The Value of Seasonal Climate Forecasts in Managing Energy Resources

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ABSTRACT

Research and interviews with officials of the United States energy industry and a systems analysis of decision making in a natural gas utility lead to the conclusion that seasonal climate forecasts would only have limited value in fine tuning the management of energy supply, even if the forecasts were more reliable and detailed than at present.

On the other hand, reliable forecasts could be useful to state and local governments both as a signal to adopt long-term measures to increase the efficiency of energy use and to initiate short-term measures to reduce energy demand in anticipation of a weather-induced energy crisis.

To be useful for these purposes, state governments would need better data on energy demand patterns and available energy supplies, staff competent to interpret climate forecasts, and greater incentive to conserve. The use of seasonal climate forecasts is not likely to be constrained by fear of legal action by those claiming to be injured by a possible incorrect forecast.

1. Introduction

Scientific developments may lead to a reliable operational capability for qualitative prediction of gross weather patterns over the continental United States three months in advance. While funding of scientific research which could lead to a high degree of skill in seasonal, and monthly, forecasting is significant, there has been until recently little study of the societal implications of this scientific research. The few studies available have focused mainly on the economic impact of weather forecasting, primarily for agriculture (McQuigg, 1968; Thompson, 1972; Murphy, 1977). One exception was the study by Glantz (1977) on the value of a long-range weather forecast for the West African Sahel region. More recently, the World Climate Conference (WMO, 1979) and subsequent World Climate Program (WMO, 1980) have recognized the importance of assessing the impact of climate on energy management, and the United States National Academy of Sciences Climate Research Board has turned its attention in this direction (NRC-NAS, 1980, 1981).

The winter of 1976–77, with its attendant natural gas crisis, demonstrated vividly the vulnerability of our economy to climate fluctuations, and many wondered what could have been done if we had anticipated the severe winter weather. The instant study addresses the problem of what difference a seasonal forecasting capability would make in managing energy resources, specifically oil and gas resources.

To answer this question, I initiated a multidisciplinary study, involving expertise in meteorology, applied physics, statistics, systems analysis, water resources engineering, political science, political economy and law. We gathered and analyzed data about the following: the status of seasonal climate forecasting; the effect of weather on natural gas and residential electricity demand in different seasons; the effect of weather on consumption of cooling water by electric power plants; the process and basis for making supply decisions in the private energy sector, and the extent to which they are weather-sensitive; federal and state policies for managing oil and natural gas supplies and energy demand; and the international dimensions of seasonal climate forecasting. This article presents the overall results of the study. I was the principal investigator for the study, and my former colleagues at Princeton University, L. Kirschner, D. Morell and E. Wood, carried out parts of the research for this article. The results from other parts of the study are reported elsewhere (Fels and Woteki, 1980; Goldberg, 1980; Greis, 1980; Weiss, 1981a,b).

In this study we originally assumed that the major usefulness of seasonal climate forecasting in the energy field would come in the management of supply. But we found that it had limited utility here. Instead, as fuels become scarcer and the prices for them rise, seasonal forecasting may have greater utility for managing demand.

2. Supply management by industry

In line with our assumption that the major usefulness of seasonal forecasts would come on the supply side, Kirschner and I reviewed the management

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and financial literature concerning how the energy industry makes decisions and runs its supply management operations (Bradford, 1975; Sampson, 1975; Blair, 1976; Engler, 1976; Simon, 1977) and conducted multiple interviews from 1977 to 1980 with representatives from seven oil companies, the three interstate natural gas pipeline companies servicing New Jersey, the major utilities in New Jersey, New York and Washington, DC, several independent producers and refiners, and relevant trade associations. What we found was quite different from what we had expected: seasonal forecasts have limited value to the private sector in managing supply.

Most of the major decisions that the oil and gas industries make are concerned primarily with corporate investment and management strategy and are not weather-sensitive. These include decisions concerning diversification of the industry, production, investment, and construction of additional refining capacity. Other decisions are highly weather-sensitive, but the relevant time frames are short-term (hours to days). These include decisions related to the daily operations of offshore drilling and production and to the curtailment of natural gas supplies to low-priority pipeline customers in time of shortage.

