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ADVANCED ENERGY TECHNOLOGY AND CLIMATE CHANGE POLICY IMPLICATIONS

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A number of significant changes are affecting electricity generation today. This talk is about understanding those changes in greater detail, to allow us to put potential business decisions into perspective. The intent of this talk is not to go into any great detail, but rather to highlight a few of the key factors that will have a profound impact on the future.

After a short introduction to cite some of the sources of this information, I will frame the overall context of the greenhouse gas emissions issue, then briefly sketch the available technology options and review the status of some of those options. Finally, I will talk about the public policy implications of addressing the challenges, from both a technology and an economic policy perspective.

I. INTRODUCTION

Recently, I participated in several studies that give insights about the challenges of reducing GHG emissions, as well as the status of the technology. Taking part in these studies and committees gave me access to a great deal of additional information.

In the context of the Kyoto discussions, you hear mostly about emissions and emissions reductions. I would like to remind you that the ultimate objective of the intergovernmental panel on climate change, the IPCC, is to *stabilize* concentrations of GHGs in the atmosphere. To do that, we will need significant reductions (from today's emissions) over the course of the next couple of centuries. The desired end result is a stable, non-increasing concentration profile.

For some insight into the nature of this challenge, reflect on this fact: If we were to cap our carbon emissions into the atmosphere at the present level of 7 gigatons per year from fossil fuel combustion and other manmade or anthropogenic sources, that would lead to a CO_2 concentration level almost twice that of the industrial concentration (of the order of 300 ppm) by the end of the 21st century.

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The challenges, as you can see, are quite dramatic. At first glance, it is natural to be concerned about the apparent dearth of suitable alternatives. But let us explore that. I have come to the conclusion that, with proper policies and technology in play, the situation may not be as grim as may have been suggested.

Net carbon emissions can be thought of in terms of an equation that multiplies the gross domestic product (GDP) by energy intensity and carbon intensity, then subtracts the sequestration term, which we will talk about later. First, recognize that GDP is world gross domestic product or its equivalent. In that context, we can say that the world population will continue to grow, as will the overall global standard of living, which in the future will really be driven by developing countries. If, then, that is a term that will increase, clearly we will need for something else to decrease if we are to reduce our net carbon emissions. One of those terms is the *energy intensity*, the amount of energy used for units of productivity. Likewise the carbon intensity or the carbon per unit of the energy must also decrease.

One thing is clear, the energy intensity of most economies is actually decreasing. Because the developing countries are presently at a depressed level, energy intensity will initially increase as their economies grow. Due to modern technology, our expectations are that they will not achieve the same level of energy intensity that developed countries have historically attained. Additionally, the change from manufacturing and heavily industrial economies to service economies is evident internationally, much like what we are seeing in the United States.

Similarly, in the carbon intensity arena, we see decreases in the emissions per unit of energy used as time goes on. Clearly developing and emerging nations like India and China still are fairly high on the carbon intensity curve. That is primarily because of the traditional use of biomass for heating and cooking at the individual household level. It is not necessarily a reflection of plant-level electricity production.

It is interesting to note that although people have different views of what the future energy source mix might look like, they can agree on a couple of things. One is that the demand for energy will continue to rise at a very rapid rate. The other is that (projecting out a couple of decades to the year 2020), it is not clear just what kind of energy sources will be available to meet the demand.

People like to quote two studies in particular. Although they are not exactly comparable, because the first is a world energy projection and the second is a U.S. electricity generation projection, I will describe both. The first is by Shell Oil in its sustained growth scenario of a couple of years back, projecting that the future source of energy will be dominated by renewables in the course of the next several decades. The second is a projection by the Electric Power Research Institute (EPRI) in a recent study. The study looks specifically at electricity generation. Although renewables play a part, the expectation is that after gas takes on a fairly significant role in the next decade or two, coal technology will re-emerge. This study anticipates that coal will have had the carbon removed or substantially reduced, which makes it a *decarbonized* coal source. And again, it is a technology-driven solution. Regardless of which one of these you believe, it is interesting to note that there is a common expectation that some significant as yet known source will meet the future demand.

United States energy flows, starting with fuel sources through our infrastructure to end use sectors, are exceedingly complex. Useful energy used and rejected energy, two outflows of this system, are disparate in size. The useful energy here is defined as work that actually provides useful output. The rejected energy is essentially the wasted energy or the inefficiency in our system. We are actually able to capture only roughly 40 percent of the overall energy that flows through our system as useful energy, with about 55 percent of the energy total being rejected energy.

