THE BROOKINGS INSTITUTION

40 YEARS LATER:
AMERICA'S ENERGY PATH AND THE ROAD AHEAD

AN ADDRESS BY ROCKY MOUNTAIN INSTITUTE PRESIDENT AMORY LOVINS

Washington, D.C.

Wednesday, November 2, 2016

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P R O C E E D I N G S

MR. JONES: Ladies and gentlemen, welcome to Brookings this morning. My name is Bruce Jones. I'm the vice president for Foreign Policy. I also co-chair along with David Victor the Cross-Brookings Initiative on Energy and Climate, and on behalf of that group and Charlie Ebinger, the whole Foreign Policy program, it's a real delight to welcome you all here this morning for what I think is an extremely special event.

It was just over 40 years ago, just after the 1973 oil crisis that shocked the American economy and our national security thinking, that Amory Lovins published an article on foreign affairs that radically altered the landscape of U.S. energy strategy and thinking.

In his landmark piece, he argued to U.S. policymakers that we should move away from fossil fuels, toward energy efficiency, and renewable energy as a core strategy for both our economy and for our security.

He drew attention to the ways in which clean energy could not only strengthen our energy independence, but also our national security and our role as a leader in nuclear non-proliferation.

It was an article that was lauded by many, and as these things are, criticized by many at the time, and drew a great deal of testimony and debate across the policy community and across the country, and became the most reprinted article of Foreign Affairs ever to this day.

The issues that Amory tackled 40 years ago are still critically important for this country. How we think about energy security. How we think about the role of energy in our economy, and how we think about climate change remain crucial issues in the national debate.

Granted, you would never know that from watching the current election, but they are still crucial issues in the debate.

By the way, I work for an NGO, so we have to do a little advertising. I would encourage you to go to Brookings, just Google "Brookings Election 2016," and you will see some terrific papers on climate change and energy security and what it means for the country at this juncture, and the fact that our politicians are ignoring it doesn't mean we should as citizens. I'd encourage you to take a look at those.

The ideas that Amory talked about 40 years ago and the notion of what was then a radical idea of low cost, zero emission, consumer focused power, is increasingly a potential reality as technology shifts and as the urgency of tackling climate change grows in both the national and global consciousness. Nuclear proliferation and energy security remain vital aspects of American foreign policy.

At the same time, of course, I think there is a kind of growing concern with questions of energy access for the poor, energy use in the developing world, and so there is still a serious debate to be had about the relative balance between low cost renewables and other sources of energy, and how we fuel the global economy in the literal sense of that word.

I am delighted on behalf of my colleagues here at Brookings to welcome Amory here this morning to talk about his article and what has happened in the 40 years since. As you all know, Amory is the co-founder and the chief scientist at the Rocky Mountain Institute.

Over the past four decades, he served as a consultant and advisor to 65 countries. He published 31 books. We don't like to admit those things in places like Brookings where we like to think of ourselves as doing a good job publishing books, but Amory is outclassing us there.

He was named by Time as one of the 100 most influential people in the world, and we are delighted to welcome him here today. He will speak for a little while, and then he will be followed by a panel that Charlie will introduce, a very distinguished panel, to give you some reflections on his thoughts on where we are on energy security

today.

So, with that, please join me in welcoming Amory. (Applause)

MR. LOVINS: Thank you for this opportunity to reflect on an article that many believe reframed the energy problem and our responses to it, both in America and abroad.

That article, the most reprinted and longest in the history of Foreign Affairs magazine, was published with the first edition in September 1976. With the help of many friends, it had worked through a dozen drafts spanning over a year.

I wrote it starting in 1975 because U.S. energy policy was simply stuck. The initial policy responses to the 1973 oil shock were confused and ineffectual, simply drilling more oil and gas wells, mining or coal building, or nuclear power plants, perhaps pursuing synthetic fuels, had strong proponents, but they were starting to look, as people dug into the numbers, too costly, dirty, slow and difficult.

They weren't even economically self-consistent because their marginal costs were so high that you would have to raise the energy prices high enough that there wouldn't be enough demand to pay for that costly supply.

It seemed to be that these unworkable solutions came from misstating the problem as how to get more energy, more of any kind from any source at any price.

I introduced the simple but radical notion of end use, asking first what services we wanted the energy to provide, like hot showers, cold beer, mobility, comfort, melted aluminum, baked bread. Then asking how much energy, of what kind or quality, and what scale from what source could do each of those tasks in the cheapest way.

To my end use emphasis, melded with Roger Sant's least cost language, which resonated with the free market economics that soon emerged under President Regan, that fusion is now called the "end use least cost approach," and ever since, it has provided superior foresight into competitive market outcomes and has become widely accepted.

The publication process was quite an odyssey. The magazine's impressive and eminent editor, Bill Bundy, was somewhat disposed to take seriously such unfashionable notions as efficiency and even renewables, which many considered outlandish and completely impractical.

His wife, Mary Bundy, whom we have the honor to have with us today, and she is also Dean Acheson's daughter, by the way -- Mary and another lady, Janet Lowenthal, whose husband, Abe, worked with Bill, and she worked for Dick Gardner at Princeton, had been feeding Bill for some time some supportive articles, so he was a little bit softened up, but he was quite skeptical that the article belonged there or I would stand for all the editing it would require.

Mary told us at dinner last night about that long, difficult evening in which she struggled to persuade Bill to accept the paper and finally succeeded, and I think therefore, even the mother or the midwife of the modern energy revolution is here among us. (Applause)

When Bill agreed to try it, he sent it out to two technical referees, Harvey Brooks at Harvard, and Carol Wilson at MIT, to get a technical read, and they flatly disagreed. Harvey said he had serious problems with a lot of the numbers. Carol, for whom Bill Martin and I were working at the time, said well, if they are Amory's numbers, they're probably right.

A great indicator of his quality, Bill said, okay, I'll give it the benefit of the doubt, I'll publish it, and if Harvey doesn't like it, he can write us a letter.

Bill did some wonderful developmental and structural edits, and by about draft 16, it was ready to go. Bill was temporarily in the hospital when Jennifer Seymour Whitaker and I did the final line editing, as I recall, about a 14-hour phone conversation from a pay phone and a shack in the Maine woods with a hurricane approaching, which if it happened to veer our way, would take down the wires for a couple of weeks, and we would miss the press date. The hurricane forebore, and with the marathon phone call,

we got it to press.

The article, toward the back of this big issue, got little attention. They didn't do features or titles on the front cover on those days. It turned out that there was an article, I believe the one by Ugala Lon, third article, mine was fifth, so this is really official, happened to have an article in this issue in which somebody made a mistake drawing the map, and this was taken as an esoteric but important restatement of an Israeli official about borders in the Middle East.

Everybody went running to this issue to see what the fuss was about, and then they couldn't help running across my paper because it was 31 pages, that was the longest they had ever published, so some people started to look at it, and pretty soon the newfangled Xerox machines started humming away with mass mail-outs. It was the equivalent of the Twitter storm. We didn't have an internet, but we had a lot of places and more august institutions had access to Xerox machines and stamps and envelopes.

Some people told me they received between 50 and 100 copies individually from their friends. Everybody was saying you must read this thing.

The general reaction was either you must read this because it changes everything or how on earth could such an eminent journal publish such dangerous nonsense. The battle was royally joined, and I was pleased to learn last night that as it went on, Bill was quite proud of what he had done.

It was the first time energy policy and foreign affairs, foreign policy, got mixed. They had been in completely different silos, but Bill had the courage and the vision to see that it was time they talked to each other. Energy would be at the heart of how the world evolved.

The effect to me as a 28-year-old author was like that of dropping a sea crystal into a super saturated solution, suddenly there is a little crackling noise, and the whole thing takes on a different shape.