The private sector does make a number of decisions in managing supply which are, at least to some degree, weather and climate-sensitive on the time frames of a season to a year. But most of these decisions are not well-suited to the present characteristics of seasonal forecasts. In particular, present seasonal forecasts have zero lead-time, i.e., the forecast is issued at the beginning of the three-month season, or at the beginning of each month, for a monthly forecast. They predict only average temperature for the season, and do not indicate concentration and duration of abnormal weather within the period. They are limited in the winter season to a three-month interval, rather than the five-month interval that industry uses. While extending the lead-time for issuing the forecast may soon be possible, predicting periods of abnormal weather within the season is not thought to be. Moreover, if industry were to rely on seasonal forecasts, they would have to be substantially more reliable than at present. As with other technological innovations, it is difficult to determine precisely what reliability would be required, and answers vary from industry to industry and from company to company within an industry, depending in part upon the institutional context of the industry and the management practices of the company.

If supplies of crude oil and natural gas become scarcer and costlier, reliable forecasts could potentially be useful to the private sector in fine tuning its supply management operations. (Recently, however, crude oil prices have stabilized, and indeed ample supply and lessening demand have caused prices in the official OPEC and spot markets to drop slightly in the last six months, which reduces the incentive to industry to turn to seasonal forecasting). Even though forecasts could have value for fine tuning certain operations, a major disruption caused by events unrelated to weather—e.g., a halt in oil exports from a Middle East supplier, OPEC price increases, suspension of foreign supply contracts for liquified natural gas—will have a far greater impact on supply than will the additional efficiency in operations that might be added through seasonal forecasts.

Having said this, seasonal forecasts could still be used to increase the efficiency of the following aspects of industry operations: exploration for oil and natural gas, calculations of refinery product mixes, transport of fuels, pipeline supply and storage operations, and utility load management.

First, seasonal forecasts could be useful in the timing of specific tasks connected with exploration for oil and for natural gas, e.g., for leasing equipment and making other contractual arrangements and in planning for the transport of people and equipment into an area. Oil companies now use climate "windows" to plan offshore drilling operations in areas with severe weather. These windows are currently based on historical data. Although seasonal climate forecasts are unlikely to affect the basic decision of whether to explore at a particular site, they could be important for adjustments in the timing of operations, the use of equipment, the allocation of manpower and safety. Delay is costly and tools for avoiding it could have a high economic pay-off.

Second, forecasts may have increasing utility to the downstream operation of oil companies (refining, transporting, and marketing). In particular, forecasts could assist in fine tuning the planning and setting of refinery product mixes if certain limitations in the current state of the art could be overcome. Seasonal forecasts could be used, instead of historical degree-day data, in drawing up winter plans for product mix. But for such purposes, forecasts would need to be available in the summer for the entire winter season, October/November through March, and would need to be quantitative, or at least substantially more refined than "above normal," "normal" or "below normal."

Similarly, during the winter season, monthly forecasts could be used to adjust the proportions of refinery product mixes as the season progresses. But if forecasts are to be used for this purpose, it would be particularly important to be able to predict the distribution of temperatures within the period. Otherwise very cold or very warm spells at the beginning of a season could skew the calculations of demand for the remainder of the season. A further limitation in the usefulness of forecasts arises from the fact that forecasts which indicate changes in estimated demand for products would not necessarily result in changes in refinery product mixes. There are many factors which limit the flexibility of a refinery to change its product mix, such as the types of crude oil available to the refinery and the costs of conversion from one product to another.

Third, forecasts may be useful in directing the international transport of fuels or the national transport of petroleum products. If additional fuels are needed in a region, tankers could be routed in response to need, or if regulations were not a bar, companies could exchange supplies to satisfy their needs. The current forecast time frame of 90 days is appropriate for this use, but since the oil market is international, the forecasts should be international in scope. Monthly forecasts are relevant for transporting products within the United States. If rivers are predicted to freeze, product inventories carried by barge can be shipped before the freeze. If regions are predicted to suffer very cold spells, inventories can be built up in the terminals.

Fourth, seasonal forecasts might be useful to certain interstate pipeline companies in planning the timing of withdrawals from storage during the winter season or in anticipating the timing of customer demand for the supplies for which they have contracted. Those pipeline companies which allow customers significant flexibility within the five-month winter period as to when they will call for their contracted supplies or withdraw them from storage, depend for their planning entirely upon utilities' estimates of their own demand. Seasonal forecasts could provide such companies with a tool for developing their own capability to estimate the timing of the demand by their customers. But for a forecast to be most useful in this capacity, it should cover the entire winter season (November–March) and should indicate the distribution of severe temperature within the interval, the duration of such periods, and approximate intensity of temperature anomalies within the period, which is well beyond our present and near-term forecasting skill.

