Boom & Bust in Power Plant Construction: Lessons from the California Electricity Crisis

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Summary

This article argues that competitive electricity markets are prone to the same cycles of boom and bust that appear in commodity markets and in a specialized industry like real estate. The article then demonstrates how boom and bust might appear in the western electricity system using computer simulation. A "business as usual" simulation shows that the west might be at the crest of a building boom and on the verge of a bust in wholesale prices. Without fundamental changes in the wholesale markets, the next construction boom would come too late to prevent a decline in reserve margins and the reappearance of price spikes. If we continue with the current market structure, we run the risk of exposing the western electricity markets to another round of reliability alerts and price spikes. The article concludes with suggestions for alternative market structures in California and a discussion of whether these suggestions apply to other countries engaged in electricity restructuring.

Introduction

The blueprint for a competitive electric industry in California was issued in 1994 and implemented by the Legislature in 1996. The new markets opened for business in 1998. By the summer of 2000, a full-blown crisis had emerged in the form of unprecedented outages and price spikes. The crisis conditions continued through the fall of 2000, spread throughout the west, and continued into the winter and spring of 2001. Then, to the surprise of many, chronic outages and price spikes did not appear in the summer of 2001. Demand was below levels reported in the previous year, and natural gas prices fell dramatically. New power plants came on line, and many more entered construction. As the year 2001 drew to a close some were predicting that the current building boom will lead to a glut of electricity supply. It appears that the western electric system is experiencing the boom and bust pattern that has appeared in other industries.

Many industries have experienced persistent cycles of boom and bust. The commodity industries suffer from chronic instability despite the fact that their products may be stored in inventory as a buffer between production and consumption. Buffer stocks do not exist in the electricity industry, so the industry looks to extra generating capacity to absorb the variations in supply and demand. In this sense, the electric industry is similar to the real estate industry with the reserve margin in the electric industry corresponding to the vacancy rate in the real estate industry. The industries are similar in several other respects as well. Developers in both industries face long delays for permitting and construction. Both are capital intensive, so developers face the challenge of recovering high fixed costs through high utilization.

Boom and Bust in Real Estate

The long history of real estate is dominated by a series of exuberant building booms and subsequent busts. To illustrate, Figure 1 shows the pattern of boom and bust documented in Homer Hoyt's detailed account of land values in Chicago. The chart shows land values, new construction and business activity, all scaled in percent variation from a normal value. Hoyt described surges in population as an important external factor, but the key to the boom-bust pattern was the way investors reacted to the population surges. In a typical example, developers did not react in time to prevent land values from increasing far beyond the increase in population. The high prices then led to an exuberant response, described by Hoyt (1933, p 387) as follows:

Developers scramble to build at many locations around the city, and a great many men work secretly and independently on a great variety of structures in many sections of the city. There is no central clearing house to correlate the impending supply of buildings with the probable demand, so that when all these plans came to fruition, an astonishing number of new structures had been erected.

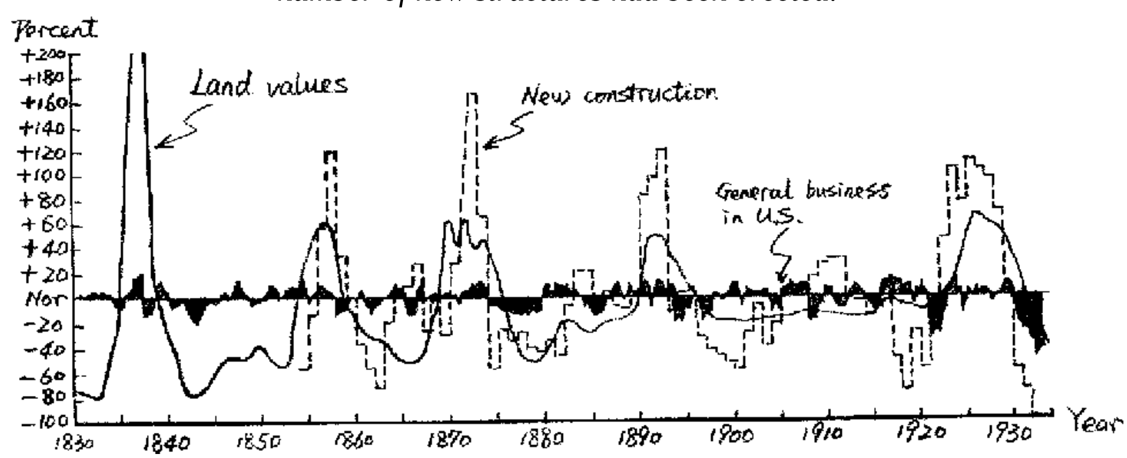

Figure 1. Land values and construction cycles in Chicago.

