



Woodrow Wilson
International
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Environmental Change and Security Program

Healthy Solutions to Climate Change

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Edited Transcript— Dr. Paul Epstein

Great, well, this is some of the biology behind and below some of what you just heard, and my friend often calls the subtitle of my talk: “It’s worse than you think.” I think we have a competitor for that just a moment ago. That was quite a panorama of where we are and how much further along we are than we thought.

I’m going to talk about climate change just a moment, then impacts, and work to what’s in our backyard, and hope to arm all of you with, as you work on these issues here. And then, finally, turn to solutions and think about how we can divide what we can do right away and what we need to study, so we don’t wind up with a whole new range of unintended consequences and stranded assets.

These first two [slides] on climate just recap some of what you heard, but put a little bit in context. Here we are with the ice cores back to 400,000 years, going between large caps and medium-sized caps. This goes back to 800,000 years in the ice record. It probably goes back two million years, because that’s when the Panama Isthmus closed off and the Gulf Stream got started, and that’s the part of the conveyor belt which helped stabilize climate for millennia. So, here we are: stable states. The earth likes stable states like we all like stable states. We’re awake and then we fall asleep, that’s another stable state. It’s actually our reticular activating system kicks off. That’s what sometimes jerks you when you fall asleep. So there are stable states, and the earth likes these, going from medium-sized to large-sized caps. Here we are with rates of change; variance around the mean increasing, a sign of instability. And for the biology, variance is not just a noise, it’s become a signal, as we look at mosquitoes and so on. Variability is a big part of the impacts of climate change.

Major outliers, punctuated equilibria: This is the theory from evolutionary theory that we are stable for long times and then go through transitions. Earth seems to do that as well, go through transitions rather quickly. So, here we are: 280, 180, medium caps. We’re up at 387. We’re outside this envelope that we’ve been in for probably two million years. So this is the real hard ice data on where we are relative to where we’ve been for probably two million



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years, those cycles being driven by the earth around the sun: the orbits, the eccentricity, the wobbles, the Milankovitch cycles. That's your natural variability. So what we're seeing is natural variability and climate change affecting our weather.

Second issue, which you've heard a little bit about: methane. The IPCC did add these up, and the forcing factors are much greater than 387: 460. That's not the whole story. We get the "soxes," the oxides of sulfur in there, cloud condensation nuclei and that cools things. Low clouds cool. High clouds tend to warm. So sulfates, we thought we'd clean the sulfur out of the fuels, things would warm up more than we thought. Well, here's the silver lining in this black cloud. It's the black soot, the particulates, black carbon, and we now know that it's a very big forcing factor. Here is 1.6 watt per meter squared. Think of a little Christmas light LED, think LED light on the ground, and this is about 2/3. Carbon dioxide lasts a hundred years, black soot lasts eight days depending on the rain. So the good news is, if we clean up fuels we may not warm up as we thought, but we actually will reduce a warming factor. Here's the brown haze over Asia, which we've known is contributing to climate locally, but now we know it's a global issue.

The third issue is ice melt that you heard about. How many saw "An Inconvenient Truth"? Great, I urge all to see it. The only problem is he tends to underestimate. Ice melt: as we lose ice shelves it doesn't raise sea level, but it does take back pressure off the ice sheets, and this is what's happening in Greenland, it's happening in Antarctica. Just as on Cape Cod if you took the sand down, the dunes come down, those ice shelves buffer and buttress the ice sheets. So we're seeing an acceleration of ice sheets. The biggest one we know, it's coming down here is the Ilulissat, the Jakobsavn, and you'll remember it because it shed the icebergs that sunk the Titanic. That's the one right off of West Greenland. It's coming down now twice as fast as it did in the 1990s. Twice as fast is nontrivial; we're talking seven kilometers, and now 14 kilometers a year. They are not all going that fast, but that's the fastest. So the behavior of ice sheets is one of the main issues and, as Amanda mentioned, the calculations are changing. Five years ago sea level rise was half from thermal expansion, half from ice melt. Today it's 80 percent ice melt. It's dramatic, and it's very much different than when the IPCC finished up in 2007.