Herein, I think, lies the opportunity for market restructuring driven by electric utility deregulation to actually produce the benefits that people have predicted. In particular, by deregulating or restructuring, you can capture the greater innovation that competitive market forces provide. Because of these inefficiencies in the system, that particular concept has significant merit.

The electricity fraction of our primary energy supply would increase from roughly 38 percent to 70 percent. In other words, we would have an electrified transportation sector. Electricity would be the energy carrier of choice, and the electricity production process would carry the burden of reducing GHG emissions. Likewise, if that were the case, electricity conversion efficiency would have to improve from roughly 32 percent (where it is now), to 50 percent or perhaps more. And if this scenario were to play out, I think it would provide implications on the kind of R&D necessary and on how you approach the evolution of our infrastructure, both for electricity production and transportation.

II. TECHNOLOGICAL ADVANCEMENTS

This leads us to a discussion of how we are going to meet these challenges. They will, I believe, be met largely by continued and significant progress in technology development. Technology developments are on all sides of this particular equation. In particular, demand side and efficiency improvements will reduce the amount of energy intensity, which we have talked about. On the supply side, we will look at new energy sources and more efficient energy production. In that case, we are talking mostly about improving the carbon intensity to reduce that particular quantity.

Finally, carbon *sequestration* or *stabilization* represents a fairly recent development in this area. Here we are specifically talking about separating the carbon component from the fuel mix, either at the beginning or at the end of the cycle, and then somehow stabilizing the carbon so that it does not find its way into the atmosphere. So we have potential contributors on the demand side, on the supply side, and in the area of carbon sequestration. I will not spend a lot of time on the first of these, but I do want to say a little about the technology status on the supply side, as well as a few words about sequestration.

First, renewable energy engenders lots of discussion. Recognize that many times, renewable energy technologies are non-dispatchable or intermittent because of the nature of the fuel source. In these cases, we must also think about either using renewable energy as a complementary energy source or in conjunction with storage and other conversion devices to help make the technology viable in the marketplace. I will not talk a lot about storage and conversion devices, other than a brief discussion of fuel cells, since those get a lot of attention these days. As I have mentioned, there is an ongoing effort in carbon sequestration, as well as international debate about what the role that carbon sinks might play. And I would probably be remiss if I did not say at least a word or two about nuclear technologies.

One thing that is clearly a major driver, both in the United States and abroad, is the restructuring of electric utilities. In the United States, in some circles it goes by the name of deregulation. Some might argue that it is more of a restructuring than it is a deregulation. But in any event, the generation component is being disaggregated from the transmission, the distribution, and the energy services. There is a great deal of associated business activity, including that taking place including disaggregation and re-aggregation of existing players and the entry of a number of new players in the marketplace. We are seeing alignment in the generation and/or the services part of the business.

There is not much investment into transmission and distribution, primarily because great uncertainties and business risks that are associated with such investments. Because there has been a relative lull in the construction of new generation capacity in the past decade, and because of the tremendous growth in the domestic economy, the nation's demand for electricity has outstripped its generation capacity. As a result, there is a flurry toward new capacity, but until that comes on-line, we will see a lot more distributed generation, both in combined heat and power and in on-site power for very specific industry applications.

It is also important to point out that there is a great deal of interest in gas because of its relatively low cost and its efficiency in performance. In addition, it is relatively clean, compared to coal technology, for example. But, even though there is a move to put gas into our electricity generating mix (where more than 90 percent of the new capacity is expected to be gas over the next few years), there are still some issues with gas. Specifically, we have observed the volatility in the cost and price. In addition, it is not yet clear that gas will be able to meet the ultimate long-term demand. So this is where we are today, and a lot of interesting dynamics lie before us into the future.

As I mentioned when I talked about distributed generation, interest in on-site generation is growing, specifically the type that can meet needs such as premium power and combined heat and power. It has been stated, and perhaps observed in the policy arena, that the reliability of power could be compromised by a restructuring. In fact, we have recently seen evidence of this in California and elsewhere. Furthermore, we are seeing an emerging market for reliable and high-quality premium power. In this market, the value of revenue lost when the power fails in orders of magnitudes is greater than the cost of ensuring the power does not fail. Restructuring is also accompanied by a greater interest in combined heat and power and efficient use of electricity, which has a collateral benefit of reducing carbon emissions. Finally, we see a growing trend for the outsourcing of bundled utilities in industrial and manufacturing operations. This allows businesses to use core resources and investment dollars more efficiently to run their core businesses.