The energy policy that was stuck suddenly had a different way to look at

the problem, and that started to open up solutions that might actually work.

The response was swift and rather ferocious. Edison Electric Institute, they put out a special issue of Electric Perspectives, and altogether there were 36 at least critiques, which the late Gray Watts for Senator Gaylord Nelson lovingly compiled in this paperweight of a Senate hearing record over the next year, and the critiques ranged, to a sputtering of outrage, together with my tedious responses.

It makes amusing reading today, but the critics were not amused. It's hard to remember how many experts in 1976 considered efficiency minor or unreliable or even risky, threatening economic collapse. People literally said we would be back to caves and candles if we decoupled energy growth from GDP growth.

Cities said obviously, since we are in a market economy, we are already using energy as efficiently as possible, nothing more can be done. The renewables were thought strange or ridiculous or just technically absurd. After a year or so when the dust had begun to settle, ARCO's chief economist, Dr. David Sternright, neatly captured the conclusion of many of the more sober observers when he said I for one don't care if Lovins is only half right, that would be better performance than I've seen from the rest of them. (Laughter)

Around that time, a year after the paper came out, President Carter called me in for a long substantive conversation with him and his energy secretary, Jim Schlesinger, later my ally on grid security issues. Miss that guy. Jim made three comments, all technical and all incorrect; the president corrected him on all of them.

Two years ago, President Carter told me the article had been exceptionally important in framing his energy policy, and that felt good because I thought apart from Jim's syn fuels attempt, which soon died of an incurable attack of market forces, the Carter energy policy was the most coherently pro-efficiency and pro-renewables and visionary in architecture energy strategy before or since, and laid the vital foundations for the investments and attention that led to today's energy revolution.

Over the next decade, many of the article's harshest critics ending up hiring me or my team at Rocky Mountain Institute, which we set up in 1982, to help them adopt its recommendations, and by the current decade, places like Public Utilities Fortnightly and Power Engineering International were praising it.

Let me rattle on a bit about what have we learned and what should we have learned and where are we headed. First, we learned the value of energy scenarios, which had been pioneered by Dierdonck, whom I just missed, and indeed, these hard and soft path graphs redrawn from the article, and I'm told it's the first time they ever had graphs, they first took shape in 1975 on Derrick Price's blackboard at Shell Group Planning in London.

Scenarios, of course, are not forecasts, rather they are powerful vehicles for telling stories that help people understand unfolding events.

At the time, a few groups like the Ford Foundation's Energy Policy Project led by David Freeman here, from whom you will hear shortly, and even the Academy's study, were introducing scenarios. They were often scored by traditional extrapolative or econometric forecasters, but it turned out the scenario tools proved a lot more useful, and they could be reality checked by a newfangled thing I introduced in the article called "back-casting."

One contemporary antidote to forecastitis is the three decade lack of relationship between the wholesale gas price in green and the official forecast of it in blue, investors believing forecasts like those have lost their shirts three times now, once for over $100 billion, the fourth one is underway, and the inherent volatility of gas prices which are worth 2 to $3, that complicates risk management, it deters finance, but even without counting volatility, efficiency of renewables have a constant price that often beats even the fuel costs of today's combined cycle power plants, and gas heat is also pressed to compete with efficient buildings, industrial processes, cogeneration, even solar process heat.

The new story about abundant and affordable energy for the long haul is less about fracked gas then about its inexhaustible carbon free stabling price physical hedges, efficiency and renewables that are outpacing and increasingly out competing it, and together, they and cogeneration in 2013 alone got over $630 billion of global investment, although that transmission is well underway.

Back to the scenarios. The second thing we learned is to start with why, start with purpose, start with end use. What's the job? What's the right tool for the job?

The article was so influential, I think, because it didn't simply propose yet another portfolio of alternative investments but because it redefined their purpose and their logic.

Here are two curves redrawn from the same data as my 1976 article. On the left, the hard path, as I dubbed it, melded the official forecasts at that time for government and industry, which extrapolated historic growth and built to meet it, and on the right, assuming the same GDP growth, the soft path combined end use and conversion efficiency with right quality, right size renewable and widely accessible supplies, which I dubbed "soft technologies."

Friends like the anthropologist, Margaret Mead, then belatedly pointed out that this terminology might arouse anxieties in middle aged men who run the world. (Laughter) By then, it was too late to change the language, and ultimately it was sufficiently accepted, that now when Joe Nye spread "soft power" all over, that term at least seems to have been accepted in this more gender balanced age.

Let's dissect how well the soft path graph resembled reality, and let's start on the demand side. That is the good news. My soft path graph was explicitly not a forecast, although it is still often misinterpreted as one, it simply described what I felt was possible and plausible, however unfamiliar.

This chart is from a paper by Jon Koomey, who we will hear from later, with Ashok Gadgil and Paul Craig at Berkeley Lab, 2002, and they found my soft path

curve was the only published mid-1970s' view of U.S. energy demand in 2000 that actually proved accurate. It was .8 or 4.0 percent above actual demand, respectively, with or without renormalizing actual GDP growth.

The big black dot representing my suggestion for 2000 energy demand is rightly described by those authors as impressionistic but driven by a large number of engineering and economic calculations, and they actually proved more useful than the best econometric tools at the time, and those ended up typically 50 to 100 percent too high, sometimes far more.

The Berkeley Lab study also assembled grades from both traditional and reformist energy experts for a variety of leading energy studies of that period. Mine scored A on influence and E on technical quality. In fairness to the reviewers, the back-up wasn't published for at least another half year, so I think a lot of folks didn't realize initially I wasn't just making stuff up.

The survey authors of this paper commented one major theme that emerges from this study is that the interviewees' assessments differed enormously regarding quality and influence, and there was little correlation between the two.

The survey authors observed that studies generally regarded as high in quality tend to be non-controversial and integrative in nature in reflecting ideas already known and accepted, they are not as likely to attract attention and exert influence, other things being equal, as studies with striking conclusions.

Another theme they continued is the assessment of analytical strength is correlated with the views of the reviewers. My paper showed the extremes most clearly. Both have favors with reviewers favoring renewables whereas analysts who preferred traditional energy systems such as coal, nuclear power, found them technically flawed.

Little has changed in the intervening quarter of a century. The same is now true 14 years later. Minds in this business are ripe with what anthropologists would call energy tribalism, changed mainly one death at a time, and even that is no longer a

reliable method.

Some of the first-generation nuclear advocates like my late friend, Alfred Weinberg, were expert and well informed and honest, but I can't say the same for the new generation of often underinformed enthusiasts who continue to distort policy and misallocate capital.

What happened after 2000? Remember that in 1975, our government and industry were virtually all in agreement that the energy needed to make $1 of GDP couldn't fall. A year later, my article suggested it could drop 72 percent in 50 years. So far, it has dropped 56 percent in 40 years. Yet, just the innovations already made by 2010 in far more powerful technologies and design methods, regulation, maturing financing and marketing delivery channels, can now save another threefold, twice what I originally thought, and a third of the real costs. Now, six years later, even that looks conservative.

An important feature hidden within these aggregates by the way is so far, U.S. electric intensity has followed only half as fast as fuel intensity. There are about ten good reasons for that, including the way two-thirds of our states still reward utilities for selling more energy and penalize them for cutting your bill, but as that perversity is slowly reformed and other causes fade, electricity demand, too, has been falling in absolute terms since 2007, as in most industrialized countries. In the long run, in the U.S., it could well keep falling by one percent a year despite complete electrification of the auto fleet and robust economic growth.

Forecast demand moderated, but on the supply side, the soft path happened only in states like California that consistently pursued it. At the national level, powerful lobbies and hence federal policy strongly favored the hard supply path.

