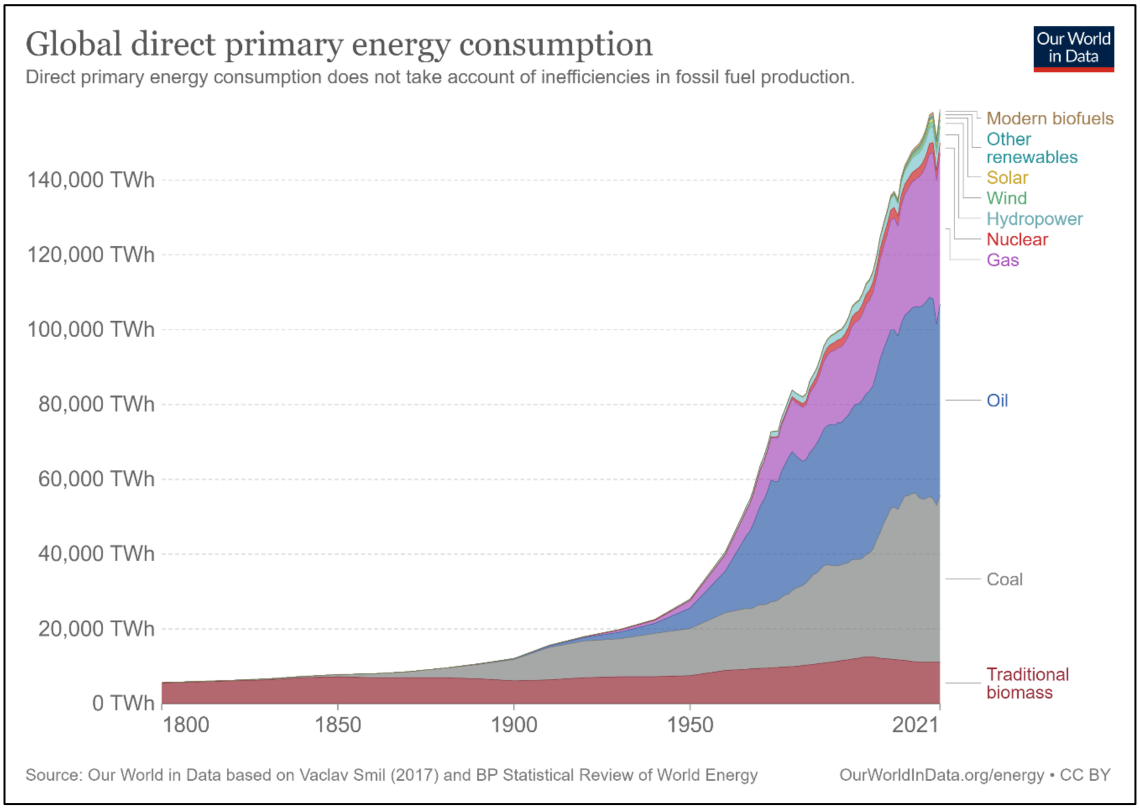
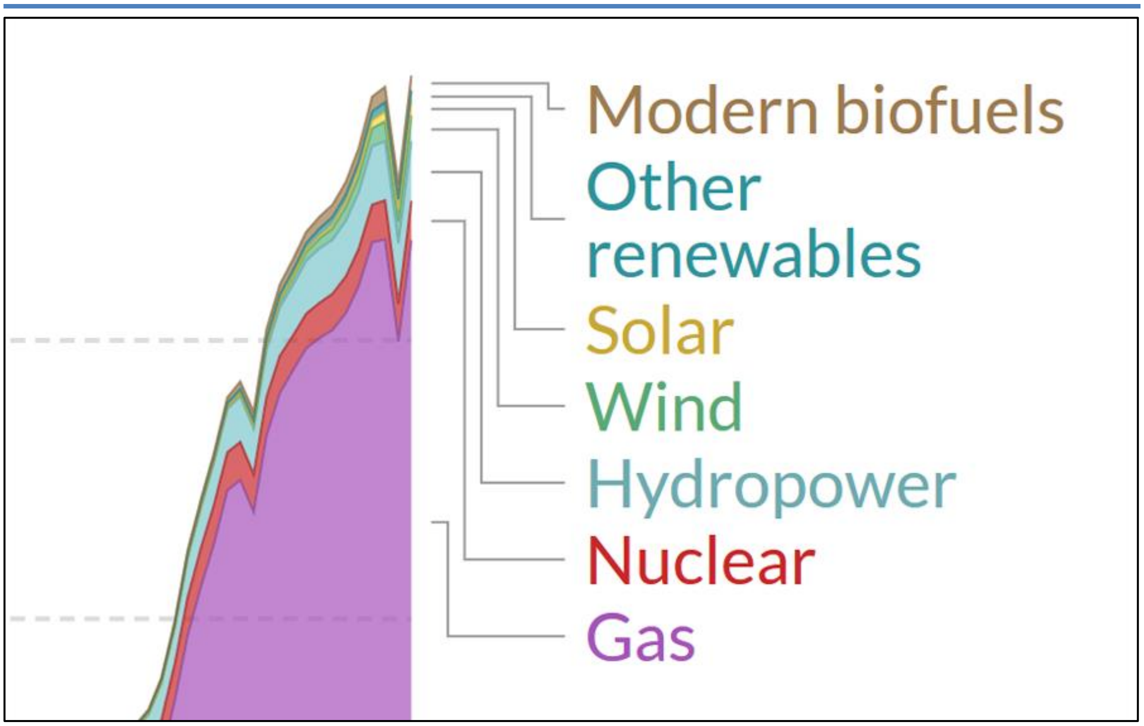
Solving the 2020s Energy Crisis