Fifth, seasonal forecasts may have limited value to utilities in planning for adequate supplies. Some utilities have long used historical weather and climate data (more than 100 years of data) to develop a design winter plan to accommodate a "worst case" scenario for the winter, which they call the design winter plan. Seasonal forecasts could be used instead, but the costs of error would be great if the utility relinquished the security of reserve supply that comes with design winter planning. Forecasts may be useful in long-term forecasting, and in short-term load forecasting operations. But the forecasts would have to be very reliable before they would make a difference in present utility operating rules.

As part of our research program, Eric Wood constructed a systems model of the behavior of the Elizabethtown Gas Company in managing its gas supply in response to climatic variability, whether foreseen or not. The utility anticipates normal climatic variability primarily by storing gas in excess of average need in old gas fields, and delivering it by its normal pipelines when needed. The utility responds to unexpected cold spells either by using synthetic natural gas from its own plant, which is expensive but available quickly, or by purchasing so-called "emergency contracts" from pipeline companies, which provide additional supplies quickly but at higher cost. Supply managers try to minimize the costs to the company of storage, of synthetic natural gas and of emergency contracts, but above all, they try to insure that the demand for their gas is met.

Wood and his collaborator, T. Peter, used a network flow optimization model for their analysis, and solved it by the out-of-kilter algorithm. They simulated the behavior of the utility during each of 20 five-month heating seasons and calculated a penalty function to represent the costs to the utility of the measures it had to take to meet unexpected increases in demand and the costs to the consumer when demand was not met. They then simulated the behavior of the utility on the assumption that it had had a prediction of whether the winter would be warm, normal or cold—taking into account the fact that the prediction might not be right—and looked to see whether any penalty had been saved by the utility. The results were quite devastating to our original assumption that seasonal forecasts would be very useful for supply management in the private sector. Utilities hate to fail to meet demand—in the jargon, they are risk adverse on the downside—and thus a seasonal forecast that predicted a warm winter did not alter the operating rules of the simulated utility. For other forecasts, the value of the information was highly sensitive to forecast accuracy. Only highly accurate forecasts for average or colder than average winter weather were shown to have value. My subsequent interviews with other utilities have substantiated these results.

3. Supply management by government

My next step was to examine the use of seasonal forecasts to the public sector, both to the federal government and to state governments. For data on the latter, I have primarily used the States of New Jersey, Maryland, Virginia, New York and the District of Columbia.

The results parallel those we obtained for the private sector, and suggest that seasonal climate forecasts are likely to have only limited value for public sector management of supply. Because they are only seasonal, they are not appropriate instruments for long-term planning of energy supply. For shorter-term management of supplies, the federal government defers largely to the private sector, unless there is an emergency.

The federal government has had considerable statutory authority to manage supply in times of crisis. (The lapse of the Emergency Petroleum Allocation Act and the Energy Policy and Conservation Act on 30 September 1981 greatly reduces this authority.) The government has been cautious about using its emergency authority, partly because of political constraints. When Iran suspended its export of oil from 26 December 1978 to 5 March 1979, the federal government acted only after the private sector had made its adjustments to changes in supply. In such situations seasonal forecasts with a zero lead-time are not a timely tool for public sector management of supply.

The federal government has traditionally been more involved in the regulation of the natural gas industry than the oil industry. Accordingly, seasonal climate forecasts might be of more direct usefulness to government in this area. For example, were reliable seasonal climate forecasts to become available, it might be possible for the federal government to use them as an informational and educational tool to alert natural gas customers to impending weather severity. This could, for example, assist industrial users of natural gas in particular in planning for the use of any alternate fuel capability. As things now stand, winter forecasts and retrospective seasonal weather data are mainly available for the Federal Energy Regulatory Commissioners to use in adjudicating cases involving the necessity for emergency purchases of natural gas.

4. Demand management

To date, attention has focused almost exclusively on the role of seasonal forecasts as a supply management tool. Indeed, the design for this research program initially focused on the utility of seasonal forecasts to supply management in the private and public sectors. But the major conclusion of our research is that as our supplies of oil and natural gas become scarcer, seasonal forecasts may have utility to the public sector in managing the *demand* for these fuels, and only to a lesser extent, to the private sector in managing their *supply*.

