Go Back

Simulating the Patterns of Power Plant Construction in California

Andrew Ford
Program in Environmental Science and Regional Planning
Washington State University
Pullman, WA 99164-4430
USA

Phone: 509 335 7846
Email: FordA@mail.wsu.edu

April 2001

Abstract

This paper describes a system dynamics model to simulate the general patterns of power plant construction that might appear in an electric system with approximately the same loads, resources and markets as those in California. The simulations reveal that construction could appear in a steady, even fashion, causing power plants to come on line exactly in time to meet the profitability goals of investors. But this is not the dominant pattern. The more likely pattern shows construction lagging behind the growth in demand, allowing prices to climb to surprisingly high values during peak periods in the summer. When new power plants are completed, they come on line in great numbers causing a bust in wholesale prices. Electricity consumers would certainly benefit from a boom in construction. Unfortunately, waiting for the boom is a difficult challenge with the current mix of state and federal rules in California.

PART ONE. INTRODUCTION

California began to rethink its electric system in the early 1990s. Its electric rates were among the highest in the country, and it was just emerging from an economic recession. Large manufacturing companies began lobbying for the freedom to negotiate with different power suppliers. They found a receptive audience in the Governor and the California Public Utilities Commission (CPUC). Governor Pete Wilson believed that the utilities had become bloated under regulation. The CPUC believed that the traditional regulatory framework was "fragmented, outdated, arcane and unjustifiably complex." It voted to open the state's electricity industry to competition in December of 1995 (CPUC 1995).

California was one of many states rethinking the necessity of vertically integrated utilities with their monopoly privilege and their regulated rates. This approach had allowed the investor owned utilities (IOUs) to expand their transmission and distribution systems and to build the new power plants for almost one hundred years. The traditional view was that the utilities needed monopoly privilege and a regulated return if they were to finance the construction of billion dollar power plants with decade-long lead times. By the 1990s, however, the utilities were no longer looking to invest in large power plants. They were either acquiring generation from independent power producers, or they were looking to invest in the combined cycle (CC) technology shown in Figure 1.

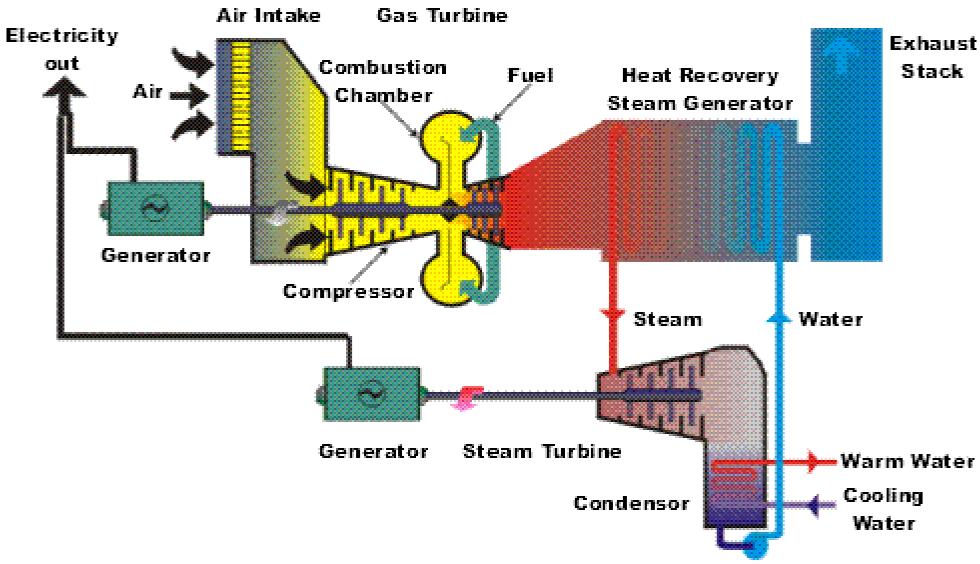

Figure 1. Schematic for a combined cycle power plant.

CCs were attractive on all fronts. They would burn natural gas much more efficiently than the existing steam boilers, and they released far fewer pollutants. More importantly, they could be constructed with small scale and with short lead time. The argument for large-scale investments was gone. CCs, and cheap natural gas to fuel them, had opened the door to deregulation in California.

Assembly Bill 1890

The shape of California's new industry was evident in the CPUC decision of 1995. There would be an independent power market, and the large utilities would be allowed to pass along an estimated $28 billion in "stranded costs." This would be a massive transformation. The parties were looking for a more permanent framework than an order from the CPUC. They turned to the legislature, and the legislators responded with Assembly Bill 1890. Legislators ratified the bill in a rare, unanimous vote in August of 1996:

Not one lawmaker voted against the bill
even though many had only a dim sense of how they were launching
what Sen. Steve Peace has called
the most complex transition of an industry anywhere in the world.

The new bill was signed by Governor Pete Wilson who declared confidently that

We pulled the plug on another outdated monopoly
and replaced it with the promise of a new era of competition.

AB 1890 was crafted in marathon negotiating sessions among the utilities, consumer advocates, power plant developers and other groups comprising a "stakeholder democracy" (CERA 2001). The final bill provided "something for everyone" (Richard and Lavinson 1996). One of its major provisions was 100% recovery of the utilities' stranded costs. Large customers were given direct access to energy providers in the near term, and small customers were to be protected with a retail rate freeze. AB 1890 also created two new organizations to promote wholesale competition in electricity generation: the Power Exchange (PX) and the Independent System Operator (ISO). The PX would create a financial market for day ahead and hour ahead trading of electric energy; the ISO would create a real time market for electric energy. These new organizations opened for business on March 31, 1998.

The peak demands occur in the summer in California, so the first major test for the new markets occurred in the summer of 1998. Both the energy markets and the ancillary services markets got off to a shaky start in the first summer. But the markets performed better in the summer of 1999, due in part to milder weather. The most severe test came in the summer of 2000. Severe price spikes appeared during heat waves in May and June, running up the total wholesale expenses of the distribution companies that were obliged to purchase electricity on behalf of their retail customers.

There were several reasons for the surge in wholesale prices. First, natural gas prices had doubled from the previous summer, and gas-fired units are typically the most expensive units bidding into the new markets. (The price is set by the highest bid to clear the market.) Consequently, a doubling of gas prices could lead to a doubling of the spot price for many hours of the year. Second, the growth in electricity demand from year to year created a tighter and tighter balance between demand and generating capacity. A third contributing factor was the surge in the market price of emission credits which drove up the cost of older gas-fired units by as much as 20-30 $/MWhr.

These three factors accounted for a substantial part of the price increases in the summer of 2000. But they do not tell the whole story. The remaining factor is strategic behavior by the generating companies. Strategic behavior can take the form of withholding units during periods of tight supply or by submitting bids well above variable costs. Strategic behavior was evident in the summer of 1998, less evident in the summer of 1999. By the summer of 2000, it was staggering. California officials argued that the wholesale markets were "dysfunctional" and the Federal Energy Regulatory Commission agreed

Never has this commission had to address such a
dramatic market meltdown
as occurred in California's electricity markets this summer

James Hoecker, Chairman FERC

If California was experiencing a “meltdown,” then San Diego Gas and Electric Company (SDG&E) was “ground zero” for the disaster. Its retail customers were the first to feel the effects of wholesale price spikes; their electric bills increased by 300% from the previous summer. Southern California Edison (SCE) and Pacific Gas and Electric Company (PG&E) felt the impact in a different manner. Their rates were frozen under the AB 1890 transition rules, but they were obliged to purchase electricity on behalf of their customers in the wholesale markets. These companies had around 40% cover, 34% from their own generation and 6% from contracts. They were in a highly vulnerable position, and by the end of the summer, they had accumulated around $6 billion in red ink.

Power Plant Construction

The California crisis has been examined by a several major agencies in California and by the Federal Energy Regulatory Commission. They all agreed that the markets were “unworkably competitive” in the summer of 2000. Furthermore, they all agreed that the lack of new generating capacity was a major reason for the unworkable situation. So, where were the new power plants?

No new power plants came on line in the summer of 1998, the first summer of the PX operation. The lack of new capacity in the first summer may be attributed to decisions in the years before the passage of AB 1890. No new power plants came on line in the summer of 1999 as well. The lack of new capacity in the second summer is reasonable given that new CCs require at least a year or longer for construction. (An investor would have had to start construction almost at the same time as the new markets started operation if the new CC were to be ready by the summer of 1999.) But what about the summer of 2000? New capacity would have been extremely useful for the overall system and quite profitable for its owners. Unfortunately, there were no new generating units completed in time to alleviate the tight conditions in the summer of 2000.

Why didn’t investors bring new power plants into service in time to benefit from the high prices in the summer of 2000? Will they bring the new power plants on line for subsequent summers? Will new construction appear in a steady fashion to allow generating capacity to keep pace with the growth in demand? Or should we expect construction to appear in waves of boom and bust, as happens in industries like real estate and commodities?

These are important and difficult questions, but they have not received the attention they deserve. Hirsh (1999) describes the common view in the early 1990s -- the new system would erase the utilities’ obligation to serve, and it would scrap the state’s role in resource planning. “In the new system, competition among suppliers would produce a match between supply and demand without intervention from the state.” According to the *San Jose Mercury News* (November 30, 2000), the topic of power plant construction was missing from the debate on AB 1890:

California's deregulation effort was based on
an unquestioning faith in the power of the free market.
Despite official state forecasts that electricity demands would increase,
for example, there was virtually no discussion
of whether California's generating capacity would keep pace.

The topic of power plant construction has also been neglected in the many studies issued since the summer of 1998. If construction is mentioned at all, the reports typically lament the lack of sufficient construction, but they provide little insight on whether the markets are designed to ensure an adequate and stable pattern of construction. Rather, the standard suggestion is to call for "expedited" siting and construction.

Previous Research

I examined research on power plant construction by the key agencies in the western United States in the summer of 1998. The review focused on computer models that could shed light on the dynamics of merchant plant construction (Ford 1999A). One key agency used a model with endogenous construction, but it relied on "perfect foresight" to calculate construction. With this approach, construction appears automatically in the model, just in time to provide a profitable return for investors.