Sample of the video aesthetic intended for the YouTube Version: https://t.co/SNjvHRXDpF

Narration Script

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Episode 3: Supercritical Deep Geothermal Renewable Energy

I'm Erik Townsend. In the first episode of this series, I explained the profound importance the supply of cheap and abundant energy plays in determining our standard of living and setting the pace of advancement of human society. Then in the second episode, I explained why I'm convinced that a global energy crisis is imminent, because of under-investment and declining oil & gas production capacity due to ill-conceived ESG and climate policies. Now it's time to explore what it's really going to take to replace the energy we now derive from fossil fuels with clean, environmentally responsible alternatives.

Let's start by defining the problem, because it's a real doozy! Total energy consumption from all sources including renewables at the end of 2021, the last year for which data are available, was 159k TWh. 136k TWh of that comes from coal, oil, and natural gas. We need to consider that energy demand consistently grows every year. Since the climate lobby has focused on 2050 as a net zero target date, let's plan around that.

Global energy consumption is expected to grow by at least 15% by 2050, meaning that the total amount of energy we need to run the economy will grow from 159k TWh today to at least 183k TWh by 2050. A linear extrapolation of this chart gives a figure of 203k TWh by 2050. So let's assume that's the target range—by 2050 we'll need somewhere between 183k and 203k TWh of thermal energy to power the global economy. And let me be first to say that while we should definitely work to conserve energy and stop wasting it, more supply is still better. The more cheap and abundant clean energy we can supply to the economy, the more we'll be able to lift billions of people around the globe out of poverty and accelerate the pace of advancement of the human race.

Let's assume the goal is to completely phase out fossil fuels by 2050. That means we're going to lose 136k of the 159k TWh total supply we currently have. Existing non-fossil fuel energy sources currently provide 23k TWh, and less than 8k TWh of that comes from renewables. Since we need somewhere between 183k and 203k TWh, to completely phase out fossil fuels we need to cover that massive shortfall, and somehow bring between 160k and 180k TWh of ***new*** clean energy online between now and 2050. That's going to be a real challenge.

If the goal is to eventually phase out fossil fuels completely, we need to figure out which clean energy sources can realistically grow to meet expected demand. Renewables are the most environmentally friendly, so we should start there. The four commonly recognized renewable energy sources are hydroelectric, wind, solar, and geothermal energy.

Hydroelectric power is a terrific source of clean renewable energy, but unfortunately it only works in places with waterways that are conducive to building that kind of power generation. As Peter Zeihan wrote in his recent book, all the best geographically promising opportunities for hydropower around the globe have, for the most part, already been developed. That explains why growth of hydropower in recent years has been so much slower than growth of wind and solar. So unfortunately, we can't expect hyrdo so solve a big share of the problem. But let's be optimists and assume that by 2050, we could double the 4,274 TWh of clean electricity we already get from hydro.

We currently get 1,892 TWh of clean electricity from wind, and another 1,033 TWh from solar. For the last five years, we've added an average of 180 TWh wind and 141 TWh solar capacity annually. But there's good reason to be a lot more optimistic than using the *trailing* 5-year average to project future growth. 2021, the last year I have data for, was wind and solar's best year yet, with Wind adding a whopping 266 TWh and solar adding 186 TWh of new capacity in 2021.

Wind uses much more acreage per megawatt than solar, and we're eventually going to have difficulty finding enough space to install new windmills. But let's be really optimistic and assume we can eventually *double* the 2021 record of 266 TWh in a single year to 532 TWh/year in future years, and sustain that average rate of growth all the way to 2050. That means we can expect to add as much as 14,364 TWh of new clean wind energy by 2050. Put another way, we can expect to have more than 8 *times* as much clean energy from wind by 2050 as we have today.

I'm even more optimistic for solar energy, because it consumes less acreage per megawatt, and because the cost of photovoltaic solar cells has been dropping very consistently for several years. So in the case of solar, let's really go out on a limb and aim to *triple* 2021's all time record for new solar power installations, and sustain that average annual rate of development all the way to 2050. Now we're really getting somewhere. That's another 15,066 TWh of clean solar energy we hope to bring online by 2050.

Between wind, solar and hydro combined, that's 33,704 TWh of clean electricity we can get from aggressively building out these renewable sources, and that's a lot! It's still less than coal at 45k TWh, but that 45k TWh figure for coal is thermal energy. Remember that the thermal efficiency of fossil fuels is terrible when they're used to generate electricity.

Intermittent renewables like wind and solar can't solve our need for 24/7 baseload power supply unless you employ energy storage technology to make the energy produced by wind and solar available for later use when it's needed. And doing that that introduces significant inefficiencies, similar to burning fossil fuels to make electricity, but without the greenhouse gasses.