Albedo, the earth's albedo overall is about 30 percent; 30 percent is going back up into space. If it goes down to 29, 28, that could be a trigger point. We don't know where that might be, but that's another issue with more heat going into the open ocean, more melting of ice, more heat in the ocean, you get the idea: a positive, amplifying feedback that could warm. Here's





the sea ice. You saw this before. It's just dramatic. This is what really alarmed even the non-alarmists, what happened in 2007, and then in winter it went back up and then not quite as much -- but, as Amanda said, the volume.

The other part of this story that we hear little about is what's happening in the oceans. This is the work of Syd Levitus and his colleagues at NOAA; our Department of Commerce taking all of the data from buoys, from satellites, from submarines since the 1950s. 1957 was the first IGY, the first international geophysical year, so a lot of global research began then. The oceans have warmed 22 times as much as has the atmosphere -- 22 times. That's a number to remember. It's the amount of joules, exajoules -- that's 10 to the 18th joules. It's not temperature, it's heat content. As we know, water warms up slower and also releases its heats slower, and that's what's happened over the last century and a half is it's warmed up slower. That's the capacitor for last century's global warming. It's what connects global warming to climate change. Climate change is warming and a change in the weather patterns, and it's through the oceans and the change in the hydrological cycle that global warming is affecting the climate and causing climate change.

I'm looking for a blackboard here, but weather patterns are changing. Winds are changing. That's one of the things not stressed enough about the IPCC recently, the westerly winds in both hemispheres, more in the southern. Think drought in Australia and winds there that are affecting the continent's hydrological regime. But it's weather that is changing, and as warming occurs, we think that this bell-shaped curve of the distribution will just move over to the left. Everything will get a little warmer, and we'll see more weather in the high tails. We're seeing in the low tails, the high tails; we're really beginning to see a bimodal distribution where there are fewer normal, shall I say, average days and more cold, more hot, more dry, more wet, more punctuations and sequences of extreme.

So this is the physics behind it. The water is warming. The ice is melting. Water vapor is rising. Those are the three states that water exists, plus snow. But the main ones are speeding up, and we're seeing more water vapor in the atmosphere, and for every 1 degree centigrade the atmosphere warms up, it holds more water vapor: 7 percent. So we've got a push and a pull on the water cycle, and this is what's drying out parts of the land.

When rain comes down, it comes down in heavier downpours. Here are the numbers over the U.S., from the National Climatic Data Center in Asheville, North Carolina, part of NOAA: rain over the continent of the U.S., up a little bit; two inches a day, up 14%. That's





an important number, because that's the number that we associate with waterborne disease outbreaks like E. coli, cryptosporidium. That's what drives sanitation into clean water supplies, so that's critical, and we've mapped that across the U.S. Four inches a day have gone up 20 percent, and then just released is the six inches a day -- half a foot of rain a day events -- have gone up 27 percent; again, this shift through the outliers.

Here's the biggest one we know in the last hundred years -- well, 1877 is our records -- one meter of rain in a day in Mumbai, with all of the consequences, not only just acute, but the conditions for outbreaks of mosquitoes, waterborne and so on.

Okay, that's the climate story. What does that do to our health? The clearest signal we have in terms of infectious disease is in the mountains of Africa, Asia, Latin America. What we are seeing in Kilimanjaro, in the Tibetan plateau, in the Andes is that glaciers are retreating, plant communities are upwardly migrating and mosquitoes that cause malaria, dengue fever and so on are circulating at high altitudes. There are three sets of maps behind this that I can make available for you to put on the Web that give you the data, sort of a simple person's GIS of mapping where the glaciers, where the mosquitoes, where the plants are moving, and they are very confluent. In fact, the temperature of the freezing isotherm, the level at which it's frozen all year round, is bumping up. That's our weather balloon. So there's four sets of data. That's the key way we know the climate, in terms of warming, is affecting infectious disease.

