NEEDED: More and better ways to think about uncertain futures

IRGC International Conference
Beijing, PRC

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In today's remarks I will:

1. Provide some motivation and background.
2. State the problem I am addressing in general terms.
3. Consider why people persist in making deterministic forecasts when it is very clear that such forecasts are often close to meaningless.
4. Suggest some alternative strategies.
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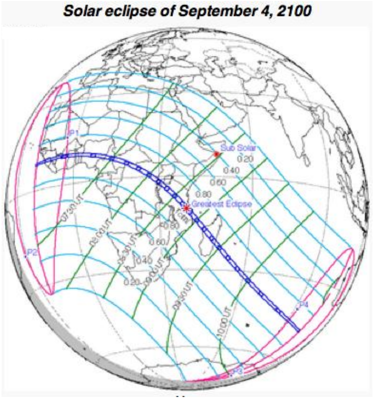
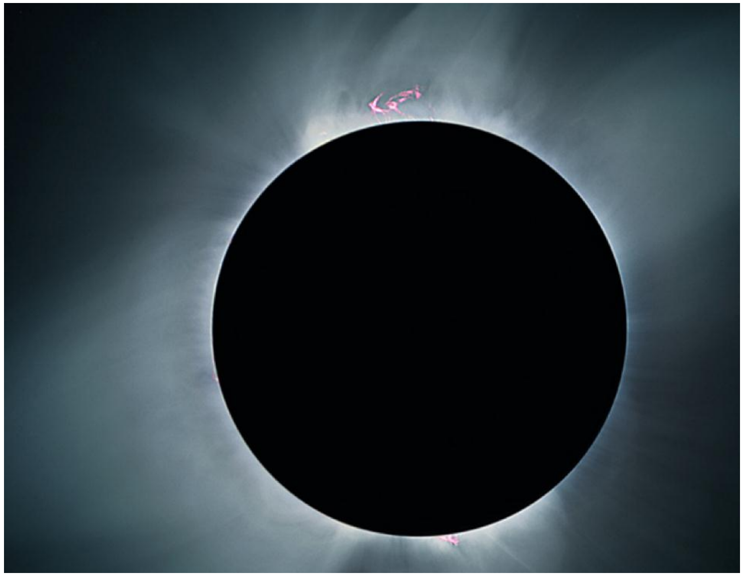
There are *some* future events…

…that can be precisely predicted. For example, thanks to Newtonian mechanics we can confidently say that there will be a total eclipse of the sun on September 4, 2100.



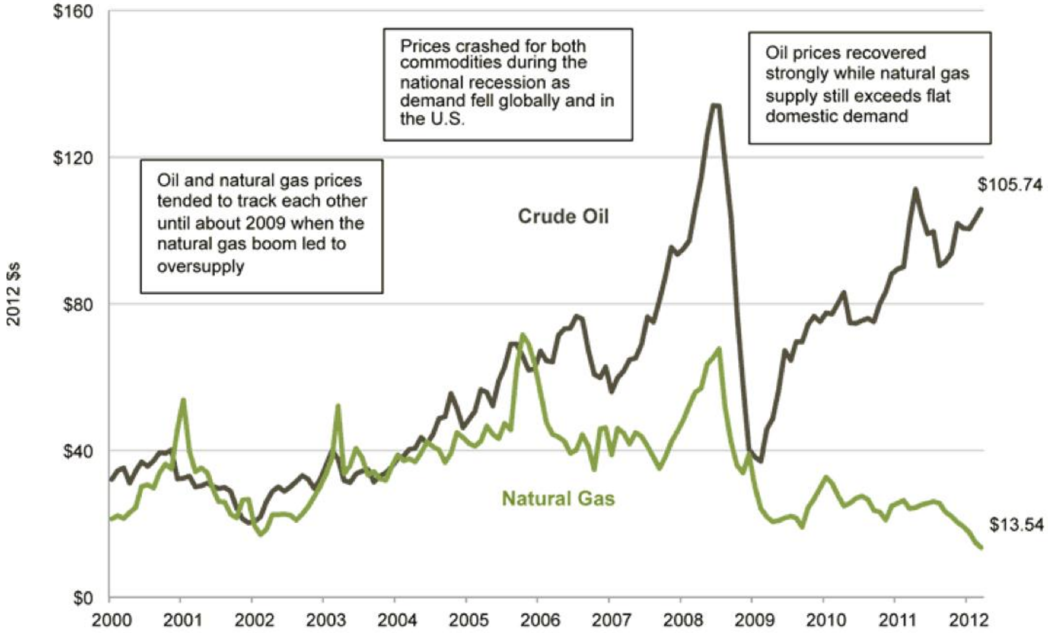
Indeed, we can even say that to within a fraction of a second, the moment of maximum eclipse will occur at 16:57:52 GMT.



Source: wikipedia; geogdata.csun.edu.

But given the plot below…

…nobody in their right mind could plausibly argue that we can predict U.S. oil or gas prices to ±50% in 10, let alone 50, years.



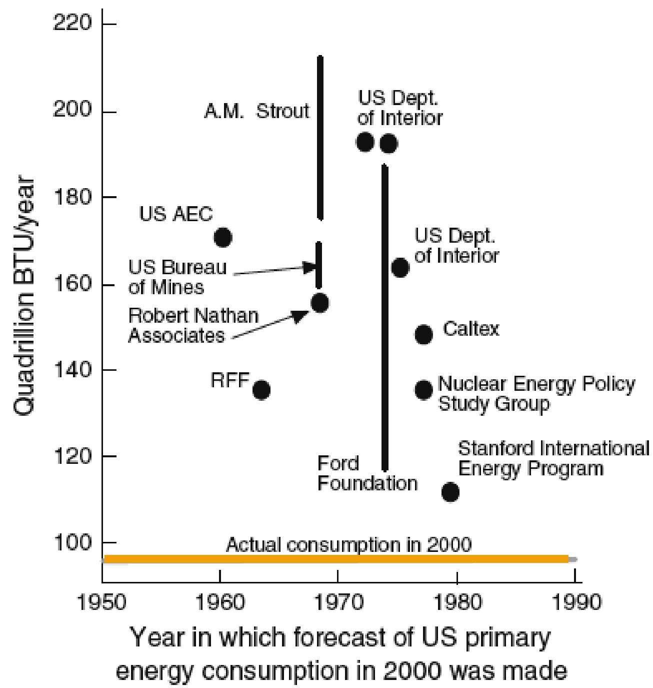
Source: headwaterseconomics.org.

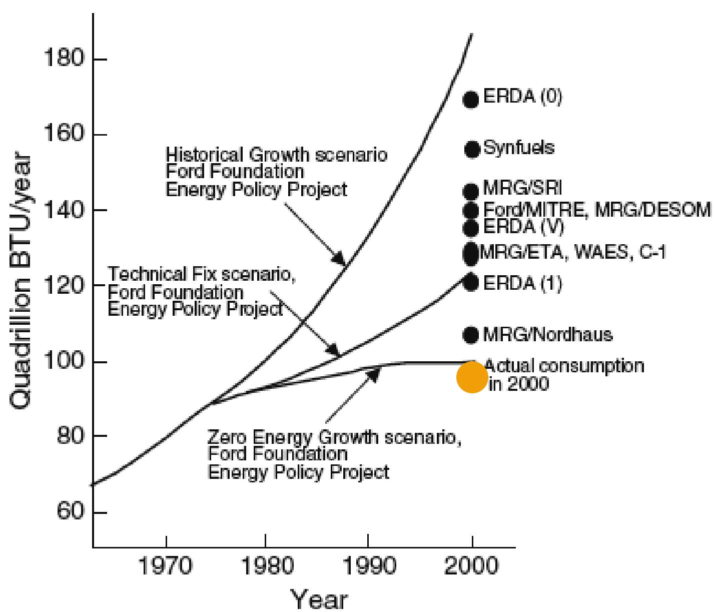
Yet…energy agencies, and many policy modelers and economists make such deterministic forecasts *all the time*!

Of course, when you look back…

…they don't do very well.

Here is a summary of forecasts of U.S. primary energy consumption for the year 2000 compiled by Smil (2003) as a function of the date on which they were made.

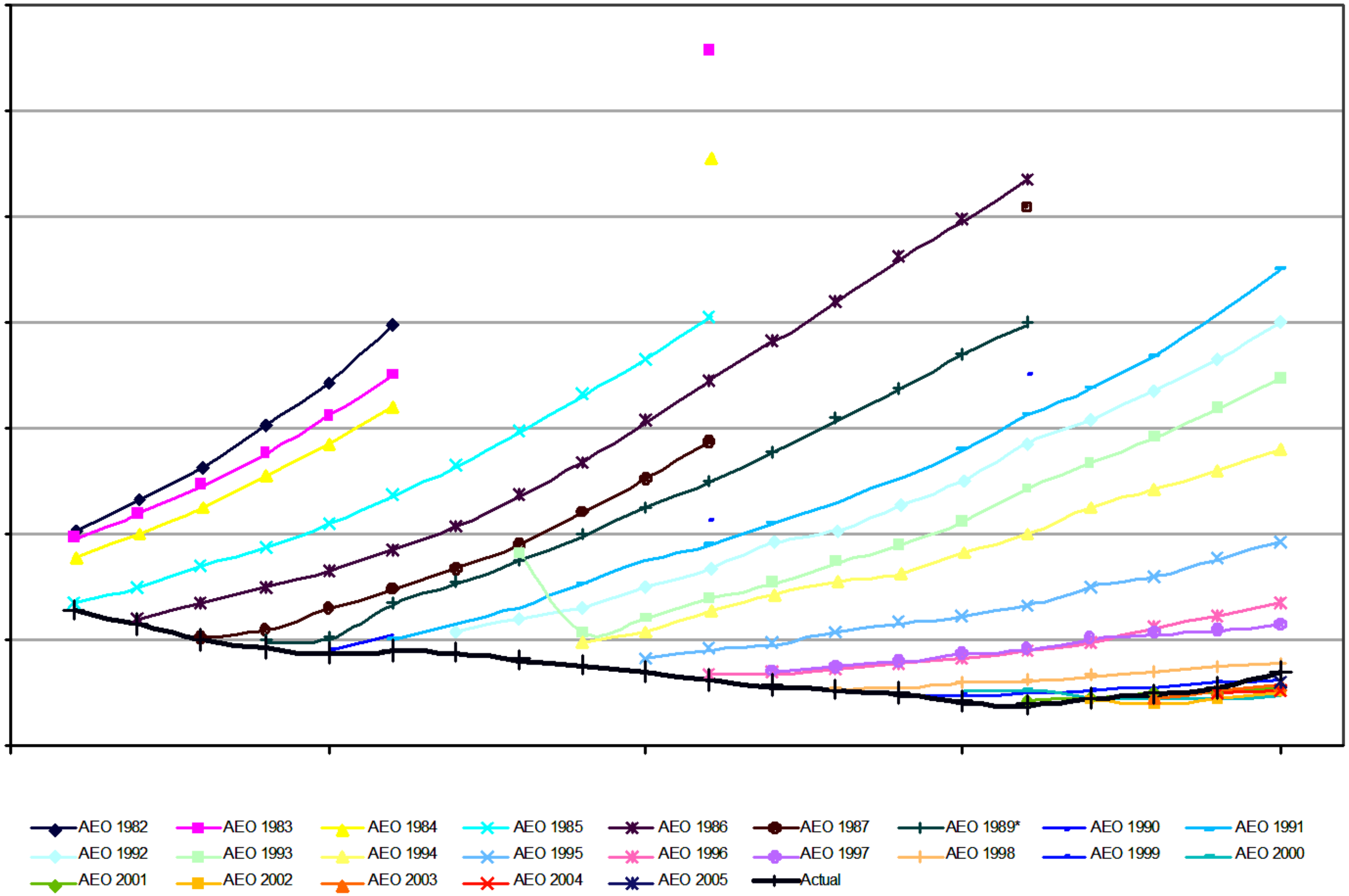




And here are forecasts of U.S. primary energy consumption for the year 2000 compiled by Greenberger in the early 1980s compared with three scenarios developed by the Ford Foundation Energy Project.