The California Energy Commission (CEC) is a key agency in the west with a long history of modeling for planning and forecasting. As the California markets were opening for business, the CEC's forecast of market prices avoided the question of power plant construction altogether (Klein 1997):

After 2002 the market clearing price is set outside of the
model to be equal to the price of a new entrant…this is
done based on the logic that the market clearing price will
rise in response to increased load but once it is high
enough to attract new entrants, new entrants will come into
the market and drive the market clearing price downward
back to its previous level.

These words may convey a feeling for the ups and downs of a construction cycle, but the CEC staff had a different vision of the future. Their 1997 forecast showed long-run market prices climbing to around 27 $/MWhr, exactly their estimate of the fully levelized cost of a new entrant. Their forecast did not describe the construction in any explicit manner.

The CEC view of power plant construction has changed over time as investors applied for permits to construct thousands of MW of new capacity. By the fall of 2000, developers had received approval to construct 6 new power plants, and they had another 34 announced projects inside California. The CEC staff believed that the large number of proposed power plants argued for "a new approach based on specific assumptions about the timing and quantity of new resource additions" (Grix 2000). They adopted two scenarios for resource additions, and they calculated the price implications for each scenario over the time interval from 1998 to 2010. Market prices can be quite high in the summer, and new generators' profitability depends largely on the prices in the summer quarter. The CEC's short-term results (1998-2001) indicated that market-clearing prices during the summer may not reach a level necessary to sustain new market entry "until reserve margins drop below historic levels usually regarded as necessary for reliable service."

The CEC's long-term results depend on their scenario for investor behavior once profitable levels are achieved within a scenario. The staff specified construction based on a plausible fraction of the power plants in various stages of development. One scenario called for "rapid development" of the proposed plants; the other called for "cautious development." The interesting result was a bust in market prices in both scenarios. The CEC staff concluded that future generating resources are not likely to be added in a smooth, even pattern. Rather, they will "more likely occur in a cyclical pattern resulting in periods of excess and lean generation capacity." In other words, construction is likely to appear in a wave of boom and bust.

I drew similar conclusions in a simulation study of power plant construction for the western United States (Ford 1999A). The simulations revealed that power plant construction could appear in waves of boom and bust, causing major changes in market prices during different phases of the construction cycle. Under some circumstances, the cycle could take the extreme form of a limit cycle. In this unfortunate situation, the industry would face repeated periods of undersupply, and regulators would be forced to intervene with price caps.

PART TWO. THE CEC STUDY

The CEC study was conducted in the summer of 2000. The staff was interested in learning if an endogenous theory of power plant construction would expand their insights beyond the findings from the scenarios study. They called for a new model to provide a more detailed portrayal of power plant permitting and construction. It was to simulate construction and market prices in a summer peaking system with approximately the same demands, resources and markets as those in California. The model was based on the system dynamics approach used in my previous study of the western United States (Ford 1999A).

Permitting and Construction

Figure 2 shows the stocks and flows for investor decisions on permitting and construction. The development process begins with the formal application for a construction permit. The agencies review the proposal and award the permit in 12 months. At this point, the approved proposal enters a "site bank" with a shelf life of 24 months. If the project does not begin construction within 24 months, the permit expires. These time intervals are some of the model inputs shown on the screen in Figure 3.

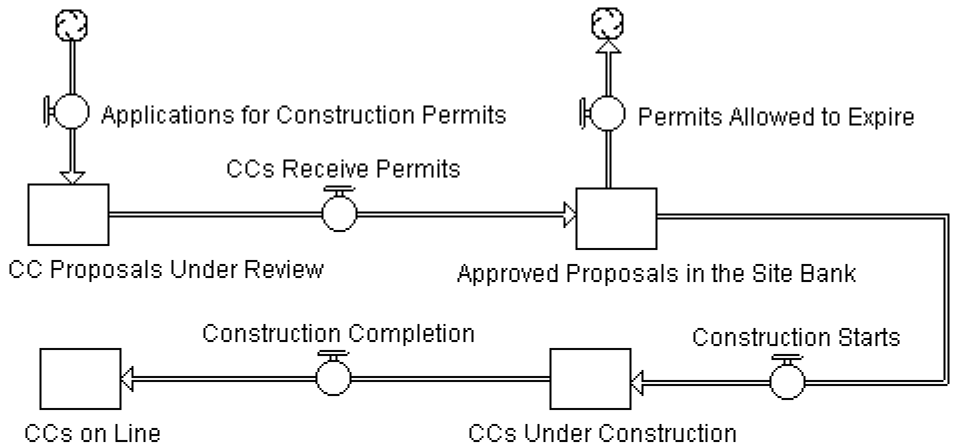

Figure 2. Stocks and flows for permitting and construction.

Power plant proposals in California are predominantly gas-fired combined cycle (CC) units. The controls on the left side of Figure 3 define the average attributes of the CCs. The base case assumptions match the assumptions by (Grix 2000): a CC owner pays $2.50 per million BTUs for gas and faces a variable cost of 19 $/MWhr. With levelized fixed costs of around 12 $/MWhr, the investor would face a total, levelized cost of around 31 $/MWhr.

Other controls allow the user to set the growth in demand and the price of natural gas. The base case begins with a peak demand of 46 GW and gas priced at $2.50 per million BTU. Demand grows at a steady rate of 2%/yr, and the price of natural gas remains constant over time. These assumptions are different from recent trends in California, and the differences are intentional. The model was designed for general understanding, not for forecasting. Consequently, staff called for a relatively simple scenario with constant assumptions. This approach allows simulation results to be traced to the cause and effect relationships inside the model.

Electricity demand varies from one hour to the next, and the California markets set different prices for each hour of the day. The model simulates prices over the 24 hours in a day, using a typical day in each quarter. The simulated price for electric energy represents the weighted average of the PX day-ahead price and the ISO real-time price for energy. The energy price is adjusted continuously as the model finds the price that will bring forth the generation needed to meet the demand. All units are bid at variable cost, except for a user specified block of strategic capacity.

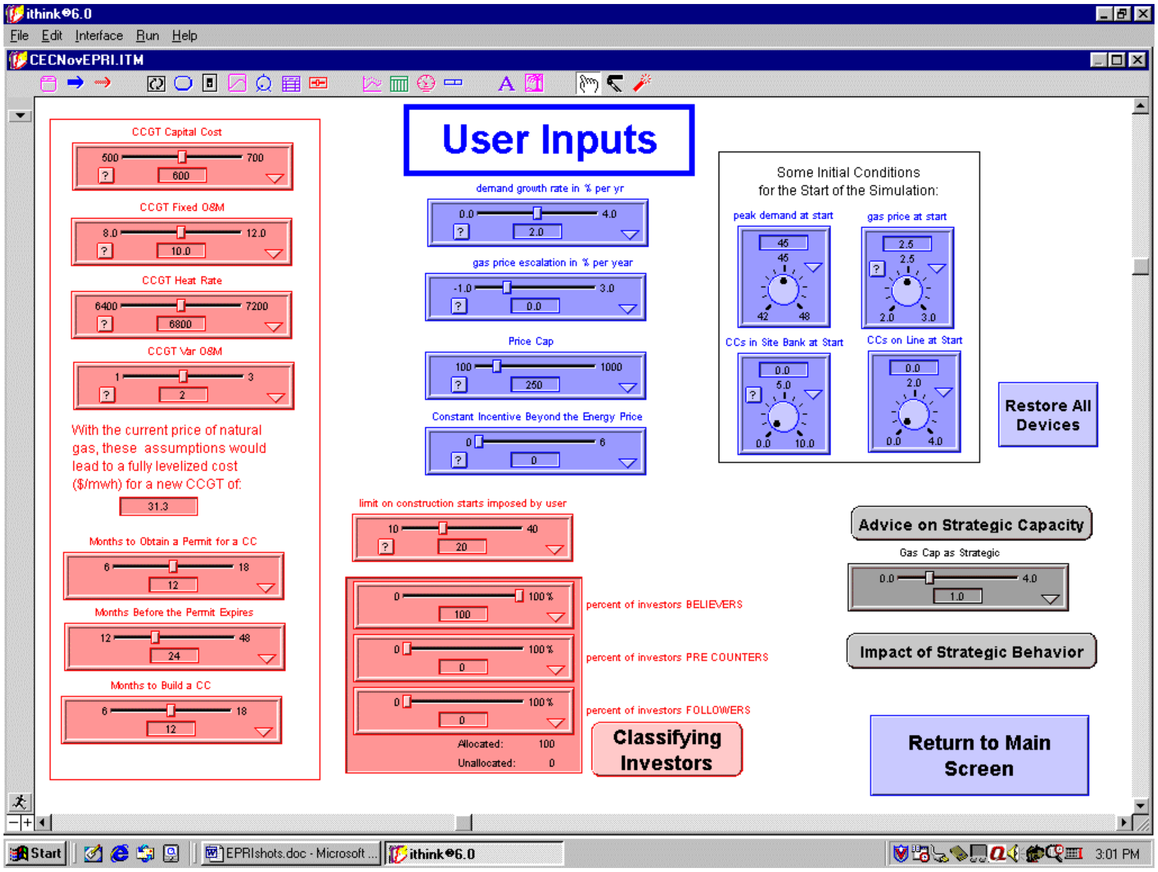

Figure 3. Inputs Screen.

Strategic capacity is expensive, gas-fired capacity whose owners are assumed to bid "strategically" during peak hours in the summer quarter. The base case calls for one GW of strategic capacity. This is a controversial input to the model, so the interface provides extensive advice for the model user. The advice button explains that setting this capacity to zero guarantees that all generators bid their units at variable cost, and the simulated market clears at the price expected from a competitive market. On the other hand, the user may assume four times as much strategic bidding by setting the slider at the maximum value. The "impact" button provides information on sensitivity tests and how the simulated prices compare with the ISO studies of strategic behavior. The model assumes that the strategic bids are spread across a wide range, from the variable cost of the region's most expensive unit to the price cap.