Mountains are great to study, primarily because of their wonderful verticality. We go from deserts to rainforests to the poles to climate in a matter of miles. If you go up one mile, it's equivalent to going 600 in latitude, so this is a very clear sentinel area. It's also material, because malaria is circulating in Nairobi, a mile high city; dengue fever in the mountains of Vietnam; dengue fever, yellow fever in the Andes, so this is having an effect already in central highlands of Africa and so on.

Turning to lovely Africa -- here, just to orient you to the map, are the four rivers: the Congo, the Niger, the Nile and this is the Zambezi. Here's the Great Rift Valley where we are all from, and the lakes and so on. But here's the Sahel -- the meningitis belt, we call it. It's one of the infectious diseases that's not vector-born, it's person-to-person. We think that drought accelerates this, because it dries out the membranes. There is a helpful story behind this, which is that we can vaccinate against meningitis, if we have early warning systems, the health early warning systems that NOAA is trying to develop now. We've been working on





this for 15 years, but now with this administration we're going to really have some climate services so that the people in Niger, et cetera, can vaccinate when they know there's going to be a drought. So this can be helpful with early warnings.

Here's a problem we just learned we didn't know we'd had: chikungunya fever. It's like dengue fever, which is called breakbone fever. And things come and go, there are cycles to these things, but here's this one that broke out in East Africa after drought. We've known that in the islands of the Caribbean when there's drought people store water around their houses and it breeds this very short flying mosquito, *Aedes aegypti*. So that's what happened in East Africa. There were 500,000 cases. It then spread throughout the Indian Ocean, which is overheated. There was an outbreak in Italy in 2007. That was on the front page of the Times. This is global warming. It's an extension of the range -- maybe yes, maybe no, it's hard to say.

This is an Asian tiger mosquito, *Aedes albopictus*, which we have in the United States. It's a vector for West Nile and so on, but not a good one, fortunately. But it was good enough in Italy, so maybe yes, maybe no, but the real issue with this disease is the drought that intensified the "conditions conducive to," and those are three keywords in thinking about infectious disease.

When that drought yielded to heavy rains, then we've got other problems: mosquito-borne, rodent-borne and waterborne. RVF is rift valley fever. That's a disease that gets cattle and ungulates and also affects humans. It affects livestock, so it affects the manure in the field, and agriculture, affects trade. It's a big issue economically. It's an issue now that's transferred to Saudi Arabia.

Amanda talked about the bark beetles, so let me just give you a couple of bits in the background here. Here's the agent. Here's the host. Here's the environment. That's the epidemiological framework. TB doesn't cause TB; you need a host that's immunodeficient and an environment that's conducive. In this case, absence of killing frosts mean that beetles are overwintering, moving to higher altitudes, moving to higher latitudes, even getting in more generations each year. What's happening with the trees, the hosts, in this case is repeated extremes, particularly drought, dries the resin that drowns the beetles as they try to drive through the bark. So the extremes weaken the host, warmings emboldening the pest, and the environment's certainly conducive; and here's the Kenai Peninsula in Alaska, four million acres just there alone. And this brings Weyerhaeuser into the discussion to be a little





into the economics here. These forest pests are the things that are of more concern, perhaps, than the bugs biting us. They are responding to the same issues. These become economic issues.

Agricultural issues, we model, and you've heard we bet that they'll do fine. It'll just move a little north, and that's fine in North America. There's a few things left out of that model. First of all, there're the extremes: the droughts and floods. There're the early heat waves in early May when the flowering of the plants, so the timing of events. And then there's the other issues: the pests, the pathogens and the weeds.