Figures from Morgan and Keith, 2008

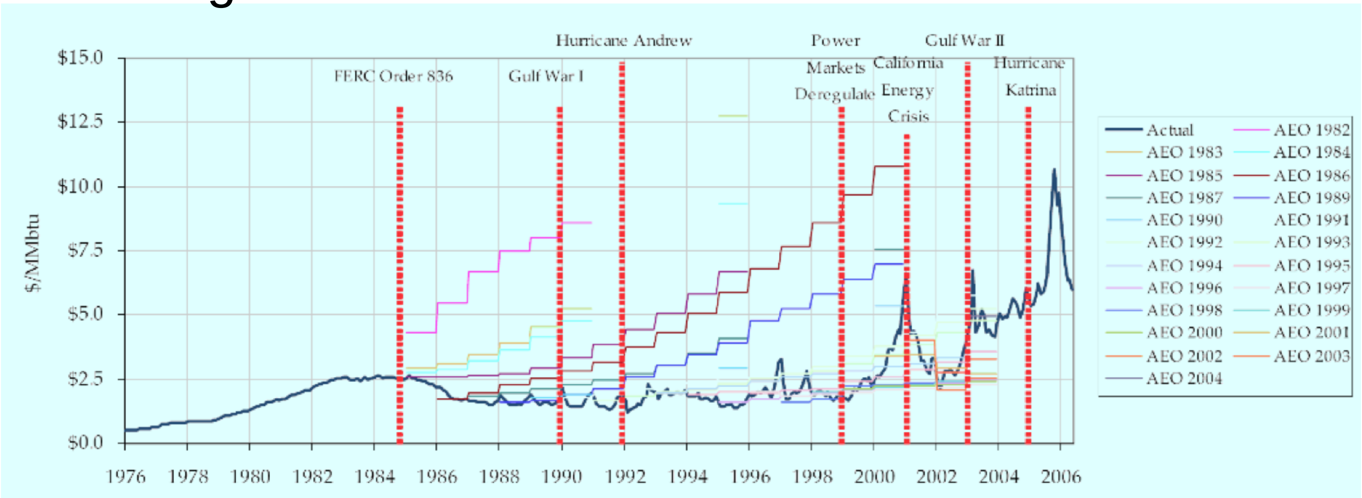
EIA - AEO



Complied by Adam Newcomer, 2007.

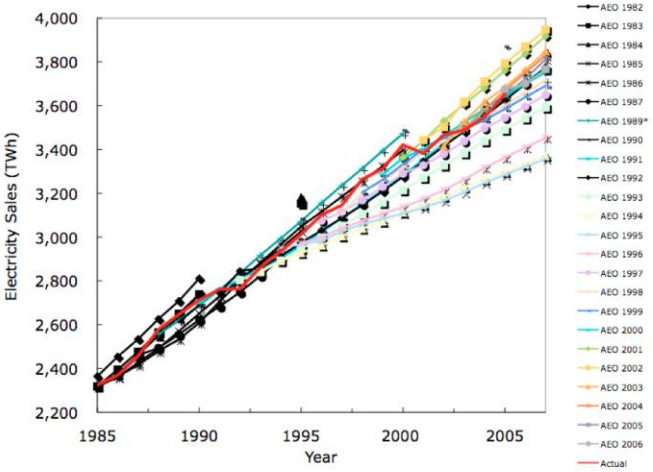
EIA - AEO…(Cont.)

Natural gas:



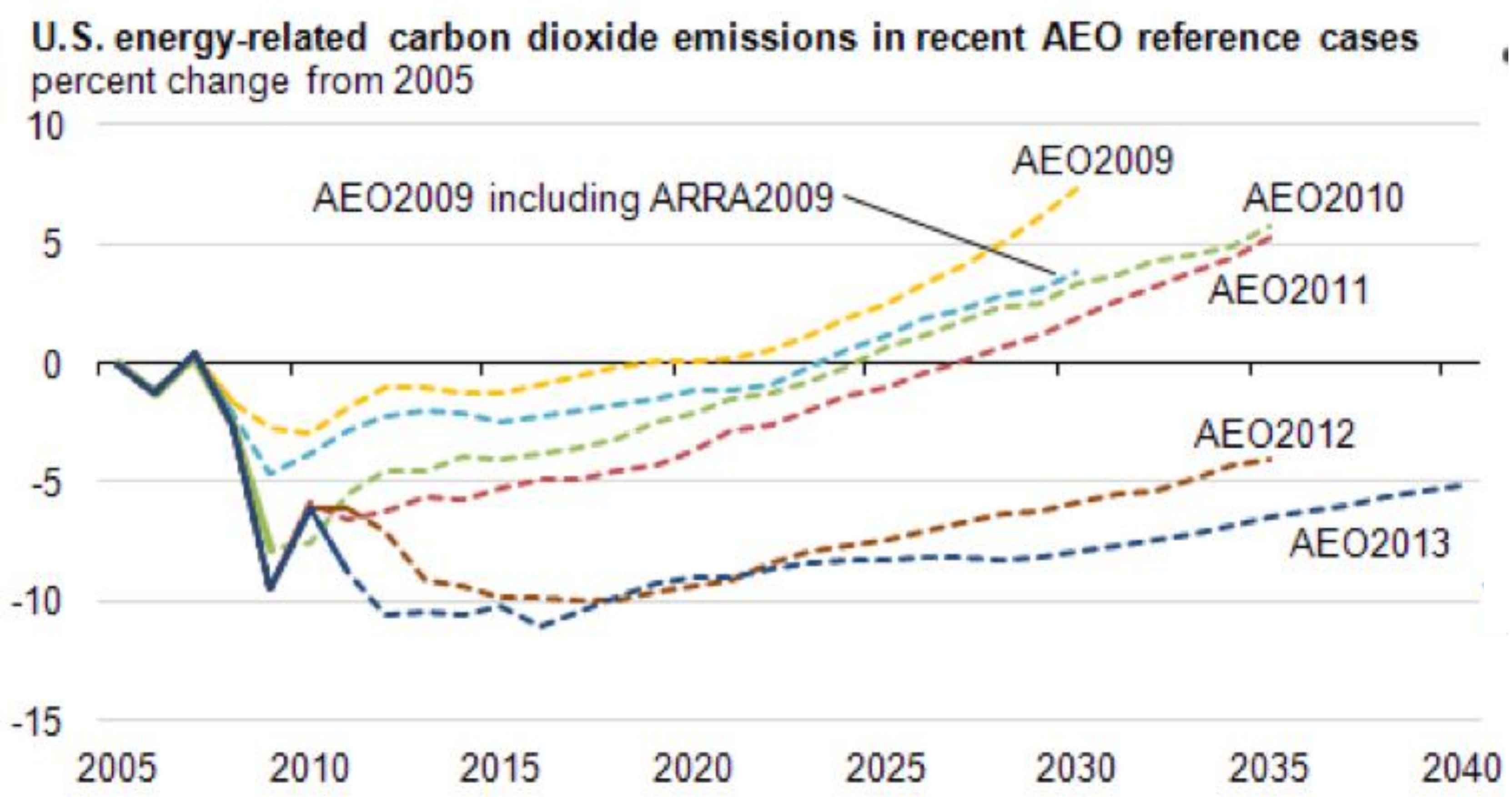
Compiled by David Rode, 2006

U.S. electricity sales:



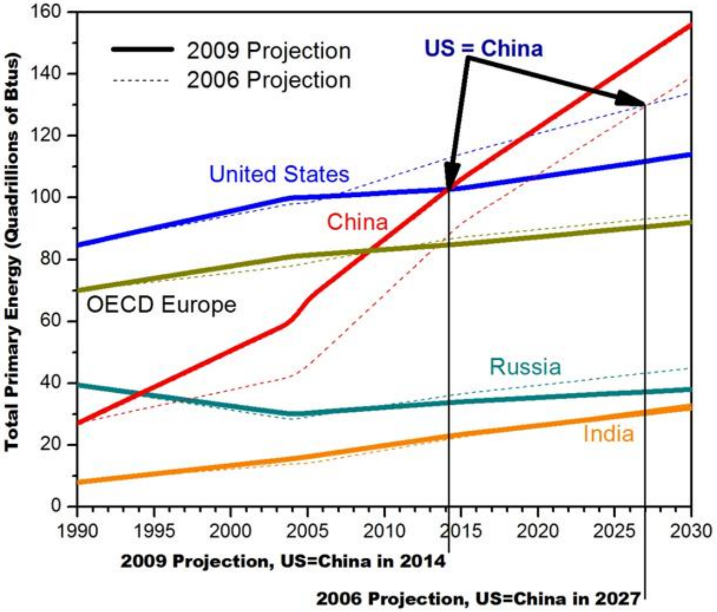
Compiled by Inês Azevedo, 2011.

EIA - AEO…(Cont.)

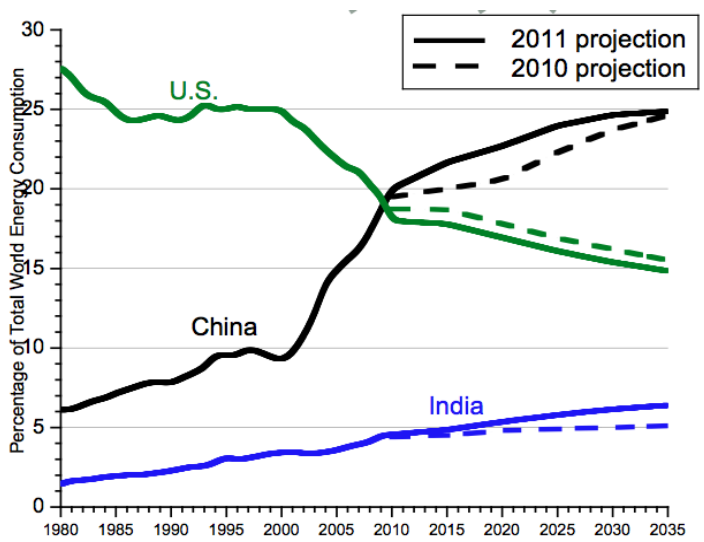

U.S. energy-related carbon dioxide emissions in recent AEO reference cases
percent change from 2005
10
5
0
-5
-10
-15
2005
2010
2015
2020
2025
2030
2035
2040
AEO2009
AEO2009 including ARRA2009
AEO2010
AEO2011
AEO2012
AEO2013

Predictions of when China would pass the U.S.