But let's ignore all that for now and give wind and solar credit for being clean sources of electricity which don't suffer those big thermal efficiency losses of fossil fuels when the energy they produce is consumed immediately. If we look at it that way, it's reasonable to double the

33,704 figure to 67,408 TWh of equivalent fossil fuel thermal energy needed to produce the same amount of electricity from natural gas.

Frankly I doubt this hypothetical scenario is really even possible, because I've completely ignored a whole bunch of challenges to sustaining that kind of wind and solar growth, such as shortages of rare earth metals needed to make the windmills, and environmental challenges to producing solar cells on that scale. But my real point is this: Even if we take the most optimistic view possible, and give wind and solar the benefit of every doubt, we still end up with only 33,704 TWh of clean electricity, or the equivalent of what we could produce from the thermal energy of 67k TWh of fossil fuels.

That's considerably less than *half* the amount we need by 2050 in order to completely phase out fossil fuels *by then.* Never mind the activists and politicians who are trying to start phasing out fossil fuels *now*, before making any substantial progress toward phasing in these replacements. Remember, as of right now, all renewables combined supply less than 5% of the energy we need to run the economy. We have a long way to go before phasing out fossil fuels will become possible.

Even after ignoring the challenges that I expect will make it difficult to grow wind and solar as aggressively as I've described, and even using the most optimistic growth estimates I can fathom, we still wind up with renewables only meeting about 35% of total energy demand by 2050. It's long past time to get serious about figuring out where we're going to find the other 65%. I only know of two realistic sources for producing that much electricity. We need to pursue both of them aggressively, in parallel with wind and solar, if we want to get serious about solving our energy problem.

I'm going to save the *most* promising option for the final two episodes of this docuseries. In this episode, I'm going to focus on a renewable energy source that seldom gets as much attention as wind and solar. That energy source is known as geothermal energy, and the reason it doesn't get as much attention as wind and solar is that in its *present* state of technological development, it's not as promising as wind or solar in terms of the amount of energy produced per dollar invested. That means bringing anything remotely close to 160k TWh of geothermal energy online using *current* technology just plain isn't going to happen.

But unlike wind or solar, which are already well-developed technologies, I'm convinced that a game-changing breakthrough is possible for geothermal if we can just figure out how to overcome a few technology hurdles that are holding it back today. If we can advance existing drilling technology to drill deeper and through hotter rock formations, Geothermal has the potential to leapfrog wind, hydropower and solar to become the *most* promising rather than the *least* promising of the four primary renewable energy sources.

Geothermal power generation isn't as well understood as wind and solar, so let's start with an introduction to what geothermal energy is and how it works, including the reasons why it's not presently as economically viable as wind and solar. Then later in this episode, I'll introduce my vision for the future of Geothermal energy, which isn't possible *yet*, due to limitations of current drilling technology. But as we'll discuss later, if we can overcome those technological limitations and figure out how to drill deeper and through hotter rock formations, geothermal energy could be a complete game-changer in our quest to replace fossil fuels completely.

If you ask most people what our planet is made of, they'll probably say dirt, rocks, and the water in our oceans. But these things are just what make up the earth's *crust*, which only accounts for 1% of the planet's overall mass. The crust isn't very thick—ranging from 10- 75km on land, and even thinner under our deep oceans, where the crust is only 5-7km thick.

The next 2,900km of depth below the base of the earth's crust is the mantle, which is very hot rock, some of it solid and some of it magma, or molten rock, similar to the lava that flows out of erupting volcanoes. Then there's another 3,400km of depth to reach the center of the Earth's core, which is mostly molten iron and other metals.

The deeper you go, the hotter it gets. The earth's core has a temperature over five thousand degrees Celsius, or almost 10,000 degrees farenheit. The deepest base of the earth's crust is about 1,000C. Within the earth's crust, the temperature gets hotter as you go deeper.

A study by the Defense Advanced Research Project Agency concluded that if we could just figure out a way to harness only $1/10^{th}$ of 1% of the heat in the earth's mantle, we could meet all our energy needs for millions of years. Put another way, all the energy we could possibly ever need is already right at our feet. Or more precisely, just a few miles straight down below our feet.

At those depths, the heat of Earth's mantle—or even just the deeper regions of Earth's crust, offers us all the energy we could possibly need, if only we could figure out how to drill a hole deep enough to access all that heat that's right there below our feet, just waiting for us to figure out how to come get it. The really hot rock that has enough energy to solve all our energy problems is found at less depth *below* the surface of the earth than our commercial airliners fly *above* the surface of the earth.

There are several different kinds of geothermal energy, but I'm going to skip the ones that don't offer a way to solve the impending energy crisis, and just focus on those which do.

To tap into the clean, free heat energy beneath our feet, we need a way to get down there and pump some of that heat up to the surface where we can use it. For decades now, the oil & gas industry has been perfecting technology which could be re-purposed for doing just that. Oil drilling technology was developed to drill oil wells in porous rock formations deep below the surface, which contain crude oil in the rock's pores, like a sort of sponge made of rock that contains oil.

The way an oil well works is that a hole is drilled deep into the porous rock containing oil, allowing the oil to seep out of the rock and into the oil well. Some rock formations are under such high pressure that the oil flows to the surface all by itself, forming a gusher. When there's not enough natural reservoir pressure in the rock formation for that to happen, a mechanical lift pump is installed to lift the oil out of the well. Not all rock contains oil. In fact, rock that's full of oil is quite hard to find. The entire profession of petroleum geology was created to find the oil deposits so they can be drilled and oil can be produced from them.