Here's one that came into the U.S. on the tails of Hurricane Ivan. You may have forgotten that we had four hurricanes that hit Florida in 2004. This was before Katrina, Wilma and Rita, and the range can be affected by warming. So, warming affects the range. Weather affects the timing, the intensity, the location of outbreaks and even the kind of outbreaks, because floods give you fungi. Fungal growth, like this Asian soybean rust, is the biggest blight of pests, of crops, and then droughts can give you other problems: aphids, white flies and locust. The mere mention of locust shakes anyone.

The sum of this issue is that 42 percent of growing and stored grains are damaged and destroyed by pests, pathogens and weeds every year -- 42 percent; that's equivalent to about \$300 billion on international markets, be it stored grains -- fleas, rodents, so on -- for growing. So this is a very important issue in terms of thinking about the nonlinear potential, the potential for nonlinear changes in crop yields.

Here's one that I'll just take a little tangent to talk about: Africa and carbon dioxide and warming and drought. Yucca, tapioca is one of the staples that fills the belly of folks. Here's in Mozambique in 1981, a drought. Here's what happened, and this is the worst picture I'll show you. From eating early crops, early tapioca, yucca: cyanide is in the plant. Why is it there? Well, that keeps the bugs away. It's part of the defense of the plant. If you harvest this early, don't process it, people are malnourished, you get neurological poisoning. Now what we've learned in experiments in Australia is that increased CO₂ also increases the cyanide in the leaves. The leaves are not what we eat, what I was mentioning, but we do eat the leaves with coconut and peanuts. It's a great mixture called *matapa* that you add to rice, and a little bit of meat if you have it or fish. So it is eaten. So this is another issue that we weren't aware of. CO₂ has effects on plants. Here's the yields of CO₂, and this needs to be reproduced in the field.





So let me sum up the problems here. Thinking about our backyard and the backyard of the people that you relate to, let's start with just CO₂. Put aside the global warming, climate change, the whole thing for a moment. Just more carbon dioxide affects plants in ways that we hadn't known.

We took ragweed and put it under double CO₂. The stalks went up 10 percent, pollen went up 61 percent. USFDA has repeated this, has done this, was doing it simultaneously, and they found the same results. It turns out that weeds like carbon dioxide, put it into their male territorial-seeking cells, the pollen -- that's how they spread themselves -- and so that may be why this happens evolutionarily. The pollen, however, become more toxic and more allergenic -- and they also are food for mosquitoes. Agricultural weeds -- remember, I mentioned pests, pathogens and weeds. Think herbicides, insecticides, pesticides: It's not what we want to go to with our organic agriculture, so that's another health dimension.

Tree pollen in the spring; spring is tree allergy season. Grass for the summer, ragweed principally for the fall, and we've got an extension of the season. It's about 20 days now, recently published in *Science*, between spring and fall, and then we get some spores, and here's some nasty synergies.

Ozone, also from burning fossil fuels: "Noxes" go up in heat waves. And then here's the nastiest picture here, which is the diesel particles that are about -- these black carbon that are ppm 2.5 or 10 attach to the pollen, which are ppm 10s, and they are delivered deep into our lungs. They irritate the mass cells that cause the allergic phenomenon, because there's nitrates in the diesel. I add this up for a moment just to be clear: burning fossil fuels and CO₂, burning fossil fuels and noxes and smog, burning fossil fuels and particles, burning fossil fuels and the aggregate of climate change affecting the seasons. Burning fossil fuels is the issue. How we burn less of everything is going to be part of the solution.

Mold: mentioned. Poison ivy is getting stronger, published in the *PNAS* -- *Proceedings of the National Academy of Sciences* -- also the chemical within it, urushiol, so a similar reaction. Lyme: I'm not going to persist on, but here we go with the last one.

I put a star just to say something good about disease, because I haven't been very kind. You'll notice the crows that were around about ten years ago -- they were accumulating in the trees, and mobbing the hawks and so on -- have gone. In fact, they've been documented.





