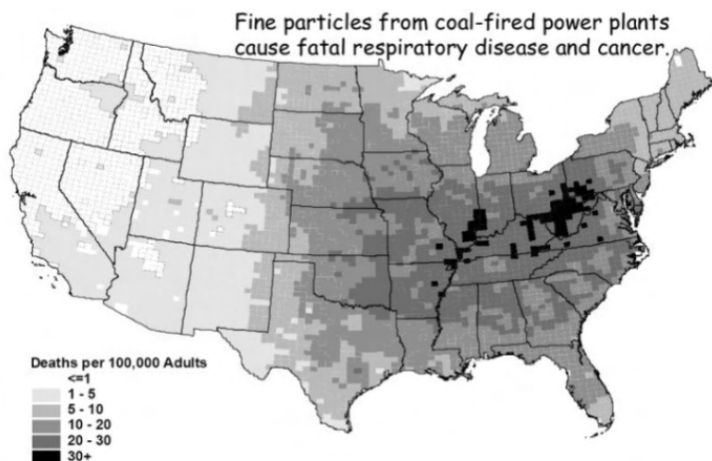
Immediate fatalities are the only number for which easy comparisons can be made between energy sources. So

that's less than fifty killed in the first fifty years of nuclear power reactors, all in one accident.

What about Three Mile Island in Pennsylvania? This accident occurred in 1979 (just thirteen days after a star-laden movie opened, a nuclear reactor control room drama, *The China Syndrome*). The steam explosion killed no one. (No injuries, either.) Though it was a cliffhanger, the release of radioactivity was largely confined to the site (unlike Chernobyl, it had a good containment vessel with absurdly thick walls). Anyone living nearby got a one-time dose less than what they got every day from the rocks beneath their house.

Delayed deaths are often difficult to attribute to a single cause, making comparisons between power plant types even more problematic. But for Chernobyl, we can safely say that another twenty-five died later, including nine children from thyroid cancer, but that the feared spike in leukemia did not materialize. Guessing farther out into delayed effects, perhaps 1 percent of the 200,000 workers exposed in the accident and during its cleanup may die from their radiation exposure, suggesting that 2,000 eventual deaths from the accident are possible.

Of course, mining coal has similar delayed effects, such as black lung disease. They involve many more people, including non-miners who simply live downwind of coal-burning power plants (in the U.S., that's almost everyone in the eastern half of the country) and breathe the ash and sulfur aerosols. Similarly, petroleum causes many delayed deaths from air pollution.



Three Mile Island had a huge impact on the future of nuclear power in the U.S. and in other countries, creating a gap that has been largely filled by coal. No new nuclear plants have been started in the U.S. since 1978, though new nuclear plants are common enough in the rest of the world (thirty-one countries now generate nuclear power).

We already know how to make safe nuclear reactors, even for the traditional style that uses water to both cool the reactor and to slow down the neutrons so they don't trigger additional, unwanted nuclear fissions. The danger here is that, if the water leaks out or the pumps fail or the water boils off, the reaction speeds up and heats up. And so you get a meltdown of the core and a radioactive slag heap in the basement.

There is not an explosion as with a nuclear bomb. These are steam explosions, the same as when the lid of a pressure cooker pops and coats the kitchen with hot food. The

reactor may also catch on fire. Any steam or ash that escapes from an overheated reactor can create radioactive fallout downwind (hence the containment dome, what kept Three Mile Island from being a problem offsite).

There is now, fifty years after the first nuclear power station was built, a much safer third-generation reactor design that uses a water tower above the reactor. Water floods the reactor if it overheats, all without relying on pumps or operator actions.

Given that we need something sure-fire, we have no choice but to start expanding nuclear. Clearly, nuclear is capable of being a big part of the solution but there are doubts in my mind about whether permit obstacles will be hurdled in time.

With any luck, we'll be able to cancel one nuclear order after another with scale-up successes in alternative C-free fuels. But order we must.

For the long run of 2025, there's a design for a fourth generation reactor that doesn't rely on water for slowing down the neutrons. Like a fast-breeder reactor, it runs on fast neutrons and thus generates all manner of radioactive isotopes. It extracts twenty-four times as much energy from its fuel pellets as conventional reactors do. This leaves the fuel exhausted and unsuitable for bomb manufacture, licit or illicit. That may handle the traditional worries about fuel diversion into nuclear weapons, what we saw in 1974 when India illicitly made a bomb using a

research reactor donated by Canada, with heavy water supplied by the U.S.

Furthermore, the fourth-generation nuclear waste decays to ordinary levels in only centuries, not the 10,000-year timescale of the current nuclear waste which has only had 4 percent of its binding energy extracted. The isotopes with the long half-lives are broken up by the fast neutrons. So the timescale for managing stored nuclear waste shrinks by 96 percent.

In principle, we know how to solve the recycling aspect as well. Because the fourth generation is so much more efficient at extracting megawatts from uranium, they can run on the accumulated “spent” fuel of the last fifty years, solving our storage dilemma for high-level nuclear waste. And when the fourth-generation fuel’s output drops off because of accumulating lighter elements that soak up neutrons, the fuel pebbles can be reprocessed on site rather than being shipped long distances (South Africa, for example, ships its spent fuel to France; oddly, U.S. commercial nuclear plants are not allowed to reprocess fuel, period.)