But now let's imagine taking that same oil drilling rig to a rock formation we know *doesn't* contain any oil. For geothermal energy, the whole idea is to avoid porous rock containing oil, and aim for dry, hot rock formations instead.

In some places like Iceland and Indonesia, which have a lot of volcanic activity, there are plentiful rock deposits not too far below the surface where very hot, dry rock can be found. This is ideal, because the shallower the hole, the less it costs to drill. In other parts of the world, where there are no volcanoes bringing hot magma near the surface, you might have to drill much deeper to find the hot, dry rock formations that are needed to produce geothermal energy. But if you're willing to drill deep enough, hot rock can be found anywhere in the world.

For our first example, let's assume we've located a dry rock formation not too far below the surface, which has a temperature of 100C, the boiling temperature of water. We'll start by drilling a well vertically into that rock until reaching the depth where the 100C dry rock formation exists. Then we'll turn the drill bit sideways and drill a horizontal hole several hundred meters long.

Turning the drill bit 90 degrees and drilling a horizontal hole through solid rock several hundred or even a few thousand meters below the surface might sound like an impossible trick, but thankfully, the shale oil revolution was made possible by the commercialization of horizontal drilling technology for doing exactly that: drilling long horizontal holes known as 'laterals' through solid rock deep below the surface. So as daunting as it sounds, we already have the technology needed to do this.

Finally, we'll drill another hole, similar to an oil well, which will connect to the far end of the lateral we just drilled back to the surface. The result is a U-shaped passage which goes straight down several hundred to a few thousand meters, then turns sideways and runs several hundred to a few thousand meters horizontally through hot dry rock, then turns up to provide a path back to the surface.

Now we can tap into free energy from the center of the earth by simply pumping cold water down one side of this U-shaped passage. As the water flows down into hot rock and then flows through the long lateral passage, the water is heated up to boiling temperature. The result is we're pumping cold water down one hole and getting boiling hot water out the other hole, without consuming any energy to heat the water. All we need to pay for is the electricity to run the pump to circulate the water through the underground passage. The hot rock formation does the rest.

The boiling water coming out the other side could be used to heat a building. Or it could be passed through a heat exchanger to heat domestic potable water, eliminating the need for a water heater fueled by natural gas or electricity. But as novel as this system might sound, the fact is that we're not getting enough heat energy out of this system to produce electricity or do much else. We can heat a large industrial building almost for free this way, once all the holes have been drilled. But guess what? Drilling those holes through solid rock costs a lot of money, and it will take quite a few years to break even.

Let's up the stakes now, and aim for a hotter rock formation. There are two ways to find hotter rock. One that always works anywhere on earth is to just drill deeper. Remember, the deeper you go in the Earth's crust, the hotter it gets. The other way is to find unusually hot rock formations closer to the surface. This is the reason that deep geothermal electricity production is presently only economic in parts of the world where there's a lot of volcanic activity, making it possible to find hot dry rock much closer to the surface.

Let's suppose we can find a 150C rock formation by drilling a little deeper than we did in the prior example. So we drill another U-shaped circuit, but this time the lateral segment is drilled through 150C dry rock. Now it's a totally different story. We still pump cold water down one side, but the temperature of the lateral segment is much hotter than water's boiling temperature of 100C. So what comes up the other side is not boiling water, but rather very hot steam. And that steam will come up under pressure because water expands considerably when it boils into steam.

Now it becomes possible to install a steam turbine on top of the exhaust well, and to produce electricity with that turbine. Some of that electricity can be used to pump more cold water down the intake well, eliminating the need for any external power to operate the system. The remainder of the electricity produced by the turbine can be sold into the electric grid, and used to supply homes and businesses and to recharge electric vehicles. The steam coming off the steam turbine can be recovered in a condensing chamber, and recycled by pumping it back down the intake shaft to produce more steam in the exhaust shaft, and therefore more electricity from the steam turbine.

If this sounds like a terrific source of clean, environmentally friendly electricity with no reliance whatsoever on fossil fuels, that's exactly what it is!

But unfortunately, there's still a catch. Geothermal wells cost a lot to drill, and even at temperatures of 150C, the heat energy recovered from them is only sufficient to produce a modest amount of electricity. High capital costs to drill the well and relatively low electrical power output results in pretty expensive electricity, when you factor in the up-front cost of drilling the geothermal well. For this reason, geothermal electricity generation has outperformed wind and solar on a cost per megawatt basis only in locations where there's volcanic activity close to the surface. Geothermal electricity is still terrific news if you happen to live in Indonesia or Iceland, but for most of the world, the economics just don't work.

Or I should say, the economics don't quite work *yet*. With a few advances in geothermal drilling technology, a game-changing breakthrough that makes geothermal far more attractive than wind and solar would be possible. And that's the reason I've dedicated this episode to discussing the technological advances needed to make geothermal a game-changer that could really help solve the global energy crisis that will begin in the mid-2020s.