This overreaction sets the stage for the bust: "Gross rents fall, and net rents fall even faster. Land values plummet, and foreclosures are everywhere." Hoyt concluded by speculating that the "real estate cycle itself may be a phenomenon that is confined chiefly to young or rapidly growing cities." But population surges are just one of many external factors that might set the stage for a boom and bust in construction. More recently, the external factor may take the form of a surge in income, as happened in cities like Dallas and Boston during the 1970s (DiPasquale 1996, Sterman 2000).

It is natural to attribute a particular building boom to an external event, but a full understanding requires consideration of internal as well as external factors. Hoyt looked closely at developers' decision-making in Chicago and concluded that there was no way for developers to keep track of the number of buildings that were under construction. When all the buildings were finally completed, "an astonishing number of new structures had been erected." DiPasquale looked at developer's decision-making in Boston through the lens of structural models. The model with the best statistical explanation of housing construction tells a similar story as Chicago – the developers simply built too much housing during the boom and "the stock of housing overshoots the target."

The overbuilding observed in Chicago and Boston arises, in part, from developers ignoring or discounting the future impact of construction "in the pipeline." The tendency to understate the impact of the "pipeline" appears in industries, ranging from "A to Z, from aircraft to zinc" (Sterman 2000, p. 792). In the case of real estate, developers from the 1980s and 1990s concentrated on picking the best location and bringing the project to market. As we think about power plant construction, it's certainly important to account for the physical factors such as capital intensity and construction lead times and to account for the tendency of developers to not fully account for construction "in the pipeline." We should also expect psychological factors to play a role in shaping investor behavior. The key psychological factors that contribute to instability in markets include a focus on external events, a tendency for "herding" and "groupthink," and simple denial that cycles could exist (ERPI 2000).

Although we have learned to live with construction cycles in the real estate industry, it's not at all clear that we should tolerate construction cycles in the power industry. A fundamental difference in the two industries is the flexibility of the demand side. In real estate, we deal with the periods of low vacancies and high rents by adjusting our demand for floor space. When rents are unusually high, we squeeze into smaller quarters and wait for the boom in construction to bring rents back to normal levels. In electric power, however, customers have little ability to react when reserve margins are low and prices are high. With the current market structure, our ultimate response to dangerously low reserve margins is to schedule rolling blackouts to protect the integrity of the system. The extraordinary reliability requirement of the electric industry sets it apart from industries like real estate. The west needs new structures that will avoid a replay of the price spikes and outages that appeared in 2000-2001.

The crisis conditions of 2000-2001 have revealed the serious consequences of insufficient power plant construction in the western system. The lag in construction has been documented in a recent report by the Northwest Power Planning Council (NPPC 2000) and in Senate Testimony by Steve Oliver (2000). Oliver suggests that the lack of construction might be attributed to numerous uncertainties that surround the transition to competitive markets. But he warned that the problem could be fundamental and persistent: “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.” Power plant developers around the US have responded to the market signals with a major increase in proposed projects. An EPRI review of proposed power plants in the US “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 review concluded that different regions of the country “could move from boom to bust in just a few years” (EPRI 2000).

Modeling Methods

I have reviewed models that might help one understand the potential for boom and bust in power plant construction. Most models require the user to specify the new generating capacity as an exogenous input. A few models simulate new construction as an internal variable, but these typically rely on a combination of optimization and “perfect foresight” to calculate construction over time. This approach may appeal to a theory of “rational expectations,” but it precludes a serious consideration of boom and bust (ERPI 2000). A new approach was needed, one which represents “decision-making as it is, not as it should be, not how it would be if people were perfectly rational” (Sterman 2000, p. 597). System dynamics is a useful approach in this situation.