The year in which EIA projected that China's total primary energy would exceed the U.S. has steadily moved closer.



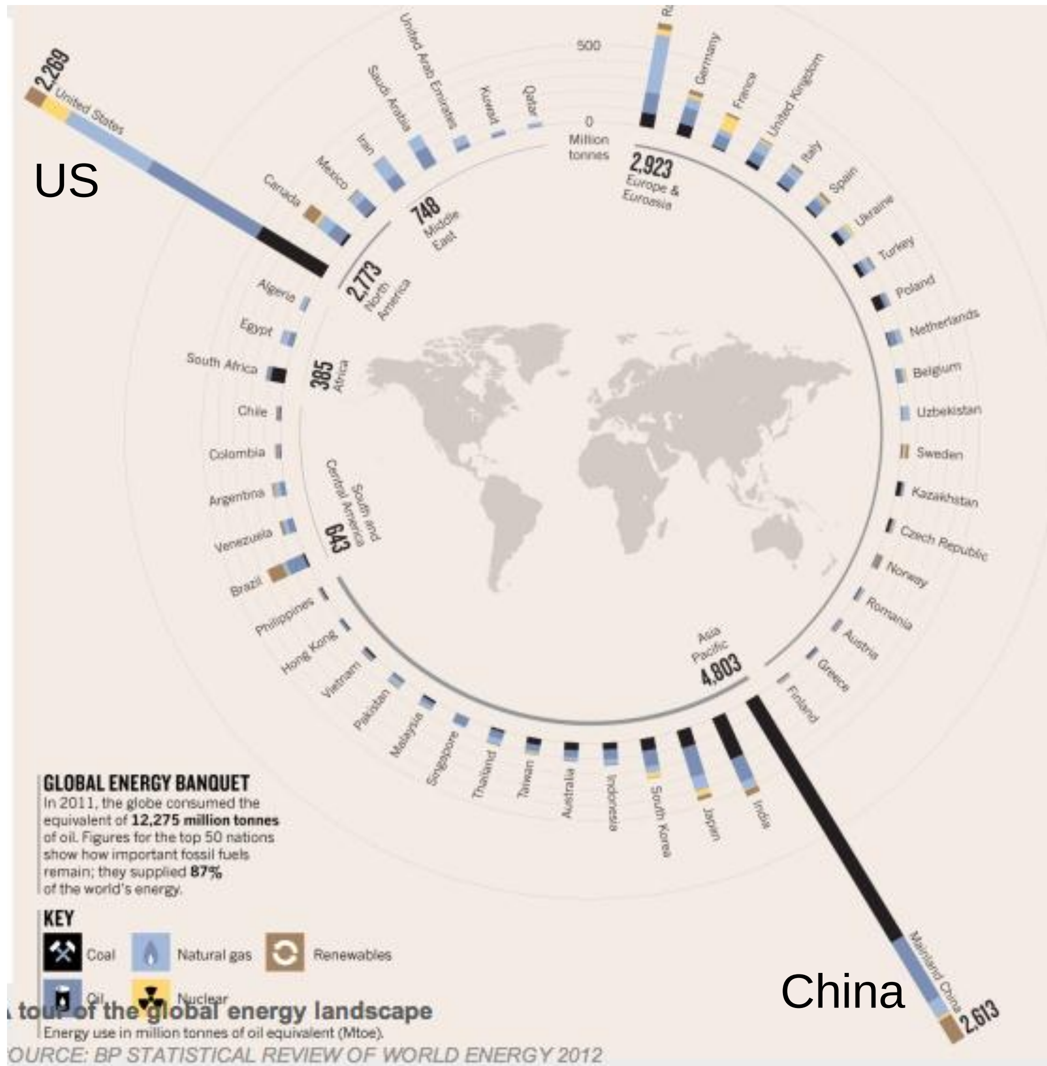
China's energy consumption actually exceeded that of the U.S. even sooner.



Data for plots from Energy Information Administration, International Energy Outlook. Figures from Maxine Savitz.

Incidentally…

…as a consequence, today China and the United States are the two largest emitters of CO_2 *by a very large margin*.



Nature, 2012 Nov 19

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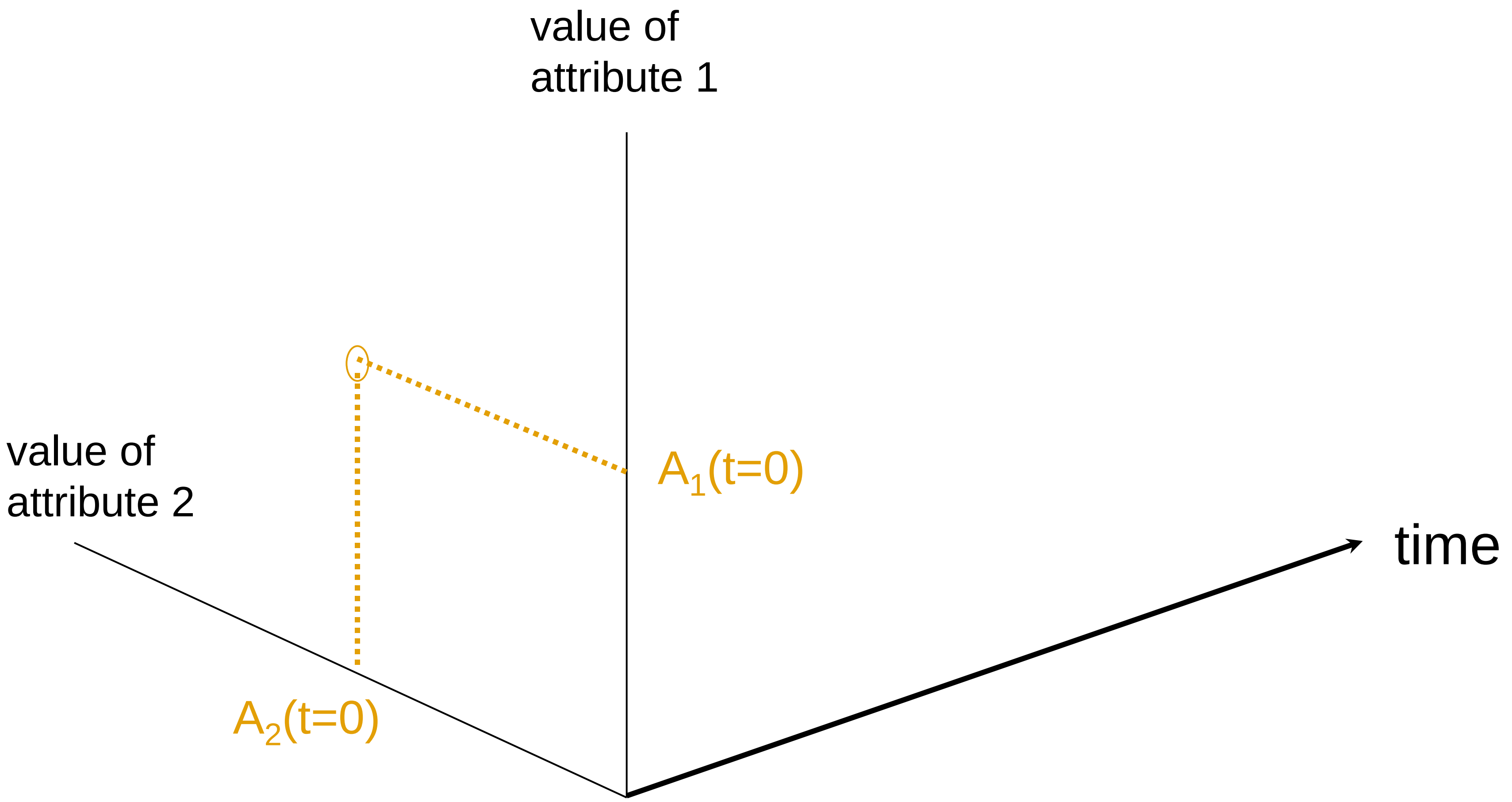
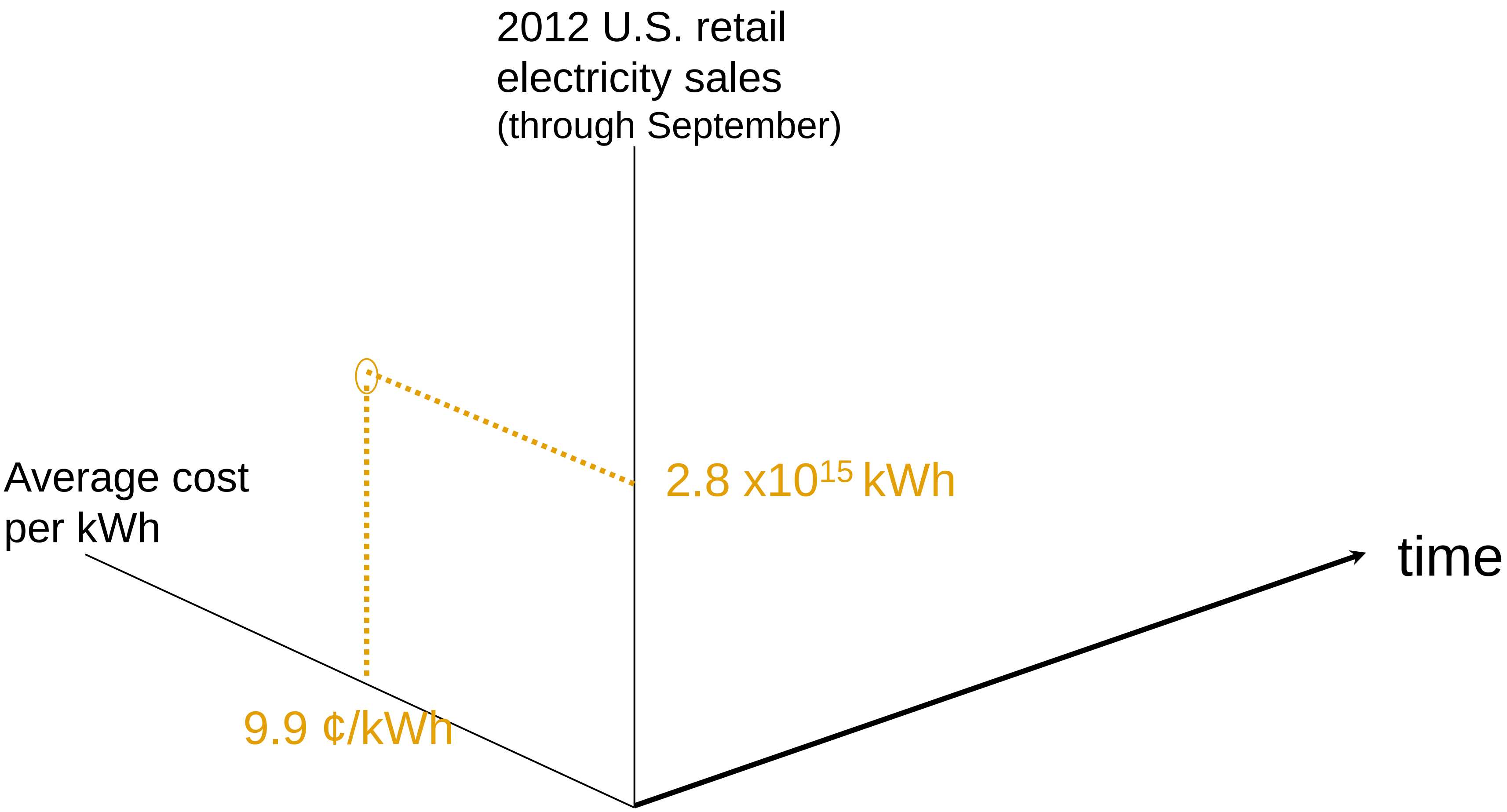
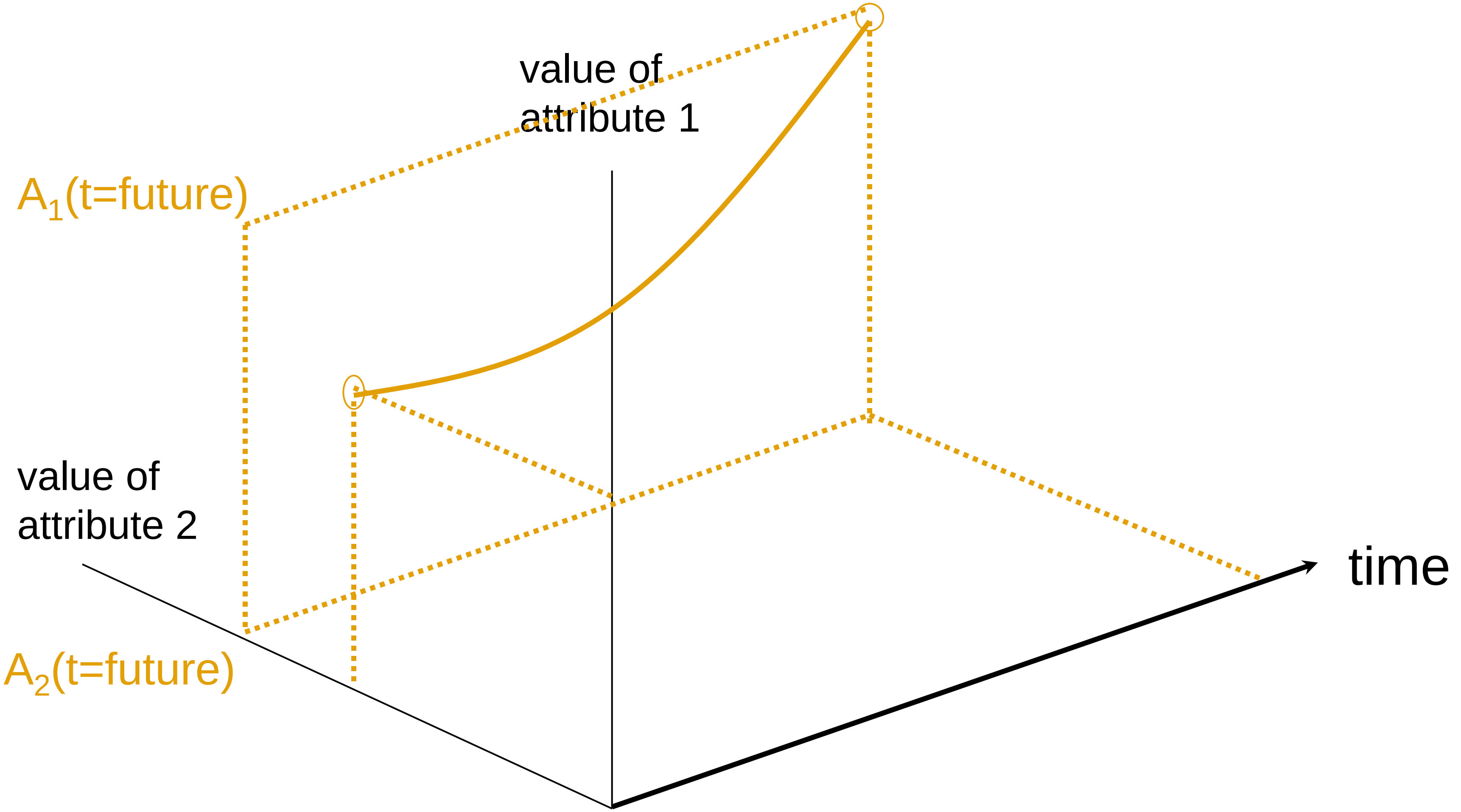
The basic problem:



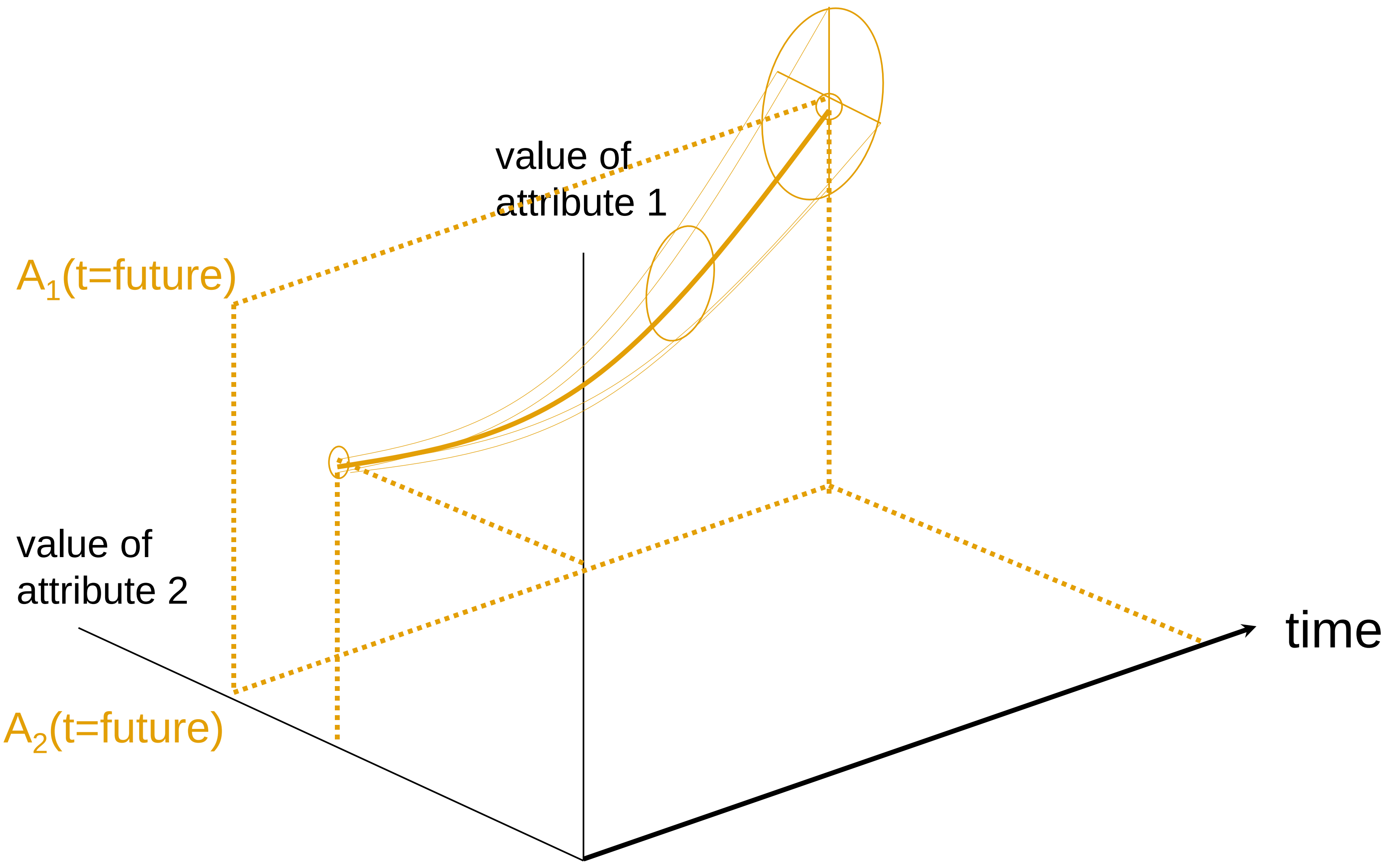
For example:


2012 U.S. retail
electricity sales
(through September)
2.8 x10^{15} kWh
Average cost
per kWh
time
9.9 ¢/kWh

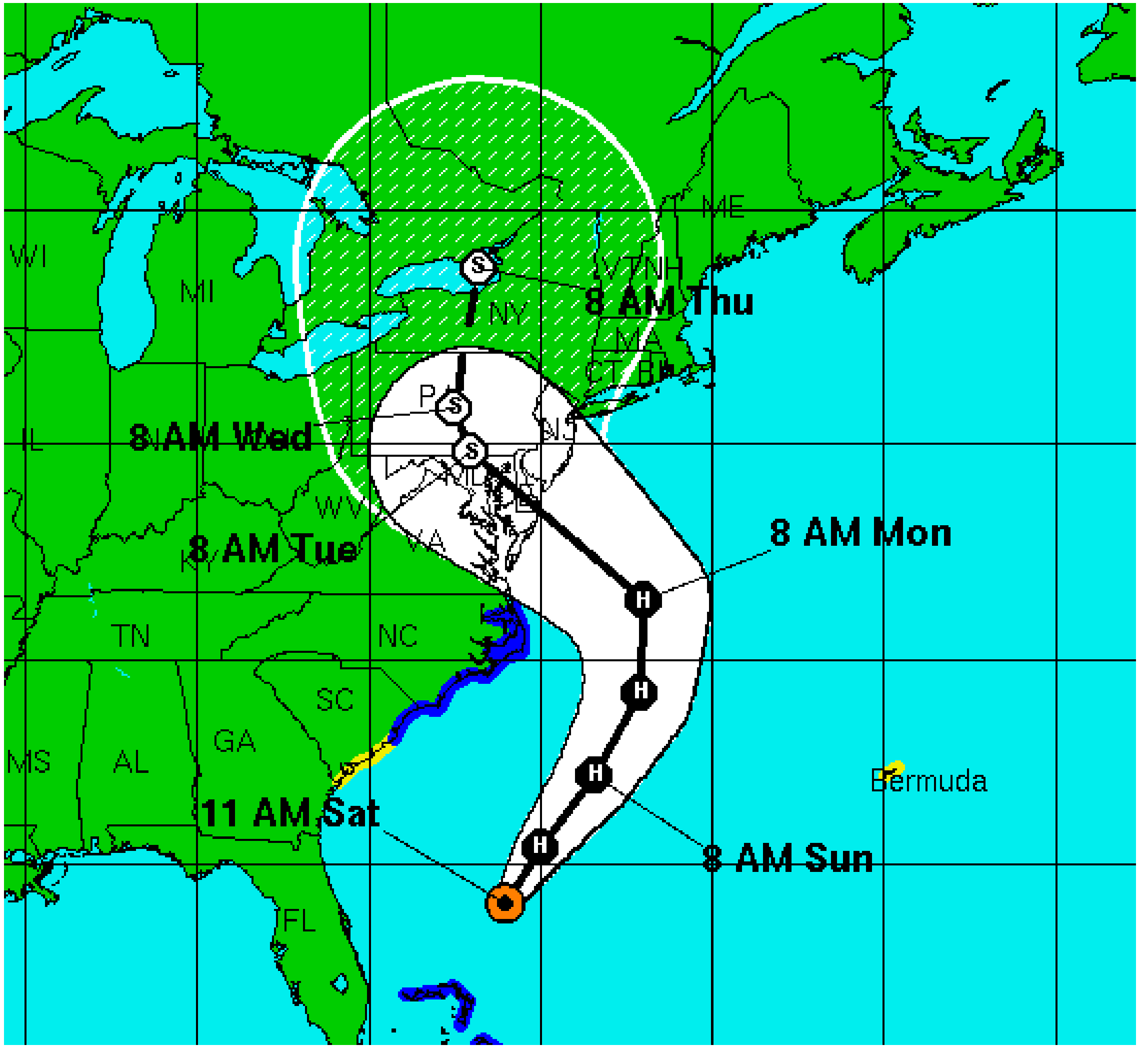
Back to the basic problem:



But the future is uncertain:



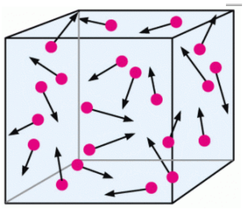
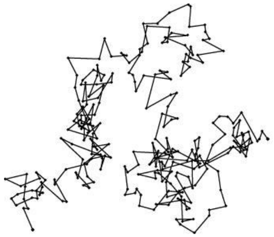
We all know about such "cones of uncertainty"



Source: NOAA.

What creates uncertainty about future values?

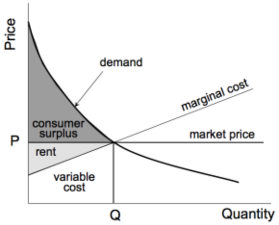
- Random physical processes.

- Choices by key decision makers.



- Emergent consequences of many individual "agents."



- New technology

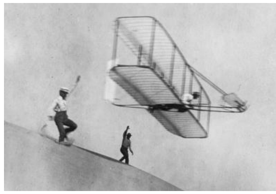
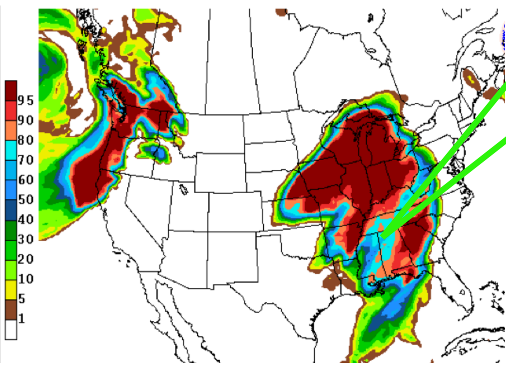


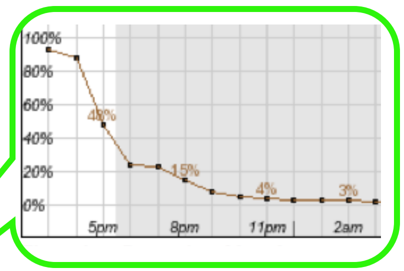
Figure sources:jimmyakin.com; www.kutl.kyushu-u.ac.jp; www.moonmentum.com; hardygreen.com; i.telegraph.co.uk; 3.bp.blogspot.com; memory.loc.gov ; vneagoie.wordpress.com; wikipedia.

As Baruch Fischhoff can explain…

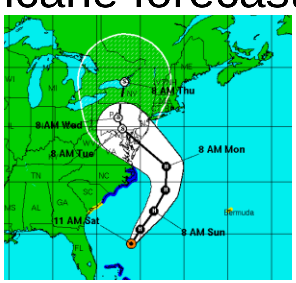
…while they do not do it perfectly, lay people are capable of acknowledging and dealing with uncertainty.

Precipitation forecasts:





Hurricane forecasts:



Race track betting odds:

	NO	RUNNER (BARRIER)	FLUCS	WIN FIXED	WIN SUPER BEST + (APPROX)	PLACE FIXED	PLACE SUPER MID (APPROX)
	1	Dunaden (16)	7.00, 7.00	7.50	SUPER BEST +	2.90	SUPER MID
	2	Americain (12)	6.50, 7.00	6.50	SUPER BEST +	2.60	SUPER MID
	3	Jakkalberry (19)	61, 61	71.00	SUPER BEST +	17.50	SUPER MID
	4	Red Cadeaux (18)	9.00, 9.00	9.50	SUPER BEST +	3.50	SUPER MID
	5	Winchester (22)	51, 51	51.00	SUPER BEST +	13.50	SUPER MID
	6	Voila Ici (13)	151, 151	151.00	SUPER BEST +	30.00	SUPER MID
	7	Cavalryman (6)	34, 34	34.00	SUPER BEST +	9.70	SUPER MID

Point spreads in sport

NFL Point Spreads For Week 16 - Week Sixteen NFL Football Point Spread - NFL Spreads 12/22 - 12/23, 2012

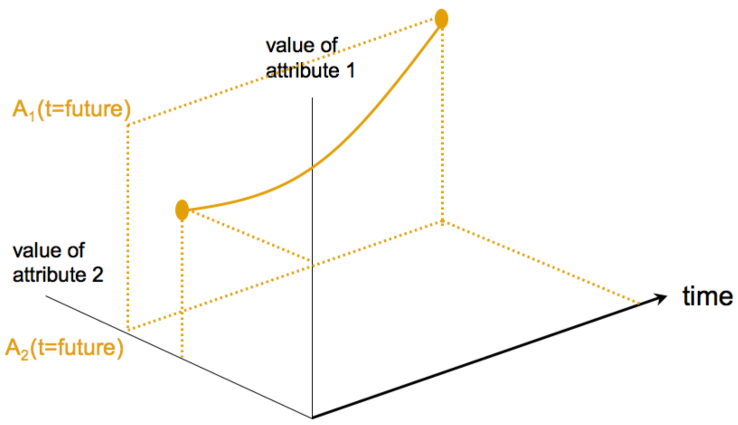
Date & Time	Favorite	Spread	Underdog
12/22 8:30 ET	Atlanta	-3.5	At Detroit
12/23 1:00 ET	At Green Bay	-12.5	Tennessee
12/23 1:00 ET	At Carolina	-8	Oakland
12/23 1:00 ET	At Miami	-4.5	Buffalo
12/23 1:00 ET	At Pittsburgh	-3.5	Cincinnati
12/23 1:00 ET	New England	-14.5	At Jacksonville
12/23 1:00 ET	Indianapolis	-7	At Kansas City
12/23 1:00 ET	At Dallas	-3	New Orleans
12/23 1:00 ET	Washington	-6.5	At Philadelphia
12/23 1:00 ET	At Tampa Bay	-3	St. Louis
12/23 4:25 ET	NY Giants	-2.5	At Baltimore
12/23 1:00 ET	At Houston	-7.5	Minnesota
12/23 4:05 ET	At Denver	-13	Cleveland
12/23 4:25 ET	Chicago	-5.5	At Arizona
12/23 8:30 ET	San Francisco	-1	At Seattle
12/23 1:00 ET	At NY Jets	-2.5	San Diego

Sources: forecast.weather.gov; www.hpc.ncep.noaa.gov; centrebet-nrl-grandfinal.com.au; www.footballlocks.com.

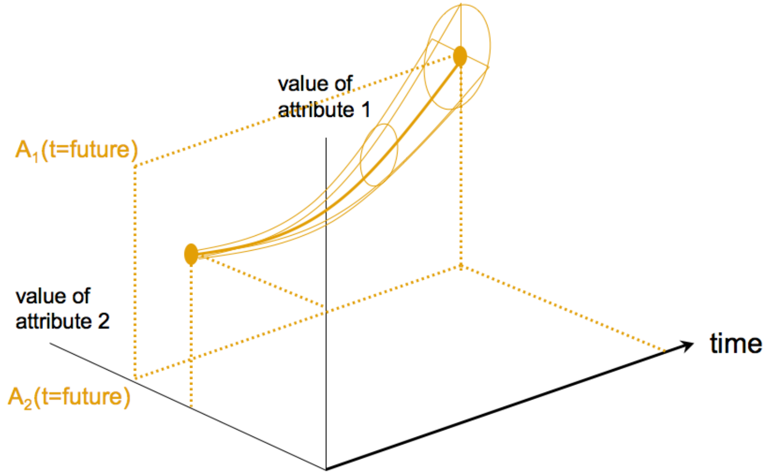
So, why is it that…

…Government Ministers; Government Ministries; economists; and a wide variety of modelers (economics, energy, climate, etc.) persist in making single value forecasts with little or no discussion of uncertainty. In short:

Why this…



Rather than this?



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Some hypotheses

Folks persist in making deterministic projections because:

- They are lazy - they find it too hard to do anything else;
- They can get away with it because most people who get their forecasts have no appreciation of how bad past performance has been;
- They believe (erroneously) that those who use the forecasts are not capable of understanding or dealing with uncertainty;
- Deterministic forecasts are more persuasive in arguments than forecasts that come with any acknowledgment of uncertainty;
- They believe that if they include uncertainty, people will perceive them to be less expert;
- They have no idea what else they could do.