On the left, I've redrawn my 1976 soft path graph to add, based on the information available in 1976, both nuclear power and hydropower, which the original graph left out because they were relatively small and constant, and then came my

illustrative sketches of how soft technologies, oil, gas, and coal could behave.

What actually happened? What actually happened on the right differs for three main reasons that affect each element of supply. First of all, natural gas in gray was thought in 1976 to be a scarce byproduct of dwindling oil, so federal policy outlawed its power plant use from 1978 to 1987, and strongly promoted massive expansion of coal-fired generation instead, as well as nuclear power subsidized to about 100 percent of its value.

The vast coal fleet was then exempted from environmental laws, and it is only now fading as those rules start to be enforced even as the newly resurgent gas persists, in more efficient combined cycle plants developed in the 1980s. So, gas and the shift to coal driven by policy and subsidy and so on, that was the first big shift.

How about oil, the black wedge? Once President Ford got auto efficiency standards passed into law in 1975, effective in 1978, U.S. oil intensity fell by an average 5.2 percent a year, and it turned out we had more market power than OPEC because we could save oil faster than they could conveniently sell oil.

The resulting 1985/1986 oil price crash fostered complaisance, everybody hit the snooze button, and lobbyists were able to persuade Congress to ignore for 20 years for autos, about 17 for light trucks, the legal mandate to ratchet up the efficiency standards in step with technology progress.

Light vehicle efficiency worsened from 1987 to 2004. It took 22 years just to get back to 1987 levels of efficiency. The pace of saving oil fell by two-thirds, about 99 percent of the major gains in power efficiency boosted acceleration instead of saving fuel. John Dingell, et al, blocked legislation until President George W. Bush's 2007 update, which was then suspended a year later.

This stagnation wasted two whole turnovers of the car fleet that were supposed to be used to implement the available and cost effective efficiency, and that is why we have this big fat oil demand continuing while oil interests sought to suppress

competing biofuels. Hence, our still high but now declining oil demand today.

Thirdly, soft technologies. They didn't do that. They did that. The main reason is their rapid progress in my soft path was explicitly predicated on aggressive support, but instead it got largely hostile federal policies for 32 of the past 40 years, and has become a political football. Even the fossil fuel firms that belatedly invested in renewables than impatiently dumped them.

The big structural change that did go well over time was President Carter's PURPA law, which mandated fair competition for independent and distributed generators. That enabled renewables in the early to mid-1980s, and although it was weakened by fierce legal and legislative attacks, PURPA ultimately did destroy the rationale for utility monopolies and laid the groundwork for competitive power markets which have replaced PURPA in half the nation. By the way, in three-fifths of the states, efficiency and demand response can now compete directly against supply. I've been asking for that since 1973. It's coming.

After a long bumpy detour, renewables since about 2010 have finally taken off as originally envisioned in the early part of the soft path curve, which is 35 years later. Of course, the official econometric forecasts had gradually been coming down to approach reality.

The resulting dominance of efficiency gains achieved only half the results sought from my soft path portfolio as the data has revealed through 2015.

If America's total energy use had grown with the economy at the 1975 level of energy use per dollar of GDP, as critics then vehemently insisted was inevitable and essential, we would have used that much energy.

Instead, we cut that by more than half, roughly two-thirds through technical efficiency, one-third through structural change. Meanwhile, total renewable energy output doubled, and that's wonderful, yet it had a cumulative impact, 31 times less than the savings.

The energy you don't use is invisible. No energy company foresaw this efficiency revolution. None today fully realizes that the low hanging fruit will keep growing back faster than we can pick it.

There are a few other things about the article I would like to mention. What is my time, Charlie?

Among the many elements of that 1976 article with a familiar ring 40 years later, readers will pick out some that are still current, and some of them, for example, political economy of energy choices, that is right with us because the article says in contrast to the soft path's dependence on pluralistic consumer choice and deploying a myriad of small devices and refinements, the hard path depends on difficult large scale projects requiring major social commitment under centralized management.

The hard path, sometimes portrayed as free enterprise and free markets, would instead be a world of subsidies, $100 billion bail-outs, oligopolies, regulations, nationalization, imminent domain, corporate statism. Sound familiar?

If we go down the list, there are a lot of quite rich intellectual capital that popped up in here that is still being exploited. I want to focus now on the last one. The commitment, said the paper, to a long-term co-economy many times the scale of today, that is 1976, makes the doubling of atmospheric carbon dioxide concentration early in the next century, this century, virtually unavoidable, with the prospect then or soon thereafter of substantial and perhaps irreversible changes in global climate. Only the exact date of such changes is in question. Are we there yet? The clean power plan of the Paris agreement.

My first professional paper on climate change was in 1968, 48 years ago.

Had the scientific community, not just a few industry visionaries like my friends, Bob Heffner and the late George Mitchell, understood in 1976 that U.S. gas is often unassociated with oil and quite abundant and profitably recoverable from deep formations, at least with pretty high prices, I would have treated it separately from oil and

emphasized natural gas rather than advanced coal as a transitional technology used "briefly and sparingly to build a bridge to the energy income economy of 2025."

Fair enough. That wasn't clear until the last decade. I did expect coal mining would peak at about twice the 1975 level. It actually hit 2.18X. Now coal is squeezed between efficiency, renewables and gas, and it has a smaller share of total U.S. primary energy than its previous World War II low in 1972.

As my article warned also, dangerous delays in the transition to a post-fossil fuel and climate safe energy system are exactly what we can expect if we continue to devote so much money, time, skill, fuel, and political will to the hard technologies that are so demanding of them.

Our continuing failure to exploit the power of example of market advantage to speed the orderly terminal phase of nuclear power which provides an innocent looking civilian cover for weapons programs, continues to blow back on us and create self-inflicted threats from the likes of North Korea, Pakistan, and Iran.

I would say that was the article's biggest failure, I didn't get that across effectively enough.

Nonetheless, slowly but with gathering speed, markets have begun to triumph over incumbents' political means of enforcing their natural desire to protect their legacy assets and capabilities. Yet the challenge of speeding that shift remains, and climate, public health, security, development, and democracy heighten its urgency.

I have a number of other slides about the energy revolution now coming at us, but I think it is better to go right to the panel, and some of those points will come up in discussion, which I think is going to get pretty rich. (Applause)

MR. EBINGER: While we are waiting to get miked up, I think I would be very remiss if I didn't note that one of the people behind us this event in addition to Brookings has been my dear long-standing friend, Bill Martin, who of course, was himself deputy secretary of energy previously, and also very involved as chief of staff in the

original founding of the International Energy Agency. We are delighted to have you here, Bill.

It is my great honor -- I cannot imagine, I don't think in my professional career that I've ever had the honor to be on a platform with such four distinguished energy observers, many of which go back many, many, many years.

I'm not going to read the individual bio's because you have them in front of you in the interest of time. Simply to say on this panel, we have phenomenal regulatory experience. We have entrepreneurial experience.

We have someone like David Freeman who transformed the way the Tennessee Valley Authority thought about their long-term energy planning. We have Jon Koomey who is one of the most prolific writers among the people in the energy field today, and my colleague, David Victor, of course, who has been in the forefront with the IPCC and many other parts of U.S. energy and international energy and climate policy.

Without further ado, I'm going to start the panel. We are going to start with you, Peter, and then we will go to David, and then Jon and David. I want to urge the panel to stay within the five minutes if at all possible.

MR. BRADFORD: Normally, I write my remarks while the other panelists speak. (Laughter) With apologies to those who heard me say this last night, let me begin with the observation that when I first met Amory, about the time this article came out, he was dominating a basketball court. If I have your attention (Laughter).