III. STATUS OF RENEWABLE ENERGY TECHNOLOGIES

Let me now turn to the status of renewable energy technologies, which, by many accounts, hold the key to solving our environmental performance concerns. However, I want to be realistic about what these technologies can and perhaps cannot provide in terms of meeting future energy needs.

It has been projected that approximately 200 GW of new generating capacity will be deployed in the United States in the next decade or so. If we look at the generating capacity currently supplied by renewable energy, the overall capacity is about 22 GW, 13 GW of which is generated by non-hydro renewables (which, by the way, many people believe is not environmentally friendly.)

We can see that renewables represent a small fraction of the new generating capacity that will be needed over the next ten years or so. I think that is significant to point out. Where renewables are a very important part of the future mix, and I am certainly a strong advocate of continuing to develop and deploy them, they are certainly not the end-all answer in the short term. Furthermore, it is debatable how much of our future domestic need or the projected international demand these technologies can fill. That answer will depend in large part on future technology development, which is a function of R&D investment, and this is difficult to predict.

Let me now briefly cover each of the renewable energy technologies that were assessed in the National Research Council report (and that continue to be evaluated).

First, let me point out that our committee was quick to acknowledge and applaud the DOE's effort in dramatically reducing the cost of all forms of renewable energy technologies over the past two decades. (I will also point out the largest criticism in our report was the lack of program in penetration of these technologies into the marketplace relative to DOE's own deployment goals. Perhaps these goals were too enthusiastic, but it is also true that the marketplace today is quite different from 20 years ago.)

Wind Energy

The first of these is wind energy. Wind is a popular choice today, primarily because of its maturity in the marketplace. Currently, more than 10 GW of capacity is installed worldwide. Of that, 2.5 MW is installed in the United States in a very rapidly growing marketplace. Where there is an adequate wind source, wind energy is today among the lowest cost renewable energy sources, ranging in life-cycle cost from 4 to 7 cents per kW hour. A number of significant projects are under way, and I am pleased to say that CH2M HILL is involved in some of the larger projects in the country. We are involved in permitting and siting, as well as in designing the system infrastructure.

An example of this is the Vansycle Wind Project, FPL Energy, Oregon. CH2M HILL carried out the environmental analysis and permitting to support development of the Vansycle wind project, a 24.9-MW wind generation facility with 38 Vestas turbines located on Vansycle Ridge, north of Pendleton, Oregon. FPL Energy is a subsidiary of Florida Power and Light Company. The Vansycle project will be the first commercial wind generation project constructed and operated in Oregon; Enron/Portland General Corporation will purchase its output. A planned expansion of the Vansycle Wind Project will result in more than 250 MW of generating capacity at that site in the near future.

Biomass Power

Another popular renewable energy is biomass power, with more than 7 GW of installed capacity operating in the United States today. An area of primary interest is biomass co-firing with coal, which is typically used to blend lower grade coal with biomass to meet EPA emissions requirements and to reduce the costs generating power with coal. Additionally, there is great interest in making biomass a closed-cycle power technology. That means growing an energy crop that sequesters carbon while it is in the growth mode, then when that carbon is combusted and released back into the atmosphere, the end result is a net zero emissions carbon cycle. Again, a number of biomass power projects are in place. CH2M HILL has been involved in the gasification of wood chips in the McNeil generating station in Vermont.

A mention of biomass as a transportation fuel is probably worthwhile, even though we are concentrating here on generating electricity. Biomass utilization presents the opportunity to actually generate an energy carrier in the form of a liquid such as ethanol or to use biomass liquids as oxygenates within the present gasoline infrastructure, or both. Although costs for generating ethanol with biomass technology are still relatively high, it is important to mention that most of the fuel costs that we pay when we fill up our automobiles at the pump are actually taxes. Prices, therefore, really reflect more of a policy driver than a technology driver.

So can we make the cost of producing biomass-derived ethanol competitive with that of fossil fuel in the next decade or so? The bigger and perhaps broader question is associated with the public policy issues and drivers that will really set the price of the transportation fuels that we use domestically and abroad.

Geothermal Energy

Geothermal energy is another important renewable source. There is more than 6 GW of geothermal energy capacity worldwide, and roughly half that (2.8 GW) is in the United States. Wherever there is a good geothermal source, it is typically quite cost effective to tap that source and use it to generate electricity. Interest is increasing in the so-called ground-coupled geothermal heat pumps, where the thermal sink provided by the earth itself can be tapped. In the United States alone, a capacity of probably close to 4 GW for heat pumps could also be developed, presenting another area ripe with opportunity.