For this reason, the emphasis of the study shifted after June 1980, to the question of how seasonal forecasts might be used to manage energy demand. Briefly, it appears that seasonal climate forecasts could be useful both as a signal to adopt long-term measures for increasing the efficient use of energy and to initiate short-term measures to reduce energy demand in response to a crisis. Knowledge of a forthcoming severe winter, for example, could be a signal to begin rather simple conservation measures in existing housing stock, in commercial office buildings, in industry, in transportation systems and in utility operations. In response to a forecast of abnormally severe temperatures, for example, the public sector could encourage or mandate a variety of temporary measures to reduce demand.

Seasonal forecasts would be most effective in both long-term and short-term management of demand if they were combined with a monitoring program which would both anticipate the effects on energy demand of the weather conditions forecast and monitor the effects of the conservation effort. Forecasts could be particularly useful tools for local, state, or regional public authorities, who are well situated to use the forecasts to encourage or to initiate conservation measures appropriate to anticipated weather conditions in that region.

To investigate how forecasts might be used to manage energy demand, I reviewed the literature concerned with energy conservation and with federal and state efforts in energy management, and then in collaboration with J. Bennett, interviewed federal officials, state officials in five Northeast and mid-Atlantic states, and county officials in some of these states.

Our results indicate that seasonal forecasts could have value to state governments, local governments, and even to utilities in their efforts

- to encourage energy efficiency;
- to plan for and implement emergency measures to reduce energy consumption; and
- to help programs to assist low-income consumers meet increased energy bills.

A primary use for seasonal forecasts is as an educational and informational tool to alert citizens to the need to conserve energy voluntarily, and to the value to them of doing so. Appropriate government agencies and local utilities can emphasize the higher energy consumption levels that accompany abnormally hot or cold weather and can promote measures designed to reduce energy consumption. There are many fairly easy steps that individuals can take to reduce energy consumption in a home or business, such as using drapes and shades to control heat loss, putting plastic around windows to supplement storm windows, insulating hot water heaters, inspecting the furnace to be sure it is operating efficiently and replacing pilot lights with automatic intermittent ignition systems. These are steps which consumers ought to take anyway. A seasonal forecast of a severe winter, for example, serves as a further catalyst. Similar arguments apply to the commercial sector.

A seasonal forecast can also have value as a signal to begin emergency planning. A forecast of an abnormally cold winter or hot summer could be used, in conjunction with supply data, to decide what measures should be taken to prevent a climate-induced shortage from turning into a crisis. Emergency plans for restraining demand could include mandatory restrictions on end-users, compressed work weeks, closures of public buildings, restrictions on vehicle use and load reductions by public utilities. Some emergency measures could be implemented when the forecast appeared, and more drastic measures could be reserved for later use if the shortage worsened. For example, industries could be encouraged to start conserving energy in advance of a crisis by promising them exemptions from later mandatory measures, such as compressed work weeks or building closures.

Seasonal forecasts could also be useful in implementing federal or state programs designed to assist low-income consumers meet increased energy bills, such as the federal program initiated under the last Administration. The administrative apparatus for the program could be put into place when the seasonal forecast appears, and eligible applicants could be certified early, to minimize the lag time between receipt of home heating bills and disbursement of funds. A seasonal forecast could provide a cue to increase the voluntary weatherization program for low-income citizens. Eligibility for fuel assistance payments could be linked to participation in the weatherization program, at least when the payments would result from increased energy bills due to unusually cold temperatures.

5. Constraints on forecasts for demand management

While seasonal forecasts potentially have significant value to states in managing energy demand, there are factors which will significantly limit this value in practice.

a. *Characteristics of forecasts*

One set of factors relates to the present characteristics of the forecasts: namely, their reliability and the lead-time with which they are issued. Most governmental officials interviewed indicated that present reliability was not high enough to warrant initiating substantial public measures to restrain demand. However, if consumers respond to a seasonal forecast by taking measures to conserve energy which involve minimal personal inconvenience, and in many instances yield long-term benefits to the consumer, the real cost incurred by consumers would be small, even if the forecast were in error. Further, if state energy offices, or public utilities can provide data showing savings in dollars by those who have taken various energy conservation measures, consumers will be more likely to respond to a public appeal to conserve which is based on a seasonal climate forecast, and less likely to complain if the winter is not as cold as predicted. Efforts are underway by states and some utilities to show such savings. Certainly, a major danger of an incorrect forecast is that the credibility of state energy offices that rely on it will suffer and that the public might not respond to future appeals based on a seasonal forecast. While this is a problem, it should not be over-emphasized by politically sensitive state planners.