The price cap is another important input to the model. The operative cap in California has been the ISO real-time cap. The ISO opened for business with a cap of 250 $/MWhr. It raised the cap to 750 $/MWhr in October of 1999. The cap was lowered to 500 $/MWhr in July of 2000 and lowered again to 250 $/MWhr in August of 2000. The price cap "slider" in Figure 3 allows the cap to range from a low of 100 $/MWhr to a high of 1,000 $/MWhr. The low value was based on the variable cost of the model's most expensive unit. The high value is higher than any previous ISO cap, but it matches the cap imposed on the PJM system. Figure 3 shows the slider at 250 $/MWhr, the cap adopted in August of 2000. This is a "hard cap" which controls the height of the price spikes in the model. The model does not distinguish between "hard" and "soft" price caps.

Investor Behavior

The focus of the model is investor behavior. We assume that all investors look into the future to assess the profitability of a new CC. If the siting and construction lead-time is 24 months, for example, investors look 24 months into the future to anticipate the profitability of a new unit when it begins operation. Some models look into the future by simply selecting a number stored in the computer for some future point in time. This "perfect foresight" approach may be possible in a computer algorithm, but it not possible in the real world. Investors can only make educated (and possibly sophisticated) estimates of future prices. The CEC model is based on an explicit theory of how they make such estimates.

Let's start with the demand for electricity. It is assumed to grow in a steady, predictable manner. Investors observe the growth in demand over time, so they are in a good position to anticipate the demand when their new units would begin operation. Next, investors know the capacity at the start of the simulation, and they know that none of the existing capacity will be retired during the simulation. Investors also know that each year is an "average year" (as far as the weather is concerned), so they are in a good position to estimate the relative balance of peak demand and generating capacity. Investors have access to production costing tools, so it makes sense to assume that they can produce reasonable estimates of the average annual market price based on their assessment of the balance of demand and capacity. As demand grows from one year to the next, the balance shifts in favor of generation, and the investors' estimates of future prices climb upward. Investors become increasingly interested in starting construction as their forecasts of future prices climb toward the full cost of a new CC. The typical cost may be 31.3 $/MWhr, but some investors have better access to natural gas or to financing. The model assumes that the advantageous investors will be ready to invest with the estimated market price reaches around 30 $/MWhr. At this point, a small fraction of the plants in the site bank will start construction. After 12 months, the construction is completed, and the new CCs begin operation.

The analyst classifies investors based on their view of the CCs under construction. Investors may be described as

- *believers,*
- *pre counters, or*
- *followers.*

The *believers* are assumed to factor the CCs under construction into their forecasts only when the new CCs have completed construction. In other words, this investor will believe the new CC is "for real" when he sees it in operation.

The *pre counters* look at power plants under construction differently. They count the new capacity into their forecasting process as soon as construction is initiated. By "pre counting" the capacity, they reveal their confidence that any unit that starts construction will finish construction.

The *followers* are quite different. Their commitment to construction does not occur until others have initiated some construction. Then they are drawn into construction based on a "herd mentality factor" and their own assessment of profitability.

Base Case Simulation

The user controls the mix of investors with the linked controls near the bottom of the inputs screen. The base case considers a situation with 100% *believers:* investors will believe the new CCs are "for real" once they begin operation. Figure 4 shows the new CCs in various stages of development in the base case simulation. The simulation runs for eight years, with time shown as 1st year, 2nd year, etc. These general labels make it difficult for the reader to interpret the simulation results as a forecast for a particular year (i.e., 2001, 2002, etc.). This difficulty is intentional. The model was built for general understanding of patterns, not for forecasting a precise number in a particular year

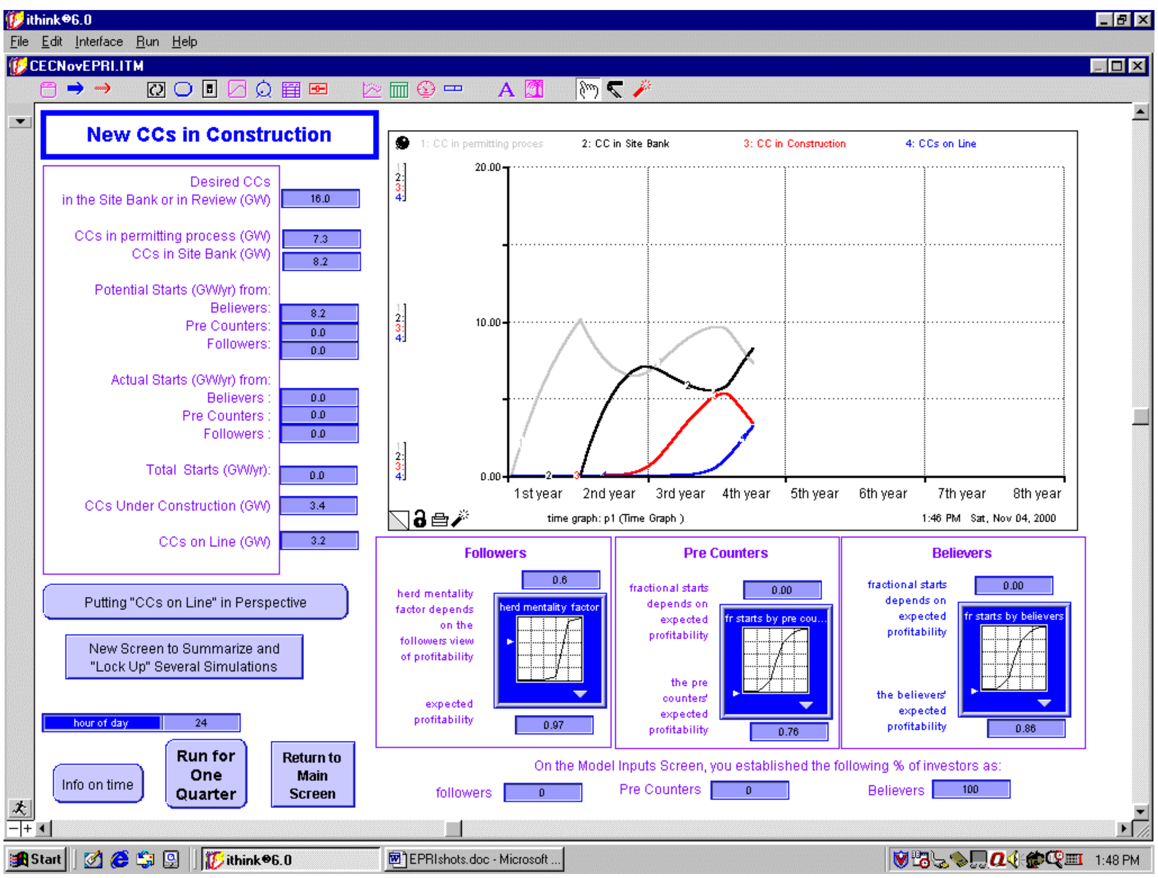

Figure 4. Construction results mid-way through the base case, a simulation with 100% of investors as *believers*.

The first two years is an active period in terms of proposed projects. By the end of the 2nd year, investors have around 7 GW under review and another 7 GW in the site bank. Construction commences near the end of the second year, and the new CCs enter operation near the end of the 3rd year. Figure 4 shows the simulation mid way through the 4th year. By this time, investors have over 8 GW in the site bank, 3.4 GW under construction and 3.2 GW in operation. Their assessment of future profitability has fallen sharply (as shown by the "believers' expected profitability" in the lower right display in Figure 4). At this point, investors are no longer interested in starting new construction; their strategy is to finish the construction of the 3.4 GW and hope for market conditions to improve.

Figure 5 shows the CCs in construction for the remainder of the base case simulation. This screen shows that construction is completed by the end of the 4th year, and the installed CC capacity climbs to 6.6 GW. The construction is confined to a pronounced wave in the 3rd and 4th years. By the end of the simulation, investors see a return to profitable conditions (the "expected profitability" in the lower right display is at 97% of the target.) They have plenty of capacity in the site bank are about to launch a second wave of construction.

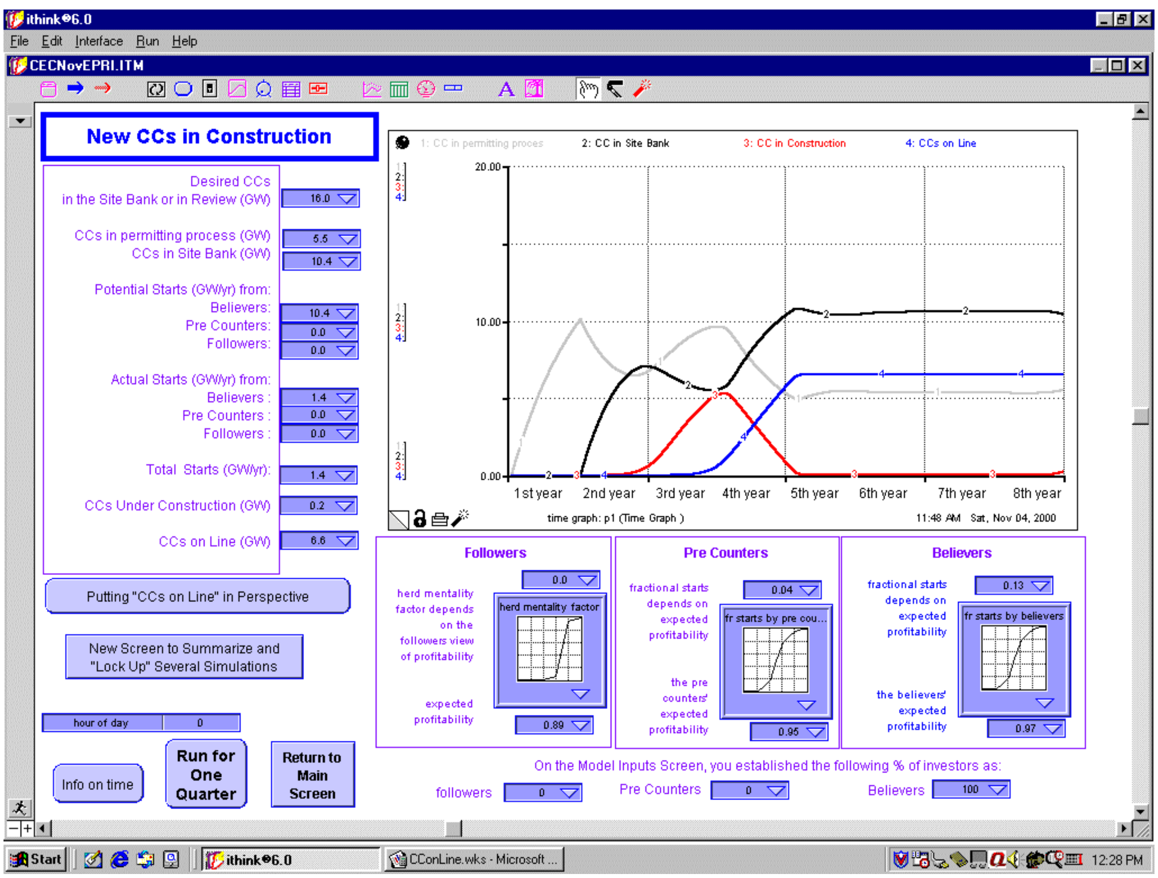

Figure 5. Construction results for the entire base case, a simulation with 100% of investors as *believers*.