They're down about 45 percent -- this is three years ago, published in *Science* -- because of West Nile. That may have opened up the ecological niches in the city for all the lovely little nicely sounding attractive birds we're seeing like cardinals. So disease can play a good role at some point, and if anyone finds something for Canada geese, let me know.

All right, so CO₂: so what do we do about this? Well, there's one other area, before we talk about solutions, that we often leave out, is our energy infrastructure, and it too is vulnerable to climate change. So as we think about adaptation to climate change in this community over here, and the mitigation community that's over here, and the REDD -- Reduced Emissions from Deforestation and Degradation -- community that's in the middle: those three communities seem to be going, hopefully, somewhere parallel, but they are not together.

Here we are with storms and interruptions still from Katrina, Wilma and, in fact, Ivan the year before. Pipelines, oil rigs and refineries: It's down 25 percent, and traders on Wall Street who were trading in energy futures are looking at storm tracks. Blackouts: the 2003 heat wave in Europe also affected the U.S.

Let me say one thing about heat waves, because that's what we often associate with health and climate change, and we are looking at a summer here. There are two things about heat waves that climate change affects. It's not just their intensity and their breadth and their frequency, but it's the warming at night, the t-minimum story -- nighttime winter temperatures have gone up twice as fast as overall warming since 1970. It's the lack of relief at night, that that's when the cows go down in the West, when there's no relief at night. It's what affects us. It's what happened in Chicago. And then there's the humidity story that I mentioned, with the hydrological cycle and warming of the atmosphere. So climate change means that the characteristics of heat waves are different. It means that as we prepare, it's not only air-conditioned malls and lovely rooms like this, it's air-conditioned hotels that we need for surge capacity. We've got to think of this in terms of the public health responses.

Twenty-four out of 104 of our nuclear power plants are in places where aquifers are already overdrawn and underfed. Heat waves, clearly, will affect their water temperature -- that's what happened in France, many of them had to shut down -- as well as droughts that you just heard about can affect our vulnerability in terms of those that we have already. Pipelines in Alaska are buckling, some of them because of the melting of the permafrost. Lightning has gone up with warming, and this is from the Hartford Boiler Insurance Company; just published, though, however, in scientific literature, this association. And here is the more





sobering issue of hydropower; water coming from the mountains for agriculture, for health but also for power. In Peru they are making plans for coal-fired plants to replace their lost hydropower. This is clearly a huge, huge issue in Asia with the Tibetan plateau.

So, what do we do about all of this? And this is where you're grappling. I would say, where we are right now, if we think about the science and what it's telling us to do, I think this community and Washington, we all move through that. As to what are the solutions, we haven't quite gotten our hands around that. What's the policy instruments to drive whatever we do, so I will end with some comments about that.

But here's the schema that was developed at Princeton by Steve Pacala and Rob Sokolow of all these ways to bend the curve, to stabilize the concentrations: first stabilize the emissions, then the concentrations of CO₂ and CO₂ equivalents.

So, here they are. Now I'm going to look at these, not just from a technical perspective, an economic, but a health and environmental lens. Now that may sound still a little fluffy -- "Okay, what are we worried about the health issues?" -- but the health and environmental issues turn out to be what Swiss Re is looking at, what AIG, what all the insurers are looking at. Bankers who invest in Wells Fargo and Bank of America and J.P. Morgan Chase and Credit Suisse, Morgan Stanley: those are the five originators of the carbon principles. They remember the long tails, precautionary long tails, of asbestos, tobacco, lead, industrial toxins. So if we don't think ahead, we are going to have problems we didn't anticipate. On the other hand, there're a whole lot of things we can do that are good for public health, good for the economy, good for the climate.