The error of greatest political concern to state energy planners is what I call the "two-class error:" a winter which is forecast to have above average temperatures, which turns out to be below-average, or a summer which is forecast to have below normal temperatures, which turns out to be significantly above normal. Officials are not willing to take political responsibility for initiating significant measures to restrain demand, if they run the risk of falling victim to such two-class errors. D. Gilman of NOAA graciously provided us with seasonal forecast prediction and observation data from December 1969 through March 1980. N. Greis and I reviewed winter and summer temperature forecasts for this period and found that forecasters had a significantly better record in avoiding such errors than the general skill score for seasonal forecasting would suggest. Of the 21 forecasts considered, six displayed these so-called "two-class" errors. The six classes were bunched in the years 1972, 1977 and 1978. If political figures are to rely on seasonal forecasts, it is most important to minimize the chances of a "two-class" forecast error.

The other characteristic of present seasonal forecasts which will limit its value to states in managing energy resources is the zero-lead time with which they are issued. Seasonal forecasts are now issued on the first day of a season, for the following three months. (A monthly forecast is also available on the first day of each month.) Should the severe weather occur in December, there is virtually no time in which to plan and implement measures to restrain demand. However, if the severe weather should occur near the end of the three month period, or if capability to predict the season's weather three or six months in advance of the start of the season were available, there would be sufficient lead-time to institute many of the energy conservation measures described above. Discussions with state and local government energy officials indicate that there is also a maximum "political lead-time" which would prevent any action to implement a voluntary program more than two or three months in advance of a season. This lead-time results from a perception that it would be futile to try to focus public attention on the possibility of bad weather six months hence, and that it would be impossible to sustain public interest for such a long period of time.

On the other hand, even a forecast with zero lead-time could be useful in energy demand management as a trigger for implementing emergency measures to reduce demand temporarily. Past experience indicates that mandatory measures will not be imposed until the crisis is apparent to the public and there is strong evidence of need to support a politician's choice of an unpopular move.

b. Capability to use forecasts

A second constraint is that many state government agencies do not have the capability to use information that the forecast provides. The state energy programs emphasize communication and education, not research or technical programs. Staff members may not have scientific or technical backgrounds, and those who are data-oriented may find themselves overwhelmed by the work necessary to comply with the data-collection requirements of federal legislation. Staff members without technical training may not understand the information that is conveyed by a seasonal climate forecast, what data the forecasts are based on, or how the reliability of the forecast is assessed. This will limit the extent to which they are willing to use the forecasts.

c. Data system for energy supply and demand

A third constraint is that states lack sufficient data on the energy supplies that will be available to them at any given time. This hinders planning for restraining demand in response to a forecast of severe weather and implementation of the plans. States cannot ask citizens to restrain demand at personal sacrifice and expense unless they know that the supplies to the state will be inadequate to meet anticipated demand. With regards to oil, states receive supply projections from oil companies on a monthly basis, but the states interviewed found reports frequently inaccurate even on short-term predictions, e.g., the gasoline shortage of 1979.

The situation with regard to natural gas is more complicated because states need to have access to a seasonal forecast not only for the state itself but for the routes of each interstate pipeline company serving the state. They also need to know the customer profile for each company, in order to anticipate whether there will be high residential demand in other areas along the pipeline that could cause supplies to utilities in the state to be curtailed.

d. Institutional barriers

There are also institutional constraints which would diminish the value of seasonal climate forecasts for managing energy demand. Some of these constraints can and should be eliminated; others appear to be intractable. At the federal level, the United States Government has established the Emergency Energy Information Management System (EEIMS) to provide supply and demand data about energy resources. However, certain critical data have yet to be put in the system, and there is little consultation between this system and either the federal conservation effort or the state energy conservation programs. Yet effective public sector use of seasonal climate forecasts would be greatly benefited by such data. This means that if we retain the system, we should facilitate access to it and coordinate with federal and state conservation programs.

There are also institutional barriers at the state level to effective use of seasonal forecasts. Few states have the powers necessary to shift supplies within the state to meet demand. New Jersey, for example, is one of the few states to have the power to authorize sharing of supplies between distributors in the state in times of shortage. The absence of such authority would limit a state's ability to respond to forecasts that predict, for example, a natural gas shortage in the state.

