Thinking Big: Getting the World to Zero Carbon Emissions

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Transcript of interview with Alan Murray

ALAN MURRAY:
So, thank you for being here. The Gates Foundation is focused on health. It's focused on development. It's focused on education in the United States. It's not focused on energy. So, why are we here?

BILL GATES:
Well, I spend a fair bit of my time on energy for a couple reasons. One is that if you want to improve the situation of the poorest two billion on the planet, having the price of energy go down substantially would be about the best thing you could do for them.

Like, fertilizer is basically energy. Their ability to get their inputs to come in to where they live, their ability to get their produce out, their ability to get to jobs and things-- energy is the thing that allowed civilization over the last 200 years to dramatically change everything. And so, if you want to reach the rest of civilization and give them lighting services, refrigeration services, you've got to bring the cost of energy down a lot.

That, along with the carbon constraint that I believe is hugely important - partly because what it does to tropical agriculture is it makes it virtually impossible. If you get enough warming, the temperate agriculture actually is a net beneficiary because of increased CO2 concentrations and certain places where warmth is good. But tropical agriculture, which is where the poorest live, is a disaster.

ALAN MURRAY:
And you've said we have to, not just slow the growth, not shrink carbon emissions, but get to zero. The goal has to be zero. Why?

BILL GATES:
Well, you'll never get to absolutely zero. But if you want there not to be increased warming every year, you have to get to extremely low numbers. Enough of the carbon stays around for about 10,000 years, the tailpiece, because of the way it equilibrates with the ocean, that what we're asking civilization to do here is very, very dramatic.

If it was just a factor of two reduction, that would be very straightforward. But it's not like that. This is something where it's ultra-different. Every year, civilization puts out more CO2. There's not a single year where we've put out less even when we had the economic recession, because China and India are moving ahead.

And so the idea of to get to an 80% reduction, you actually have to have a year where you get less - it's kind of a mathematical thing. And then you have to have years where you get a lot less. And so this is very tough. The likelihood of us meeting any of the goals we've set seems very daunting.

ALAN MURRAY:
So you heard the conversation between Dan Yergin and Vinod Khosla. The question was, how long will it take until only 50% of our global energy needs, as opposed to 80% today, are met by fossil fuels? Vinod said 25

years. Dan said 40 years, right? You said 2050? What's your answer to that question?

BILL GATES:
Well, this is a numeric question.

ALAN MURRAY:
That's right.

BILL GATES:
You have to look at the different sectors, like power generation, transport industrial use, and say to yourself, "What is possible?" Other than Daniel Yergin, the best writer in the energy space is Vaclav Smil.

And he has at least a dozen books, but two that are pretty succinct and I highly recommend are *Energy Myths and Realities* and *Energy Transitions*. And they both are economic and numeric on the issue of how hard it is, how long it is, how difficult it is to change our energy system. If you take any one of these sectors, let's just take electric generation, the designs we know today are what we will permit and build for the next 20 years.

And those plants will last - the lowest lifetime of any plant, even a natural gas peaker, is about 30 years. And so the notion that that sector, and the same logic applies to the other one, the notion that that sector will be 50% non-hydrocarbon in 50 years, it's not possible. It's not going to happen.

ALAN MURRAY:
Not even in 50 years?

BILL GATES:
No.

ALAN MURRAY:
You're going further out than even Dan Yergin went. When do you think we could get to global consumption 50% or less?

BILL GATES:
The two basic views I have - one is that people underestimate how hard it is to make these changes. That is, they look at intermittent energy sources, they don't think about storage and transmission. They look at things that are deeply subsidized, and they forget that they are deeply subsidized. They look just at the rich world, and they don't look at where all the energy increase is taking place, which is in middle and low-income areas.

I think the problem is way harder than many observers think. I'm in the Smil camp on this. But I also think, to counterbalance that a little bit - and here, I'm very much with Vinod - that the potential for innovation, not innovation in the next ten years, because you have to invent in this next ten years, but innovations that will start to be rolled out in say the 20 year timeframe, means that we can be in terms of the first derivative, in terms of the rate of change, we can be pretty dramatic.