Figure 6 shows the main screen of the model at the end of the initial simulation. The demand for electricity for a typical day in each quarter is shown along with the available generating capacity on a scale from 0 to 60 GW. Planned maintenance is scheduled in the off-peak seasons, and all thermal units are ready for scheduled operations in the summer. Figure 6 portrays the tightness of the summer conditions by the comparison of the peak demand with the available capacity. The simulation shows tight conditions by the 2nd summer, even tighter conditions by the 3rd summer. The tight conditions are eliminated in the 4th summer by the wave of new construction. No further construction is completed during the second half of the simulation, but the peak demand continues to grow. By the end of the simulation, the system has returned to the tight conditions observed at the beginning of the simulation.

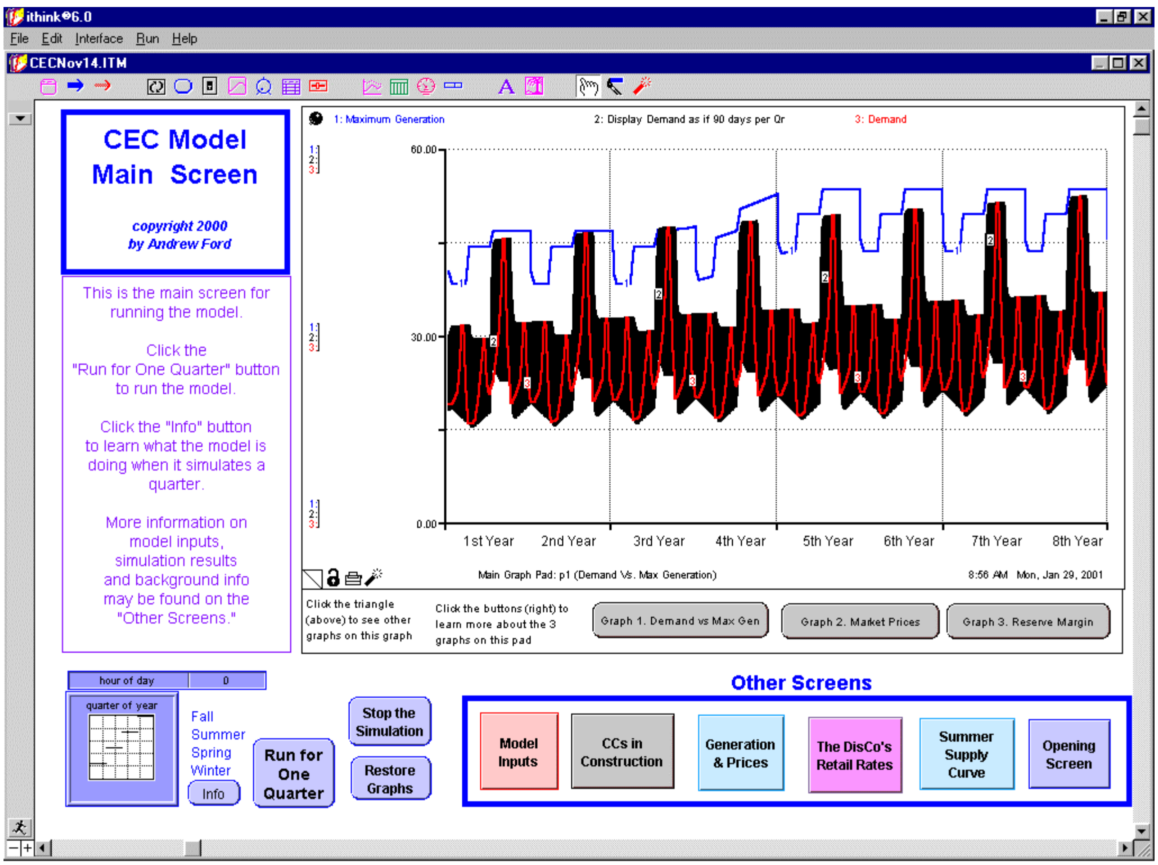

Figure 6. Capacity and demand in the base case simulation.

The quarterly prices for the base simulation are shown Figure 7. This is the main screen of the model with a different graph from the graph pad in view. It shows average market prices observed over each previous quarter and each previous year on a scale from 0 to 60 $/MWhr. The summer quarterly prices are most prominent in Figure 7; they average around 32 $/MWhr in the 1st summer, 36 $/MWhr in the 2nd summer and 47 $/MWhr in the 3rd summer. These high prices are due, in part, to price spikes during the peak hours in the summer. The spikes tend to appear in about 1-2% of the hours of the quarter. They are caused, in part, by strategic bidding, and they are controlled by the price cap (which is set at 250 $/MWhr).

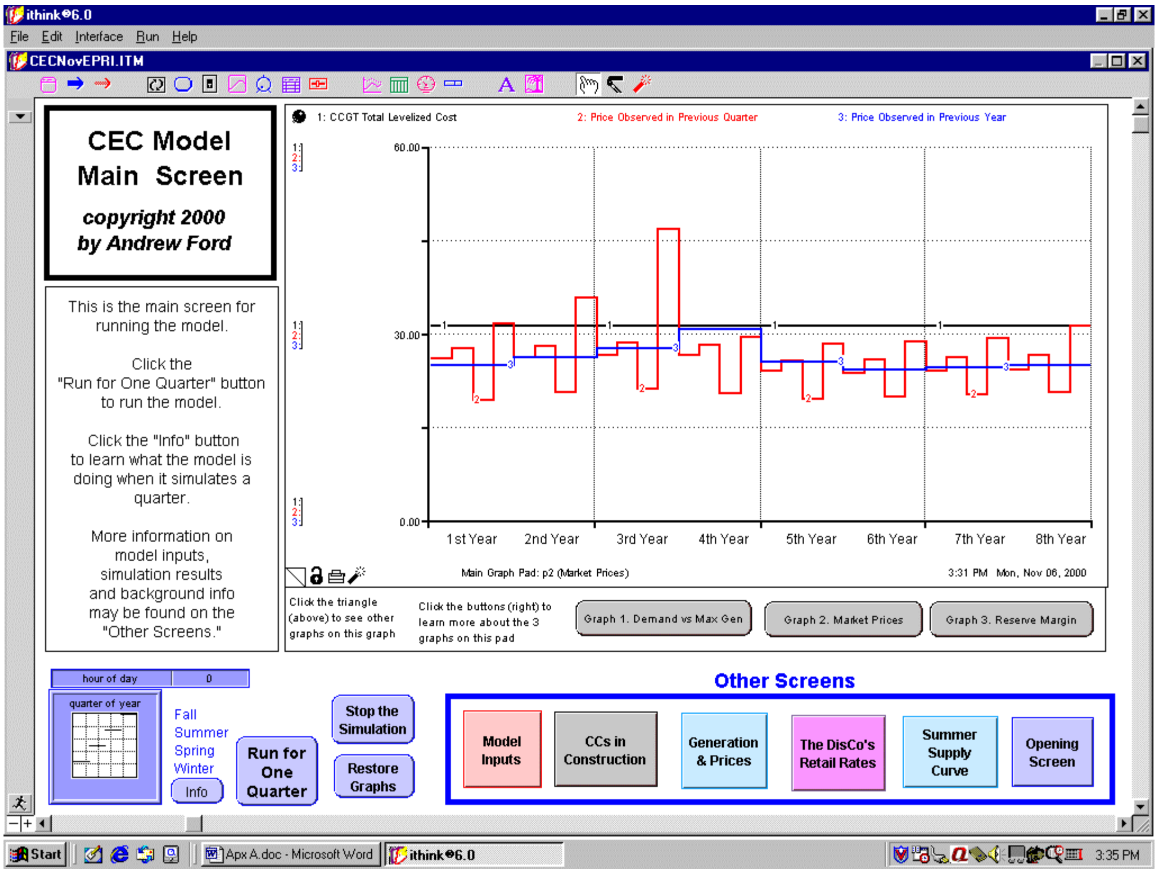

Figure 7. Market prices in the base case simulation.

The growth in summer prices is largely responsible for lifting the average annual price toward the total cost of a new CC. By the 3rd year, the average annual price reaches 30.8 $/MWhr, only slightly below the 31.3 $/MWhr cost of a new CC. Figure 7 shows that high summer prices are eliminated for the second half of the simulation. The summer prices fall below the value seen in the very first summer when the new CCs enter operation. The drop in summer prices pulls down the average annual price to well below the total cost of a new CC. Average annual prices range from around 24 to 26 $/MWhr during the second half of the simulation. This is the “bust” in the boom/bust simulation. Demand continues to grow at 2%/yr, and the market experiences a gradual increase in prices. By the final year, summer prices have climbed back to the value observed at the start of the simulation.

Thinking About Boom and Bust

The base case simulation shows the classic pattern of boom and bust. There is no construction early in the simulation as investors wait for their estimates of market prices to climb sufficiently high to cover the full cost of a new CC. By the time they view new CCs as profitable, there are plenty of pre-approved projects waiting in the site bank. They initiate construction on some of these plants, but they do not commence operation soon enough to prevent high summer prices in the third summer. Investors continue to initiate construction of additional plants while their previously initiated plants are under construction. Their enthusiasm for the construction boom is not diminished until some of the CCs enter operation. By this time, however, they are stuck with too much capacity under construction.