States lack incentives to undertake serious conservation efforts. States would like to have ways to keep "conserved" fuel within the state, rather than have it shifted into another state along the pipeline, which may not even be conserving fuel. States are wary that an all-out conservation effort may not make a difference in energy sufficiency within their state, because they have little control over supplies coming into their state. If they are to be encouraged to conserve, national programs for allocating fuels to states should reflect state efforts at conservation. Programs which are based on fuel consumption rates can penalize those states that have made a conscientious effort to lower fuel consumption. For seasonal climate forecasts to have value to states in managing energy demand, careful attention needs to be given to the incentives that political institutions give or do not give to states to conserve and to reduce demand.

e. Liability for erroneous forecasts

If states were to use seasonal forecasts in managing energy resources, questions concerning liability for erroneous forecasts could arise. A careful review of the cases concerned with liability of the federal government or of state governments for weather forecasts or river flow forecasts indicates that liability will not be a significant constraint upon seasonal forecasting. Almost all of the cases which concern liability of the United States for negligent weather forecasting have involved the Federal Aviation Administration and airplane crashes. Most of these cases involved negligence in reporting weather conditions to pilots, and only two involved the more narrow question of the liability of the United States for an erroneous forecast. In neither case, did the court impose liability. *Gill v. United States*, 429 F.2d 1972 (1970) and *Complaint of Stewart Transportation Co.*, 435 F. Supp. 798 (1977).

Several cases have involved liability for incorrect forecasts of hurricanes. *Carrier v. United States*, 369 F.2d 322 (5th Cir. 1966), *Bartie v. United States*, 216 F. Supp. 10 (W.D. La. 1963), *aff'd* 326 F.2d 754 (5th Cir. 1964), *cert. denied* 379 U.S. 852 (1964); *Chanon v. United States*, 350 F. Supp. 1039 (S.D. Tex. 1972), *aff'd* 480 F.2d 1227 (5th Cir. 1973). In none of these cases did the courts find negligence. One case in the federal courts, and one in the state court of California, have raised the issue of liability for erroneously forecasting the effect of weather on river levels. *National Manufacturing Co. v. United States*, 210 F.2d 263 (8th Cir. 1954); *Connelly v. State*, 3 C.A. 3d 744 (5th Dist. 1970). The former case raised the issue of liability of the federal government for a publicly disseminated forecast of anticipated levels of a river subject to federal flood control. The court denied liability, by relying on a clause in the 1928 Flood Control Act, 33 U.S.C.A. §702c, which provided immunity from liability.

By contrast, in the *Connelly* case the court found liability for an incorrect river height forecast. There, the plaintiff had spoken with the state government employee and communicated his special needs for the forecast. He explained that he had to tie his marina at an appropriate level or it would be damaged. The agency assured him that the river would not rise above 24 feet. When the river, four hours later, rose to 29 feet, it damaged his property and he sued to recover. The court found that the state agency had a duty to proceed with due care in making the forecast to Connelly. The *Connelly* court distinguished between the dissemination of public information of a non-personal nature, which the concurring opinion in *National Manufacturing* said is at common law "without any basis of tort in respect to its accuracy," from the fact pattern in *Connelly* where the plaintiff had dealt on a one-to-one basis with the government. The latter created a duty at common law to proceed with due care.

With regard to liability of the federal government for erroneous weather forecasts, the Federal Tort Claims Act, 28 U.S.C. §1346(b) (1952) allows suits against the government for tortious conduct but this does not apply to cases in which the government is exercising a discretionary function. While the decision whether to issue weather forecasts comes within this exception, courts have found that the operation of weather forecasting is outside the scope of this exception. These courts have relied on *Indian Towing Co. v. United States*, 350 U.S. 61 (1965), in which the United States Supreme Court found liability when the federal government was performing the public service of operating a lighthouse and negligently failed to keep it in proper repair. In this case, the Court said that "one who undertakes to warn the public of danger and thereby induces reliance must perform his Good Samaritan task in a careful manner." *Indian Towing Co. v. United States* at 64–65. Weather forecasting, like operating a lighthouse, must conform to standards of due care. But United States liability would have to be based on more than just an error in judgment in making the weather forecast. In *Chanon v. United States*, 350 F. Supp. 1039 (1972), the court, in dictum, indicated that a weather report that is "reasonably accurate" and based on "reasonable methods of compilation" should not by itself be the basis of liability, even if the forecast is erroneous. Even if a party could show negligence in formulating the forecast, the court would still have to find that this negligence was the proximate cause of the injury, which will be difficult to prove. These issues are being litigated in *Honour Brown v. U.S.*, Civil Action No. 81-168-T, United States District Court for Massachusetts, in which a widow alleges that NOAA, by relying on inaccurate/insufficient data from a badly maintained weather buoy, negligently failed to forecast the storm off the coast in which her husband drowned.

