TechCast A VIRTUAL THINK TANK
TRACKING THE TECHNOLOGY REVOLUTION

TechCast Article Series

Report to the Environmental Protection Agency

TECHNOLOGY FORECASTS TO IMPROVE NATIONAL ENERGY MODELS

Submitted by TechCast LLC
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Editor's Introduction to this Summary for TechCast

This study was conducted for Skip Laitner of the EPA to demonstrate the feasibility of incorporating Delphi forecasts into National Energy Models. An extensive "trend/breakthrough analysis" was created for 18 technologies, and a panel of 32 experts was asked to review this background information and estimate when each technology would reach the 30% adoption level. The panel consisted of two groups: authorities in energy and environment, and a variety of more general experts. Of the 18 technologies, five that were considered especially energy intensive were also forecast at the 50% and 70% adoption levels, thereby sketching out complete adoption trajectories.

Results compared favorably to previous forecasts, and only minor differences were noted between the two groups of experts, confirming that the method produces results that are reasonably valid and reliable. A five-part approach was recommended for implementing this method in National Energy Models: 1) Form a small group to conduct the project, 2) Update the trend analyses periodically, 3) Update the expert forecasts periodically, 4) track the results, and 5) Work online.

The study provides a good example illustrating practical applications of the TechCast method. By pooling knowledge and iterating through this process, a "community of practice" constitutes a "learning system" capable of producing a "best possible forecast" based on "scientific consensus." The following is an abbreviated version of the report.

STUDY OBJECTIVES

TechCast was asked to conduct a demonstration project to explore the feasibility of using Delphi technology forecasts to improve the accuracy of national energy models used by the EPA in various policy exercises. These models include the Energy Information Administration's (EIA) National Energy Modeling System (NEMS), the Argonne National Laboratory's AMIGA Modeling System, the Pacific Northwest National Laboratory's Second Generation Model (SGM), and ICF Consulting's Integrated Planning Model (IPM). The goal was "to develop a list of 18-20 emerging technologies that are expected to significantly affect U.S. energy consumption … establish milestones that allow comparison among emerging technologies, including rate and magnitude of penetration into the mainstream."

The study team reviewed a wide range of emerging technologies and chose the 18 reported on here as being of greatest interest because they were deemed to have the greatest impact on energy use in the U.S. Of these 18 technologies, five were singled out for more intensive study because they are thought to be particularly energy intensive.

The study was conducted using the method developed by TechCast, an improved version of Delphi, consisting of two phases: 1) Summarize the best possible background information available and organize it into a "trend/breakthrough" analysis." 2) Move to a higher level by pooling the tacit knowledge and judgment of diverse authorities into forecasts.

RESULTS

The table below compares results between two different types of experts assembled for this study. 17 of the 32 experts were authorities in energy and environment, while the remaining 15 experts were technology forecasters, technology consultants, futurists, and other authorities. These two groups are identified as "EPA Experts" and "Other Experts." The results match very closely, usually within 1-2 years, which is why t-test scores show a significant difference in only two cases out of 18.

The forecasts and the distribution of the data conform to past experience quite well. TechCast forecasts show a standard deviation of 4.3 years, compared with the standard deviations reported here averaging 4.7 years. [1] The absolute forecasts figures also compare closely with other forecasts made by TechCast, highlighting again how variances are usually contained within a 4-5 year error band.

Data for the five technologies deemed energy-intensive extended these estimates for the 30% adoption level to include forecasts of the 50% and 70% levels. Attempting to forecast complete adoption trajectories is ambitious, but the results show that standard deviations and expert confidence levels remain in the normal range, which is assuring.

[1] www.TechCast.org

We also note that the expert confidence levels reported here generally run well above 50%, which is also comparable with our previous results and shows reasonably high support by the expert panel. It should be stressed that ***expert confidence levels*** are not to be confused with ***statistical confidence levels***. In addition to providing forecasts, experts are asked to judge the confidence they place in their estimate on a scale of 0 to 100%.