And so if you took a period like 75 years, if we really fund basic research at a reasonable level, which the U.S. does not, other countries do not, if we have policies to encourage experimentation, which just take any one of the things - nuclear, carbon capture - we're not doing a good job on that - transmissions, storage. If you do the right things, there is a chance to meet very aggressive goals in a 75-year timeframe.

ALAN MURRAY:
You're talking about 75 years and beyond to get under 50% on your way to zero.

BILL GATES:
You can get the first derivative to be such that you can get way below 50%. Because the power plants you build between now and, say, 2025, you will be in a position to start replacing those in the 2060 timeframe. If you were hardcore and you could get to the point because of the economics, where you would actually end-of-life things maybe a decade soon and you made sure that all new builds were zero CO2 emission - that is, whatever the winning technology is. I think people underestimate what can be done in the near term. Because of this installed base phenomena, you can get the new plants to change 30 years from now. But certainly by 2050 if we do a good job in innovation, we could have all the new plants in rich world be zero CO2 emission. But you'd still need more time before you get to 50% of that installed base.

ALAN MURRAY:
You've said there are five miracles that we need to make this happen. Can you talk about those five?

BILL GATES:
We don't need five. We need one of the five.

ALAN MURRAY:
Just one?

BILL GATES:
Some of these are combo things. Let's just take carbon capture. If supplies of natural gas continue to expand and drilling technology, understanding geology through digital techniques, keep getting better, all you need to do is put carbon capture on that and be willing to pay for it.

It's expensive to capture from the flue. There's a bit of expense for storage. You have to have the regulatory who takes long-term liability, which essentially has to be governments, but that hasn't been done. You can imagine a future where you're just using a lot of natural gas and you're able to do the capture, extremely good capture, like 95% capture, which needs some innovation.

Seventy, 80% capture, we understand, it's too expensive and that's not a high enough percentage. That miracle alone would get you a long ways, because the planet has a lot of coal and a lot of natural gas. The next miracle - these are ors so far - is nuclear energy. Not particularly popular right now in Japan and Germany and never been that popular, even France, the French public is more negative towards nuclear energy than the U.S. public.

ALAN MURRAY:
Even though they are, what 70%..

BILL GATES:
Seventy percent of electricity. We have more nuclear plants than they do. We have over 100 nuclear plants of the 400 in the world. We are the biggest in absolute nuclear electricity generator.

ALAN MURRAY:

But you were personally investing in nuclear.

BILL GATES:
Right. The plants that are out in the world today are basically generation one and two plants. There's a few generation three plants, including at the conference Westinghouse Toshiba talked about the AP1000, which is a gen three plant. That and the Areva EPR are the two gen three plants.

I think you can build watt AP1000s. And I think partly because what the Chinese are doing, that has by far the inside track. A lot of those can get built, the Chinese have this goal of 80 gigawatts. Assuming there's no more accidents, that that actually can be done. Unfortunately, because their demand increase is so great, it only gets you up to, at most, say, 12%, best case of Chinese energy. The thing I'm investing in, and not because I expect to make a ton of money on it, it's because it's zero CO2, because the economics are so good, is a fourth generation design. And there are many fourth generation designs. This one is very, very attractive from an economic point of view, I mean, way cheaper than today's nuclear.

ALAN MURRAY:
We had Nathan Myhrvold here last year. But can you explain a little bit about how this technology works? And you're among friends here.

BILL GATES:
The part of uranium that's fissile, that is that when you hit it with a neutron it splits in two, is about .7%. And when you break a uranium atom in two, you get a million times as much energy as you do from burning a carbon molecule.

You think, "Wow, this is good technology." It's a million times better. Now, you have to take that factor of a million advantage and say, "Oh, crumb, that stuff that it's splits in to, that's radioactive." That's thesium, some bad stuff, some short half-lives that means it's intensely radioactive, some long half-lives that means that it's around for a long time.

Basically, the reactors we have today are burning that .7%. And that works fairly well. There was a concept a long time ago that you would do a different type of reactor, called the fast reactor that would make a bunch of another element called plutonium. And then you would pull that out and then you would burn that. That's called breeding in a fast reactor.

