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From Prognostication to Prudence:

The Importance of Failure in Renewable Energy Planning

Preamble

My thanks to EASAC and the sponsors of this workshop for inviting me, a lowly non-scientist, to speak to such an august group. I was for many years an academic, so I know how unusual it is for a non-scientist to have a voice in such a forum. Many scientists have little or no training in how to address issues of policy and thus I imagine that what I have to say might provide some balance.

I have for years been involved either as an equity stakeholder or managing member of first and second stage companies and am currently involved with two companies. One has a fundamental new heat engine and the other has a technology that produces hydrogen on demand. May I also say that I am an unabashed supporter of scientific work as an ethical calling.

Introduction

Attempting to predict the future and preparing for the future are two very different things. The future of renewables must proceed without confusing predicting and preparing. If we take the need for renewables seriously, we must consider more than pure scientific research or government subsidies. We must understand the entire path from R & D to economically viable systemic implementation if aspirations are to turn into something more concrete.

Unlike NASA's race to the moon or the Manhattan Project, where money was no object and commercial outcomes came after the fact, the push for renewable energy must be accompanied by policy that enables the fruits of R & D to succeed in the market. Only commercial success will provide the motive force to drive systemic global change in a manageable timeframe. And only the continuous cycle of observation, hypothesis, experiment, and results in the market can help separate the successes from the failures.

I present here a set of cautionary remarks related to the differences between prognostication and prudence and their relationship to the commercial outcome. In addition, I suggest that the value of learning from commercial failures and basic failure analysis is missing in the arena of renewable energy and storage technology. I further argue that without governmental policy that encourages this type of failure analysis, better policy decisions cannot be made to aid in the creation, development and dissemination of these technologies on a global scale. I subsequently discuss a number of hurdles in the path from R & D to systemic adoption and use some examples from the "green" arena to demonstrate some of the issues that have policy design implications. Finally I provide recommendations for decision makers about how to make failure assessment a vital link in the chain to better outcomes.

Prognostication and Prudence

The intersection between science and policy is an uneasy one. Scientists rightly complain that most policy advisors and decision makers are ignorant about the scientific and technological universe, while policymakers complain about the inability of scientists to provide clear answers or understand the realities of business, politics, and government. Large, complex systems are difficult enough to model, but they can quickly become fruitless exercises when key parameters lack clarity. When assumptions such as life expectancy, death rates, discount rates, rebound effects, and geo-political perils must be accounted for, predicting the future with any sense of confidence becomes a hollow pursuit at best and a cynical exercise at worst.

Of course this has not stopped scientists and policymakers from acting as clairvoyants. The author Daniel Gardner has coined the term "future babble" for this activity, based on long-standing work by Philip Tetlock showing that forecasting by highly specialized "experts" is of dubious value. For some, the future is a dystopia full of gloom and doom, while for others it is a new Golden Age where technology solves all our problems. Each of these narratives has been used and abused, twisted and turned until almost any combination of hope and fear can be asserted. The science at play can be reworked to any purpose and the costs, benefits, and risks of the technology can be bent to the will of the storyteller.

Prognostication (from the ancient Greek, *prognostikos*, meaning to "fore-know") creates stories for consumption by an audience. It often clothes itself in the rhetoric of belief and certitude, projecting a direct path to the desired future. Gardner gives us a nice analogy: "Predicting the future by projecting the present is like driving with no hands. It works while you are on a long stretch of straight road, but even a gentle curve is trouble, and a sharp turn always ends in a flaming wreck." (<u>Future Babble</u>, 95.)

Prognosticators fear skepticism and ignores risks. The certitude of their beliefs is all that is necessary to get from the idea to the new reality.■ They often become experts in magical thinking, requiring the world to be different than it is and people to behave differently than they ever have. The history of prediction regarding renewable energy solutions is littered with such prognostications. Electric cars will sell in the millions, the new hydrogen economy is coming, solar and wind can work without subsidies or redundant back-up—are all common stories from the last thirty years. All of these solutions are fully grounded in science and technology. Why, then, have they not succeeded at a commercially viable scale? Because they didn't attend to the full context—the economics, business, markets, governmental and non-governmental constraints that are ever-present in the commercialization of innovative technology. Science is a necessary but not sufficient condition. Meeting the challenges of that full context requires prudence, not prognostication.

Prudence is the skill of making decisions under conditions of uncertainty across time. It has two distinct attributes. First, prudence recognizes what economists call “bounded rationality”: accounting for the limits of human reasoning, information, and time in any choices between competing options. Second, as a result of this recognition, prudence welcomes skepticism regarding the established status quo as well as the certitude of one’s own beliefs. Richard Feyman put it well when he said, “the first principle is that you must not fool yourself and you are the easiest person to fool.”