Aggregated comments from the expert panel made useful points. For instance, there was a recognition that political forces play a central role in energy use. Many thought the adoption of "Green Business" practices and other issues need better definition. Many experts thought adoption of various e-commerce practices will hinge on resolving the security issue.

CONCLUSIONS AND RECOMMENDATIONS

This demonstration study was shown to match previous forecast data quite well and found little difference between two groups of experts. We conclude with good confidence, therefore, that the method produces stable results that are reasonably valid, and it should be considered a useful complement to more traditional forecasting approaches.

The significance of this controversial step is to move the development of national energy models up a notch. Energy models were traditionally based on extrapolated trend data and other quantitative methods, avoiding subjective approaches like Delphi that involve uncertainty. As we argued elsewhere, however, quantitative forecasts also produce great uncertainty, and possibly even greater uncertainty, although it is not usually visible. The most effective approach is to include quantitative forecasts in the trend/background analyses and then allow a panel of experts to use their judgment in reaching the most likely estimates.

The net effect is that energy models would synthesize the total knowledge available, including both quantitative and judgmental methods. And if this process can be iterated, the group of experts becomes a "community of practice" using an online "learning system" to create a higher level of knowledge. When done well, results could approach that ideal of a "best possible forecast" based on the "scientific consensus" that results.

Drawing on this approach, the ideal method recommended for national energy models would consist of the following components:

1. **Plan the Project** The project should be planned to incorporate Delphi forecasts within the present modeling framework, and a small group designated to assume responsibility for conducting the project on a continuing basis. Plans should include defining methods for transforming the forecast data into inputs for the more conventional models.

3. Update Trend/Breakthrough6. Analyses Incorporate comments from experts and gather new background information continually, updating the analyses every year or so.

4. Update Expert Forecasts The panel should be provided the updated analyses described above as well as the most recent forecast data to assist in improving their judgments, and asked to update their forecasts.

5. Track Forecasts After data has been gathered for a few years, it would be useful to provide experts with a more sophisticated level of analysis where adoption curves and forecasts are tracked over time.

6. Work Online Finally, we recommend that this entire process should be conducted online, preferably using a dedicated website.

Table 1

Comparison of Results between EPA Experts vs. Other Experts

Technology	T Test (%)	EPA Experts (N = 14 to 17)			Other Experts (N = 12 to 15)		
		Most Likely Year		Expert Confidence (%)	Most Likely Year		Expert Confidence (%)
		Mean	Std. Dev.		Mean	Std. Dev.	
Broadband	33	2005	4.3	72	2004	1.9	83
Online Finance	70	2009	4.9	54	2008	4.1	72
Business-to-Business (B2B)	71	2010	1.6	56	2009	3.8	66
Wireless	26	2010	5.2	53	2008	4.4	71
Entertainment-on-Demand	19	2011	3.0	57	2010	2.8	64
Green Business	77	2012	4.7	58	2009	3.4	72
E-Government	49	2012	3.4	47	2011	4.4	62
Telemedicine	48	2012	7.5	57	2014	4.0	61
Global Grid	59	2013	6.1	52	2015	8.9	69
Teleworking	92	2014	4.1	44	2014	6.3	61
E-Tailing *	3	2016	4.1	49	2012	3.4	63
Alternative Energy	27	2016	6.4	58	2018	6.5	61
Online Publishing	70	2016	5.1	48	2016	5.2	58
Virtual Education	33	2018	3.8	46	2018	6.1	59
Hybrid & Fuel Cell Cars	68	2019	3.3	53	2019	4.7	59
Distributed Power	43	2020	5.8	56	2022	5.1	59
Organic Farming	59	2021	3.8	43	2020	6.2	58
Nanotech *	2	2021	3.6	47	2015	5.8	56

* Statistically significant difference