Mapping reasons to players

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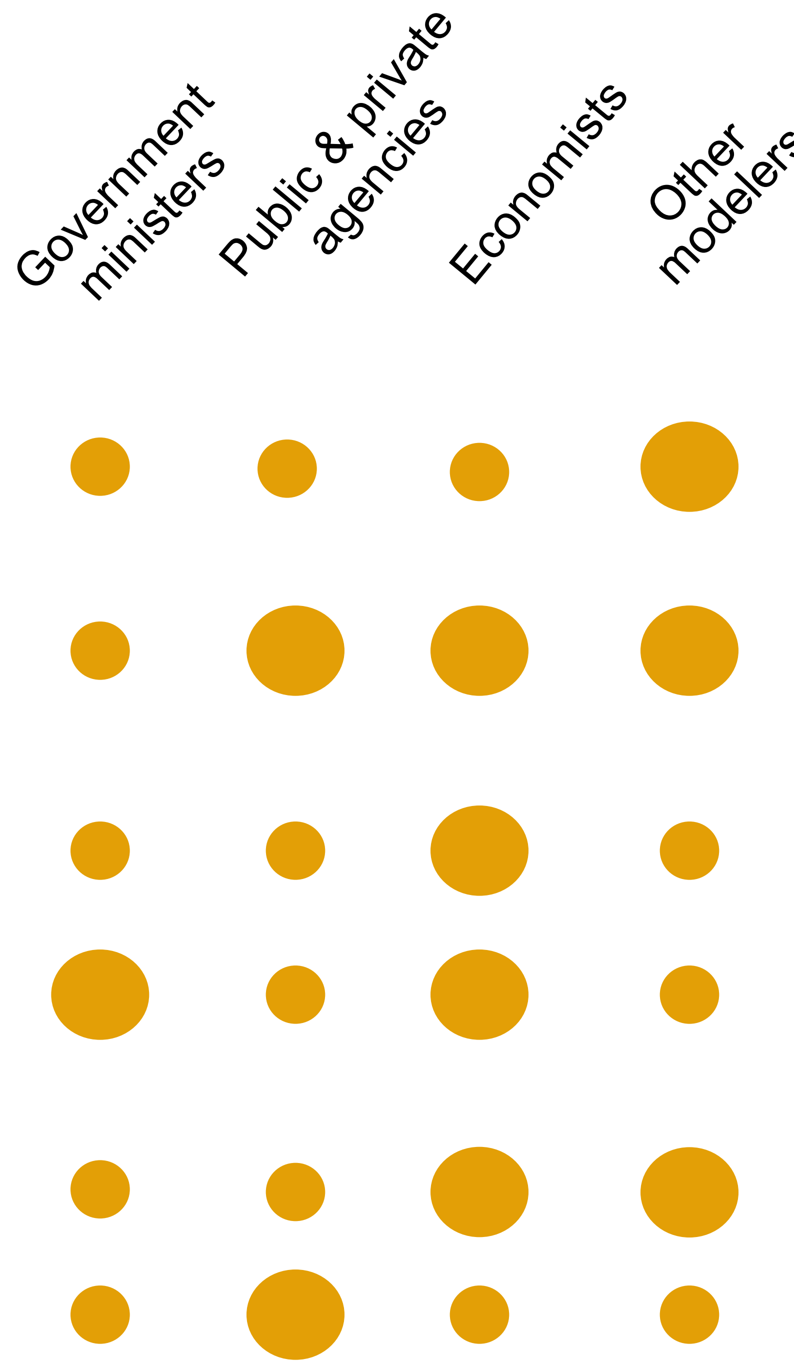

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The fact that past projections…

…have done so poorly suggests strongly that in many cases we should adopt some different strategies.

I'll talk about four:

1. Model switching
2. Bounding analysis
3. Bayesian methods
4. Working the problem backwards

Models of…

…different parts of the climate problem are believable for different periods of time into the future.

For example, I would not trust a general equilibrium model of the world's economy to be very reliable for more than perhaps a decade or two. In my view, running it out a century or more is not informative and could be misleading.

The Bayesian philosopher's solution:

Build separate models of all the possible futures, then combine them all by weighting each according to its likelihood of being the correct model.

Implication: the less you know, the more complicated your analysis should become!

Risk Analysis, Vol. 19, No. 1, 1999

Mixed Levels of Uncertainty in Complex Policy Models

Elizabeth A. Casman,[1] M. Granger Morgan,[1] Hadi Dowlatabadi[1]

The characterization and treatment of uncertainty poses special challenges when modeling indeterminate or complex coupled systems such as those involved in the interactions between human activity, climate and the ecosystem. Uncertainty about model structure may become as, or more important than, uncertainty about parameter values. When uncertainty grows so large that prediction or optimization no longer makes sense, it may still be possible to use the model as a "behavioral test bed" to examine the relative robustness of alternative observational and behavioral strategies. When models must be run into portions of their phase space that are not well understood, different submodels may become unreliable at different rates. A common example involves running a time stepped model far into the future. Several strategies can be used to deal with such situations. The probability of model failure can be reported as a function of time. Possible alternative "surprises" can be assigned probabilities, modeled separately, and combined. Finally, through the use of subjective judgments, one may be able to combine, and over time shift between models, moving from more detailed to progressively simpler order-of-magnitude models, and perhaps ultimately, on to simple bounding analysis.

KEY WORDS: Uncertainty; model uncertainty; epistemic uncertainty; integrated assessment.

1. INTRODUCTION

The past two decades have witnessed substantial progress in the way in which routine quantitative policy analysis deals with uncertainty. From a norm of single-value-best-estimate analysis, with sporadic discussion of sensitivity, the field has now progressed to the point where the use of probability distributions to describe uncertain coefficients and the use of methods such as stochastic simulation to propagate that uncertainty through policy models have become the norm in engineering safety analysis and common in health and environmental risk assessment. Of course, there are still holdouts, particularly among the biomedical community,[1-3] but continuing progress is apparent.

Uncertainty about coefficient values can arise both because the world is full of variability and random processes, and because our understanding of how it works is incomplete.[2] Sometimes it is important to distinguish between these two sources of uncertainty. However, recent emphasis on the distinction,[5] particularly by EPA[2] has sometimes resulted in the distinction being overdrawn.

While an adequate treatment of parameter uncertainty is important, in many domains of risk and other forms of policy analysis, uncertainty about coefficient values is swamped by uncertainty about the appropriate functional form of the models that should be used. Model uncertainty is frequently im-

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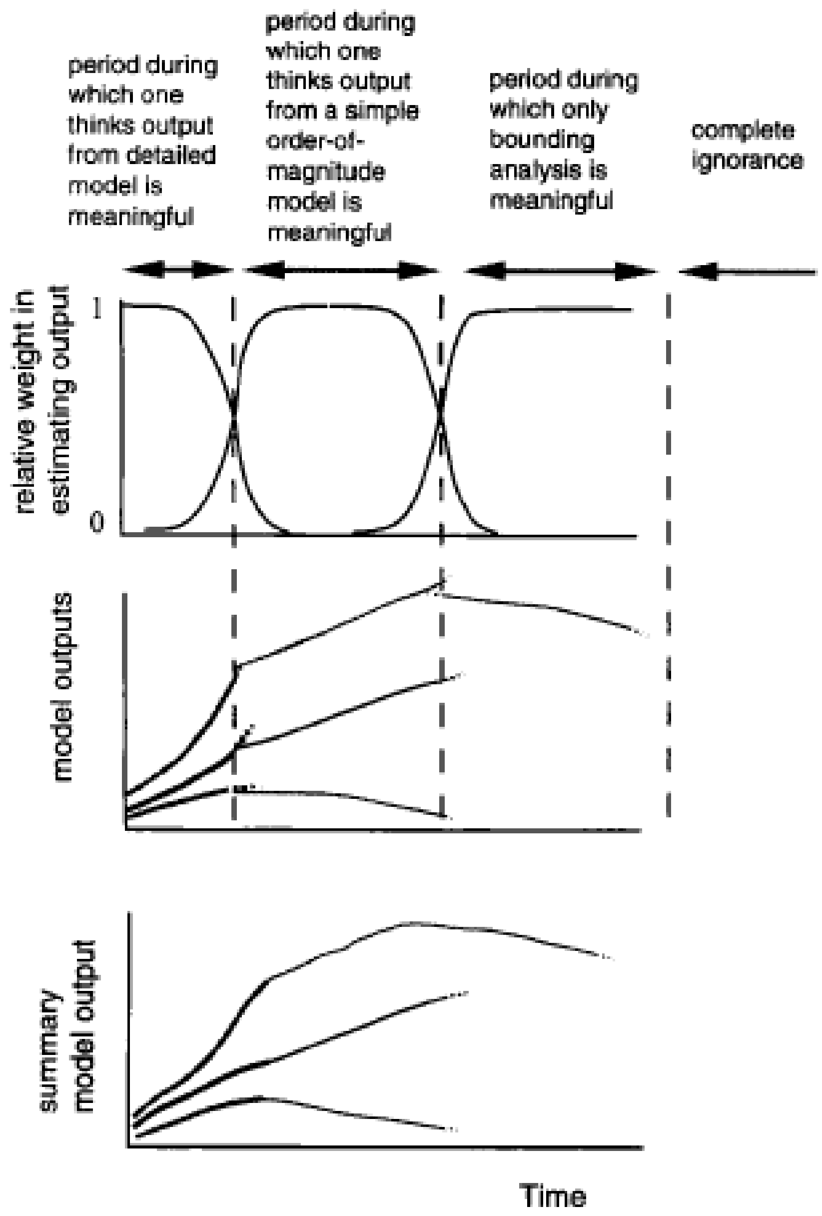
[2] These two sources of uncertainty are sometimes referred to as "aleatory" and "epistemic."[4] While we have no disagreement with this classification, we avoid the use of the terms simply because we and many others have difficulty remembering what they mean, and which is which!

Elizabeth A. Casman, M. Granger Morgan and Hadi Dowlatabadi, "Mixed Levels of Uncertainty in Complex Policy Models," *Risk Analysis*, *19*(1), 33-42, 1999.

An engineer's solution

Start with a complex model (about which you are confident), merge to simpler order-of-magnitude models as you become less confident about the results, and finally switch to bounding analysis.



For details see:
Elizabeth A. Casman, M. Granger Morgan and Hadi Dowlatabadi, "Mixed Levels of Uncertainty in Complex Policy Models," *Risk Analysis*, *19*(1), 33-42, 1999.

Problems with conventional scenarios

In my view, scenario-based analysis often leads to systematic overconfidence and an underestimate of the range of possible future outcomes.

Because of the cognitive heuristic of "availability" the more detail that is added to the story line, the more probable it appears, and the greater the difficulty people will have in imagining other, equally or more likely ways in which the same outcome could be reached.

Climatic Change
DOI 10.1007/s10584-008-9458-1

Improving the way we think about projecting future energy use and emissions of carbon dioxide

M. Granger Morgan · David W. Keith

Received: 20 March 2007 / Accepted: 4 April 2008

Abstract A variety of decision makers need projections of future energy demand, CO_2 emissions and similar factors that extend many decades into the future. The past performance of such projections has been systematically overconfident. Analysts have often used scenarios based on detailed story lines that spell out "plausible alternative futures" as a central tool for evaluating uncertainty. No probabilities are typically assigned to such scenarios. We argue that this practice is often ineffective. Rather than expanding people's judgment about the range of uncertainty about the future, scenario-based analysis is more likely to lead to systematic overconfidence, to an underestimate of the range of possible future outcomes. We review relevant findings from the literature on human judgment under uncertainty and discuss their relevance to the task of making probabilistic projections. The more detail that one adds to the story line of a scenario, the more probable it will appear to most people, and the greater the difficulty they likely will have in imagining other, equally or more likely, ways in which the same outcome could be reached. We suggest that scenario based approaches make analysts particularly prone to such cognitive biases, and then outline a strategy by which improved projections, tailored to the needs of specific decision makers, might be developed.

For those of us who work on climate and energy policy it would be extremely useful to be able to predict a few simple things such as the future demand for energy and the future mix of energy technologies over the coming decades—if not as sharp point estimates, then at least as well-calibrated subjective probability distributions. However, the track-record of past efforts to make such predictions is anything but

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University of Calgary, Calgary, Canada

Indeed, in preparing this talk…

…I found the following very troubling (and almost certainly true) assertion from one of the strong proponents of using scenarios:

> Practitioners can…use scenarios to enhance a person's or group's expectancies that an event will occur. This can be useful for gaining acceptance of a forecast…Second, scenarios can be used as a means of decreasing existing expectancies…Third…scenarios can produce greater commitment in the clients to taking actions described in them.