System dynamics is a simulation method pioneered by Forrester (1961) and explained in texts by Ford (1999) and Sterman (2001). It’s origins are in control theory and it has been defined as that “branch of control theory which deals with socio-economic systems and that branch of management science with deals with problems of controllability” (Coyle 1977, 2). The approach is valued in a rapidly changing electricity industry with high risk (Dyner and Larsen 2001) and as a complement to traditional optimization methods (Bunn, Larsen and Vlahos 1993). Moreover, it has been used to warn of the potential for volatile patterns of power plant construction arising from some of the market rules used in the UK shortly after privatization (Bunn and Larsen 1992).

I began the development of system dynamics models of power plant construction in the summer of 1998. The first model represented the average annual energy loads and resources in the WSCC, the Western System Coordinating Council (Ford 1999B). The approach was extended in the summer of 2000 with a model to represent construction and market prices in a summer peaking system with approximately the same loads, resources and markets as those in California. The simulations revealed 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 the investors. But this was not the dominant pattern. The more likely pattern showed construction lagging behind the growth in demand, allowing prices to climb to surprisingly high values during peak periods in the summer. When power plants are completed, they tend to come on line in great numbers causing a bust in wholesale prices (Ford 2001A). The previous article concluded that the lack of power plant construction is a western problem, not just a California problem. The article called for an expansion in the model boundary to include loads and resources throughout the west. The expanded model is designed for highly interactive use to promote experimentation and discussion. Such models are sometimes called “management flight simulators” because they are designed to promote learning through interactive experimentation (Ford 1999A, Morecroft 1994). This article presents the model with an emphasis on the interface to promote interactive simulation for general learning. Readers interested in a deeper understanding of the general tendency for over building in electricity markets are referred to previous work (EPRI 2000, Ford 2001A).

The Western Market Model

Figure 2 shows the opening screen of the model with one of the information buttons in view. The button explains that the model operates as if the entire loads and resources in the WSCC interact in a single market place.