As the authors of a *Scientific American* article in December 2005 write, this fourth-generation design “could overcome the principal drawbacks of current methods—namely, worries about reactor accidents, the potential for diversion of nuclear fuel into highly destructive weapons, the management of dangerous, long-lived radioactive waste, and the depletion of global reserves of economically available uranium.”

Much of our traditional rationale for opposing expansion of nuclear power (or even, as Germany plans to do, retiring all nuclear power plants) needs reevaluating. One of the great hurdles is the public’s perennial confusion of nuclear electricity generation with nuclear bombs.

I have a suggestion: let us rename the fourth-generation reactors as, say, binding energy extractors (BEEs) on the model of what medical equipment manufacturers did about 1979. Magnetic resonance imaging (MRI) avoided the long-standing scientific name, nuclear magnetic resonance (NMR), probably because the marketing people warned that including the word “nuclear” was a downer.

	Ability to expand	Public view	Down side	Ups & Downs	Foot print	Storage needed	Enough by 2020?
Third Gen Nuclear	10X	caution	many	steady	mining	spent fuel	••• to •

Even if the developed countries bring their addiction under control, fossil fuel use has soared in the rest of the world. Unless we can provide an alternative to burning coal and oil, they won’t change their ways fast enough. If we can convert them to using electric or compressed-air vehicles, then the issue becomes clean and cheap electrical power. In the long run, in-country deep geothermal might be best. For 2020, we need an additional, sure-fire strategy.

Fifteen wires to move 10 gigawatts with high-voltage AC, lose 10% by 1,300 km



Four wires to move 10 gigawatts with high-voltage DC, lose 10% by 2,100 km

One way of solving this would be connecting all countries to regional power grids constructed with efficient DC transmission lines. It's an old technology commonly used for underwater and underground power lines; the aerial versions of DC are now used for power lines over 1,300 km long. (That's the length of the DC line from the Washington-Oregon border down to Los Angeles.)

The longest DC transmission line in the world, completed in 1983, spans 1,700 km in the Congo. A 3,000 km DC line from Spain would cover all of northern Africa; one from Johannesburg would cover all of southern and eastern Africa plus Madagascar; one from Mexico could cover the Caribbean and into South America; one from Hong Kong or Australia could cover southeast Asia.

This would enable nuclear power plants to be restricted to the present thirty-one countries. That's important if, rather than waiting for the fourth-generation BEEs, we are to use the current generation reactor designs that incidentally yield bomb material.

The architects' sensible plans for green buildings are long-term only, unable to help much in closing The Gap by

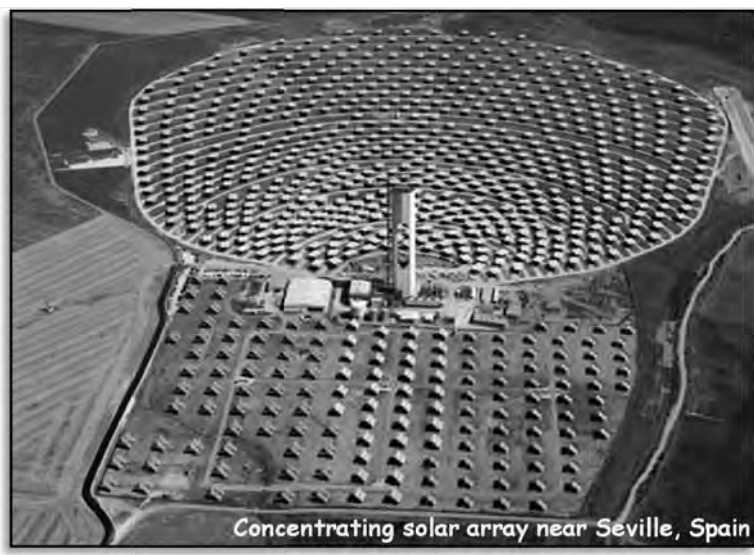
2020. It's the same for rapid transit. I'm inclined to encourage their growth but put the big money elsewhere for now. Our enthusiasm for long-term thinking is, sad to say, short sighted given the 2020 emergency. What we do for 2020 will reframe the problem, and new science and technology by then will hopefully show us a better path.



The growth in solar panels since 1995 has been impressive. Solar currently provides about 1 percent of world electricity (much less in the U.S.). The photovoltaic version is especially suitable for off-grid use in modernizing countries.

“Concentrating solar” heats a fluid that runs the usual steam turbine. It’s being tried out in sunny Spain with

mirrors that track the sun, keeping sunlight focused on the top of the tower. Both solar versions have unpredictable ups and downs as the clouds move by. Solar is also used for direct (no electrical middleman) heating, such as rooftop hot water heating.



Hydropower is the current big item (after nuclear) in the C-free power portfolio and efficiency improvements can be made by modernizing existing dams. The number of dams in the world grew from 5,000 in 1950 to more than 45,000 today—that's two dams a day for 50 years—but it is close to saturated. Low-rise and stream-flow hydro are not going to be big players for 2020.