That is bad, because plutonium's nuclear weapons material, it's messy, the processing you have to get through is not only environmentally difficult, it's extremely expensive. The concept of this so-called TerraPower reactor is that in the same reactor, you both burn and breed. And so, instead of making plutonium and then extracting it, we take uranium, the 99.3% that you normally don't do anything with, we convert that and we burn it. It's like a candle. A candle wax doesn't burn at room temperature. It's the flame converts it to be a liquid, and that burns. So, this is just like a candle. Our flame is taking the normal depleted uranium, the 99.3% that's cheap as heck, and there's a pile of it sitting in Paducah, Kentucky, that's enough to power the United States for hundreds and hundreds of years. You're taking that and you're converting it to plutonium. And then you're burning that. And we have super high-power densities. We have total failsafe. Any reactor that a human has to do something, that's a little scary.

ALAN MURRAY:
What's the scale? Is scale important here? Or is it the same?

BILL GATES:
The TerraPower reactor, the current design is about the same scale. That is typically, it's somewhere around a gigawatt type design. Because of the surface to volume ratio things, the first design we're doing doesn't scale down very well.

Now, we have another design that works for the smaller type, the more, like, 100 megawatt, 200 megawatt design. But our first design, which on paper really works well. One thing to point out is that digital simulation, and that's applies to all these energy technologies, the ability to digitally simulate things is night and day different than in the past.

When they built, say, the reactor at Fukushima, their ability to simulate things was very limited. We take our reactor, we have magnitude 10 earthquakes. We have volcanoes flow over it. We have tidal waves passing by. And we look at and we say, "Oh, okay, let's put some more concrete in."

You can understand what's going to happen digitally in a way that you never could before. And so the idea of full passive safety, gen three takes us to much, much, much better passive safety, not full passive safety. Gen four, whoever's gen four gets built, will be a "no human required," "no zirconium turning into hydrogen to explode," type design.

ALAN MURRAY:
Time table for TerraPower?

BILL GATES:
Okay. This is really fast. You're going to be amazed. By 2022, if everything goes perfectly, our demo reactor will be in place. And by 2028, again, assuming everything continues to go perfectly, it will be a design that could be replicated and built in many, many, many places. At that point, because you have no fuel constraint, and according to me, you have extremely good economics, good safety, no proliferation, no waste, then you could go nuts.

ALAN MURRAY:
If everything goes perfectly.

BILL GATES:
Absolutely.

ALAN MURRAY:
How often does everything go perfectly?

BILL GATES:
In nuclear? Well, you know, if you ignore - no, no, come on. If you ignore 1979 and 1986 and 2011, come on, we've had a good century. No, seriously. In terms of raw figures, coal mining, natural gas, more people die. It wasn't far from here a natural gas pipe blew up and incinerated people. It's important to keep in perspective that nuclear energy in terms of an overall safety record is better than other energy sources.

ALAN MURRAY:
Okay, so we got two miracles down. We got the carbon capture miracle, the nuclear miracle. You got three

miracles to go.

BILL GATES:
The rest of these energy sources are intermittent low-density energy sources. The only really dense, you know, you'd take a plot of land and you can put a lot of energy in, and you can put that anywhere in the world - that's hydrocarbons and nuclear - those are energy factories.

Everything else is energy farming, whether it's sun, wind, bio-fuel. And so the amount of land and the place that you can do it suitably and in the case of wind and sun, the intermittency creates a huge problem. Because society is very dependent on reliable power. Power's not one of these things where you say, "Oh, the hospital can't keep your heart monitor going. Come back in a couple hours." We are addicted to super reliable power.

And there's a lot of weirdness about this. If you bring in intermittent sources, literally the price of power during the period when the wind is blowing could be as low as just the marginal cost for the natural gas, for the peaker. And then all the price would be in the time when the wind is not blowing. So, reliable systems that require integration, those are much different economically than just coming in and being a five percent or ten percent, particularly when you have artificial economics in terms of deprecian, production tax credit and very artificial in terms if you bid your wind farm in right now, and many cases, if you don't deliver, you're not penalized for doing that…

ALAN MURRAY:
This is not sounding very optimistic.

BILL GATES:
Well, okay, so the next three miracles, whether it's solar or bio-fuel or wind, and bio-fuel includes solar chemical where you actually get away from the normal photosynthetic processing as other processes, all of them require storage and transmission. And so, these are end miracles, where you have to have an energy source that's extremely economic and you have to have storage and you have to have transmission.