The amount of electricity we can produce from geothermal wells depends primarily on the temperature of the rock the well penetrates. Even at a temperature of 150C, one and a half times the boiling point of water, the amount of energy that can be extracted and therefore the amount of electricity produced, just barely makes geothermal wells economic sources of electricity in volcano country, where 150C rock can be found at unusually shallow depths.

But what if we aim for even hotter rock formations. Let's say 250C, well over twice the boiling point of water. We can produce a whole lot more electricity with super-heated steam at 250C coming out the exhaust well and driving a much bigger steam turbine than we ever could have hoped for with 150C steam. Hotter rock makes a huge difference in how much electricity can be produced from geothermal wells.

But it's *much* harder to drill a geothermal well through 250C rock than 150C rock. Unless you're drilling in volcano country, you have to drill much deeper to get to the 250C rock. The deeper you drill, the more it costs to install the geothermal well, and therefore, the higher the cost of electricity produced from that well.

But the cost of drilling deeper is actually the easy part. 250C is pretty darned hot. By comparison, Aluminum melts into molten metal at about 660C. The way most drill bits work is they *grind* a hole through the rock, by pressing a very hard, sharp drill bit often made from diamonds against the rock at high pressure, and then turning it to slowly grind the rock away through abrasion, slowly boring a hole through the rock.

This process is incredibly friction-intensive. Drill bits used to drill through granite countertops above ground where the ambient temperature is only 25C can heat the drill bit and the granite at the bottom of the hole up by a more than 100C because the friction of drilling something as hard as solid rock creates so much heat-generating friction. When we take the same operation miles below the surface of the earth into solid rock that's already 250C and then heat it up even more from there with all the additional heat produced by the drill bit, temperatures rise to levels where even solid metal tooling begins to lose its strength. The engineering challenges are suddenly quite substantial!

At 250C, we're pushing the limits of current technology. The engineering challenges can be overcome, but overcoming them doesn't come cheap. The much higher cost of drilling a geothermal well into very hot 250C rock would negate the benefit of being able to produce more electricity from the hotter rock. The hotter geothermal well will produce much more electricity, but the cost per megawatt-hour won't be any lower because the hotter well costs so much more to drill.

This conundrum of geothermal electricity economics is the whole reason you don't hear very much about geothermal energy. It's a brilliantly innovative way to tap into a literally limitless source of clean energy that produces no emissions. But *for now*, it's generally less economic than wind and solar except in volcano country, where very hot rock is found much closer to the surface.

Now I'll explain why I'm convinced that a breakthrough is possible to change everything, making deep Geothermal a big contributor to the energy transition.

The shale oil revolution of the 20-teens was enabled by two principal technological advancements. The first was horizontal drilling. The ability to drill an oil well down to the depth where oil is abundant, then turn a corner and drill a long, horizontal hole through the rock at the optimal depth for recovering oil. That horizontal segment of the well deep below the surface is called a *lateral.*

The second major technology breakthrough behind the 20-teens shale oil revolution was hydraulic fracturing. This involves pumping water and sand into the newly drilled lateral, and then subjecting it to extraordinary pressure shocks that literally crack the rock around the edges of the lateral. The purpose of the sand is that it becomes wedged into the cracks in the rock, preventing them from closing again after the pressure is removed. This process allows much more oil trapped in the rock to flow into the lateral and be pumped to the surface.

The shale revolution began with natural gas, starting in 2006. By 2010, shale *oil* became a hit as well. By 2011 U.S. oil production really started to take off. By 2017, total U.S. production set a new record high, eclipsing the prior record set when conventional oil production peaked in the early 1970s, just as Hubbert predicted it would.

Now I have a quiz for you. Recall that the shale boom began in 2006 with natural gas, and shale oil hit the stage by 2010. The media hailed the "brand-new" technologies of horizontal drilling and hydraulic fracturing as technological breakthroughs that made it all possible. Can you guess when the very first horizonal oil well was drilled using this breakthrough new technology of horizontal drilling? Was it 2005? 2003? 2001? Or… 1929??? Ok that must be a typo and it's supposed to say 1999, right?

Wrong. The correct answer is 1929. That's when horizontal drilling really was a brand-new technology, and that's when the first oil well was drilled using horizontal drilling.

Hydraulic Fracturing is a much newer technology. The first successful commercial application of hydraulic fracturing wasn't until 1950. Yes, you heard that right; 1950, fully six *decades* before the shale oil boom really took off.

Ok, what the heck is going on here? If the technologies that made the shale oil boom possible had all been invented by 1950, why didn't we start using them much sooner? This is a critically important point to understand, and in just a minute I'll explain why it has *everything* to do with making a breakthrough in geothermal energy.

The oil industry knew all about horizontal drilling and hydraulic fracturing for decades before they were commercialized at scale. The reason they went unused was simply that they were expensive, and there was no economic justification for using them.

Does this sound familiar? It should, because the whole reason horizontal drilling and hydraulic fracturing went unused for fully 6 decades *after* they'd both been proven to work is exactly the *same* reason deep geothermal isn't popular now: because the economics don't quite work yet, and the expense of drilling deep geothermal wells through really hot rock is hard to justify economically.