This pattern of behavior strikes some as irrational. After all, why would a rational investor initiate construction on new power plants when the number already under construction is more than is probably needed to keep pace with the growth in demand? Of course the important question is not whether this behavior is rational. It's whether this behavior is realistic.

We have little experience with competitive markets in the electric industry, so we don't have direct evidence of a boom/bust pattern shown here. We do have signs of a huge accumulation of power plant proposals all around the country, however. For example, a recent review for the Electric Power Research Institute (EPRI 2000) "anticipated that approximately 212 GW of new gas-fired capacity additions" could appear over the next five years." This would be approximately "two to three times more than would be needed to keep pace with demand growth. The supply-demand balance would be shifted significantly, and market prices would probably fall substantially below the level needed to support new construction." The EPRI review concluded that different regions of the country "could move from boom to bust in just a few years." The EPRI warning may seem incredible, but it probably comes as no surprise to system dynamics practitioners familiar with the boom and bust patterns in the "beer game." The EPRI warning also comes as no surprise to readers with experience in the commodity industries.

A commodity is defined as an undifferentiated product, often supplied by many small, independent producers. Examples include minerals such as copper, forest products such as lumber and agricultural products such as hogs. The common pattern among the commodities is a highly persistent cycle in production, prices and investment (Meadows 1970; Ford 1999; Sterman 2000). The restructuring of the power industry has made electricity similar to other commodities in that many independent companies will be able to enter the competitive market and produce electricity that is undifferentiated from electricity produced by others. But electricity is fundamentally different from other commodities because it cannot be stored in inventory as a buffer between producers and consumers. Electricity production and consumption must occur simultaneously across the electrical system.

The electric industry is more usefully compared with an industry like commercial real estate. In real estate, there are no product inventories to serve as a buffer between producers and consumers. New buildings are like new power plants – they provide their owner with the opportunity to rent space in a competitive market. If the space isn't rented on a particular day, the ability to earn income on that day is lost forever. Power plants provide their owner with the opportunity to sell electricity into a competitive market. If the sale is not executed on a particular day, the ability to earn income on that day is lost forever. Investors in the two industries face long lead times for siting and construction. They erect their facilities on site, and the site location may be extremely important to their competitive advantage. Developers face high fixed costs, and they look to high capacity utilization to recover those costs. Finally, both industries may experience large swings in prices, especially during periods with tight vacancy rates or with tight reserve margins.

Learning from the Real Estate Industry

The lesson from the real estate industry is to expect persistent cycles of boom and bust. One of the best accounts of the real estate construction cycle is Homer Hoyt's (1933) detailed account of *One Hundred Years of Land Values in Chicago*. He describes five major construction booms, each of which is followed by a bust in prices. Surges in population were the key factor contributing to the booms, but Hoyt looked beyond the obvious, external factor. He focused on the way investors reacted to the population surges. Developers did not build in advance of growing demand. This allowed prices to surge upward, and developers would "scramble to build at many locations around the city…. so that when all these plans came to fruition, an astonishing number of new structures had been erected."

Hoyt closed his book by speculating that "the real estate cycle may be a phenomenon that is confined chiefly to young or rapidly growing cities." However, the recent evidence from cities like Dallas and Boston (DiPasquale and Wheaton 1996) tells a different story. The external factors triggering the booms have changed, but the response of developers is still the same. Their construction lags behind demand allowing a surge in real estate prices. Then a wave of over-building causes vacancy rates to soar and prices to plummet. Interviews of developers who suffered from the bust in real estate prices have revealed that a variety of psychological factors obscured their vision of the construction cycle.

The question for this article is whether power plant investors will follow the same pattern seen in real estate. For example, will their construction lag behind the growing demand for power? This part of the construction cycle is already evident in California, and the evidence is clear. New power plant construction has not occurred quickly enough to prevent the surging prices in California. Now, what about the power plants now under construction and under review? Should we expect to see a pattern of over-building similar to the over-building in commercial real estate?

Over-building could make sense if investors do not have access to information on power plant construction. But most states report the proposed power plants working through their permitting agencies in one form or another, and investors have access to the state reports. But the question remains, will the investors pre count the power plants under construction when formulating their own estimates of future market prices? One complicating factor that could cause companies to discount reports of plants already under construction is the disparity between construction lead times. The lead-time for installing new peaking units or for refurbishment of existing units is much shorter than the construction lead-time for a new CC. Skepticism about completion of announced power plants is also to be expected in a state with a history of environmental activism and serious air pollution problems. Investors may be skeptical of plants in the construction pipeline if construction could be delayed or canceled when opposition groups present new evidence on power plant impacts. The uncertainty in power plant construction is particularly important when investors must look to the summer months to capture the benefits of high prices (including price spikes) during peak periods.

There is a strong case for viewing power plant investors as influenced by the same combination of factors that have led to over-building in other industries. But the CEC study did not limit the simulations to a single view of investor behavior. The model was constructed to promote experimentation with many different assumptions, so let's consider a new situation where investors react quite differently to power plants under construction.

Alternative Simulation

Figure 8 shows a simulation with all investors reacting as *pre counters. Pre counters* is an informal term to describe investors that count the CCs under construction in their forecasting of future prices as soon as they begin construction. With this assumption, all investors have full knowledge of the construction activity and they adjust their estimated prices downward as soon as construction is initiated. The construction in this scenario will be identical to the first two years of the simulation. Once some construction has begun, however, investors will limit annual starts to around 1 GW, the amount needed to keep pace with growth in demand. This construction is quite small compared to the 10 GW of approved projects in the site bank. Some readers may wonder how the companies competing for a share of the California market would find a way to limit their construction to only one tenth of the approved projects.

The limited construction is simulated endogenously in the model by the diversity of costs among the investors. For example, a company with an advantage in fuel costs may initiate construction when its forecast reaches 30 $/MWhr. Once this company initiates construction, the CC is in the "pipeline" for all to see. At this point 100% of the investors take the new CC into account and adjust their price forecasts downward. The model demonstrates that this combination of assumptions would allow the CCs under construction to equilibrate at around 1GW, exactly the amount needed to match the growth in demand.

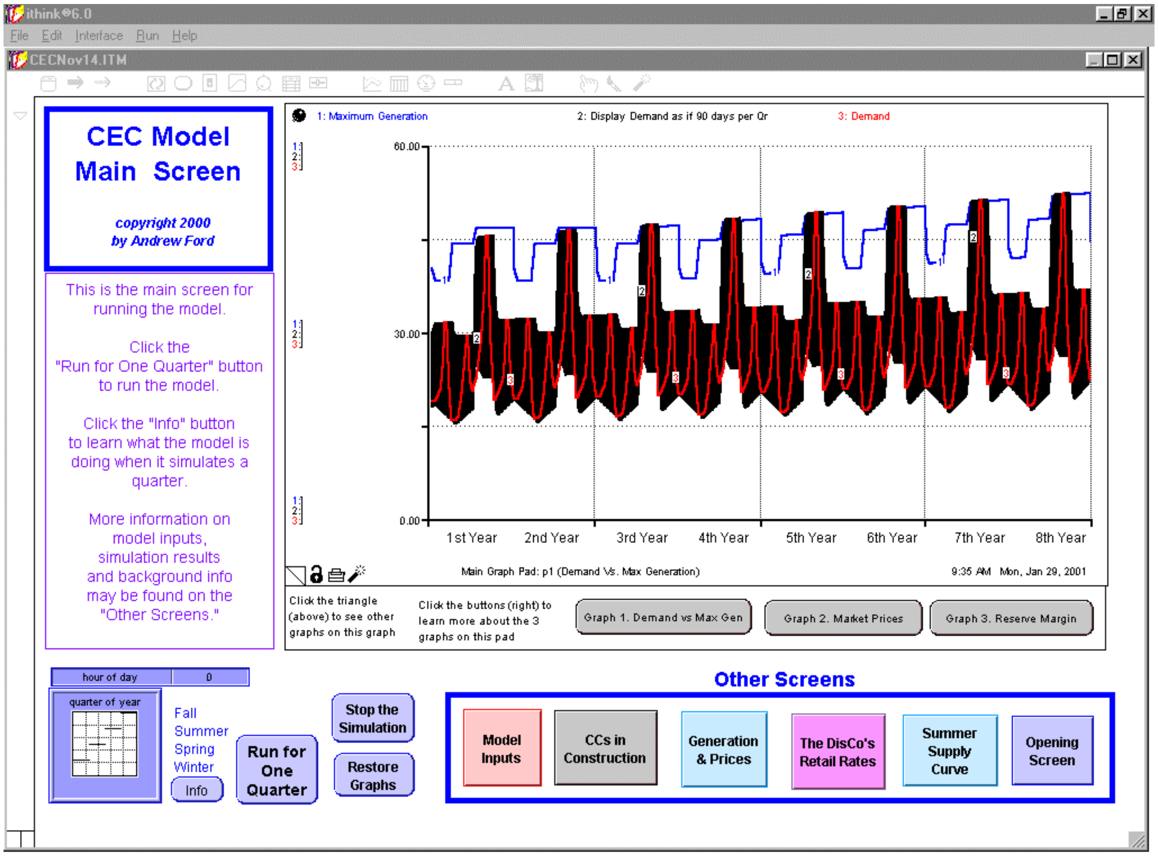

Figure 8. Capacity and demand in a simulation with all investors as *pre counters*.

Figure 8 shows the demand compared to the available capacity in the new simulation. As before, the tightness of the summer conditions is visually apparent when the demand peaks during a typical day for each summer. The first three summers are the same as the initial simulation. The important differences show up in the 4th summer --- it's just as tight as the previous summer. The same situation appears again in the 5th summer, and in all subsequent summers

Figure 9 shows the price implications of this theory of investor behavior. Once again, the most important implications appear in the summers. Summer prices are pushed to high levels by the tight balance of capacity and demand (and the ensuing price spikes). The distinctive feature in Figure 9 is that high summer prices appear in the 3rd summer and remain for each and every summer. We see average quarterly prices of around 45 $/MWhr year after year after year. These high summer prices cause the average annual market price to hover around 30 $/MWhr, somewhat below the average cost of a new CC. This equilibrium level is achieved inside the model by the simulated actions of the investors.