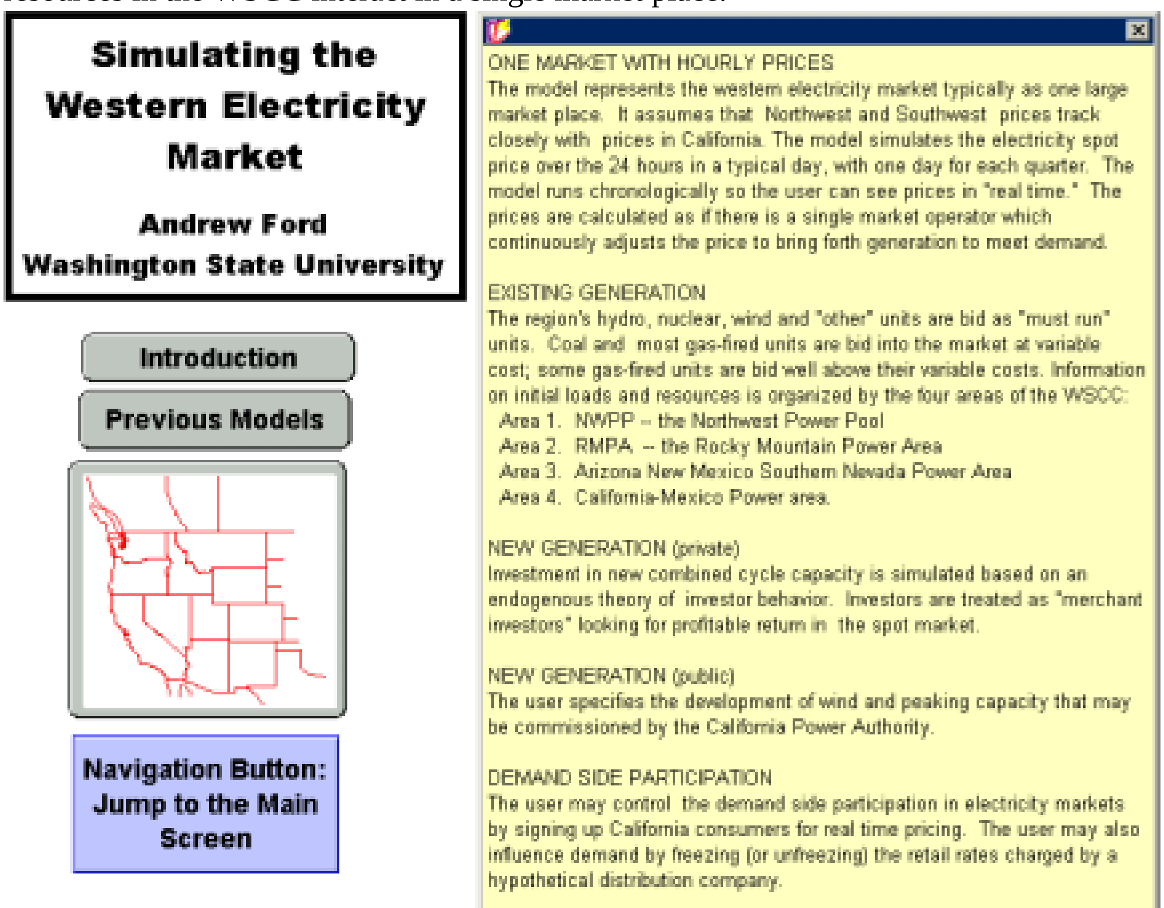

Figure 2. Opening Screen of the Western Market Model.

The fundamental assumption is that wholesale prices at various points in the west will rise and fall together (Oliver 2000, NPPC 2000, FERC 2001). Although the western wholesale market behaves as one market, there are important differences in reliability of service and in the financial vulnerability of the distribution companies across the west.

These differences account for the greater severity of financial impacts on California distribution companies. My view of the special problems of the distribution companies in California appears in a previous article (Ford 2001A); this article focuses on the wholesale market.

The wholesale market simulations begin in the winter of 1998, with existing generation reported by the WSCC. The model simulates a typical 24-hour day for the winter of 1998, records the results as representative of the winter quarter, and proceeds to simulate a typical day for the remaining three quarters of 1998. This approach continues over the historical period and into the future. Figure 3 shows simulated market prices over the historical interval from 1998 to 2001 with the vertical axis scaled from 0 to 400 $/mwh. The hourly prices tend to increase in the day and fall at night; the first price spike appears in the spring of 2000. The price peaks at nearly 200 $/mwh during the typical day in spring of 2000. Figure 3 shows larger and more persistent spikes in the remainder of 2000 and in the first half of 2001. The model calculates averages over the 24 hours in a typical day for each quarter. These quarterly results appear in Figure 3 as abrupt changes when the model posts new results at the conclusion of each quarter. The quarterly price climbs to around 130 $/mwh in the summer of 2000 and even higher in the fall of 2000 and the winter of 2001. The winter price is around 250 $/mwh, nearly ten times higher than prices at the start of the simulation. These prices may seem shocking, but they are similar to quarterly prices reported by the ISO.