In the state of Maine, there are not many hearing rooms large enough for a major occasion, so an awful lot of the important public proceedings take place on convergent basketball courts, and that was the case with the 1975/1976 Central Maine Power Company rate case, which was primarily about raising the money to pay for the Seabrook nuclear power plant, in which CMP was an owner.

Amory arrived at the hearing with a suitcase and a light bulb more or less the size of a football, and the promise that it would over time could replace a very large

part of the electricity used for lighting and therefore, also the heat that had to be taken away by air conditioning, to 30 year old more or less utility commissioners trying to grapple with the various tentacles of what was then the energy crisis, rising oil prices, electric rates, nuclear power controversies, this was a window opening on a very different world.

The challenge was how to move the actual infrastructure in that direction. After all, Amory would be gone on a plane within 24 hours, leaving behind a group of utility executives who didn't regard this as a particularly congenial set of insights. That trouble really has continued ever since.

Just a few observations of things that struck me in thinking back over these years. Dick Cheney was the White House chief of staff when the article came out. Twenty-five years later, as his energy taskforce laid out the energy plans for the Bush administration, a hard path recipe if ever there was one, he said that energy efficiency might be a sign of personal virtue, but it was no basis for a national energy strategy.

I think the point that Amory has already made and that is made in the original article as well about exclusivity, about the fact that choosing one path excludes the other, is one of the most important points that one has to absorb.

To illustrate how important and how unabsorbed it is, consider that in many conversations about energy policy today on television and the media and Congress, it is regarded as a sort of solemn and wise statement to say, I'm for an 'all of the above' energy policy.

Well, what could be more contradictory to the concept of exclusivity than an all of the above energy policy? You can't have one.

When I wrote a few years ago that we're not going to fight world hunger with caviar, we're not going to eliminate energy shortages with nuclear power, one of the most flattering things that happened to that statement was it popped up a few months later as a quote from Amory Lovins. (Laughter) It does have a kind of Lovins-like ring to

it, I'm proud to say.

If you want another illustration of the fallacy of the all of the above or the non-exclusivity arguments that were made vigorously when Amory's article came out, just look at what is happening now in Illinois and Ohio, New York, California, where reactors are threatened by a combination of things, low gas prices, their own rising costs, but also renewable energy.

The owners of those plants have turned on renewable development after years of more or less treating it with benign neglect, and are directly going after the renewable portfolio standards, the production tax credits, and seeking to curtail the place of renewables and efficiency, too, in those states' energy futures in order to keep the reactors running, and in order to keep the price of electricity high enough to support the reactors.

In fact, interestingly enough, no reactor undertaken after Amory's article came out was ever completed. So, in that sense, the proposition that we need not build more plants and that the lights would stay on, and for that matter, that we would still reduce oil dependence in the electric sector, has proven to be true.

A number of reactors that were under construction were completed, some of those are the plants that are closing now. No new ones were built from then on. The fact is we haven't missed them. We miss the billions of dollars we spent on some of the ones that were cancelled, but we haven't missed the plants themselves.

We are still left with the ratemaking challenges that confronted me on the basketball court 40 years ago. As Amory said, some states have now adopted ratemaking methodologies that harmonize energy efficiency, renewables, and paying for their existing infrastructure, but the entire South is still very much on a hard path ratemaking structure.

I think that in the utility sector remains the greatest challenge in furthering and speeding up the transition to a soft path energy future. It's not really a soft

path kind of comment, but perhaps the most succinct statement of this proposition came from a utility CEO, John Rowe, then of the New England Electric System, later the CEO of Exelon, when he said of ratemaking and energy efficiency, you know, the rat has to smell the cheese, and we're still working on getting the aroma of the cheese to drift into the offices of the -- let's not call them rats -- the folks who will build the system going forward. (Applause)

MR. EBINGER: Thank you, Peter, very interesting as always. David?

MR. FREEMAN: To speak about Amory in five minutes is a challenge of a lifetime. I have considered myself a first lieutenant in Amory's army for over 40 years now. Of all the people, including myself, in the energy arena, Amory is the only person that I know that has said the same thing for 40 years and has been right every day, every hour, all those 40 years.

The frustrating thing is even now when the evidence is overwhelming that Amory foresaw what the future needed to be, we still have intelligent people that are fighting city hall, that are not accepting the fact that the renewable efficiency option is the low cost option.

What is frustrating is the environmental knowledge has reached the point that what Amory has preached, advocated, and sold to a lot of people over a 40-year period, used to be desirable. Now, it's a matter of life or death for the planet, and we still have people with over a 100 IQ that fight it, including some people in this room, I suspect.

The issue is whether we human beings are a modern-day version of a dinosaur, are we using our brains? Are we willing to accept yes, favorable facts?

I view Amory in a somewhat different perspective than I think most anyone else because I had been advancing these efficiency ideas in the federal government ever since the late 1960s with some modest success, but I didn't have a voice. I was talking to myself primarily. The world at large didn't know about this. Amory gave breadth, depth, understanding, and coherence to the notion that a combination of

efficiency and cleaner technologies was an option that made sense, and he has taught the world in a very unmistakable manner, in a way that people like me just never had the ability to do.

I feel like we have had an unwritten partnership where I ran over my lifetime five different utilities and tried to implement with some success occasionally his ideas whereas he was educating the world.

I must say Amory's numbers are now as solid as gold, but they haven't always been. His ideas have always been solid as gold, but I have to recite once when I was running a utility in Central Texas, he came to Austin to teach the city of Austin efficiency. He gave a lecture. He was up there with his chalk, and he was telling them they could save this percentage on this and this.

I just came there and listened, but I do math in my head. I realized that Amory had them saving 110 percent of their load. I went up and whispered to him, and he made a few corrections. It didn't faze him in the least. It was all okay. (Laughter)

The important thing is the impact that he had on President Carter and some of the rest of us. The breakdown in American energy policy was the election of Ronald Reagan. Plain and simple. We were on the soft path in 1979, the projections were pretty much in line with what Amory was saying, and we haven't been on it since then.

A great tragedy was the Clinton administration, where Al Gore, a personal buddy of mine, and Bill Clinton, they know as much about this subject as anybody, and they didn't do diddly squat in the years they were in office. That is another story.

Amory is a young man. He has reached the midpoint in his career, and I think he is going to be around to witness an all renewable, all electric economy that is emerging. The real issue is will it emerge in time. That is the big question, can we persuade the people on earth that this is not something that is desirable but absolutely

necessary, and it is cheaper.

What is so frustrating to me is we fought this fight when it wasn't at all clear that we were right. Renewable energy was kind of a dream back then. Now, it is a reality, and still we are not able to move to a simple law, like all new power plants have to be greenhouse-gas free. No one is even suggesting things as simple as that that are absolutely necessary.

Why are we fooling around with taxes, which for 41 years no one has been able to enact a tax, why are we fooling around with things that incentivize and maybe when it is life or death -- when the DDT was killing the birds, we outlawed it. The family doctor is telling us that the emission of greenhouse gases is poisoning the environment, in plain language. Yet, rather than outlawing it, and we can outlaw it for the future, and we have a better product, we are fooling around with complicated measures that nobody in Paduka, Kentucky can understand, you know.

Somehow or another we are so wedded to a market solution to things that we have forgotten the only reason on God's green earth that we have a government is to do the things that we can't do individually, and you can have a carbon tax as high as it is, rich people will buy gas guzzling cars if they want to. This is an issue that requires 100 percent participation, and it requires that we take mandatory action, in my view.

So, the big fight now is, are we going to implement Amory's dream, which has come true, or are we just going to sit by and let the market do it, which it will do over a 50-year period, but which may very well be way too late.