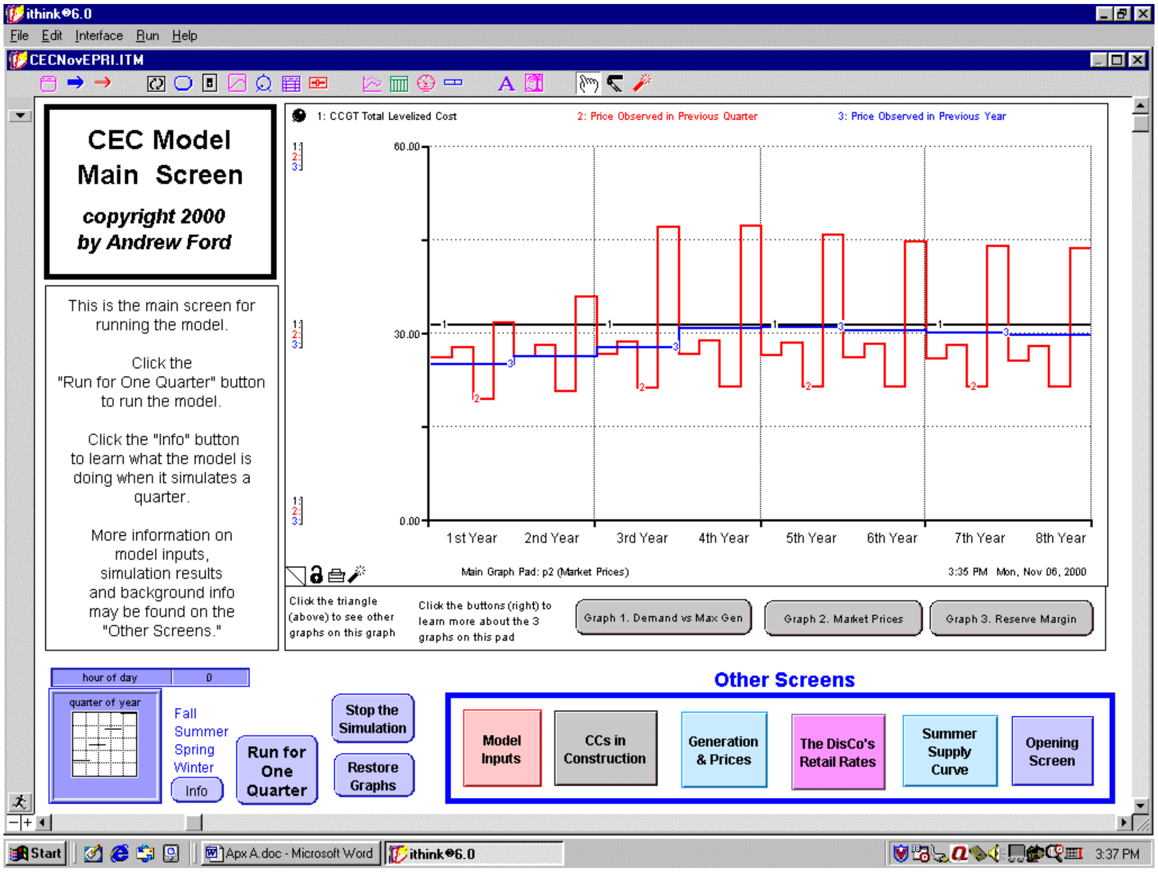

Figure 9. Market prices in a simulation with all investors as *pre counters*.

The prices in Figure 9 show the classic pattern to be expected in a future with rational expectations. Construction does not appear in waves of boom and bust, but occurs in a tightly controlled pattern that exactly matches the growth in demand. Average annual prices find their way to approximately the levelized cost of a new entrant. Then they remain at that level if there are no important disturbances in the system.

Multiple Views of Investor Behavior

The previous simulations classify all investors as either *believers* or *pre counter*s to help the reader appreciate how the model simulates investor behavior. These two simulations provide useful benchmarks as we explore the patterns of power plant construction that would appear with a mix of different investors. Figure 10 provides a side by side comparison of the construction results from five simulations. The 1st and 2nd cases have been described previously. The 3rd, 4th and 5th cases show the installed CC capacity in simulations with a mix of investors.

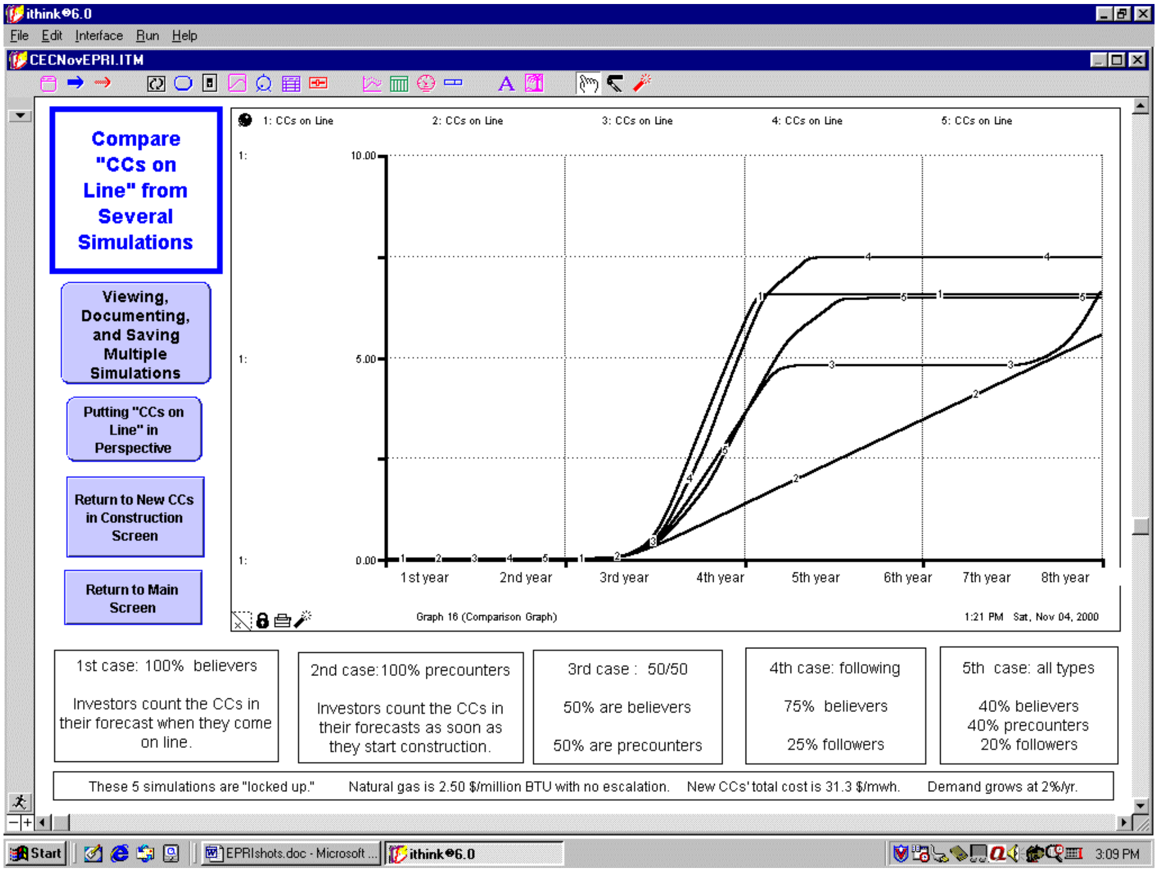

Figure 10. Comparison of new CC capacity in five simulations.

The five simulations are identical during the first two years --- no new CC capacity comes on line because all investors are watching and waiting for their forecasts of market prices to hit the threshold values. All five simulations show new CCs coming on line mid way through the third year. At this point, the results head in dramatically different directions. The qualitative differences are the focus of the model. The first case is the classic boom/bust described previously. It shows a rapid rise in CC capacity to 6.6 GW in the fourth year of the simulation. The 2nd case assumes that all investors are *pre counters*, and this assumption leads to a qualitatively different pattern. It shows perfectly linear growth in CC capacity once investors enter the market.

Now consider the third case with an equal mix of *believers* and *pre counters*. This simulation shows a construction boom in the third year and a rise in CC capacity during the fourth year. Both the *believer*s and the *pre counters* participate in the early phase of the boom. But once a significant number of CCs are in the construction pipeline, the *pre counters* withdraw from the market. The *believers* continue to invest in new CCs, and it's their actions that lead installed capacity to grow to around 5 GW by the fifth year of the simulation. Installed capacity is flat for the next three years, as investors wait for improved profitability. Investors see improved profitability near the end of the simulation. A second wave of construction occurs in the seventh year, and capacity climbs to around 6.7 GW by the end of the simulation. Once again, construction is dominated by the *believers* even though they hold only 50% of the permits for construction.

The 4th case assumes a 75%/ 25% mix of *believers* and *followers*. The followers need to see something in the construction pipeline before they commit to construction, so we would expect to see this simulation lag behind the base case during the early phase of the boom. Later, when the "herd mentality" factor takes hold, we expect to see a greater degree of over-building. Figure 10 confirms our expectation. Installed capacity grows to around 7.5 GW by the fifth year of this simulation. The 5th and final case assumes that all three types of investors are competing for a share of power plant construction. The 5th simulation shows *believers* and *pre counters* beginning construction in the third year, with the *followers* following close behind. The *pre counters* withdraw from the competition early in the boom, and the remainder of the simulation is dominated by the combined actions of the *believers* and *followers*. Total installed CC capacity by the fifth year is almost identical to the value shown in the base case simulation.

Implications of the Dominant Pattern of Behavior

The dominant pattern of behavior is evident from four of the five simulations in Figure 10. Installed CC capacity grows rapidly in the third and fourth years reaching a plateau of around 5 to 7.5 GW depending on the assumed mix of investors. All four simulations show that construction would appear in an exuberant boom which delivers more than enough new capacity to keep pace with growth in demand.