In acting prudently, you recognize that you often make wrong decisions, but you use them as opportunities to make better choices.■ To use an analogy, prognosticators believe in picking the one or two stocks that will lead to financial success; prudence accepts a smaller return via a fully diversified portfolio of assets with a full range of risk and rewards. Applying that analogy to renewables, rather than making them a primary source of supply, a prudent policy might see them as a way to diversify the total energy supply portfolio.

We may not be able to predict the future, but we can learn from the failures of the past as they relate to energy utilization, efficiency, and supply. With this learning we can create more robust institutional processes using a mixture of market and non-market techniques to achieve desired collective goals. (See for example the work of the recent Nobel laureates in economics: Eric Maskin on mechanism and implementation design, and Elinor Ostrom on sustainability and common pool resources.) At the same time we should remember Roger Bezdek's sage remarks regarding the history of energy forecasting written in 2003:

> Over the past 40 years, some of the most egregious forecasting errors have often been made by the smartest people, working for the most prestigious organizations, with the most money; for example, the 1974 Ford Foundation study, the 1977 Stanford study, the 1979 Harvard study, etc. Thus it is important to keep in mind that the accuracy and validity of an energy forecast is not necessarily correlated with the status of the persons making it or the money invested in the project. (Bezdek and Wendling, Journal of Fusion Energy, December 2002)

The Difficulties of New Technology

A great deal of knowledge already exists as to why many once-promising technologies have failed. This includes a series of hurdles that are well known and commonly faced with the introduction of new technologies and disruptive innovations. The noted economist and historian of technological development Joel Mokyr gives us some useful insight.

In the very long run, technological progress in its widest sense remains indispensable to sustainable economic growth. Of course, the failure to adopt a new technology can have many reasons: new technology is often embodied in expensive capital goods; it often requires scarce complementary factors such as infrastructural capital or a highly skilled work force. Yet outright resistance is a widely observed historical phenomenon. Precisely because such resistance must work outside the market and the normal economic process, artificial distinctions between the "economic sphere" and the "political sphere" for this class of problems are doomed. The adoption of a wholly new technology is often the target of long debates and public discourse, unlike many other technical and economic choices.

I would like to highlight here, in recognition of our time constraints, a few major hurdles from the US context that are relevant to our discussion. The examples below have been simplified for the sake of clarity and come from personal experience.

The first hurdle is government or regulatory dependence, which creates misaligned incentives. Wind and solar lobbyists and advocates have succeeded in creating Renewable Portfolio Standards (RPS) in the US (similar standards exist in the European countries) which require utilities to purchase and deliver an escalating percentage of renewable energy to their customers. It is not uncommon for the level to start at 15% and rise to 20% or even 33% (California) by some arbitrarily chosen date like 2020 or 2030.

This "creates" a "market" in renewable energy at a very large scale. If 15% of all energy being delivered via the Texas grid must be from renewable sources, infrastructure must be built to fulfill the governmental fiat. But given the fact that the actual amount of solar or wind when this was announced was well below 5%, Texas couldn't possibly pay for the cost of this vast energy infrastructure improvement. In fact, the only way to attract the right partners from the engineering, construction, operational, insurance, and capital formation sectors was to provide what is known as a Power Purchase Agreement (PPA) in combination with very large subsidies. In such a PPA, the government agrees to purchase electricity from the renewable energy facility at a given price for a long period of time, usually 20 to 30 years. The most striking attribute of this situation is that the artificially created market subjects companies delivering this technology to political and regulatory risk too large for reasonable capital decision-making without the PPA or subsidies. The collapse of residential solar with the price destruction initiated by Chinese overproduction, and wind markets with the withdrawal of subsidies in the US are good examples of the downside of regulatory dependence.

The misaligned incentives show in who reaps the upside of the equation. The use of the PPA creates a de facto Public Private Partnership (PPP) where the sovereign entity absorbs all the risk. The partnership makes investors whole no matter the future outcome and also guarantees the revenues for the contracted time period. A small number of investors win, while utilities are forced to pay all the extra costs of managing an intermittent source at locked-in prices that is passed on to the unfortunate customers.

Techniques such as PPAs can help accelerate adoption of renewables if the underlying technology is already commercially sound and is subject primarily to non-market resistance. In that case, regulatory nudging may prove useful. But when the nudging becomes social engineering, things often prove destructive to aggregate benefits and are particularly injurious to the most vulnerable in the population. Witness the attempts to prevent new nuclear plant licenses and to create regulatory compliance schemes to make coal-powered plants impossible to build in the US. I see that Germany has embarked on a vast experiment using exactly such a tactic to help create an aura of "political vision" to attract voters. To my knowledge, no modern society has succeeded in improving the lot of its citizens with policies structured to make the economy less globally competitive over the long run. Certainly this grand experiment is worth watching, but I am very dubious.

A second hurdle arises when policy only seeks solutions at vast scales requiring massive capital expenditures. One of the hallmarks of disruptive technology is that it often eliminates such vast capital needs while decreasing unit costs and improving functional value. A triple bottom line that decreases the quality of life or overall choice opportunities will not be sustainable. Take for example natural gas or hydrogen vehicles. When targeted to appropriate market sectors both of these options can be of real overall benefit and can be integrated into the economic landscape. But by setting the goal of having these vehicles completely replace petroleum-powered ones, the size of that goal has created equally large problems in associated infrastructure change.