We have a challenge, and that is the challenge that we face. Are we enough of mind to break the habits that we have had all these years and recognize that even though we don't trust either candidate for president, the governmental structure is the only structure that we can make things happen that are life or death matters, and this has got to be thought out in the category of a health issue, health of the planet.

That is kind of where I am. I will always be a fan of Amory Lovins.

(Applause)

MR. EBINGER: Thank you, David. Jon?

MR. KOOMEY: I'm going to call out three conceptual changes that Amory's work first encouraged in us. One is energy services tasks. Another is economies of scale, and the third is path dependence. I will talk about each of these in turn.

In the 1970s, it was widely believed that energy and GDP had to grow together, and that electricity had to grow at twice the rate of GDP growth. This was known as the iron-clad link between energy and GDP.

Now we know that people are smart and institutions are innovative and faced with policy changes and price changes, and they will change their behavior, they will modify their structures, they will change property rights, and they will alter how they think about a product, given the right incentives.

It was a radical notion back then to say if you focused on energy services, on tasks that people wanted to perform, you would be able to substantially increase energy productivity.

What we now know is when you think about energy in terms of the tasks we want to perform, there are many options for improving efficiency. In 1974, the American Physical Society published a now famous report that talked about looking at tasks and then thinking about what is called the second-law efficiency of those tasks. What they found at that time was the overall second-law efficiency of the economy was only about five percent. That meant the prospect for improving energy efficiency was much, much greater than if you focused just on the first law.

If you look at a power plant, new gas combined cycle might be 55 or 60 percent, your likelihood of improving that efficiency is limited at 100 percent, right? Even less.

The point is if you think about the tasks and say what do we want to

accomplish and what is the least cost and least energy using and least emitting way to do that, there are many different possibilities, and that allows you to achieve very substantial efficiency improvements.

The second important point is economies of scale. In the utility industry, historically, it has been very important to scale up the unit size of power plants. There was a very rapid improvement in efficiency over time. That drove costs down, that drove use up. It was very powerful. You can call this economies of unit scale.

The industry had it in their mind that this was the only way you could do anything. You could only improve by making bigger and bigger reactors or bigger and bigger coal plants.

One of Amory's key insights was there is another kind of economy of scale, economies of manufacturing scale. If you build a lot of something, you are able to drive down the cost per unit. Typically, this is characterized in terms of what is called the learning rate, so the percentage change in unit costs for a doubling of cumulative production.

What you find in photovoltaics, for example, that learning rate is 20 or 25 percent. Every time you double cumulative production, costs come down 20 or 25 percent. We have shown historically for solar, wind, for cogeneration, for mass produced technologies, that these rates of learning can continue for decades.

That power of economies of manufacturing scale was something implicit in Amory's analysis that I think many people at the time didn't understand, but now we know because of historical developments that was true.

The last is path dependence, the idea that our choices now affect our options later, that the future is not a question of fate, it is a question of choice, and that's another radical shift in how people in those days thought about energy futures. I think there are still many people who still have this idea that the future is something that just happens. Really, the future is what we choose.

Economies of scale and understanding those energy service task level analyses give you more options, allow you to choose a future that's inherently more hopeful, that is lower emitting, lower cost, and that allows us to accomplish our tasks in a way that is simply better for the planet and better for society. (Applause)

MR. EBINGER: Thank you. David?

MR. VICTOR: Thank you very much. It is a year of anniversaries. Brookings turns 100 this year. Amory, your article turns 40. I first learned about this from Bill and Mary Bundy, my aunt and uncle, actually. I learned about it mainly from Mary who told me while Bill's mother, my great grandmother, cooked hamburgers, and somehow didn't kill all of us because she mostly undercooked hamburgers, about the insights in this piece.

I just want to echo something you said about the editorial process. I think it is very easy in this business to be controversial. It's hard to be insightful. It's extremely difficult to be controversial and insightful. It may be even harder to get all that published.

I think it is telling that the most controversial and insightful article about energy policy probably ever published was published in a journal that to that date published almost nothing about energy, very little about energy.

I think it is very hard to work with established journals and swim against the tide, and I want to commend you for constantly swimming against the tide, and getting the tide to turn in your direction in various ways.

I just want to make three comments in my five minutes about the substance of the article and the debate and the technologies that have unfolded since then.

The first comment is when I re-read the article, I see it as really two broad arguments. One argument is an argument about efficiency, and there is a lot of data and insight about how it's cheaper to save energy and to focus on tasks, as Jon

says, and functions.

People care about cold beer and warm burritos, and they don't want warm beer and cold burritos, so they are interested in performing a task in the beer and burrito world, and they don't care how much primary energy is used to do that, and we can improve that radically.

I think clearly that part of the article has really stood the test of time. Other people, Dave Freeman talked earlier, Art Rosenfeld in California, John Holdren, who later became Harvey Brooks' colleague at Harvard, a lot of people were talking about this but you really gave that argument a voice.

Just to put some numbers on it, when you first wrote the draft of this piece, I'd say the economy was about 75 quadrillion BTU, and the typical projections out in the year 2000 were for 120-130 so-called quads, some people were at 200, total primary energy consumption is basically flat at 100 quadrillion BTU. Really impressive. It is because of this focus on efficiency, it is partly because the tasks themselves have changed. We have found ways to generate much greater economic output with smaller primary energy input.

This article helped focus that debate, and I think that has been incredibly important. Most of the power industry is struggling with reality. Electric power demand is flat. If you're in a business that in some states in this country require increasing power sales, that is not a good business necessarily to be in.

When you look across the entire industrialized world, you see the same story, flat primary, flat primary energy consumption, and you are starting to see some telltale signs of the same thing in China, maybe eventually in India. It's a really impressive story.

The second thing I want to talk about is the other part of the article which is kind of soft versus hard. I guess maybe to kind of paraphrase Bill Clinton in a different setting, it depends on what you mean by the word "soft." (Laughter)

I think when you go back and re-read the article, the soft vision was a much more decentralized energy system, probably less dependent upon electricity, much more local production, increasing local production from coal and fluidized bed, combustions and so on, a lot of renewables.

What has happened since then is we have seen a lot of renewables in particular, but I think in some sense we have seen a hard, lean version of the original path, which is more renewables, lower emissions than we would have seen otherwise, but much more interconnection through power grids.

In some sense, we have continued to build out a vast machine, electric power machine, and I think one of the interesting points in the debate right now is whether that is good or bad, whether we are on the cusp of seeing a real decentralization of the electric power system, or maybe the opposite, centralization of the power system.

As Charlie mentioned, I spent some large fraction of the last few years of life working on the Intergovernmental Panel on Climate Change Reports, and one of our main findings was that a world that radically reduces emissions is a world that is probably a lot more electrified, and I think one of the open questions is whether that is a decentralized or centralized electric power system.

I had some insomnia last night, so I watched the keynote address for the Blumberg new energy finance annual update on the state of renewables, it cured the insomnia.

One of the things that is interesting in that annual address is they talk about the world leader, the best renewable energy contracts, and they are all grid connected, large grid connected power systems. In some parts of the world where you see decentralized power is becoming more viable, maybe parts of India and so on, but I think centralization around the grid is actually one of the most interesting things.

The third thing I'll say is what would you do if you wrote the article differently now than before? Part of Amory's answer is exactly right; it is about gas. I

think it is really interesting, the world in the 1970s was one where we were grappling for source scarcity, so we were looking at beyond oil and gas, and what has happened since then is innovation has made source scarcity almost everywhere a non-problem, at least source scarcity in a physical sense. The world is awash in hydrocarbons.

We had in this country at least moved actually to gas, and not moved beyond oil for a variety of reasons, and Amory talked some about that.