Source: W. Larry Gregory, "Scenarios and Acceptance of Forecasts," 519-540, in *Principles of Forecasting: A handbook for researchers and practitioners*, J. Scott Armstrong (ed.), 849pp., Kluwer Academic, 2001.

Probability and scenarios

As some of you may know, Steve Schneider, as well as others, argued that without probabilities, scenarios are of little value to climate scientists and impact assessors who are trying to understand how the climate is likely to evolve over the coming centuries.

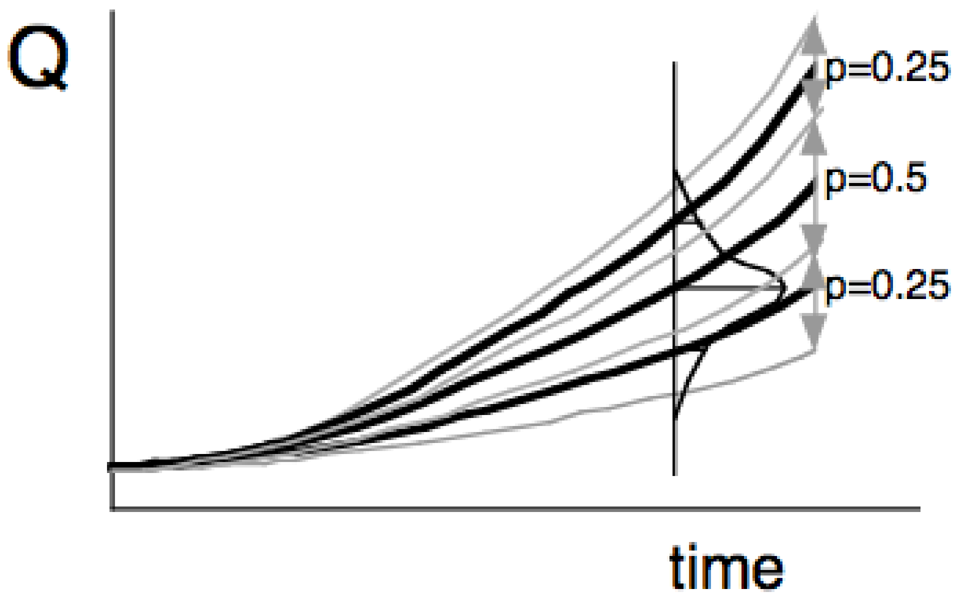
> While acknowledging the logic of avoiding fruitless debate, I strongly argued…that policy analysts needed probability estimates to assess the seriousness of the implied impacts; otherwise they would be left to work out the implicit probability assignments for themselves… I urged the expert group to provide a subjective probability assessment for less expert users, but I was not persuasive enough, and the SRES authors expressed "no preference" for each scenario.

Source: Stephen H. Schneider, "What Is 'Dangerous' Climate Change?," *Nature*, *411*, 17-19, May 3, 2001.

Of course…

…if we think of a scenario as describing a series of points over time through a multi-dimensional space of future possible socioeconomic conditions, scenarios cannot be assigned probabilities since, in any probability distribution over a continuous variable, the probability that attaches to any specific point value or line through that space is zero.

BUT…one *can* attach probabilities to intervals in such a space.



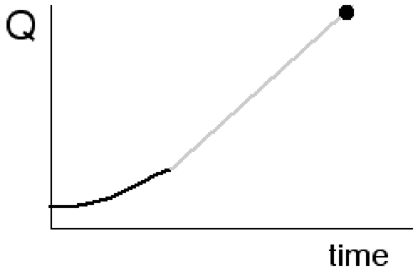
For more elaboration of these and related ideas see:

M. Granger Morgan and David Keith, "Improving the Way We Think About Projecting Future Energy Use and Emissions of Carbon Dioxide," *Climatic Change*, *90*(3),189-215, October 2008.

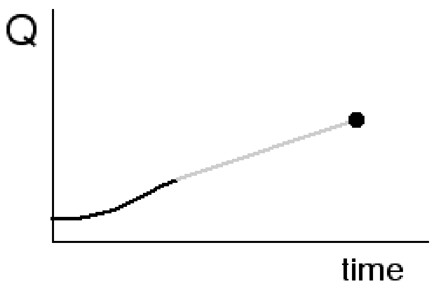
One alternative is bounding analysis

Given some quantity Q, whose value you want to project in the future, rather than developing a few very detailed "story lines" instead work to build a list of:

All the developments that might lead to its having a high value



All the developments that might lead to its having a low value

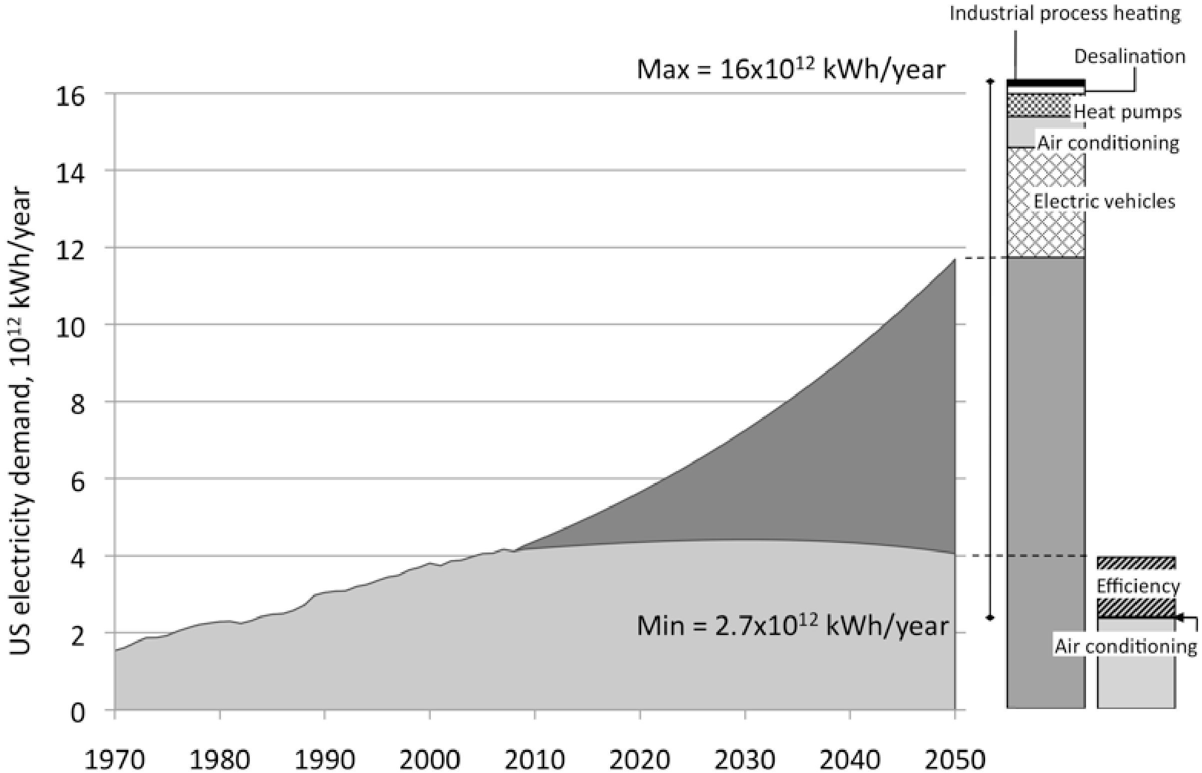


Then, subject the resulting lists and analysis to repeated critical review and revision.

Again for details see: M. Granger Morgan and David Keith, "Improving the Way We Think About Projecting Future Energy Use and Emissions of Carbon Dioxide," *Climatic Change*, *90*(3), 189-215, October 2008.

Without going through any details…

…here is the result of a bounding analysis of future U.S. electricity demand produced by my former PhD student Vanessa Schweizer.



Bayesian approaches

The best example I have seen is by Adrian Raftery et al.

PNAS

INAUGURAL ARTICLE

SOCIAL SCIENCES

STATISTICS

Bayesian probabilistic population projections for all countries

Adrian E. Raftery[a,1], Nan Li[b], Hana Ševčíková[c], Patrick Gerland[b], and Gerhard K. Heilig[b]

[a]Departments of Statistics and Sociology, University of Washington, Seattle, WA 98195-4322; [b]Population Division, Department of Economic and Social Affairs, 2, United Nations Plaza DC2-1984, United Nations, New York, NY 10017; and [c]Center for Statistics and the Social Sciences, University of Washington, Seattle, WA 98195-4320

This contribution is part of the special series of Inaugural Articles by members of the National Academy of Sciences elected in 2009.

Contributed by Adrian Raftery, July 5, 2012 (sent for review January 28, 2012)

Projections of countries' future populations, broken down by age and sex, are widely used for planning and research. They are mostly done deterministically, but there is a widespread need for probabilistic projections. We propose a Bayesian method for probabilistic population projections for all countries. The total fertility rate and female and male life expectancies at birth are projected probabilistically using Bayesian hierarchical models estimated via Markov chain Monte Carlo using United Nations population data for all countries. These are then converted to age-specific rates and combined with a cohort component projection model. This yields probabilistic projections of any population quantity of interest. The method is illustrated for five countries of different demographic stages, continents and sizes. The method is validated by an out of sample experiment in which data from 1950–1990 are used for estimation, and applied to predict 1990–2010. The method appears reasonably accurate and well calibrated for this period. The results suggest that the current United Nations high and low variants greatly underestimate uncertainty about the number of oldest old from about 2050 and that they underestimate uncertainty for high fertility countries and overstate uncertainty for countries that have completed the demographic transition and whose fertility has started to recover towards replacement level, mostly in Europe. The results also indicate that the potential support ratio (persons aged 20–64 per person aged 65+) will almost certainly decline dramatically in most countries over the coming decades.

double logistic function | Lee-Carter method | life expectancy at birth | predictive distribution | United Nations *World Population Prospects*

Projections of countries' future populations, broken down by age and sex, are used by governments for social, economic, and infrastructure planning by international organizations for development planning and monitoring and global modeling, by the private sector for strategic and marketing decisions, and by academic and other researchers as inputs to social and health research.

Most population projections are currently done deterministically, using the cohort component method (1, 2). This is an age- and sex-structured version of the basic demographic identity that the population of a country at the next time point is equal to the population at the current time point, plus the number of births, minus the number of deaths, plus the number of immigrants minus the number of emigrants. It was formulated in matrix form by Leslie (3) and is described in detail in ref. (4, chap. 6).

Population projections are currently produced by many organizations, including national and local governments and private companies. The main organizations that have produced population projections for all or most of the world's countries are the United Nations (UN) (5), the World Bank (6), and the United States Census Bureau (7), all of which use the standard deterministic approach. Among these, the UN produces updated projections for all the world's countries every 2 y, published as the *World Population Prospects*, and these are the de facto standard (8). We refer to the 2010 Revision of the *World Population Prospects* (5) as WPP 2010.