CH2M HILL has been heavily involved in geothermal energy in California, where (after some technical difficulties with the aquifer reservoir being inadvertently depleted), we were actually able to divert treated wastewater into the aquifer and re-inject into that particular well, resulting in the world's first wastewater-to-energy project.

Photovoltaics

Because of its simplicity and elegance, photovoltaics is considered one of the "glamorous" renewable energy technologies. Its semiconductor technology converts solar energy directly to electricity. A great deal of progress has been made over the last 20 years in photovoltaics, and costs are already competitive in some remote power markets. Where there is a good solar resource, it was already been shown that photovoltaic systems achieve a better life cycle cost than that of diesel generator sets. This implies that there is already a growing niche market opportunity for photovoltaics. There are also great expectations that the technology will eventually compete in the bulk power market, starting first, perhaps, in the distributed generation market.

Around the world, there is about .1 GW of installed capacity, and the overall global production capacity today is on the order of 200 MW a year. Although this must increase dramatically before photovoltaics really begin to make a significant contribution to the world's energy needs, we are confident that will happen over time. We continue to see many large demonstration projects, and although these are heavily subsidized, these installations will encourage the marketplace to help drive down the manufacturing costs. In my opinion, this technology will continue to improve progress, and it will play a fairly large role in the mix of the future. Again, CH2M HILL has helped manufacturers in the U.S. and abroad to improve their manufacturing processes, driving costs down and productivity and efficiencies up.

Solar Thermal

Solar thermal is another technology that has great potential. In the case of simple space heating, and what I would call passive solar (or even active solar hot water) heating, it already makes good economic sense to incorporate these features into a building design wherever possible.

A more sophisticated type of solar thermal is solar thermal electric systems, where concentrating systems generate high-temperature working fluids that can be used in thermodynamic cycles to produce electricity. These are still a few years from commercialization. Although several demonstration plants are in operation or plan to be in operation in the next few years, the technology is still not competitive in the commercial marketplace and is less attractive, due to its high initial capital costs.

According to the President's Committee of Advisers on Science & Technology (PCAST) report, certainly in the case of photovoltaics and wind, it suggests that these technologies are following a traditional relationship in the form of a so-called 20 percent curve, with respect to their cost and cumulative installed capacity. This means that the costs are coming down 20 percent for every doubling of the installed capacity, which is very typical of the kind of curves we have seen for other technologies, such as gas turbines, for instance.

As the technology matures, similar to the gas turbines, those learning curves will perhaps begin to flatten out a bit. The point to consider here is that these technologies follow a natural progression. Based on this data, it is unlikely that we will see quantum leaps in progress toward reducing costs unless some serious market intervention takes place. The PCAST report suggested such a market intervention, in the form of dramatic buy-down projects or programs.

IV. HYDROGEN CYCLE RESEARCH

If we were to design our energy infrastructure today, we would more than likely base it on a hydrogen cycle. This would allow us to split water, to generate hydrogen as a fuel carrier, and then through the re-combination with oxygen we could extract energy, both heat and electricity (with only water as a by-product). This makes it clean and a very appealing cycle.

Our energy infrastructure, however, is based on a carbon cycle because we rely on fossil fuels. So perhaps it makes sense, at some point, to begin a transition from a carbon cycle to a hydrogen cycle. For this reason, hydrogen research is vitally important. The existing infrastructure could be used if we reformed or otherwise processed fossil fuel streams into hydrogen streams. In this way, we could begin to build a hydrogen carrier infrastructure that could lay a path to ultimate conversion to a hydrogen cycle infrastructure.

Hydrogen research continues along two paths: (1) converting fossil fuels into hydrogen carriers and (2) doing the science that will allow us to generate hydrogen from non-fossil-fuel sources.

Where do fuel cells come in? Fuel cells are electrochemical devices and do, in fact, operate on hydrogen. If the hydrogen is derived from non-fossil sources, the result is a very clean conversion technology from a hydrogen stream to electricity through the fuel cell. However, to date, that route is still quite costly, mostly because it is expensive to generate and use hydrogen as an energy carrier. So we convert fossil fuels into hydrogen-rich streams to be used with the various kinds of fuel cells.

Although fuel cells are progressing, they are still not entirely commercial; the only current commercial product is the phosphoric acid fuel cell. Additionally, there are some new demonstration plants for molten carbon technology and it will be the next technology to come on line commercially very soon.