In the case of seasonal forecasting, a possible further bar to liability would be the misrepresentation exception to the Federal Tort Claims Act, which precludes suits deriving from the misrepresentations of government employees. While *Connelly* and other cases have indicated that actions for physical injuries caused by incorrect weather forecasts are outside the scope of the misrepresentation exception, the seminal case of *United States v. Neustadt*, 366 U.S. 696 (1961) suggests that courts could treat seasonal climate forecasts differently. *Neustadt* distinguishes between cases where the damages are physical and those where they are purely economic, and concludes that the tort of misrepresentation, and thus the exception, encompasses only those communications which lead to mere economic harm. Erroneous seasonal forecasts which could only reasonably lead to economic harm, might thus fall within the exception to liability.

The analysis outlined above leads to the conclusion that at least in the near-term, governmental liability for incorrect seasonal forecasts should be a negligible problem. It will not constrain the development, dissemination and use of such forecasts.

6. Conclusions

As our supplies of oil and natural gas become scarcer, seasonal climate forecasts could have some limited utility to supply management, but most decisions on the supply side are ill-suited to the present characteristics of the forecasts. The greatest potential value for the forecasts is to the public sector in managing the demand for these fuels. Here the characteristics of present forecasts are more acceptable. Forecasts may be most useful to *state* and *local* officials in managing demand, and state climate offices may be useful in this effort. But the apparent value of the forecasts must be tempered by an appreciation of the political and institutional constraints on using the forecasts effectively in the public sector.

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REFERENCES

Blair, J., 1976: *The Control of Oil*. Pantheon Books, 441 pp.

Bradford, P., 1975: *Fragile Structures, A Story of Oil Refineries National Security and the Coast of Maine*. Harper and Row, 392 pp.

Engler, R., 1976: *The Politics of Oil; A Study of Private Power and Democratic Directions*. University of Chicago, 565 pp.

Fels, M., and T. Woteki, 1980: Indices of energy consumption: An exploratory analysis of a utility's monthly billing data. *Energy*, **5**, 1117–30.

Glantz, M., 1977: The value of a long-range weather forecast for the West African Sahel. *Bull. Amer. Meteor. Soc.*, **58**, 150–158.

Goldberg, M., 1980: Residential energy consumption: Use of aggregate data to measure physical properties of housing stock. Rep. PU/CEES 105, Princeton University, 126 pp.

Greis, N., 1980: Water demand by the electric power industry: A weather sensitive analysis. Dept. Civil Engineering, Princeton University, 148 pp.

McQuigg, J., 1968: A review of problems, progress and opportunities in the use of weather information. *Agroclimatological Methods*, UNESCO, 175–185.

Murphy, A., 1977: The value of climatological, categorical and probabilistic forecasts in the cost-loss ratio situation. *Mon. Wea. Rev.*, **105**, 803–816.

National Research Council, 1980: *A Strategy for the National Climate Program*. National Academy of Sciences, 66 pp.

——, 1981: *Managing climatic resources and risks*. Report of the Panel on the Effective Use of Climate Information in Decision Making, National Academy of Sciences, 51 pp.

Sampson, A., 1975: *The Seven Sisters, The Great Oil Companies and the World They Made*. Viking, 334 pp.

Simon, H., 1977: *The New Science of Management Decision*. Prentice Hall, 175 pp.

Thompson, J., 1972: The potential economic benefits of improvement in weather forecasting. Dept. Meteor., California State University, San Jose, 80 pp.

Weiss, B., 1981a: International implications of seasonal climate forecasting. *Stanford J. Int. Law* **17**, 315–45.

——, 1981b: Seasonal climate forecasts and energy management, *Climate and Risk*, Mitre Corp., 5/1–36.

Wood, E. F., and T. D. Peter, 1979: A management model for a natural gas utility subject to seasonal demands. (Unpubl. report), 192 pp. [Available from the author.]

World Meteorological Organization, 1979: *World Climate Conferences, Declaration and Supporting Documents*, 50 pp.

——, 1980: *World Climate Programme 1980–1983*, 64 pp.