The CEC model reveals the implications of the construction boom in Figure 6 and Figure 7. Figure 6 shows that the tight balance of demand and capacity would be erased after the construction boom, and Figure 7 shows the high summer prices would be erased as well. California would benefit from adequate generating capacity and lower wholesale rates. This would be an attractive long-term future for the distribution companies and their consumers. The challenge is surviving the tight conditions in the 3rd year of the simulation while waiting for the boom.

On the other hand, the boom/bust pattern could pose serious problems for the generating companies. The low prices in the second half of the simulation shown in Figure 7 would pose serious cash flow problems for companies investing primarily in California. However, most of the generating companies are large corporations like Calpine (with investments around the country) and Duke (with investments around the world). For these companies, the challenge is to balance the losses during the bust period in California with the profits in boom periods elsewhere.

Implications of the Extreme Pattern of Behavior

One simulation stands alone in Figure 10. It's the simulation with each and every investor categorized as a *pre counter*. It shows CC capacity growing by 1 GW per year after the 3rd year of the simulation. This turns out to be exactly the amount needed to keep pace with the growth in demand. The CEC model reveals the implications of this view of investor behavior. We see linear growth in new capacity, tight supplies in each and every summer and higher prices in each and every summer.

Although it is possible to simulate this future in a computer model, it is difficult to imagine that such a future would be tolerated for long. Of course, the generating companies would prosper under these conditions. But the retail companies would not do well under such a future, especially if their retail rates were frozen by state rules. If the retail companies were allowed to pass the high prices along to their customers, it's hard to imagine that customers would tolerate such a future. One might imagine that customers would tolerate a single summer with low reserve margins and high prices. But it is hard to imagine that they would tolerate six summers in a row. The more likely response is the sort of "rate payer revolt" described by Governor Davis in his appeal to FERC for rate caps and refunds.

Summary

This paper describes a computer model to simulate the general pattern of power plant construction in a system like California. The simulations reveal a tendency for new capacity to be added in an exuberant building boom. The results appear in simulations with widely varying assumptions about investor behavior, and they are consistent with building booms observed in industries like real estate. The results suggest that the new markets could deliver long-term benefits if California is able to survive the near term challenges of a tight supply of electricity.

Part Three. Post Script

The simulation study was completed in the summer of 2000. This was certainly a challenging summer with wholesale prices four-five times larger than the previous summer. Retail rates increased three fold in San Diego, while SCE and PG&E accumulated $6 billion in red ink serving retail customers at rates frozen by the AB 1890 transition rules. California normally expects a reprieve from price spikes when the summer is over. Peak loads in the fall and winter can be 30% below the summer peaks, and market prices are normally expected to fall. Under such conditions, the large IOUs might have made some progress paying off the $6 billion in red ink. Under such conditions, California's consumers would have enjoyed reliable supply (without the threat of interruptions). Perhaps a boom in power plant construction would deliver major additions in generating capacity in time for the next stressful period – the summer of 2001.

Unfortunately, the ISO experienced difficult conditions throughout the fall and winter months. Reserve margins remained dangerously low, and the ISO issued numerous Stage1 and Stage 2 alerts. The ISO was forced to issue the first Stage 3 Alert in California history on Dec 7, 2000. The first rolling blackout in California's history occurred on Jan 17, 2001. By this time, stage 3 alerts (and rolling blackouts) had become a regular part of the California economy.

Wholesale prices remained high during the fall and into the winter. The prices were reported in the range of 300 to 400 $/MWhr revealing the "softness" in the 150 $/MWhr price cap imposed by FERC. By the end of the year 2000, the red ink at SCE and PG&E had grown to $12 billion. The utilities' warned that they were on the edge of bankruptcy, and generators were not paid for previous generation. The electricity crisis had grown into a credit crisis, and reluctant generators continued to sell electricity into the California market under emergency orders by the Secretary of Energy.

The West Coast Crisis

The winter of 2000/2001 revealed that electricity supply is more than a California problem. It's a problem for the entire WSCC, especially the northwest states whose electric system is tightly interconnected with California. The northwest system is dominated by hydro-electric generation in the Columbia River system which can vary by over 50% from one year to the next. The northwest utilities have lived with this variability for the past 60 years, and they have developed a variety of mechanisms for managing the system and planning the capacity additions needed under "dry" conditions. But the utilities have much less experience with deregulation. Although the northwest states have not followed the same approach to deregulation as in California, they have seen the same lack of power plant construction. The lag in construction is documented in a recent report by the NPCC (2000) and in testimony by Steve Oliver from the Bonneville Power Administration (BPA 2000). He testified that

the most significant challenge – though by no means the only challenge – is the shortage of generation supply at a time when the region's economy is growing

and that development of new generation has lagged due to the numerous uncertainties that still surround the transition to competitive markets. He also raised a concern that may persist even after the transition is completed:

The two-to-three year time lag in the market's ability to respond to price signals
with new generation supplies
may reflect an inherent challenge for competitive electricity markets.

Oliver warned that Bonneville is vulnerable to market price volatility over the next five years because it has commitments to serve firm loads beyond the firm generating capability of the federal resources. "These commitments were made in an effort to widely distribute Federal benefits in the region." By the end of January, BPA announced that its wholesale customers should expect a 60% increase in rates.

California Enters the Power Business

On January 4, 2001, Carl Wood, the Chairman of the CPUC, announced that "deregulation is dead" in California. On January 8, 2001, Gov. Davis described California's deregulation scheme as "a colossal and dangerous failure." The Governor lobbied aggressively for an effective price cap to limit the wholesale prices, but FERC did not view a hard cap as part of the solution. The CPUC raised retail rates by 10% in early January, and the legislature met in special session on the crisis. It moved immediately to dissolve the governing boards of the PX and the ISO and to postpone the scheduled sale of the IOUs hydro-electric assets to private generators. The legislature then tapped the State Water Project (SWP) to buy power in the spot markets on behalf of the cash starved utilities. The IOUs red ink (from under collections) has been estimated at around $13 billion, and the State is looking for major steps to prevent their bankruptcy. The options under consideration included state purchase of the IOUs transmission assets, the state purchase of the IOUs hydro-electric assets, and State equity ownership in the IOUs. By March of 2001, the state was concentrating on the purchase of the IOUs transmission assets.

The State is looking to long term contracts to reduce the dependence on the volatile spot markets. It has called on the SWP to negotiate long-term contracts under a $10 billion program authorized by the legislature. The legislature initially asked for long term contracts at 55 $/mhw, but the asking price was soon increased to 74 $/MWhr. (This approach had encountered opposition from consumer groups and economists, but the State is proceeding deeper into the power business as of March, 2001.) The current plan calls for the State to resell the contracted power to the large IOUs who would be allowed to sell the electricity to their consumers at cost. To ensure that the State is not stuck with “stranded costs” (in the event of a decline in spot prices), the legislators are considering a prohibition on residents and businesses from seeking cheaper rates through direct contracts with power generators. Meanwhile, everyone is anxiously watching the progress of power plant development.

Power Plant Construction

Figure 11 summarizes CCs in various stages of development as of Jan 25, 2001. No new CCs have come on line. There are 6 plants under construction with a combined capacity of 4,308 MW. Three of the plants, with a combined capacity of 1,308 MW, are scheduled to begin operation by the summer of 2001. The other three plants are scheduled to be on line by the summer of 2002. Figure 11 shows that 3 proposals have received construction permits, but are not yet under construction. These would provide 1,970 MW with 500 MW scheduled to be on line by the summer of 2002. An additional 12 proposals with a combined capacity of 6,584 MW are under review by the CEC. The CEC also tracks proposals that have been “announced” but which have not yet formally entered the review process. As of late January, 10 proposals with a combined capacity of 5,920 MW and been “announced” and were “expected to apply.”

Figure 11 shows almost 13,000 MW of capacity in various stages of development. The total would be almost 19,000 MW if one counts the projects which have been announced and are “expected to apply.” Figure 11 shows serious construction underway and the potential for an exuberant construction boom (if a majority of the proposed plants actually enter construction). The challenge for California is to restructure the electric business while encouraging the developers to follow through on the proposed projects. The State is accepting bids for longer-term contracts through the SWP. The terms and conditions of these contracts will be crucial to ensuring that developers follow through on the proposed projects. For example, longer-term contracts could give the developers some protection against the risk of the boom/bust pattern simulated in this paper.

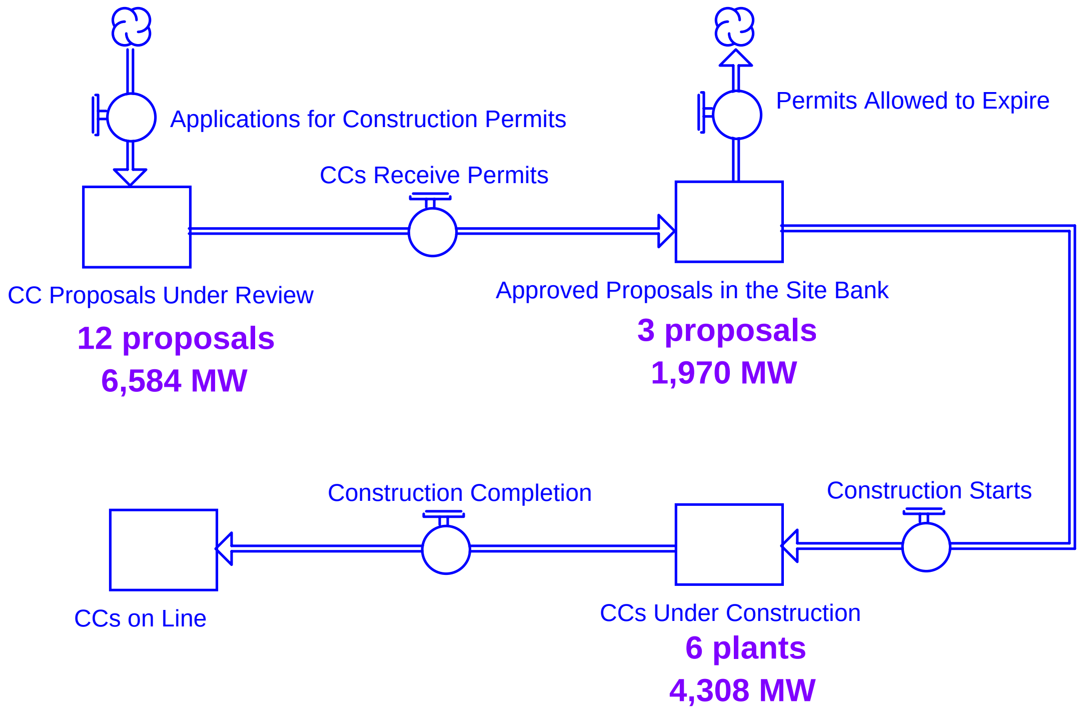

Figure 11. New CCs in development in California in January of 2001.