ALAN MURRAY:
Storage, you mean batteries?

BILL GATES:
It can be hydro. It can be, you can lift heavy objects up to the top of the mountain and roll them back down. It can be hot sodium…

ALAN MURRAY:
But batteries would be the most efficient, wouldn't it?

BILL GATES:
No, not necessarily.

ALAN MURRAY:
Not necessarily?

BILL GATES:
If you have the right geographic features. Another good energy author is David McKay, spelled McKay who's

take in the U.K, and it's a brilliant book. It's kind of a must-read. Because it actually explains to you, why do cars use energy? How could that change? Why do households use energy? How could that change? Why do planes use energy? How could it change?

Takes and adds it up, and then says, "Okay, given even very optimistic assumptions, here's how much energy we'll need. And here's the choices of how we get it." He has a chapter on hydro storage. And, yes, there are places where you can do some hydro storage.

ALAN MURRAY:
Is that where you pump water up to the top of the mountain and then let it run down?

BILL GATES:
And that works perfectly. Anyplace you have the right feature that has actually good efficiency, low capital costs and good efficiency. Batteries today aren't in the same league. Vinod's backing a lot of battery companies. I'm directly backing a lot of battery companies.

Batteries and compressed air are interesting in that it's possible you could get - I even have a gravity storage company that I'm involved with - you could get numbers that are very, very good. And that would help a lot. Then intermittent storage can come in. But you have to add the cost of the batteries or the equivalent of batterage, whatever the storage is, to whatever your cost of your intermittent storage is.

ALAN MURRAY:
You say you have a gravity company that you're investing in. That’s lifting things up to then drop down at peak power.

BILL GATES:
It's basically gravel on ski lifts. If you have a period of energy availability, you take the ski lift and you pour gravel on it. And then if you have no energy, you take the gravel itself to the top of the hill and you put it on the ski lift and it actually does a frequency regulation as well as energy generation. All these systems, they're pretty simple to characterize. They're capital cost and there's an efficiency level.

ALAN MURRAY:
You passed over bio-fuels pretty quickly. Vinod was pretty excited before dinner about wood chips. Can wood chips get us there? Does that count as a miracle?

BILL GATES:
Well, it's up to the woodchucks. His ability to breed woodchucks is unbelievable. How did they come up with that? I don't know. Venture capital. He has a company KiOr that uses a proprietary catalyst to deoxygenate these sources.

Biomass sources don't look like hydrocarbon sources. They've got a lot of nitrogen, oxygen in them. Turning them into either energy or a liquid fuel is fairly difficult. And there are many, many ways to do it as was said. None of them yet are that economic. Now he's got some that are scaling up their pilot plants right now. And the numbers actually look pretty good.

ALAN MURRAY:
But can you do it at a scale big enough to turn that global energy curve?

BILL GATES:
Basically, if your key interest is the price of gasoline, and if bio-fuels can come in - not ethanol, because that was artificial in terms of how it was subsidized - but if you can get economic bio-fuels like his wood chip thing, and that can even take even 10 or 15% of the gasoline market, if you combine that with some degree of electrification, say 10%, which, say that's modest, and then efficiency - he has another company I love that has this really efficient motor, there's multiple of those, but he has one of them - if you combine all those things and get, say, a 30 to 40% reduction in rich country use of liquid hydrocarbons, then you completely change the supply/demand economics.

Yes, you have field depletion going on. But you also have innovation and drilling techniques taking place. If things like that come together, the idea that you'd have $100 barrel cost you can probably get down to 50 or 60. If you get much below that, you do get a significant supply reduction at that point.

In the long run, because things like that, I do think, can get to 10% - and I think all those things can happen - I think the price of oil will tend to come down. I think the price of natural gas for a variety of reasons will tend to go up. Can he get above 10%? Okay, I'm willing to be surprised. If bio-fuels broadly, including wood chips, can get to 30 or 40% of liquid fuel supplies, I'll be very impressed by that. I think the logistics and cost make that hard. But that's what venture cap's all about. We basically, for every one of these five paths, we need at least 200 crazy people who think their idea alone can solve…

ALAN MURRAY:
You're not calling Vinod crazy.