I've got a list of 15 of them here, all of the wonderful things that we know are good for us in the first place: efficiency, conservation, renewables, PV, solar -- there are issues within those, like siting of wind and so on, but in general, we know these are the directions we have to go in. Natural sinks: conservation tillage, forest nurturing. Another wedge of avoided carbon emissions. Each wedge: 1,000,000,000 tons avoided, one gigaton. And we may need bigger wedges, but the idea is this is a portfolio. Then there's the fossil fuel base, then nuclear. That's the gamut. There are new ones coming up, like waste disposal and capture of methane, and that's the cleanest burning fossil fuel. So there are others that are being developed now but this is the heart of it.





So what are no regrets? Everything is on the table. We haven't taken nuclear. We've separated between what can we do now that's really good that we know has lots of promise, lots of opportunities, and what do we need to study?

So here we are. Well, we are over seven with things that we know are good for us. The two on the left, forests and agriculture, those are huge ones. How do we incentivize, get our policy instruments, financial mechanisms lined up for those? That's not so easy to solve, and there's our REDD trying to work that out. Agriculture is a big one, and 5/6 of agricultural emissions come from clearing land to grow seed or graze, that's the main issue with agriculture. In general, we have a whole lot of things we could be doing.

On the other hand, there are some issues with biofuels. I'm suggesting we have to study hard. And then nuclear fission, just getting three "S"s here. The "Healthy Solutions" report you may have picked up goes through this, but here's a quick summary. We think about nuclear, and nuclear and carbon capture and storage is about all we are hearing now. So let's just think about those for a moment.

Nuclear fission: storage, safety and security. Safety is probably the least of it. We know pebble technologies, we can get there. Security is a huge issue, particularly if we double what we have now and get a wedge. There's going to be more of this on the roads, and to think we can put in Yucca or something like it, 70,000 or 140,000. None of that takes into account decommissioned plants, so that's a big issue and it's perhaps being solved in Sweden only. France has not solved its permanent storage either, and then there's the other two stars I put up there: 10 to 12 billion apiece, 10 to 12 years to build them; it takes two years to build wind farms and solar, and so on. This is not a rapid response. This is not something without a lot of fossil fuels put into it to build the plants, to get the uranium. It's not a renewable resource. So there are lots of problems that we have to be thinking ahead before we give our subsidies and our government insurance plan to expand a wedge.

Here's what we're trying to do with figuring out liquid fuels. So here are the technologies, again, warranting this lifecycle analysis. We're going to take a look at biofuels here. Liquid fuels to replace them, we're looking at all of these: shale oil, tar sands -- lots of issues with those in terms of water and energy use. Here's the lifecycle of oil: extraction, transport, refineries, transport again of refined, and then combustion, and then we burn it and so on. All of these stages are what is leading to what's happening today in Peru, in Ecuador, and the uprising of people because of the headwaters of the Amazon with oil exploration. We have





not come to grips with the ecological dimensions of our addiction to oil, and I would remind us, our last president said we are addicted to oil, and that's the first of the 12-step program.

But the biofuels issues: there's a lot to be said about land use and food security and so on, but the one I want to highlight here is the health issue. Burning mixtures of ethanol and gasoline gives you formaldehyde and aldehyde, acid aldehyde. These are volatile organic compounds. This is the one you'll remember from your labs. They combine with the noxes to give you ozone. There are three types of ozone. There's the good, the bad and the ugly. There's the good stuff -- this is Kevin Trenberth, from NCAR. The good stuff is in the stratosphere. The bad stuff is a greenhouse gas. The ugly stuff is photochemical smog. In the cities it's contributing to the heat island effect of trapping heat in the cities. It's corrosive to the lungs. It's worsening our adaptation to climate change. Biofuels are going to worsen our adaptation to climate change. We have to think about that dimension of the lifecycle. They've known about this in São Paulo, Brazil, for many years. We're now studying it again, but this is not an unknown among respiratory physicians and air pollution specialists.