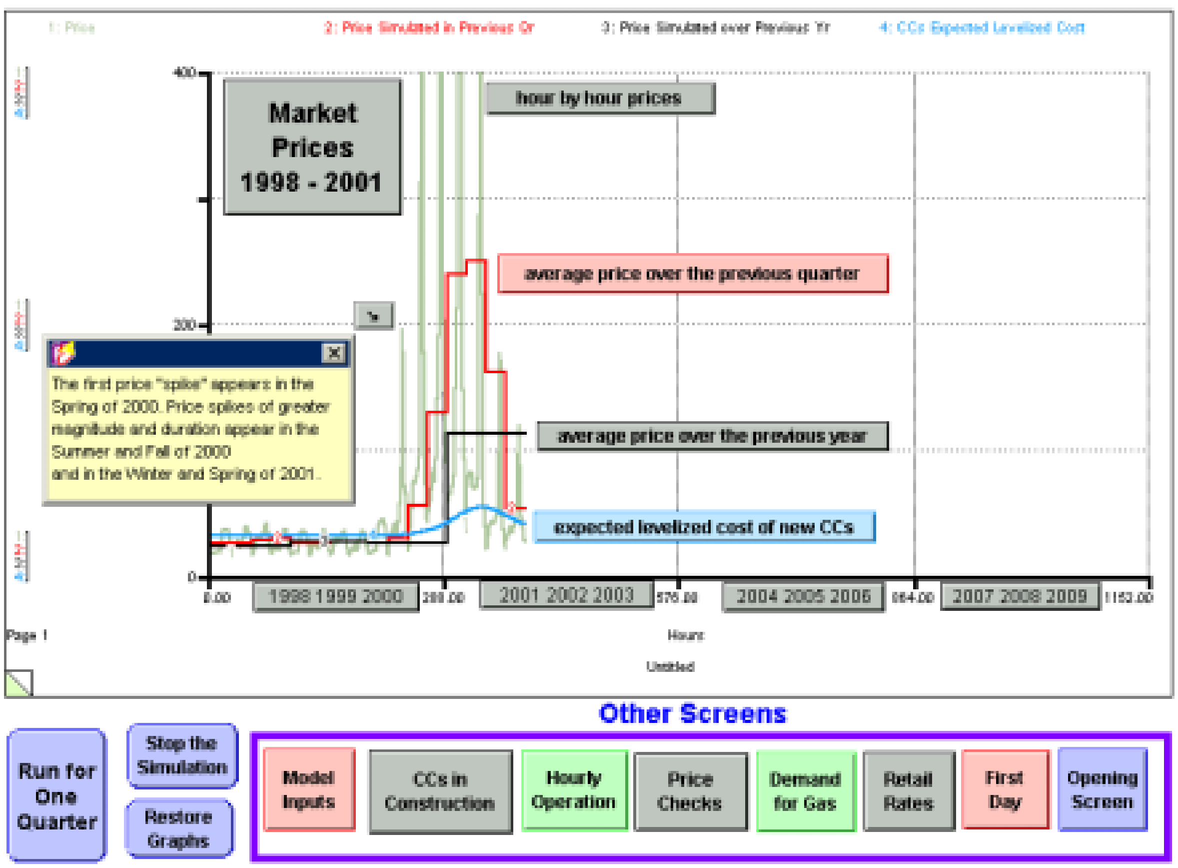

Figure 3. Main Screen with Four Years of Simulated Market Prices in View.

Figure 3 also shows annual prices and the investors' expected levelized cost of a new CC. The lower portion of the main screen is filled with operational and navigation buttons. There are buttons to run or stop the simulation and a row of buttons to jump to other screens for setting the inputs or for viewing the results.