BILL GATES:
No, he backs crazy people. He is the paymaster of crazy people. Some of whom we will declare sane at some point in the future.

ALAN MURRAY:
And you're saying, we don't need all of these miracles. One of them? A couple of them?

BILL GATES:
You've got transport. Transport is special, where either you have to have solar chemical work or it's hard because your individual point sources that are putting out CO2 aren't very much. If you can't convert transport to electric and convert electric to zero CO2, if transport continues to be liquid fuels based, because you don't have the mobile battery miracle - which many people are working on and some people think can be solved, some reasonable people don't think it can - then you need either bio-fuels that are made that are carbon-neutral or you need some sort of free air carbon capture. There are companies that are also kind of crazy, including one I back called Carbon Engineering that literally does free air capture. That is, the wind blows by and it has this device…

ALAN MURRAY:
Somebody in the room here who claims to have a car that does capture while it's driving down the road.

BILL GATES:
That another possibility. The scale of a car as an energy plant, the percentage of capture you can do, it's extremely unlikely that economically you could do, say, 95% capture. Unless you've made the fuel in a carbon-

neutral way, it's unlikely you'll get full recapture.

ALAN MURRAY:
Do you put probabilities on each of these miracles?

BILL GATES:
Yeah, it's pretty hard. I think for society's sake, we need to fund basic energy research at least twice as much as we do right now.

ALAN MURRAY:
What needs to happen to make these things happen? Government research

BILL GATES:
Things like that would increase the probabilities. And if you take the nuclear space, does the U.S. have the guts or the money or the will, to actually go out and do new design demo plants? Probably not. I mean, when TerraPower's going to go in, I went to the Secretary of Energy and I said, "Hey, how do you get this thing to be piloted in the U.S.?"

And he was very helpful. We work with national labs, great relationship. But the chance for a variety of reasons of the government funding such things, the regulatory approving such things in the U.S. is very, very low. So, that's a path that really depends on some country other than the U.S. to build the demo plant. A lot of the ideas, the invention come from a tradition of fast reactor work here in the United States that's really brilliant. But it'll have to be a very international project.

ALAN MURRAY:
More funding from the government. What else would help speed up the transition?

BILL GATES:
Well, some of these things like carbon capture, you either have to put on a serious carbon tax, which is the most important thing to do. Doesn't have to kick in immediately, but people have to believe that it will kick in in a meaningful way during the life of power plants, so that their power plant decisions are changed and therefore the people who invent and supply power plants are incented to come up with low CO2 power plants. That's the greatest failure in our energy policy, is not to have out there, at least in the 10, 15-year timeframe, a carbon tax really expect to happen.

ALAN MURRAY:
And we're further from that today than we were four years ago.

BILL GATES:
Yes. That particular bill had had some serious flaws in it in terms of how the system worked. But, yes, the House did pass a bill, amazingly, hard to believe, that would've taken a meaningful step erratically in that direction. Whether that's likely to happen or not, it's hard to say. But it's what should happen, because it drives both conservation and innovation.

ALAN MURRAY:
I want to open it up to questions in just a minute. But one other question, because we've spent a lot of time today before you got here talking about natural gas and the effect that natural gas has had on this whole

equation. In your view, is it a good thing or is it a bad thing? Is it delaying change or is it helping create a bridge of change?

BILL GATES:
Well, if you put aside climate change, which you should not do this natural gas thing is phenomenal. And the upper bound on what might be out there in different layers, different drilling technology, fracking technologies, it's quite amazing that there may be dramatically more than the proven reserves we have right now. And there's a lot of innovation that can take place there.

So, that's a very good thing. The price of electricity is very important. And it appears that shale gas is available in a lot of geographies around the world. In fact, the estimate for China even though they haven't really gotten going on it, is actually higher than the United States. And so these are big, big numbers.

ALAN MURRAY:
So, go for gas and stop worrying about it.

BILL GATES:
Well, no, because unfortunately even though natural gas has less CO2 emission per unit of energy, people can argue it's less than half as much. You get some natural gas leakage in the processing. Natural gas is a very potent, warming molecule.