The third one is coal. So here I'm touching on lots of toes in this nation, because we are trying to bring the coal industry into this century. But here's the lifecycle: underground mining, lots of problems for health, silicosis, injuries. Then we come to mountaintop removal: deforestation, importing of cancer clusters where the water is contaminated. Retention ponds, we just became aware of on December 22, three days before Christmas. That's when the TVA, Tennessee Valley Authority went. We didn't know they were there. Well, they happen to be all around coal-fired plants. They're all around the refineries, meaning pulverized coal. They're all around these mountaintop removals. Sludge and slurry; the ponds are retained with hardened sludge and slurry. This is not secure in any way.

Seventy percent of our rail traffic is taken up with coal. Imagine what we could do with that, with getting public transport. Then we burn the stuff. I want to call attention first to mercury, 48 tons of mercury, and that's a huge issue for all of us. But this is one that gets little attention: nitrogen coming into our coast on the East Coast, half of it is from coal-fired plants. The other half is nonpoint sources from agriculture and point sources -- sanitation and sewage. Half of it, half of the nitrogen in this nation; it's probably a lot more in the China South Sea and the Bay of Bengal from India. They're losing their fisheries. They're creating dead zones from burning all the coal, just as we are. This is an issue now, dead zones throughout the world. Coal is a contributor to that, and to our fisheries.





Then, finally, we're going to bury this. So just for a moment think about clean coal, and think about all of this before we get to this issue of CCS. Can we do that successfully? That's the next issue. But does that answer this question? I'll leave that as vague as I did.

Here's what's up in these mountains, just to give you a glimpse of it. I just went to Kentucky. This is what's happening up in these mountains. This is what you see. They just blasted the top off these, first the trees and all the stuff is pushed into the side. Here's the lovely towheads in the bottom. And here's what happened after a 2-inch rain, five days before I got there: all these trees, all these boulders, down in people's lawns, in their streams, on their houses, on themselves sometimes. This is creating zones of vulnerable populations. "Mountaintop removal" is a misnomer. It's mountain range removal. These are ranges, and this is the kind of an extent of this, and this is creating this vulnerability. It's changing the local climate just as what we're doing in the Amazon changes the hydrological regime there. This is serious stuff that makes you wonder what you hear from the industry. I'll leave that as it is.

So how are we going to do this CCS just to take that on its own? Putting the carbon underground; here's what we first proposed to do it -- coal, oil, these hydrocarbon reservoirs. That's where a lot of the pilots are going to be. We might get methane. That could be a good thing. That's the cleanest burning fossil fuel. But here's the big reservoir: saline aquifers. What's happening to saline with carbon dioxide? What's happening to the oceans? Carbon dioxide in the oceans is acidifying the oceans. It's 30 percent down in its pH than it was pre-industrially. It's not trivial. It's still basic, it's .1 pH scale, but it's 30 percent, and I'm quoting Tom Lovejoy in that analysis. It will do the same thing with saline aquifers underground. That can leach arsenic and lead into the saline, into the groundwater. That's a health issue, but the bigger issue is what it does to the microbial communities, other gases and limestone. Limestone is chalk, calcium carbonate, and with more acidification we're going to actually disintegrate that CO₂. So can we find enough plates to put this under? This is a whole issue in terms of is this secure and is this insurable?

Saline aquifers have some connection to the outside, and then -- this is the calculations of Ed Rubin at Carnegie Mellon, that with one gigaton we'd need 5000 square miles. This is a big issue. How do we study this? Locally is one thing; how we extrapolate and figure out can we do the abundance in saline is quite another question that I'm concerned we're not going to be able to answer with our local experiments.





And just a few words on climate meddling: geo-engineering. Sulfates and space; we have to worry about more acidification, we have to worry about crop yields. Mist is another one proposed. Plankton at sea; we've really measured it a hundred meters down, that's [unintelligible] zone that we've known it really doesn't quite work. CO2 removal in scrubbing; that might actually be something we have to get to, and we'll have to bury some of that or sequester it. And solar panels in space I just want to mention, because this isn't really geo-engineering, but this is, with microwave: this is a source of energy, and this is the one that I think we should give the maximum attention to. That may be something that boosts the solar energy.