Biofuels, however green in small amounts, turn out to be a bad idea when scaled up. First, a serious drought (and

in the coming decades, they are very likely) would impact both food supply and transportation fuel simultaneously. All prices would soar and the economy would stagger. As any investment advisor will tell you, spread your bets to avoid simultaneous downturns. Hydro power is already at risk in a drought and we should be adding drought-resistant alternative power, not biofuels.

Biofuels in developing countries will also require more land clearing, reducing the world’s carbon sinks and depleting poor tropical soils—as is already happening with “deforestation diesel.” European subsidies prompted an enormous boom in planting palm oil trees in Indonesia and Malaysia. Cutting the forests and draining the swamps emitted far more carbon than could ever be saved from using biodiesel.

My take:

	Ability to expand	Public view	Down side	Ups & Downs	Foot print	Storage needed	Enough by 2020?
Solar	lots	OK	few	night, clouds	multi use	some	••
Wind	lots	ugly	noise, bird kills	fickle, unstable grid	multi use	some	••
Biofuels	compete with food	organic fuel	not C-neutral	drought	huge	some	•
Flow & tidal hydro	some	caution	ecology	drought	large		unlikely
High-rise Hydro	nearly full	nice lakes	dam failure	drought	large	lakes	none

My father ran a medium-sized insurance company in Kansas City in the 1950s, back when fire departments fought a lot more home and building fires than they currently do. When we were driving around town in my youth, he was always pointing out everyday situations that had gotten some people into big trouble. (And so I grew up naïvely supposing that it was standard practice to routinely estimate risks and take sensible precautions!)

Indeed the reason that there aren't as many fires these days is because society has incorporated into building codes and regular inspections what the fire chiefs and insurance executives had noticed over the years.

Later, twenty years of talking shop with the neurosurgeons every day helped to form my notions about when you can afford to wait and when prompt intervention is needed. James Lovelock, Jared Diamond, and I are all Ph.D. physiologists who, during decades of medical research en route to looking at things more broadly, also learned to think like physicians.

Note that both my father and my neurosurgical colleagues were at the top of a pyramid of information. For example, few people in medicine forty years ago really suspected how dangerous it was to ride a motorcycle without a helmet. But the neurosurgeons were the ones who had to cope with the broken heads and they realized the protection that the helmet conferred. This gave them the responsibility to do something, to try and prevent the ruined lives. So they pushed for better helmet designs and

for laws that required helmets to be worn. Earlier they and other physicians had done the same thing for seat belts.

It used to be that you had to be a scientist in order to realize how serious the climate problem was becoming. You needed the view from the top of that pyramid of information. Now anyone who can read a book on global warming or watch a documentary film can gain much of that formerly rarified view.

Consider for a moment your present situation. You are now better informed about climate than thousands of your neighbors. What can you do with that knowledge?

For myself, I recall the moment which led to this book—a sinking feeling when it finally became clear that there was a 2020 emergency developing. It felt like what many have described for the eve of a great war, where future plans have to be put on hold, superseded by civic duty. It becomes payback time. I realized, as Tim Flannery put it, that “in the years to come, this issue will dwarf all the others combined. It will become the *only* issue.”

Even the well-informed politicians, who understand the actions needed, will require reassurance that starting a major makeover won't result in budget-conscious voters throwing them out of office at the next opportunity. (In the U.S., there is a perception that this happened in 1980 and 1994, following modest energy initiatives.) So serious political action on an energy re-make may need an overwhelming advance endorsement, repeated over and over—not just an initial expression of concern on your part.

My advice would be to set a good long-term example for the kids and developing nations, but don't count on it solving our big 2020 problem in time. Remember that the real focus needs to be on political action to stop this runaway train, real soon.

Ranking the Major C-free Candidates
for stopping emissions growth by 2020

		Ability to expand	Public view	Down side	Ups & downs	Foot print	Storage needed	Enough by 2020?
ENERGY	Hot Rock Energy	huge	Just another well?	Month of small EQs?	very stable	very small	none	•••• to ••
	Nuclear	10X	caution	many	steady	mining	spent fuel	••• to •
	Solar	lots	OK	few	night, clouds	multi use	some	••
	Wind	lots	ugly	noise, bird kills	fickle & unstable grid	multi use	some	••
	Biofuels	compete with food	organic fuel	not C-neutral	drought	huge	some	•
	High-rise Hydro	nearly full	nice lakes	dam failure	drought	large	lakes	no
	Coal but capture the CO2	large	caution	storage burp	steady	67% more coal	huge	no
OTHERS	Plankton iron blooms	large	caution	side effects?	likely	fleet of ships	some	•
	Plug-in hybrid cars	large	very good	mining battery				•••
	Compressed air car	large	none yet	air tanks				•
	Improve efficiency	good	in favor	slow grind	—			•
	Energy Diet	limited	a pain	easy to fail	yo-yo			no

Not comprehensive. Opinionated. Likely outdated (updates at *Global-Fever.org*).

GLOBAL How to Treat Climate Change FEVER

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Visit <http://Global-Fever.org> for additional chapters

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