I think it is interesting to look back at history and realize in the 1970s one of the big questions was where are we going to build 300-400 nuclear reactors. Clearly, we did not do that in this country. In fact, right now we are in the process of potentially retiring a quarter or fifth of the fleet, and I think there are a lot of people who are rightly concerned about what that does to the balance of the energy system.

If I were writing it today and looking at new questions, I think there are two that really stand out to me. One is climate. Amory mentioned that was discussed in passing. It seems to me climate really changes almost everything. If you need to get to zero emissions, not small reductions in emissions, zero emissions, you have to envision an energy system that is radically different from today's.

I think one of the open questions, as I said earlier, is whether that is a decentralized system or a centralized system.

The last thing that I think is different today is the role of other countries. In the 1970s, Amory could say the United States can make choices about its nuclear fleet and the rest of the world will follow. Today, I think the situation is really very different. Much of the frontier innovation is playing out in the emerging economies.

Frankly, what we do in our nuclear fleet is borderline irrelevant for what the rest of the world does because the frontier for low cost construction of reactors has moved to Korea, in particular, China, perhaps, and has a really different and possibly more difficult world to operate in where there is no hegemon, if you like, no country that can through its own policies. Thank you. (Applause)

MR. EBINGER: I'm going to ask one question, and then in the interest of time, because of the expertise we have on the floor, we want to hear from you all.

The one thing that bothers me about some of the things we have heard today is yes, we have made phenomenal strides in the United States, and we know a number of other advanced countries, particularly in Scandinavia, Japan, and elsewhere, have done so, too.

How do we really embark on the soft energy path in the emerging markets of the world? Amory has shown us very well that forecasts can be dead wrong by an order of magnitude, but yet most of the forecasts still show that if we look out to say 2040, over 90 percent of the growth in primary energy demand is going to be in Asia. In Asia, we have literally hundreds of millions of people that don't even have a light bulb.

Unfortunately, in many of those countries, we have very large low cost to produce coal. India is awash in coal. Ten million people are employed in the coal production movement, whatever, of coal in India.

My concern is when you have societies like this that do not have cost reflective tariffs, so markets are not probably going to get you where you want to go, when you have massive power theft that despite billions of dollars by many, many different donor agencies around the world, have not significantly improved in the last 30 years, and you have billing and collection systems in fast growing economies that often bills don't get to where they are needed or bribery, bills don't get paid, how do you make these utilities functionally solvent, and yet at the same time do what I think David Freeman has said, we have to move away from fossil fuels altogether.

This is where I think we sometimes get too caught up in the tremendous progress we are making in the developed world and not recognize the very real challenges that are really going to deal with climate change. We ought to do something about them.

I don't expect a response unless you want to, and then we will go to the

floor.

MR. LOVINS: Five years ago, we published “Reinventing Fire” (Inaudible) No oil. No coal. No nuclear energy. (Inaudible) No act of Congress. So far, in the first five years, that is on track with what the market is doing because the private sector has held to $5 trillion, which is what ought to be happening.

This got the attention of China’s National Development and Reform Commission, the super-ministry that tells most of the other ministries what to do, so they tasked their top energy analysts at their Energy Research Institute in Beijing to see what this would look like for China, with support from the NDRC sponsored Energy Foundation in China, the U.S. Department of Energy’s Lawrence Murphy National Lab, and Rocky Mountain Institute.

Fifty odd experts worked on this for three years. The results were published two months ago at the G20. The finding was -- again, this is their best energy model, it is not foreigners telling China what to do, that China could be 2050 have a seven-fold bigger economy than in 2010, but using today’s energy. In other words, seven-fold higher energy productivity.

Shift 62 percent of their primary supply off fossil fuel, so that absolute carbon emissions would go down 38 percent while the economy grew seven-fold. That is a 12-fold gain in carbon productivity, $3.5 trillion cheaper than business as usual, and indeed, our customers for this work were the authors of the ’13 five-year plan, which was approved in March, and it strongly influenced and informed that plan, and all of China’s energy strategy, thus helping create the trust and confidence that were important to the U.S.-China climate collaboration at a presidential level that then was important to the Paris agreement.

I feel good about how this is turning out, and now our Virginia office and our many partners there are pivoting to implementation.

To Charlie’s important point, China’s coal burning actually has declined

in each of the past two years, despite roughly six or seven percent a year economic growth. They now have a large surplus of capacity. They are in the process of suspending or cancelling 100 or 200 gigawatts of coal plants that are now clearly pre-stranded assets.

The next thing to work on is their new International Development Agency is in effect the eighth biggest country in driving carbon emissions because it is mostly financing coal plants elsewhere, just like the Bank of Japan is, to try to keep the power plant vendors in business without being properly aligned yet with national climate policy.

In India, there are similar things going on. Piyush Goyal, the energy minister, has done a brilliant job of using competitive bidding to bring down renewable costs in just a year or two to already less than imported coal power and within less than a year, less than domestic coal power.

He has recently been remarking that the coal expansion he thought he would need will not be so necessary because renewables are taking over.

As we have a team now raising Rwandan electrification to 70 percent by the middle of 2018, now 24 percent, I just want to call your attention to what very efficient technologies can do in a decentralized context.

The 1.2 billion people without light, that Charlie rightly referred to, typically $2 a day or less household income, are spending $38 billion a year on kerosene. If they were a country, those kerosene lamps would be the eighth biggest carbon emitter, and their emissions kill at least two million people a year from bad air.

It turns out there are sparks in this long night because in many places now, you can get a package -- this is called the WakaWaka, it's an example, of a very efficient photovoltaic, very efficient LEDs, high temperature lithium batteries, and good chip controls, and this will shine like that very brightly for 10 hours on one-day charge in the sun or two days in the cloud, or if I crank it down four notches, 150 hours per day's charge. It will sit up on a coke bottle, shine down on the table. You can teach your kids

to read, particularly your daughters.

This pays back in weeks to months against kerosene. It is like a perpetual annuity giving you a month's extra income per year. There goes the last bit of Rockefeller's 156-year-old kerosene business.

You get this from an entrepreneurial woman in the village, you finance it through scratch cards or through the smartphone that you recharge here off the U.S. D port.

This sort of thing is spreading like wildfire, and I think it is an interesting play, David, on your important point about centralized and decentralized. A lot of the decentralized solutions are bubbling up in places where there is on grid, and you can't afford a grid. People are leapfrogging, just like cell phones, leapfrog wire line phone companies.

The centralized stuff is also changing economics rather radically because of course, most of the cost in countries like ours is not to generate the electricity, it is to distribute it, you can bypass that by doing it on your roof, and then you can make the grid resilient so major cascading failures become impossible by design, because 98 or 99 percent of power failures originate in the grid.

I think the issues you have raised are the right ones, and in that battle, the decentralized systems are gaining the upper hand.

MR. VICTOR: For any question, something will come out of his pocket and he will give you a demonstration. (Laughter)

MR. EBINGER: Please identify yourself and ask a question.

MS. WASYLIW: I'm Mitzie Wasyliw. I started something 10 years ago called the Energy Conversation funded by the Defense Department to get everybody thinking about energy, and Amory was one of our first speakers.

My observation about this is we have enough talent to deal with the technical issues. My question is getting the public to understand what needs to be done

and demand it. Two-thirds or three-quarters of the U.S. do not know we have three branches of government. We have a serious education problem.

I have a suggestion, that all people who write academic papers have a requirement to write a version for non-technical people with lots of graphs. It's a very complicated story.

My question is how do we make that happen? How do we get universities to require it of academics and students and think tanks?

MR. EBINGER: Thank you. Does anybody want to take that on?

MR. VICTOR: Just very briefly. I'm not sure you want to be completely successful in your suggestion, because there is a lot of academic papers out there. I'm pretty encouraged about this. I agree, public knowledge about how government functions and so on, but it is pretty extraordinary what is happening in the energy business right now.