Waiting for the Boom

The simulations reported in this article suggest that power plant construction will appear in a major boom of over-building. Policy makers, utility executives, developers and consumers are all wondering about the timing of the boom. The question on everyone's minds is how long must we wait to see enough new generating capacity to lower market prices and improve reliability? One forecast warns of a 5,000 MW deficit in California and a 10,000 GW in the west for the year 2001 (CERA 2001). It also warns that "the west is unlikely to add sufficient new supplies until 2003 at the earliest." If we take summer of 2000 as the first year of soaring prices, this warning suggests that we must endure three successive years of difficult conditions. A similar warning appears in a recent speech by Steven Hickok, BPA's Chief Operating Officer. He explained that the "lights are on" in Portland only because 3,000 MW of industrial load was shut down. He offered encouragement for the long term: "the fundamentals for electric power in the Northwest are excellent." But he acknowledged that the current structure is "producing ugly spikes" which he believed will be part of the difficult circumstances to be faced for the "next two to three years." (Hickok 2001)

Forecasting is hazardous business, and the simulation model described in this article was designed for general understanding, not for year-by-year forecasting. Nevertheless, the model does show certain dominant patterns which can help us think about the duration of difficult times. With the assumption of a 12 month construction interval, for example, the boom/bust simulation suggests that the system will experience one year of difficult conditions before feeling the benefits of a construction boom. Construction intervals may now be closer to 24 months (EPRI 2000), so I have repeated the boom/bust simulations with the longer interval. The new simulations (which are not shown here) suggest that the system would experience two difficult years before seeing the benefits of a construction boom. If we consider the year 2000 as the first of the two difficult years, the new simulations alert us to prepare for difficult conditions for the rest of 2001.

References

Backus 1996
George Backus and Susan Baylis, "The Dynamics of U.S. Electric Utility Deregulation," report for the Office of Utility Technology, U.S. Department of Energy, available from the Policy Assessment Corporation, Denver, CO.

BPA 2000
Testimony of Stephen Oliver, Vice President, Power Business Line of the Bonneville Power Administration, before the Senate Energy and Natural Resources Subcommittee Hearings on Northwest Electricity Prices, October 5, 2000.

Bower 2000
John Bower and Derek Bunn, "Model Based Comparisons of Pool and Bilateral Markets for Electricity," The Energy Journal, Vol 21, No. 3.

Bunn 1992
Derek Bunn and Erik Larsen, "Sensitivity of Reserve Margin to Factors Influencing Investment Behaviour in the Electricity Market of England and Wales," Energy Policy, May 1992.

Bunn 1994
Derek Bunn, "Evaluating the Effect of Privatizing Electricity," Journal of the Operational Research Society, 45(4).

Bunn 1997
Derek Bunn, Issac Dyner and Erik Larsen, "Modeling Latent Market Power Across Gas and Electricity Markets," System Dynamics Review, 13 (4).

CERA 2001
Cambridge Energy Research Associates, "Special Report – Beyond California's Power Crisis: Impact, Solutions and Lessons, March 1, 2001, http://www20.cera.com

CPUC 1995
California Public Utilities Commission, "Final Policy Decision," December 1995.

CPUC 2000
California Public Utilities Commission and Electricity Oversight Board, "California's Electricity Options and Challenges: Report to Governor Gray Davis," August 2, 2000.

Deb 2000
Rajat Deb, "Rethinking Asset Valuation in a Competitive Environment," Public Utilities Fortnightly, February 1, 2000.

Dyner and Larsen 2001
Isaac Dyner and Erik Larsen, "From Planning to Strategy in the Electricity Industry," working paper, Erik Larsen, City University Business School, Northampton Square, London EC1V 0HB, UK.

DOE 2000
Bill Richardson, Secretary of Energy, "Comments of the Department of Energy," FERC Docket No. EL009-95-00, November 22, 2000.

EPRI 2000
F. Graves, A. Ford and S. Thumb, "Prospects for Boom/Bust in the U.S. Electric Power Industry," Electric Power Research Institute, Palo Alto, CA: 2000. Technical Report 1000635.

FERC 2000
Federal Energy Regulatory Commission, "Response of the Staff of the FERC to Questions Posed at the December 20, 2000 Western Governors Association Denver Meeting," available from the bulk power section of http://www.ferc.fed.us/

Ford 1997
Andrew Ford, "System Dynamics and the Electric Power Industry," System Dynamics Review , Vol 13, No 1, Spring 1997, pages 57-85.

Ford 1999A
Andrew Ford, "Cycles in Competitive Electricity Markets: A Simulation Study of the Western United States," Energy Policy, Vol 27, 1999, pages 637-658.

Ford 1999B
Andrew Ford, Modeling the Environment, Island Press.

Forrester 1961
Jay Forrester, Industrial Dynamics, Pegasus Communications.

Grix 2000
Richard Grix, “Market Clearing Prices Under Alternative Resource Scenarios: 2000-2010,” CEC Report, February 2000.

Hickok 2001
Steven Hickok, Chief Operating Officer, BPA, “Fundamentals of the Electric Power Situation in the Pacific Northwest,” speech to the Portland Metropolitan Chamber of Commerce, February 20, 2001.

Hirsh 1999
Richard Hirsh, Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System, The MIT Press.

Hoyt 1933
Homer Hoyt, One Hundred Years of Land Values in Chicago, University of Chicago Press.

ISO 2000
Presentation to the ISO Governing Board, “Summer 2001 Preparedness and 2001 Demand Relief Program,” October 25, 2000.

ISO DMA 2000
California ISO Department of Market Analysis, “Report on California Energy Market Issues and Performance: May-June 2000,” August 10, 2000.

ISO MSC 1999
California ISO Market Surveillance Committee, Frank Wolak, Chairman, “Report on Redesign of California Real-Time Energy and Ancillary Services Markets,” October 18, 1999.

ISO MSC 2000A
California ISO Market Surveillance Committee, Frank Wolak, Chairman, “An Analysis of the June 2000 Price Spikes in the California ISO’s Energy and Ancillary Services Markets,” September 6, 2000

ISO MSC 2000B
California ISO Market Surveillance Committee, Frank Wolak, Chairman, “Analysis of the Order Proposing Remedies for California Wholesale Electric Markets,” Dec 1, 2000

ISO MSU 1999
California ISO Market Surveillance Unit, “Annual Report on Market Issues and Performance,” June 1999.

Kahn and Joskow 2000
Ed Kahn and Paul Joskow, “A Quantitative Analysis of Pricing Behavior in California’s Wholesale Electricity Markets During Summer 2000,” FERC Testimony, November 21, 2000.

Klein 1997
Joel Klein, “Interim Staff Market Clearing Price Forecast for the California Energy Market,” CEC Report, December 10, 1997

Krapels 2001
Edward Krapels, “Was Gas To Blame?” Public Utilities Fortnightly, February 15, 2001.

McCullough 1998
Robert McCullough, “Can Electricity Markets Work Without Capacity Prices?” Public Utilities Fortnightly, March 15, 1998.

Meadows 1972
Dennis Meadows, Dynamics of Commodity Production Cycles, Pegasus Communications.

Michaels 1997
Robert Michaels, “MW Gamble: The Missing Market for Capacity,” The Electricity Journal, December 1997.

Moore 1999
T. Moore, “Merchant Plants Drive Market Competition,” EPRI Journal, 24 (2), Electric Power Research Institute, Palo Alto, California.

Morecroft and Sterman 1994
John Morecroft and John Sterman, editors, Modeling for Learning Organizations, Pegasus Communications.

Newbery 1995
David Newbery, “Power Markets and Market Power,” The Energy Journal, 16, (3).

NPPC 1996
Northwest Power Planning Council, “Northwest Power in Transition,” March 1996.

NPPC 2000
Northwest Power Planning Council, “Study of Western Power Market Prices,” Final Report, October 11, 2000

PJM MMU 2000
PJM Market Monitoring Unit, “Monitoring the PJM Energy Market: Summer 1999,” paper published in the Proceedings of the Fifth Annual Research Conference on Electricity Industry Restructuring,” University of California Energy Institute.

Puller 2000
Steven Puller, "Pricing and Firm Conduct in California's Deregulated Electricity Market," working paper, University of California, Berkeley, California. Nov. 2000.

Schuller 1996
J. Schuler, "Generation: Big or Small? Public Utilities Fortnightly, September 15, 1996.

Sioshansi 2000
Fereidoon Sioshansi, "California's Flawed Market," Newsletter of the International Association of Energy Economists, Fourth Quarter 2000.

Sjoding 2001
Dave Sjoding, Deputy Director, Washington State University Energy Program, "Energy Price Increases and Energy Trends," Olympia, Washington, January 25, 2001.

Sterman 2000
John Sterman, Business Dynamics, Irwin McGraw-Hill, 2000.

Stoft 2000
Steven Stoft, "Soft Price Caps and Underscheduling Penalties: How Would the FERC Plan Affect California Electricity Markets," working paper PWP-079 from POWER, the Program on Workable Energy Regulation, University of California Energy Institute, Berkeley, California.

Teece 2001
"Manifesto on the California Electricity Crisis," convened under the auspices of the Institute of Management, Innovation and Organization, David Teece, Director, Hass School of Business, University of California, Berkeley, California, Http://hass.berkeley.edu/news/california_electricity_crisis.html).

Thurston 1999
C. Thurston, "Merchant Power: Promise or Reality? Public Utilities Fortnightly, January 1, 1999.