In 2005, when conventional oil production peaked globally and offshore drilling was becoming more popular, the oil industry already knew all about horizontal drilling and hydraulic fracturing. But they'd done their homework and figured out that it wasn't economic to employ those technologies with anything less than $85 per barrel crude oil prices. At that time, oil had never commanded a price anywhere close to $80/bbl in all of history, so it made no sense to deploy these decades-old technologies, which were too expensive to be economic.

But then oil prices moved dramatically higher in early 2008, setting an all-time record price of $147/bbl before the Great Financial Crisis took hold and crashed oil prices back down below $40/bbl. Horizontal drilling and hydraulic fracturing were definitely not economic at $40/bbl, but the most visionary entrepreneurs in the oil patch read the proverbial writing on the wall and started making plans. By 2010 oil prices were back over $80, horizontal drilling and hydraulic fracturing finally became economic, and the rest is history. U.S. oil production took off, and by 2017 U.S. production had eclipsed its prior record level from the early 1970s, something most experts thought impossible.

Now here's the most important part of this story I really want you to take to heart. In late 2014, Saudi Arabia changed its competitive strategy and allowed oil prices to crash all the way down to $27/bbl by early 2015. Skeptics immediately declared the shale revolution to be dead, and predicted fracking would never be economically viable again.

The reason they were dead wrong is that by then, the industry had learned to *optimize* horizontal drilling and fracking technologies, making them much more cost-effective than just a few years earlier. Suddenly a case could be made for drilling and fracking new shale wells with crude oil prices as low as $40/bbl, *because economy of scale had transformed previously expensive niche technologies into much more affordable mainstream technologies.* By 2015, horizontal drilling and fracking could be economic at oil prices half the break-even threshold for using these technologies just five years earlier!

Now let's return to the topic of deep geothermal clean electricity. If we take a narrow view and just focus on the immediate economic balance point, deep geothermal is very hard to justify.

Drilling geothermal wells deep enough to get to really hot rock is expensive, and drilling through hot granite at those temperatures challenges the limits of current drilling technology.

But let's take a step back and consider the big picture. We already have an extremely well-developed oil and gas industry which has become expert at cheaply and efficiently doing one thing incredibly well. That one thing is drilling wells deep below the surface, then turning them sideways to form laterals. Between 2010 and 2016, the cost of doing that was cut almost in half thanks to innovation, hard work, and economies of scale.

But investment in that industry is in steep decline now because everyone agrees that the age of fossil fuels needs to be brought to an end. Long-term investment is almost unheard of in oil and gas, because everyone knows that governments around the world are united in the net zero initiative, and that oil and gas will be phased out just as soon as we can find viable replacements, something that will actually take decades longer than most people realize.

What if we stopped vilifying the oil and gas industry as public enemy number one as a matter of government policy, and instead *supported* that industry while giving it a new dual mandate that could extend its life indefinitely? Part one of that mandate would be to keep producing oil and gas for as long as necessary in order that society can ***continue breathing***. Part two of that mandate would be for the oil and gas industry to evolve itself over time, transforming into the clean geothermal electricity industry of the future.

What if the smartest young engineers choosing careers, who avoid oil and gas like the plague now because they see it as a zombie industry, were presented with a very different picture? What if they saw entering the oil & gas industry as a stepping stone to becoming the geothermal renewable baseload energy pioneers of tomorrow? And what if we actually had *leadership* in government that was smart enough to recognize that the best way achieve net zero policy goals is not to scapegoat the oil & gas industry as the bad guys, but rather to create incentives for them to become heroes of the climate transition, by redirecting every bit of ingenuity and experience they have at drilling holes through rock, and using those skills to revolutionize geothermal energy and make it economic at scale, just like they did for shale oil & gas?

Geothermal is currently a niche field that doesn't receive enough investment capital to make meaningful progress at the pace needed to solve the global energy crisis. But what if all the talent that made the shale boom possible were refocused on Geothermal? How long do you think it would take before geothermal suddenly became *more* economic than wind and solar?

It took the U.S. oil & gas industry less than a decade to commercialize horizontal drilling and fracking, cut its cost in half by optimizing its design and deployment, and then make the United States the biggest producer of Crude oil in the history of Planet Earth by 2019, something nobody thought remotely possible in 2010.

Do you really think that figuring out how to find hot dry rock deep underground and then drill holes through it economically is beyond their abilities? I sure don't. But I also know that there's no way for them to be the ones to solve the energy crisis with a Geothermal energy revolution on par with the shale revolution, if we continue to make it public policy to scapegoat them as if they're our enemies!

The shale boom delayed the coming energy crisis for more than a full decade. Without it, the Peak Oil predictions of 2007 would have come true, and we'd have been in a world of hurt a full decade earlier.

Does it make sense to make political scapegoats of the very people who have the skills needed to advance geothermal energy technology, and who have a proven track record deploying those skills to create miracles in record time? I sure don't think so.

Maybe instead of trying to "Just Stop Oil", we should instead Just THANK the oil industry for figuring out how to efficiently drill laterals through rock miles underground, and then ask them to refocus their skills on drilling clean, carbon-free geothermal wells instead of oil wells, taking full advantage of all the expertise and drilling equipment the industry already has at its disposal.

I want you to imagine a world where we have political *leadership* that sees the energy picture more clearly. A world where instead of pointing fingers and vilifying entire industries for the sake of political theatre, we instead engage in sound, level-headed thinking. That would mean taking a close look at what it's going to take to truly solve this energy crisis and replace fossil fuels with green alternatives.