So, what can we do? Well, with traffic, transport, with cars, trucks -- we need to change from the internal combustion engine to electric vehicles; plug-in, hybrid, electric vehicles -- lawn mowers, caterpillars, all this stuff. But that has to plug into somewhere, so here's our cleanly powered smart grid that many of you are getting involved in, and to complement that, healthy cities, and connected with light rail. This is where we could put our stimulus packages: into the healthy cities, into the grid and helping Detroit become something different.

What is a cleanly powered smart grid? Multiple means of distributed generation at each site: so redundant species, resilience. Complementary systems of triangulization, capturing heat. Two thirds of the heat, two thirds of the energy is lost from heat at any plant; capturing it in steam and so on. Smart technologies to manage this, smart within cities; we can all be fractals of this, so that every center, every institution, every house, every university can be fractals of a grid that can get smarter, and then plugs into the grid. So this is a project that we can all be part of. And here are the cleanly powered ways to do this, with hydro and natural gas. And I want to mention Ken Zweibel's paper in *Scientific American*, January 2008, "A Grand Solar Plan," a phased-in plan. It's a model of how we could get to where we need to go with now with wind, 85 percent of the grid by midcentury.

A word on green chemistry, because we have to get off petrochemicals. Here's our bio-plastics. You shred it. Here's BioWillie. But we need to get off of food sources, so algae and tobacco is another one for all of these things. We don't have time to belabor all that.

I want to mention the Healthy Cities for a moment. This is part of the solutions: green roofs, green buildings, tree-lined streets, biking lanes, walking paths, open spaces, smart growth, public transport. They're all about creating jobs, creating new industries, decreasing this





heat-trapping CO2 in the city, ozone -- black carbon, now we know. Cleaning up our cities; they're healthy, they're job-creating and they advance these technologies for climate stabilization.

Here's one that's a really easy one to do. Dark roofs have this temperature often in Chicago, this was measured. So, white roofs are something that we could do. And in developing nations, we need energy for development; development is needed for adaptation. When the wind doesn't blow and the sun doesn't shine, we have a rope around it and ride it with a motorcycle. We've got confluent crises where -- a lot of failing "F"s here, and we've got to deal with all of them at the same times. This is our challenge for today, our challenge for these days. This can create a confluence of agendas. It's this clean development, clean energy as the first necessary step toward sustainable development.

Here's your Washington consensus -- and this is the penultimate slide. This is what we've gone on for the last, some people think 500 years. We need more regulation. We're finding that out in financial markets. We need public/private partnership writ large. We need more constraints on the way we function, and not on goods but control over investments and the flow of international capital. We learned that from Bretton Woods, that we needed rules, fixed exchange rates and constraints on the transfer of capital. It couldn't just go into Tokyo, out to Singapore, and then to Bangkok in five seconds on the computer. You need to make investments that last, and that was one of John Maynard Keynes's insights: To solve the whole thing, we don't have to really figure out the whole thing, we just have to change the rules. That was one of the key rules that was relaxed by Nixon in 1971. We need to deal with a whole lot of other issues that we hadn't had to deal with back in '44 like debt, terms of trade, tariffs and subsidies, swords with no shields denied.

So, finally, how do we do all these wonderful things I'm suggesting we have to think about? We need carrots. We need sticks. We need an institutional framework. We need to realign the rewards, the rules, the regulations. There's only some things the public sector can do, like large procurement practices and fleets and so on and infrastructure. We need a comprehensive plan that's phased in. We have some strong lobbies, not coincidentally, with those three things I suggested we put on this side of the table to study. If we get them to decide and think about rationally with a lifecycle analysis what we can do now, this can be the engine for the 21st century. We've got to lead with those carrots. We're going to need institutional framework that's a little different than what we have now and we need regulations -- all of those. If we do this right, it can be good for public health, good for





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security, good for the economy and we certainly hope it will stabilize the climate. Thank you very much.



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