This in some respects, not to be offensive to my colleagues up here, but this used to be a fairly dull industry where you woke up in the morning and you kind of did the same thing you did yesterday. Now, everything is changing. Attention to this by the younger generation is enormous.

I'm actually very encouraged. I agree with you about the academic world needs to be more articulate, but there is a real step change that has happened over the last decade or so.

MR. FREEMAN: I would just add this comment. It's up to the president of the United States, and he's failed.

MR. BRADFORD: I actually wonder to what extent major changes in other sectors have ever depended on having a huge majority of the public deeply convergent with the policy debates as they go on.

When Amory's article was published, there was another large monolithic utility, the Bell System. Everybody had either a rotary or push button hard wired phone.

The intelligence in the network was all somewhere between Lily Tomlin and the switches. (Laughter)

Without the public being deeply involved in what then transpired in the 1980s and 1990s, we have gone from that system to one in which the intelligence is here. It's decentralized. It's migrated out to the customers. The old switches that we used to be involved in on rate increases as to how to support them are largely irrelevant now, not completely, but largely.

The public was responding to the products and services that were available and the prices, and yes, they had some awareness and feelings about the changes, the elimination of the Bell System, but they weren't reading the academic articles, even the ones that were in plain English for the most part.

MR. LOVINS: Now this thing (holding up cell phone) has more intelligence, more computing power than the Strategic Air Command had the year I got out of high school.

MR. EBINGER: We are going to take three questions at a time, and then we will get the panelists to respond.

MR. KATZ: Hi, Andy Katz. I work for Eversource Energy, we are one of these utilities on a death spiral, I guess. I think I still have a job.

I convinced our company to file an Amicus Brief in support of FERC in the EPSA v. FERC decision for jurisdiction over price response. We won that. I was inspired by Amory as an early attorney at the FERC.

My question is talking about smelling the cheese. What we are finding is the standard market design rules and the organized market that we deal in up in New England has a lot of barriers to the transition to the kinds of things that are desirable, the path we want to be on.

I say specifically treat all electrons the same regardless of how they are produced, the ISOs, RTOs are neutral with regard to that. There is a lot of barriers

between -- it is really a federalism question, I think.

So, I throw it out. What kinds of barriers or do you see barriers to achieving these outcomes that we want through federalism and the kind of interaction between state and Federal policies?

MR. EBINGER: We have another question here.

MR. ALAHDAD: My name is Ziad Alahdad, the former director of operations at the World Bank. Excellent presentation and panel, as expected. My question regards shale gas. You mentioned this as a transition source. How transition is this actually?

The reason I ask this is we have been having some very -- there was a lot of enthusiasm in the earlier years that this was going to fuel a lot of our more benign environmental oriented development. As it went on later, these projections became lower and lower, about how much actually is there.

Of course, there is price elasticity, sensitivity, and so forth. What is the real picture? How much can the U.S. and then by extension the rest of the developing world, if the technology is in fact transferred, how much can they really benefit from this transition source?

You alluded to it, and I think, David, you had mentioned something.

MR. EBINGER: Thank you. Question in the back.

MS. KNUDSON: Hi. Peggy Knudson, ecoAmerica. I worked at Brookings for eight years. EcoAmerica works with people that people trust, like doctors and rabbis, to message exactly the things that you are saying. Climate affects our health, so the gentleman second from the right seemed to insinuate that the government can do this and we don't need a lot of people on board. On the other hand, I will tell you, I'm getting that wrong. I think it needs to be a combination of policy and people understanding. We throw away 40 percent of the food we buy, for example.

I guess my question is how much of this is going to come from above

with the policy, and what kind of a campaign do we need to get Americans on board the way we did with smoking, the way we did with other campaigns, that got this society completely changed and on the right path?

MR. EBINGER: Let's see what the panelists say about any of those.

MR. LOVINS: I think the poll evidence is very strong that there is an overwhelming majority of Americans across the political spectrum who want efficiency of renewables and sooner than later, and the government and the private sector are going to have to give it to them.

When we now have U.S. energy productivity having more than doubled, relentlessly driving down oil and electric demand, 68, I think, percent of our new capacity at the end of last year was renewable. The market is responding very nicely despite all the barriers still in the way.

I don't think this is a problem of lacking grassroots support and Jeffersonian common sense.

On the fracking question, speaking for myself, but I am a member of the National Petroleum Council, I think there have been many bad practices in the industry that give everyone a bad name. We advise our clients to adopt gold standard best practice, which inconveniences their competitors more than themselves, but even if they do that, there are about eight major issues around fracking, some of which may end up being satisfactorily resolved, some may not because eight is a big number.

I wouldn't bet a lot of money on they are all coming out right, and the depletion curves, leakage, the water issues are complex and difficult, methane leakage is particularly worrying across the entire supply chain, and may be a lot bigger than we thought.

I think already we are seeing even operating costs alone for combined cycle gas plants beaten by wind and solar in many places. Then you add to that the price volatility of gas that probably gets worse downstream if you have abundant cheap

wellhead gas, and that volatility, you can deduce from the straddle in the options market is worth enough to roughly double the gas price. It is really not that cheap.

Then the geology is generally a good deal worse in other countries. I'm not very sanguine about where that is going to go.

MR. FREEMAN: If I could just add one sentence. The shale gas is not a transition to anything but hell. (Laughter) The fatal flaw in the Clean Power Program and the great failure of our president and the current administration is not to recognize that methane for a 20-year period is 100 times as bad as carbon; they don't count methane.

If you switch from coal to natural gas, Mother Nature doesn't notice the difference. It's a big lie that it's a transition. It is just as bad. We're not making progress if we switch from coal to natural gas. We need to outlaw both of them for the future if we are serious about listening to the climatologists.

I think the bad guys that don't believe in climate, I can forgive them, they are just dumb. (Laughter) It is the folks that make the eloquent speeches and claim that they believe the climatologists and then engage in hypocrisy and essentially lies about not recognizing that it's not just carbon, that methane is very, very seriously -- if it's only one percent leakage, it is about as bad.

We don't know but I can tell you from experience that some of these gas distribution systems leak five, seven, eight, ten percent. We just need to give people the facts. We are not doing that.

MR. EBINGER: I don't think we have a good answer to the institutional obstacle question.

MR. VICTOR: I have a very different view. There is a commercially infinite quantity of gas in North America, the geography is a little different than the rest of the world. I think it really depends, water issues, leakage issues, and so on, I'm not sure I am with Dave on 10 percent, but I think this is one of the three or four great questions in the energy business right now.

Is it a transition fuel or is it a cul-de-sac, and if I were a gas company and in it for the long haul, I would be very focused on what is the vision I am articulating for how this is an actual transition fuel and investing around that.

On the institutional question and the power markets, I think this whole effort to treat electrons differently is going to be a disaster. It is going to make it harder for markets to work. What we really want are for markets to function particularly with demand response.

If there is one thing that I would really focus on is to not do this crazy stuff with treating electrons differently, but to get the demand response sort of picture, because in a world where you have a lot of demand response, is a world you can imagine integrating a huge amount of renewables and less storage requirements, and in a world where you don't have demand responses, it is a hard energy, a really hard energy path world.

I am not persuaded right now that most of the regulators are actually going down that road, and it really concerns me.

MR. KOOMEY: I just want to rephrase something David Freeman said, because I think it is true but it needs perhaps to be a little softer. I think there is a misconception among many people in the energy world that we can burn it all, and we can't. If you want to stay within climate constraints, you can't burn it all.

If you have an all of the above energy strategy that includes supporting fossil fuels, either domestically or internationally with loans for coal plants or anything else, you are not facing the real problem. The real problem is that huge fractions of current proven reserves will have to stay in the ground if we are to meet climate constraints.