And so any leakage in your system is a dramatic negative in terms of this overall equation of global house gases. Getting a half reduction doesn't help. It really is not a big deal. There's a recent paper from Ken Caldeira and Nathan Myhrvold that actually goes through it. If you shifted overnight the whole system to natural gas. And so a 50% reduction, you're just going to keep warming and warming and warming and run this experiment that, in natural history, that's a faster warming rate than has ever been seen in the history of the planet.

So, in that sense, it's a challenge. And when TerraPower or other people look at their energy things, they've got to compare themselves, not to the spot price. The spot price electricity generators can't call up and get a 20-year contract at that $2.50 price. They, right now, are being quoted things more in the $6.00 range. Maybe at some point there'll be long-term contracts on a $5.00...

ALAN MURRAY:
So, that's what you have to look at, $5.00, $6.00…

BILL GATES:
Yeah. And so, you have to have an energy thing that is very economic compared to $5.00 natural gas.

ALAN MURRAY:
Would you rather have a higher marginal price for energy?

BILL GATES:
There's a huge number of trade-offs involved. The ideal, by far, is to have very cheap natural gas with a carbon tax. And so, even if the market price for the gas is, say, $5.00, you're taking, say, $40 per ton of CO2 emission collecting that…

ALAN MURRAY:
And the odds of that happening in the next couple a years?

BILL GATES:
It depends on the I.Q. of the U.S. public.

ALAN MURRAY:
And your current assessment of that? That's a numeric question.

BILL GATES:
Over time that's worked out for us. I mean, seriously, it's easy to get really close to the current politics. But you have to say to yourself, anytime you really look close at politics, it's looked pretty ugly. And yet, the U.S. has managed to do the right thing in a variety of issues. And so, I do think over time, that consensus will emerge. And the actual pocket of the cost of that is reduced by innovation like natural gas innovation.

Also, I'm not involved in gen three nuclear, but to the degree that volume manufacture in China gets component prices down, gets offsite building percentages up, gen three nuclear could surprise people. I mean, the Chinese build these things not that much more than cold plants. They're gen two, and over time the gen three. And so, even that, their innovation should get things down so that we can afford to differentiate in favor of the non-CO2-emitting sources.

CHRISTINA LAMPE-ONNERUD:
We met at Davos, actually, on the mentor program in the entrepreneurs. Thank you. Boston Power. Founder of Energy Storage. Complexity going forward with technically complicated systems that require multidisciplinary and interdisciplinary teams at a pace that we have not seen before in the need and search of new systems. How would you characterize and what advice would you give to those of us now alive, likely not alive in 75 years and active when these problems have basically resulted in wherever we're going? What would you like to see and what encouragement and advice would you give to all of those who are trying to bring together complex new systems in an environment that it not likely to view data?

BILL GATES:
Well, the IT revolution makes people, in a sense, over-optimistic about the pace of innovation. That is, because things could happen at small scale, because companies could fail and succeed, and the ones that succeeded could get additional capital at these very rapid rates, if you made innovations either through trade secrets or patents, you could be immensely rewarded for it. It created this paradigm that is way too easy compared to energy innovation.

I mean, just take energy storage. What are they gonna price it at? It’s a very strange system, where the prices are basically rigged by rate commissions. And so the ability to do variation over time, the pricing of reliability, creates these extreme things where the intermittent people are going to hate it. When you really properly price things, those intermittent guys are going to look terrible, until they figure out how to couple their thing with a really good storage system.

And this is done in 50 states and a political environment. You've got to hope that some of them - and it's sort of done at the ISO level, too, so that's confusing because that crosses state boundaries. You have to hope somebody prices the value of storage properly, so that innovators have a good price signal there. It's very

strange, we subsidize massively the intermittent generation, mostly wind.

And so, of our spending on energy as a country today, the portion that's on R&D is about 2%. The portion that's on production tax credit, accelerated depreciation is over 80%. And people make these weird arguments about learning curve benefits of that. Wind isn't going to get five times cheaper than it is today. And it's not going, because it's subsidized, it's not going to manage if we figure out how to store wind. "Oh, we just put it up there on the blade or something." And so, we're spending our money very, very, very foolishly. If we could subsidize storage, if we could clear the regulatory problems for transmission, which that's a huge problem - you compare the U.S. and China, it's night and day - then you would get the economics right. But we're spending, the money we're spending, it's almost $300 billion a year.