Unless you are converting natural gas into a hydrogen-rich stream, you really are not making a significant dent in greenhouse gas emissions. These emissions reductions result primarily from the efficiency improvements or efficiency enhancements that fuel cells represent over diesel gensets or other methods of burning fossil fuels.

V. CARBON SEQUESTRATION AND NUCLEAR POWER

I would like to say a little about carbon sequestration and sinks, an area that is receiving a great deal of attention from a number of different perspectives. There is an attempt to reduce the amount of fugitive methane emissions from mining operations, as well as a variety of other sources. There is also interest in capturing more carbon dioxide, in particular, through agricultural practices and forestation. And increasingly there is interest in capturing carbon out of traditional fossil fuel sources and finding a way to stabilize it.

The Department of Energy, through its fossil programs and its office of science, has named lead centers of excellence for carbon sequestration on land, in air, and on water. In those cases, science and technology development are progressing toward a better understanding of the available options for sequestering and stabilizing carbon. This continues to be a topic of great public policy on the international as well as domestic arena.

I would be remiss if we did not say a few words about nuclear power. Specifically, I think it is important to point out that nuclear power today accounts for about 18 percent of the generating capacity of the electric utility grid. And contrary to popular belief, the cost of production for nuclear power in 90 percent of the power plants that are operating is very comparable with coal and gas. Furthermore, the capacity load factor is greater than 75 percent, and projected to be as much as 85 percent within one decade. So, nuclear power offers a significant contribution, both to economical and low carbon emission power.

The major issues that are, of course, continuing to be problematic for the industry really have mostly to do with public opinion. Something on the order of 8 percent of the plants representing that capacity are scheduled to have their licenses expire within 10 years. At present, there is not a lot of public appetite for re-licensing those plants and this may, in fact, exacerbate our capacity issue as time goes on. One main issue is what to do with spent fuels, and the process for developing a permanent storage repository is both slow and heavily embroiled in political debate. It is our opinion that a prudent approach is to begin to develop next generation nuclear power that can be safe, cost effective, and that can minimize the environmental impact by having a viable fuel disposition strategy.

VI. POLICY IMPLICATIONS

Now, let me turn to the public policy implications of this discussion. Let us first assert that the global, long-term environmental challenge that climate change presents can not be solved with techniques developed to address the narrow scope and the short-term environmental hazards, which were more local and regional in nature, of the past. A hallmark of the new generation of environmental issues is the opportunity to integrate environmental, energy, and economic factors as distinctly interdependent components. This will place a premium on crafting new solutions that move beyond traditional environmental management options based on *command and control* regulations.

These new solutions will recognize eco-efficiency as a critical element; they will encourage pollution prevention in design and engineering; they will emphasize energy and material use efficiency; they will rely on superior and systematic approaches to information management; and finally, these new solutions will involve control and mitigation strategies that create value from superior environmental performance. Fundamentally, energy and environmental sustainability and performance must be permanently linked to superior business performance.

It is imperative for coupling environmental and energy policies to encourage the development and deployment of advanced energy technologies. Only through this type of synchronization can we expect to evolve a new global energy economy that minimizes negative impacts on the world environment while solidly supporting the world economy.

A couple of years ago, the eleven Department of Energy national laboratories developed a report on technology opportunities for reducing U.S. greenhouse gas emissions. In that report, they proposed a strategy architecture. Specifically, the strategy suggests that it is possible to reduce greenhouse gas emissions and to continue to see robust and significant economic growth. But doing so will require a blend of public policy measures that would encourage technology development and deployment, as well as policy mechanisms that could encourage the acceleration of technology into the marketplace. Techniques that are market driven must be developed. In the marketplace, we must harness efficient mechanisms that can solve the challenge of reducing greenhouse gas emissions while continuing to grow the economy.

We still have a long way to go toward using technologies that can compete in the marketplace and also have the minimal environmental impact that we all desire. In that context, the public policy imperative is really to aggressively support R&D efforts, not just in deployment, but also in the basic science that is required for developing some of these advanced approaches. Likewise, the policy instruments must be flexible and market driven. But I also think it is important to point out that they must be global and cooperative across international boundaries. Obviously, embracing this challenge as a *global* challenge will require significant new efforts.

VII. CONCLUSION

In conclusion, we sum up by suggesting that the energy economy of the future is a complex mix of social, economic, and environmental drivers, all of which will need to be met simultaneously to lead us to the desired end-state. Because technology will play a pivotal role in supplying solutions to these challenges, we must gain cooperation both in our public policy and in the developing and deploying of advanced clean technologies.