So, all of the above is incoherent, it makes no sense. People are reluctant to believe this, but the literature is very clear. I think this is the essence of what David was saying, you can't keep building more infrastructure that is going to burn fossil

fuels, emit carbon, emit natural gas for leakage, because we don't have the climate. We don't have enough climate for that.

I think that really is what the policymakers have failed to face. You can make these incremental changes but really by mid-century, we have to get off fossil fuels.

MR. EBINGER: We will try to get another five minutes, so let's take another three questions. I am sorry for those of you we may miss.

MR. BLACKWELDER: Brent Blackwelder, Friends of the Earth. It was mentioned the southern part of the U.S. is on the hard path, and we know some of the utilities are really fighting to kill any advances in renewables. What would the panel suggest for an approach to change the hard energy path?

MR. EBINGER: We have a question all the way in the back.

MR. SWAGEE: Dean Swagee, I'm an Indian lawyer, work for tribal governments. I first met Amory in 1983 at Lawrence Wilson College. My question is considering that we have 567 federally recognized tribes in the U.S., which have sovereign powers roughly comparable to states, have any of you given any thought to how tribal governments can play roles in bringing about the transition that needs to happen?

The follow up question is if anyone would like to help me with my book project on the subject? (Laughter)

MR. HARVEY: Bert Harvey, Resources for the Future. An important source of efficiency has been the advent of marginal cost pricing in wholesale power markets, and now we are talking about the emergence of zero marginal cost technologies. So, to allow further progress on the soft path going to happen through changes in wholesale markets or should we be looking to distribution system changes and the way they are organized?

MR. EBINGER: Thank you. Okay. Simple set of questions.

MR. LOVINS: The tribal question has had some very creative attention

from Bob Guff in Boulder, and there was a time in the previous Bush administration when he was preparing an open letter to the president saying Dear Mr. President: From watching wind talkers, you know that we Native Americans have stepped up when our nation needed us, but we are doing it again, we're offering to meet the U.S. obligation at no cost to the United States by building X gigawatts of wind power in the high plains financed by European carbon credits, and the transmission will be financed by our sister tribes that have $11 billion a year in casino income, but if they put it in the stock market, they don't know where it is, and it is not really invested according to their values, and all we ask, Mr. President, is you get out of our way and let us do it, what do you say?

Well, it turns out a lot of that is happening, and tribes do have some very interesting opportunities because they are not sovereign enough to sign a Kyoto or Paris agreement, but they are sovereign enough not to be part of the United States that backed away from Kyoto. It is a very interesting zone.

Of course, many impoverished people are off the grid, so there are efficiency and renewable projects coming to Indian country that are a great example to all of us and building a lot of important capabilities. There are very, very talented people in those communities.

I understand, for example, one of the most impoverished reservations in the country has the highest concentration of any community of certified aircraft mechanics trained in the Air Force. A lot of interesting pockets of expertise which could contribute for us all.

MR. VICTOR: There is a big effort in some states, New York, California, a few others, to try to do more on the distribution side. I think we have made some progress. I'm actually very skeptical that we are going to make most of the progress there, and I wouldn't give up on the wholesale markets.

It seems to me right now we have been able to ignore the effect of zero marginal cost to energy sources because they have been small enough to not be material

in those markets. That has not changed a lot.

Amory's arch enemies in the nuclear industry have been doing this interesting stuff with Nuclear Promise, and a variety of other efforts.

We have to find a way to get the ancillary services markets functioning properly. Otherwise, we will find ourselves with a real nightmare on our hands in terms of reliability, and I think what is kind of ultimately holding the whole system together right now is utilities and other operators that have reliability obligations are kind of keeping the grid functioning, but if you continue at scale with more zero marginal cost power sources, then I think that is not so obvious.

MR. LOVINS: I should just add there are four European countries with modest or no hydro that are getting about half their electricity from renewables, and indeed, the ultra-reliable former East German utility was 49 percent powered last year by variable renewables, wind and photovoltaics. Their last high voltage power failure was 35 years ago.

These operators without adding bulk storage have learned to run their grids the way a conductor leads a symphony orchestra, no instrument plays all the time, but the ensemble continuously creates beautiful music.

If you had asked them 15 years ago, they would have said that is impossible, but as they gained comfort and experience with it, they realize they can do it and they can go much higher than 50 percent, and they are saying so.

MR. BRADFORD: Staying within the framework of Amory's article, you all want ideas, not words. Words are just kilowatt hours, the carriers. There aren't a lot of good ideas about how to change the southern utility culture out there.

I have testified in a number of proceedings in Florida, Georgia, Carolinas, with the same lack of success. Obviously, there are different interpretations one could put on that, but the one I prefer is it is a very difficult culture. It is a hard path culture, a red state culture.

Dave's answer obviously would work, pass laws, and the country complies, but those are the states that will fight you and obstruct the passage of the laws as well.

I think in the end, what will make some difference is as the technologies evolve and the costs come down elsewhere, there are plenty of astute customers, industrial, commercial, residential customers in that region, who will ultimately insist on the adoption of these technologies.

I just don't see any political steam roller that is going to change --

MR. FREEMAN: I do have a softer answer. (Laughter)

MR. BRADFORD: You're from that region.

MR. FREEMAN: The federal government owns a big utility; it is called the Tennessee Valley Authority. The next president could ask/require that utility to do something in the national interest, since it is a federally owned utility, and show the way to a big utility going down to zero greenhouse gases over the next 30 years.

Assuming one particular person becomes president, she can order the Tennessee Valley Authority (Laughter) with her green yardstick, and I think it would have a powerful impact on the rest of the South.

MR. LOVINS: And the greening of the coop movement is important, too, even say in Florida. I would just point out in the Sunshine State where a lot of solar power is effectively outlawed, wind power is now cost effective.

It is in every one of the United States now because higher towers and higher solidity rotors produce low wind speed and have made wind power cost effective, not just in the high plains but everywhere, including the entire Southeast, which was thought to be a wind desert.

The whole U.S. wind resource has increased by two-thirds in the last seven years. That is continuing. It therefore becomes harder and harder for utilities to block that kind of competition with their legacy assets. The smart ones are already

starting to switch over.

We are seeing some of that with Duke in North Carolina, and customers can also install the stuff themselves. They are just prohibited in states like North Carolina and Georgia from third party finance where there is the bizarre interpretation that if I finance solar on your roof, I'm not selling you money, I'm selling you electricity, so I'm a utility.

Sooner or later, the courts or the legislature will fix that. Watch the North Carolina gubernatorial elections.

MR. EBINGER: Jon, you have the last word.

MR. KOOMEY: Just a very quick point on the South. Many of the rural electric coops are tied to coal debt. Their coal plants will keep operating until their debt is retired. One of my former students, Holmes Hummel, is working on a way to do a kind of debt forgiveness, debt something, that would free them up to make this more soft-path decision.

It's not just culture. I think it is also they are tied to these assets. If we could figure out a way to free them from those fossil fuel assets, then change can happen faster.

MR. LOVINS: In other words, there is an issue not just there but all over the country, all over the world, of stranded assets and trapped equity that needs a way to relocate into the good new stuff.

The capital markets are already decapitalizing the oil and electricity industries. If you are in or in it for the toaster, they sniff that out very quickly, and they don't wait for the toast to get done. They shift to the new thing.

I think the capital markets could be our friend here.

MR. EBINGER: I want to thank Amory and all of our panelists. (Applause) It is good to know that we have come a long way from the famous dictum that real men don't save energy, they build dams and nuclear power. (Laughter)

Thank you all very much. (Applause)

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Expires: November 30, 2016