ALAN MURRAY:
So, it's not more money. It's how it's spent.

BILL GATES:
Well, no. It's not enough money if you count the government explicit budget. Because the Department of Energy budget for research is actually very modest. It's only when you count the tax expenditure which - and the RPS price effect. So, when you bring in those pieces, you are spending a lot of money. Now, it's hidden from you. But you're spending a lot of money. You're just spending it foolishly.

CATHY BESSANT:
Thank you. I'm Cathy Bessant. I work for Bank of America, run our global technology and operations work and also chair our environmental council. I'm struck by the five miracles. And I've heard you talk about some of them before. Sometimes I get myself lost in the sixth miracle, like, restoring the credibility of the banking system. So, maybe we can talk about that at some point. But when I think about the five miracles and I have, in the end, no doubt that there are actual technical capabilities that either today or in the future will take us to a path to zero carbon emissions, I wonder a lot about the political will.

Because everything that you're talking about, whether it's revamping the way that we provide incentives, whether it's the cross-jurisdictional cooperation that has to go on, whether it is changing the way we incubate until there's sector profitability, all of that requires some element of political change. And I agree with you also that you can count on our political system on a lot of complicated issues to do the right thing.

But generally, that happens when there's a strong will - either a populist will or a national will or a business will. And I'm just wondering what you think about what the source of the will is to cause the global or, in some case, individual jurisdictional political change that has to happen.

BILL GATES:
Well, generally, will comes through competition. And, of course, countries don't go bankrupt, well, actually, they can. That's your first area. But to the degree that other countries are able to have cheaper energy than we have, then we will look at that and over time will adapt to it. There's two problems right now. One is that we need to take our willingness to spend money and be smart about it. The second thing is, broad adoption only happens when these things are economic. And it could happen that these things are economic, say, in China, when they're not economic here, because we don't do site permits right, we don't do transmission right, we don't have the right price signals for things like storage.

We will look and see the Chinese do those things well, which I'd say in each of those, the chances are they will

do way better than we do. They don't have elected rate electricity boards that are just looking at a short-term constraint. They're actually looking out at the long-term needs. And so, they permit transmission lines 50 times faster than we do.

And, you look at all the innovation in transmission, and we don't even have super-high voltage transmission here. All of that is being done in Asia and all the equipment that comes along with it. I do think when the U.S. gets behind on something, it responds. This is an unfortunate one, because we have so much of the I.Q. and entrepreneurial activity. It's a shame for us to get behind.

And so I hope we don't have to use that mechanism. I hope we use just pure logic to fix some of these things. And some of it can happen on a regional basis. The basic R&D budget, though, that's one that has to happen on a federal basis.

DAN BARSTOW:
I'm Dan Barstow from TERC, an educational non-profit. And I guess I'm concerned about one of the resources that hasn't come up yet much at all in any of the discussion. As we look forward to problems that we have to solve over 30, 50 years, it's not going to be us. It's going to be the next generation. And our schools are currently so focused on pouring in content knowledge that you can regurgitate on a test and not on developing the kinds of creativity and innovation that we need. Schools need a fundamental change. And I want to thank the Gates Foundation for so much that you've done to help schools change. And maybe you can comment about your vision, about how schools need to change to develop the kind of skills that we need.

BILL GATES:
Well, that's not a simple question. The Foundation invests about $800 million a year in U.S. education. And the majority of that goes to having a feedback system for teachers where they're observed and they get feedback on what the very best teachers are doing that they're not doing.

And so that the average quality of teaching moves up in a measurable way. And doing that type of evaluation system so that it's not capricious, so that it's very helpful, it's a hard thing. We have a bunch of pilot districts where it's going very well. You actually have to be willing to fund an evaluation system to have peers come in and train those peers. It costs about 2% of payroll to do.

So there’s a goal on evaluation to help people do as well as the very good teachers. Very good teachers do an amazing job. And all we have to do is move slightly in that direction and we'll have a good education system. And the second thing is the use of technology in education, which is not a panacea. But if used in the right way to extend the school day, have personalized learning, have feedback, have the best lectures in the world, you know, we think there's a lot that can be done there.