If we look at just the problem of refueling, it can take about 20 minutes to refuel a hydrogen vehicle. What will a standard refueling station on the side of a common US highway look like? It will take up much more space and create a massive queuing problem. This will be completely unacceptable to the customer and the owner of the refilling facility will face a big loss of revenues because so many fewer cars can refuel in a given period of time.

On the other hand, deployed into the proper niche context, natural gas and hydrogen vehicles are already operating in a commercially viable manner. Take the use of natural gas vehicles for redi-mix concrete trucks and hydrogen fuel cell powered forklifts in logistics facilities as examples. Each application of the renewable energy source is uniquely suited to the conditions and makes full sense for total cost of operation and initial capital expenditure. For the forklifts, there is less maintenance and continuous availability to the facility owner is significantly improved. For the concrete trucks, having a single location for refueling and traveling short distances to deliver the time-sensitive concrete mix makes natural gas a perfect fit. Encouraging smaller-scale applications like these makes perfect sense to solidify and disseminate renewable fuel solutions and allows the market to test the hypothesis of a particular application.

Finally, we must at least look at the standard hurdle that many technology innovators face when political or other concerns create outcome blindness and thus are not able to recognize the value of real performance criteria. Public health programs suffered from this for many years and attempts to solve the problem of energy issues often mimic this rhetoric. As the Gates Foundation has insisted on outcome-based philanthropy, so we must pursue an outcome-based sustainability.

In the US, for example, there has been a long-standing program for the improvement of building performance based on a system created by the Environmental Protection Agency named Energy Star for commercial buildings. This system ostensibly "measures" the relative performance of individual buildings in the use of source energy by comparing them to a much larger data set of national commercial buildings. This program has now become the de facto standard by which municipalities, states, and federal governments benchmark building performance.

This program is unfortunately based on sham underlying algorithms. The program managers know this, but the program continues marketing to real estate stakeholders and prevents anyone from engaging the outcome metrics. Whether consciously or not, Energy Star has become outcome blind but it continues to waste the resources, time, and effort of a large number of public and private real estate and building rating-system customers.

Conclusion and Recommendations

One important conclusion of this cursory examination is that innovative technology has an extremely difficult time succeeding unless it has a very clear functional and cost advantage that can be extracted quickly and effectively. Disruptive technologies have such attributes, which is why they have such a decisive impact on demand creation and destruction of status quo chains of manufacturing, supply, and distribution. There is a huge worldwide demand for low-cost, reliable energy. No one doubts for an instant that an energy option that could supply these reductions in price per relevant unit or crucial functional attributes would need little help to generate massive demand and capital investment.

On the other hand, it is also common that viable scientific breakthroughs lie fallow or miss their window of opportunity because of many non-scientific, market, and non-market forces. It is important to note, especially as scientists, that one should keep in mind the differences between prognosticating the future and seeking prudent policy options unaffected by apocalyptic rhetoric or the convenient validation of vested interests.

In the interest of prudent renewable energy policy, I offer the following recommendations.

1. Create an interdisciplinary advisory group that brings economics, policy, regulatory, and business clarity to the table for detailed, objective discussions. Keep scientific considerations and value judgments scrupulously separated.

2. Stress first principle activity not only from the scientific community but also in non-scientific policy activity.

3. Interrogate the various scientific/technology options for commercial viability assessments by the interdisciplinary team.

4. Create a prioritized list of scientific/technological options based on commercial viability assessments for policy recommendations and provide transparency for the basis of prioritization.

5. Provide a list of the scientific, economic, market analysis, and potential non-market forces that will impact the prioritized technology options.

6. Review on an ongoing basis the success or failure of prioritized technologies to assess what scientific, economic, market, or non-market problems or flaws led to failure of commercial viability. (In essence, do a mortality and morbidity analysis with the scientists and others involved in the technology.) If this review were done annually a good set of data could be established in five years to help the EU discuss policy more meaningfully. It would also show the value of scientific/technological research and implementation, and the importance of the Academies' roles.

7. Keep an ongoing record of objective successes and failures to help understand the general outlines for subsequent scientific/technological opportunities. This prevents the need to reinvent the wheel each time and protects against loss of objectivity in subsequent iterations. Add new information that becomes relevant for helping to guide successful transition to commercial viability.

8. Repeat as needed and change as needed to improve outcome performance.

I leave you with a quote that I think sums much of this up nicely by the great American jurist Oliver Wendell Holmes:

> Certitude is not certainty. We have been cock-sure of many things that were not so. . . . But while one's experience thus makes certain preferences dogmatic for oneself, recognition of how they came to be leaves one able to see that others, poor souls, may be equally dogmatic about something else. And this again means skepticism.

Thank you.