The oil & gas industry has vitally needed skills, equipment, and infrastructure that we simply cannot afford *not* to leverage as part of the clean energy transition. And oh, by the way, as soon as we stop believing in rainbows and unicorns, we're going to realize that we still need to GROW oil & gas production for at least another full decade in order to ***continue breathing*** until sufficient clean energy alternatives can be brought online.

We need to stop thinking of oil & gas as an industry we need to get rid of, and instead think of it as an industry that needs to be *re-purposed* as the *clean geothermal energy industry*. What we need to do away with are the politicians who stand in the way of progress by making enemies and scapegoats of the very people who are most qualified to help solve the real problem at hand.

Now let's return to our discussion of the current state of the art in geothermal energy, because the story definitely doesn't end at 250C. Things *really* start to get interesting at 374C and hotter. Why that specific number? Because with the combination of temperatures above 374C and very high pressures more than 218 atmospheres, hot water takes on completely different properties than water or steam as you and I know it. Scientists call it *supercritical water*, and it could be a game changer for deep geothermal energy because it can carry fully *ten times* as much heat energy to the surface as regular water or steam.

But now we're *really* going to hit some technological barriers. 374C is the minimum threshold temperature for producing supercritical water. Let's assume that we'd need to drill laterals through 400C rock in order to heat the water we pump through it to 374C. After all, just pumping water through the laterals will cool the rock slightly, so we need to start with a rock formation a little hotter than the water temperature we ultimately need.

250C was already pushing the limits of what's possible with current commercial drilling technology. It's impossible to drill through 400C rock using a normal drill bit that uses friction to grind through the rock. Adding the heat of friction pushes the temperature even higher, and almost any drilling equipment anyone has ever invented would literally melt at those temperatures.

There are already a couple of experimental approaches to solving this problem. One is known as hammer drilling, where instead of holding the drill bit against the rock being drilled at high pressure, the drill bit is intermittently "hammered" into the drill hole instead. This technique has already been employed in at least one experimental geothermal project where the goal is to reach the temperature threshold for producing supercritical water.

Another experimental technology is the brainchild of billionaire entrepreneur Robert Friedland, founder of the Ivanhoe mining empire. That technology replaces *drilling* with an entirely new technology called *spalling*. With spalling, there's zero pressure between the "drilling" bit and the rock. It works by zapping the rock being drilled with pulses of incredibly high energy electricity, which only last a few nanoseconds. Think of it as tasering the rock instead of drilling it. This process literally vaporizes the rock formation for just a tiny fraction of a second, allowing the spalling operation to proceed without adding any heat from friction to the rock being drilled or the tooling. That technology is still experimental, but it has the promise of someday making it possible to spall geothermal wells in rock that's 400C or even hotter.

To be sure, we're talking now about experimental drilling and spalling technologies which aren't ready for prime time yet, and as of this recording, geothermal wells capable of producing supercritical water are not yet practical or economic.

But I want you to focus on what's *possible*, not just on what we have today. We literally sent a man to the moon more than fifty years ago. That was an incredible technological achievement, and it was possible only because we had political *leadership* focused on making the most of our technology industries, rather than on scapegoating them as villains in sophomoric political theatre.

I'm going to paraphrase the words of U.S. President John F. Kennedy, from his infamous May 1961 speech calling for a moon landing before 1970. I believe that all nations on this planet should commit themselves, to figuring out how to drill holes through hot rock over 374C and to commercialize a process for doing so economically, before this decade is out!

We can’t get through the coming crisis without true *leadership*, and that’s exactly the kind of message we need to hear from our elected leaders. The people with the skills needed to solve our greatest challenges need to hear that government is going to have their backs, not scapegoat them as villains, and that we will all come together to work in partnership to bring about the technological advancements needed to make economic, supercritical geothermal wells commonplace by the late 2020s if not earlier.

And by the way, if I were the coach assembling the dream team for that mission, my first draft picks would be the men and women of the U.S. oil & gas industry, who figured out how to commercialize horizontal drilling and hydraulic fracturing, cut their price in half, and then use those technologies to make the United States the biggest oil producer in the world, all in less than a decade. President Kennedy would be proud if he knew that story. President Biden and other politicians with his attitude toward the oil & gas industry need to wake up and stop looking a gift horse in the mouth. These are the people who are best qualified to develop and commercialize game-changing deep, supercritical geothermal energy, and they’re not our enemies.

Do you want to know the *ultimate* game-changing scenario, in which Geothermal energy could literally bring about another *acceleration* in the advancement of human society on the scale of the steam engine and the age of oil, while at the very same time eliminating carbon emissions and the need for fossil fuels completely?

Let’s take this discussion of advanced geothermal energy a step farther and consider the scenario of drilling nearly to the bottom of the Earth’s crust, and drilling laterals through 600C rock instead of 400C rock. Forget the supercritical water, and replace it with a closed-circuit molten salt circulation loop to move heat energy back to the surface even more efficiently than supercritical water. With a continuous supply of 600C molten salt, we could produce enough electricity to meet our energy needs for the next ten thousand years.