ALAN MURRAY:
This last question over here.

MIKE HART:
My name is Mike Hart and I'm with Sierra Energy. And we haven't done a lot of discussion here today about what the Bill and Melinda Gates Foundation has been doing in Africa but we are huge fans.

We have a waste energy technology. And it's at a small scale, at a village scale. And before I came here for this meeting, we had a meeting with our board of advisors and our board of directors and all of our employees,

the Department of Defense, who's our sponsor on this, as well as CR Railroad, which is our principal owner. And we decided that we would like to offer as a donation to the Bill and Melinda Gates Foundation the use of our technology for free forever for the continent of Africa. We believe very strongly in what you're doing. And we think this could help tremendously with what you're doing there. And so, we just wanted to offer that, because we're so impressed with what you're doing there.

BILL GATES:
Well, I'd love to look into that. The irony for poor people is they pay more for energy than anyone. Because if you can't have a reliable grid, you're basically buying diesel fuel and using very inefficient generation technology. And, you know, it's really holding back African countries. Even ones that are on the verge of doing well – Tanzania, Nigeria, Ethiopia - the power sector is a particularly - because of the state loan, it really is a huge constraint on the positive economic developments there.

ALAN MURRAY:
But Foundation doesn't really do energy work, right? This is something you do personally.

BILL GATES:
Energy that's for the world at large, I will do on a private side. If I happen to make money, that all goes to the Foundation. Any energy solution that's specifically addressed to the poor, the Foundation would do. And the Foundation only has two things it does. We do U.S. education and we do livelihoods for the poor. And so, agriculture for the poor, financial services for the poor, mostly health for the poor is the biggest thing we do. But, if we saw a way that they could have energy access which, for them means light at night, refrigeration, vaccines stay cold, fertilizer gets cheaper - if we saw a way to get energy to them uniquely then we'd be interested.

ALAN MURRAY:
Dan, you need to be very quick and you need to be very good, because it's the last. And the burden on it is especially heavy.

DAN YERGIN:
So, Bill, you talked about those 200 crazy people that are necessary. You understand as much as anybody on this planet about entrepreneurship and willpower making something happen. What thoughts would you have from your own experience and from your understanding of entrepreneurship to apply to people, many of whom are in this room, about entrepreneurship in energy to make the kind of changes you're talking about?

BILL GATES:
The advances that are necessary here are very based on an understanding of science and engineering. And so the current strength of U.S. universities in those areas is a fantastic thing. And if you look at the breakthrough energy portfolios - Vinod has the best one, but there's others as well - over half the really amazing work that are those, you know, 200 times five, you know, 200 in each of the directions of one or two which will succeed. The U.S. has a huge part of that. And so, making it possible for them to get capital, making it possible for them to scale up, having a relationship with China where if they have a breakthrough, the big increased market, that they are not handicapped because of, you know, tit for tat trade problems between the U.S. and China.

We can create a framework that's very favorable for them. The returns for some of those people, for N node technology, the returns the normal sort of capitalistic market works, when you want to do systems that relate to

power generation or storage, we need to make sure the rewards are there. And that is very unclear right now what'll be there. If you look at, particularly grid-related generation type technologies, I mean, there's no way something like TerraPower, there aren't a lot of nuclear start-up companies because of the timeframe involved.

And so you have to think, why don't we have more of that? And, you know, what's holding these people back? In the case of solar, actually, solar chemical's somewhat underinvested in. But there's a lot of good entrepreneurial spirit, you know, sometimes combining the U.S. and overseas manufacturing, which is not necessarily a bad thing.

I would just encourage the people who work in this area that the importance of this is right at the top. The reason I spend time on it is because I think it is so critical to the environmental challenge and to helping the poorest. Cheap energy is like a fantastic vaccine in terms of what it does for livelihoods. It’s great that energy is somewhat more popular as a topic than it was, say, ten years ago.

It’s important. We need to keep that trend going. We need to look at science and engineering skills. Is the U.S. relatively continuing to decline in that? Because that's where these smart entrepreneurial people are coming from.