Standard population projection methods are deterministic, meaning that they yield a single projected value for each quantity of interest. However, probabilistic projections that give a probability distribution of each quantity of interest, and hence convey uncertainty about the projections, are widely desired. They are needed for planning purposes. For example, those planning school construction may wish to be reasonably sure of building enough capacity to accommodate all students in the future. For this the relevant projection is an upper quantile of the predictive distribution of the future school population, that is relatively unlikely to be exceeded, rather than a "best guess." Probabilistic projections are also useful for assessing change and deviations of population outcomes from expectations and also for providing a general assessment of uncertainty about future population.

The most common approach to communicating uncertainty in population projections is the scenario, or high-medium-low, approach. In this approach, a central or main projection is first produced. Then high and low values of the main inputs to the projection model, such as fertility or mortality, are postulated, and a projection is produced with the high values and another one with the low values. These high and low trajectories are viewed as bracketing the likely future values. This approach has been criticized as having no probabilistic basis and leading to inconsistencies (9, 10).

Previous approaches to producing probabilistic population projections include ex-post analysis, time series methods, and expert-based approaches (10, 11). Ex-post analysis is based on the errors in past forecasts (12–16). The time-series analysis approach uses past time series of forecast inputs, such as fertility and mortality, to estimate a statistical time series model, which is then used to simulate a large number of random possible future trajectories. Simulated trajectories of forecast inputs are combined via a cohort component projection model to produce predictive distributions of forecast outputs (9, 17). In the expert-based method (18–21), experts are asked to provide distributions for each forecast input. These are then used to construct predictive distributions of forecast outputs using a stochastic method similar to the time series method.

Our method is most closely related to the time series approach. We simulate a large number of trajectories of future values of the total fertility rate (TFR) and convert them to age-specific fertility rates using model fertility schedules. We simulate an equal

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Source: Raftery et al., *PNAS*, 2012.

For example…

…rather than generating a deterministic forecast for any given county, they generate probabilistic forecasts such as these for China:

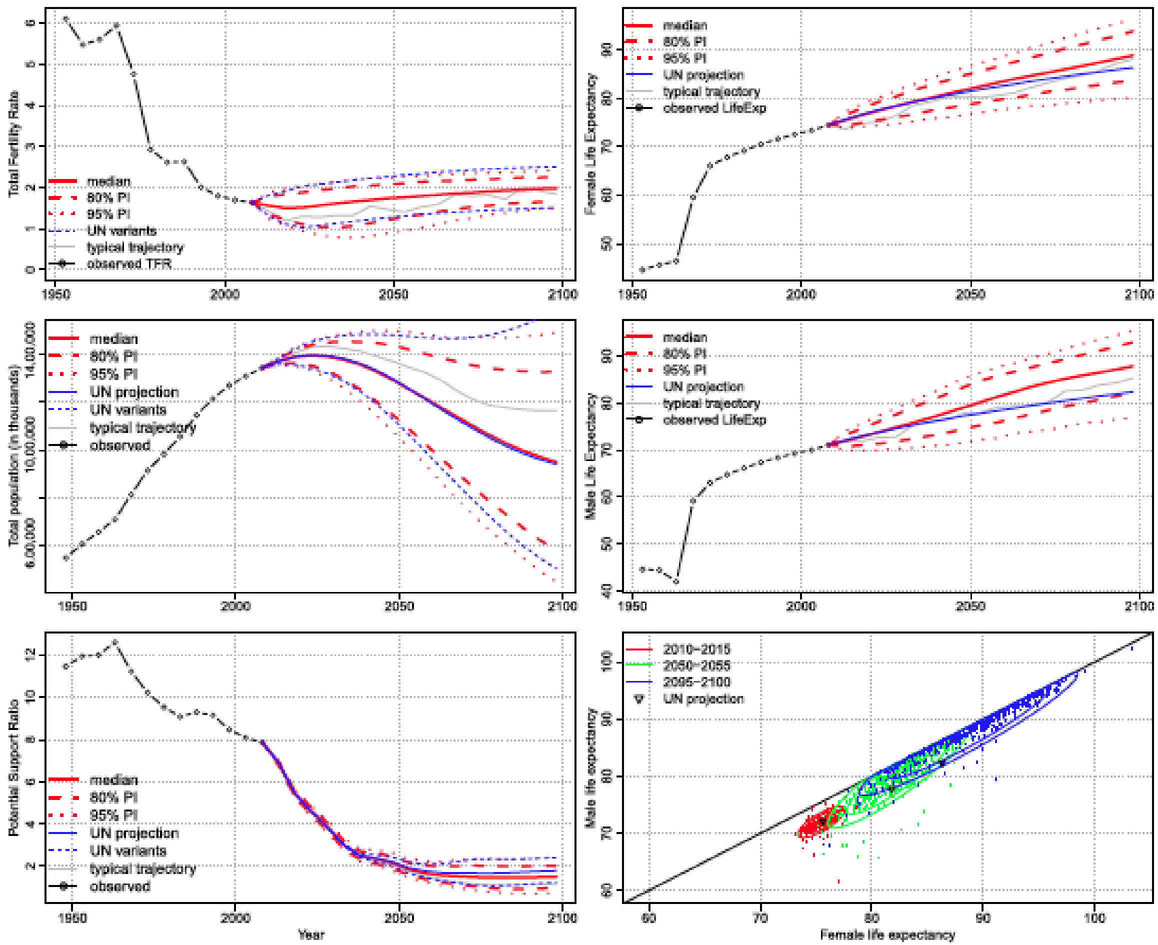


Fig. S3. Bayesian probabilistic population projections for China, 2010–2100: major population indicators. *Left*, *Top* to *Bottom*: total fertility rate; total population; potential support ratio (20–64 population/65+ population). *Right*, *Top* to *Bottom*: female life expectancy; male life expectancy; joint predictive distribution of female and male life expectancy for 2010–2015, 2050–2055 and 2095–2100. The Bayesian predictive distributions are shown in red: median—solid; 80% prediction interval—dashed; 95% prediction interval—dotted. The UN WPP 2010 projection is shown as a solid blue line. The typical trajectory is shown as a solid gray line.

Source: Raftery et al., *PNAS*, 2012.

Working the problem backwards

We all have a strong desire to work in the direction of the causal influences. For example, in the case of climate change:

GHG emissions → Δ climate → Δ impacts → Valuation of impacts

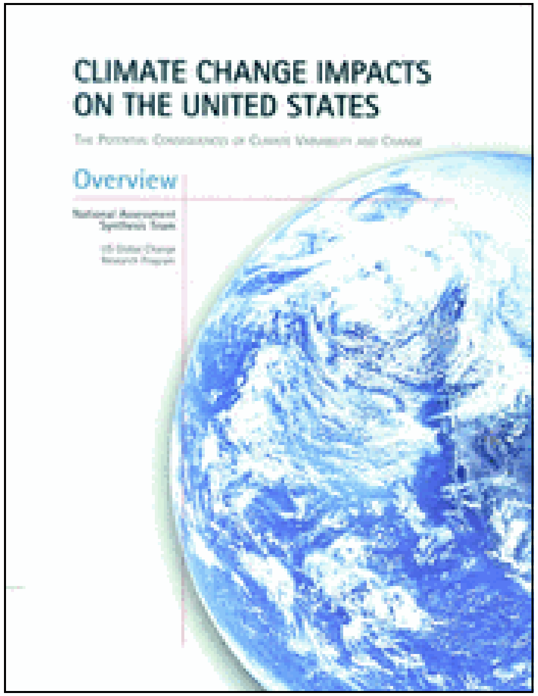
However, there is often so much uncertainty in the earlier steps that if we are honest, we get PDFs on the latter stages that are so broad as to be almost useless.

Sometimes a better strategy is to ask, what possible outcomes might we most care about, and then work backwards, to ask, what sorts of things would have to happen to lead to those outcomes (some of the tolerable windows work did this).

Backwards…(Cont.)

Many people find it *very* hard to approach things in this way.

For example, several of us tried to get the regional and sectoral groups to adopt such a strategy in the 2000 U.S. National Assessment but found that folks without significant analytical experience were not comfortable doing this. Nevertheless, I believe that the approach deserves serious consideration.



For details on the National Assessment experience see:
M. Granger Morgan, Robin Cantor, William C. Clark, Ann Fisher, Henry D. Jacoby, Anthony C. Janetos, Ann P. Kinzig, Jerry Melillo, Roger B. Street, and Thomas J. Wilbanks, "Learning from the U.S. National Assessment of Climate Change." *Environmental Science & Technology*, *39*, 9023-9032, 2005.

In today's remarks I will:

1. Provide some motivation and background.
2. State the problem I am addressing in general terms.
3. Consider why people persist in making deterministic forecasts when it is very clear that such forecasts are often close to meaningless.
4. Suggest some alternative strategies.
5. Conclude with a few thoughts on where we should go from here.

We need two things:

1. Better methods and worked examples that illustrate alternatives to making single-valued deterministic projections of quantities we know can't be accurately forecast.

2. A set of folks who are prepared to start using these methods so as to point the way to better practice.

On the first point:

As part of the work of our NSF center on climate and energy decision making, we are planning a small workshop for this spring that will focus on what sorts of time series it does and does not make sense to try to predict (as point/line estimates), and what alternative strategies we should be developing and promoting.

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WHAT CAN HISTORY TEACH US? A Retrospective Examination of Long-Term Energy Forecasts for the United States*

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■ **Abstract** This paper explores how long-term energy forecasts are created and why they are useful. It focuses on forecasts of energy use in the United States for the year 2000 but considers only long-term predictions, i.e., those covering two or more decades. The motivation is current interest in global warming forecasts, some of which run beyond a century. The basic observation is that forecasters in the 1950–1980 period underestimated the importance of unmodeled surprises. A key example is the failure to foresee the ability of the United States economy to respond to the oil embargos of the 1970s by increasing efficiency. Not only were most forecasts of that period systematically high, but forecasters systematically underestimated uncertainties. Long-term energy forecasts must make assumptions about both technologies and social systems. At their most successful, they influence how people act by showing the consequences ...g. They are useful when they provide insights to energy planners, influence ...ions of the public and the energy policy community, capture current under... f underlying physical and economic principles, or highlight key emerging ...onomic trends.

...ue that at best we see dimly into the future, but those who acknowledge ...uty to posterity will feel impelled to use their foresight upon what facts and ...g principles we do possess. Though many data are at present wanting or ...ful, our conclusions may be rendered so far probable as to lead to further ...ies... (1), p. 4.

Our hope is to build on previous work by folks like Craig et al. and develop recommendations and a research agenda.
We would welcome advice!

On the second point:

A set of folks who are prepared to start using these methods so as to point the way to better practice.

My sense is that we should not start by focusing on ministers, agencies like U.S. EIA or the IEA that routinely produce deterministic forecasts.

Nor would I expect many economists who do forecasting of economic performance to be very receptive.

Rather, once we have provided clear pointers to improve methods, we should begin to work on persuading the energy, climate, and other modeling and assessment communities to make greater use of such methods.

That is the way in which…

…uncertainty analysis was developed and spread throughout the risk analysis community over the course of the past 50 years.

Let's hope it doesn't take another 50 years to get improved methods adopted in the forecasting community.

But, as Laozi is reported to have said:

千里之行，始于足下

End

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