Now at this point I’m sure the geologists and petroleum engineers in the audience are rolling on the floor laughing their tails off, ridiculing me as an imbecile who obviously has no clue how impossible it would be to drill laterals in 600C rock formations. Just proposing to drill laterals in 400C rock already tests the limits of what’s theoretically possible, and 600C would add a full order of magnitude of engineering complexity to the problem.

President Kennedy knew that his May 1961 speech proposing a mission to the moon had been received by some scientists and engineers as the ramblings of a lunatic politician with no clue about the engineering challenges involved. So, in 1962, he gave another speech saying this to the students and faculty of Rice University: “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”. He was trying to acknowledge the challenges involved, and rally the country around a common goal of great difficulty. And he succeeded.

So when I propose a hypothetical closed-circuit molten salt circulation loop geothermal well with laterals drilled through 600C rock, I do so not because I'm so naive as to think that doing that is easy, but precisely because I know how much is at stake if we could somehow pull it off.

The steam engine and the oil age ended human slavery, got the vast majority of us off the hook for having to work on farms, made widespread university education possible, and enabled the development of the modern world we now live in. We could have another acceleration of the pace of human advancement on that scale if we could just perfect a process for economically drilling geothermal wells anywhere on earth in sufficient scale to pump at least 180k TWh of heat energy out of them globally on an annual basis by 2050. And if we could figure out how to drill laterals through 600C rock, we could easily pump twice that much heat out of them.

So, I have a serious question for the professional petroleum geologists and engineers I know we have in the audience. Look, as a former technology entrepreneur and engineering manager, I really do have an appreciation for how monumentally challenging it would be to figure out a way to drill laterals in 600C rock deep in the Earth's crust and circulate molten salt through them. But here's my question: Is that really and truly ***harder*** to achieve than it was to send a man to the moon in the 1960s? Is it even ***harder*** than that? Really? For context, remember that in 1961, when Kennedy gave that famous speech, electronic ignitions for production cars hadn't even been introduced yet. And Kennedy declared we should literally build space ships, travel a quarter *billion* miles to the moon, land there, take a few selfies, and then return to Earth. Now I get that 600C is awfully hot, but is drilling holes in really hot, really deep rock ***really harder than traveling to the moon and back in the 1960s?***

I'll even give you a head start: I know a company in Denmark that's already commercialized a molten salt circulation pump with magnetic levitation bearings, designed for continuous duty at up to 700C for ten years without service. Geology is not my field, so I have no idea whether the rest is possible. But what I do know is that the benefit to society if we could somehow pull it off would be much greater than going to the moon.

The energy crisis we're headed into is going to be a really big deal. We literally cannot feed all 8 billion inhabitants of this planet without the energy we now derive from oil. We're a long way from running out of oil, but we're at very high risk of a supply-demand imbalance that will force energy prices dramatically higher. Mass starvation and resource wars are very real possibilities. The stakes couldn't be higher, and we need to prioritize solving the coming energy crisis with the same kind of commitment we gave to the space race. Nothing is more important to humanity than solving this energy crisis.

To summarize this discussion of Geothermal energy, to my thinking two key points differentiate geothermal from the other two popular renewable energy sources of wind and solar. The first is that I see clear and obvious technology breakthrough opportunities for geothermal which could be total game-changers. I'm not aware of any similar breakthrough opportunities for wind or solar. The second key point is that geothermal also offers the ability to produce *baseload* electric supply, that runs 24/7, not just when the sun is shining or the wind is blowing. That means geothermal is a perfect candidate for the 65% of energy demand that intermittent renewable sources like wind and solar can't meet.

For those who feel committed to the idea that our energy strategy should focus *exclusively* on renewables, this is a match made in heaven. If we could just figure out how to overcome a few technological hurdles, we could form a realistic energy strategy centered on Geothermal providing the baseload supply and wind and solar providing the rest of the energy we need.

And we don't even need to achieve supercritical temperatures over 374C for that to be possible. A geothermal revolution that makes it possible to drill geothermal wells through 250C dry rock as easily as we drill shale wells today would be enough progress to make geothermal economically viable for baseload power generation.

The key take-away from this episode I really want you to focus on is that we already have a very well-developed oil and gas industry, which is *expert* at efficiently and economically drilling lateral wells in rock formations deep below the surface. That industry knows its days are numbered, and already needs to reinvent itself. What could be better than a strategic plan to *re-purpose* the oil & gas industry on commercializing and perfecting geothermal well drilling just like they perfected shale oil production?

So I propose that we need a completely different attitude from government toward the oil & gas industry. We need to stop thinking of them as the polluters who should be treated as enemies, and instead recognize the extraordinary opportunity to re-purpose this industry with a dual mandate to invest heavily in commercializing geothermal electric power generation and making it economic, while at the same time, continuing to increase oil and gas production capacity until we can bring enough clean energy from geothermal and other sources online to truly phase out fossil fuels.

The things I've described in this episode aren't possible today, but in my opinion, if anything can change that and make them possible, it would start with a complete change of government attitude toward the oil & gas industry. The people with both the skills and the track record to pull off a clean geothermal electricity revolution are not our enemies.

Deep, supercritical geothermal was the first of two energy sources I'm aware of that could realistically provide the energy we need to solve the coming crisis on the scale we need it. The remaining two episodes in this docuseries will focus on the second one.