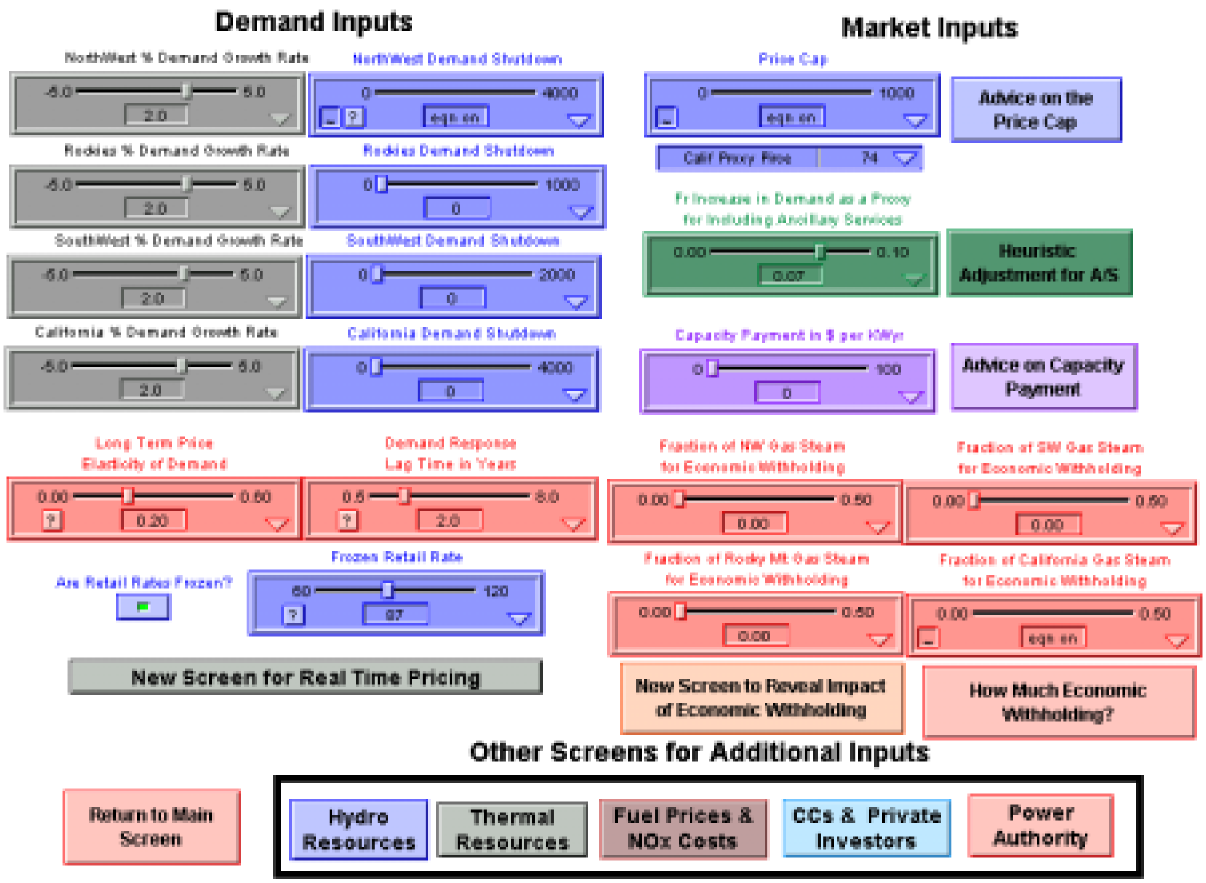

Figure 4. Model Inputs Screen.

Figure 4 shows the main screen for setting model inputs. Initial loads are based on the WSCC data for each reporting area, and the user specifies the growth in demand using the four sliders in the upper left portion of Figure 4. The historical simulation assumes a general trend of 2 % annual growth in each of the four years. Variations from this trend are imposed to account for known changes in the weather. Figure 4 shows four additional controls to allow one to impose the unusual reduction in loads that have appeared during the past few years. Additional "demand inputs" in Figure 4 are the price elasticity of demand and lag for consumers to respond to changes in retail prices. The long-term price elasticity is set at 0.2, but the retail rate for the hypothetical distribution company is frozen at 87 mills/kwh so there is no consumer response in the "Business As Usual" simulation.

The right side Figure 4 shows the key parameters for representing market design and market behavior. The first input is the price cap, expressed in $/mwh. The cap in the ISO real-time energy market is the defacto price cap in the California markets, so the historical simulation follows the variations in the cap set by the ISO. The next control in the market inputs column is the "fractional increase in demand used as a proxy for including ancillary services." The base value is 7%, which means that the actual demand is elevated by 7% before calculating market prices. The generating resources are bid into a market to serve the elevated demand, and the price is taken as an approximation for the energy price that would result when generators can bid into multiple markets. (The control allows this input to be set as high as 10%, which would mimic the "conservative approach" used by Kahn (2000) and by Hildebrandt (2000) to estimate counterfactual market prices.) The remaining sliders shown in Figure 4 allow the user to control the extent of "strategic behavior." The model is designed as if the impact of strategic behavior can be represented by a user specified fraction of older gas units subject to economic withholding. To simulate competitive outcomes, one sets these fractions to zero, and all of the gas capacity will be bid at variable cost. Turning the California "equation on" sets withholding to match studies by the ISO.

Figure 5 shows the results on the "CCs Under Construction" screen. The four variables are displayed on a graph scaled from 0 to 60,000 MW. The "paperwork on proposed CCs" grows to almost 45,000 MW by the end of the historical period. The first gray button is located to represent the 33,000 MW either approved or in the formal review process at the end of 2000. The next gray button shows a historical benchmark of 43,000 MW of paperwork midway through 2001. The simulated accumulation of paperwork comes close to the two benchmarks. The three red buttons represent benchmarks for new CCs under construction. The third button is open, so we can read that around 21,000 MW of capacity was under construction midway through 2001.

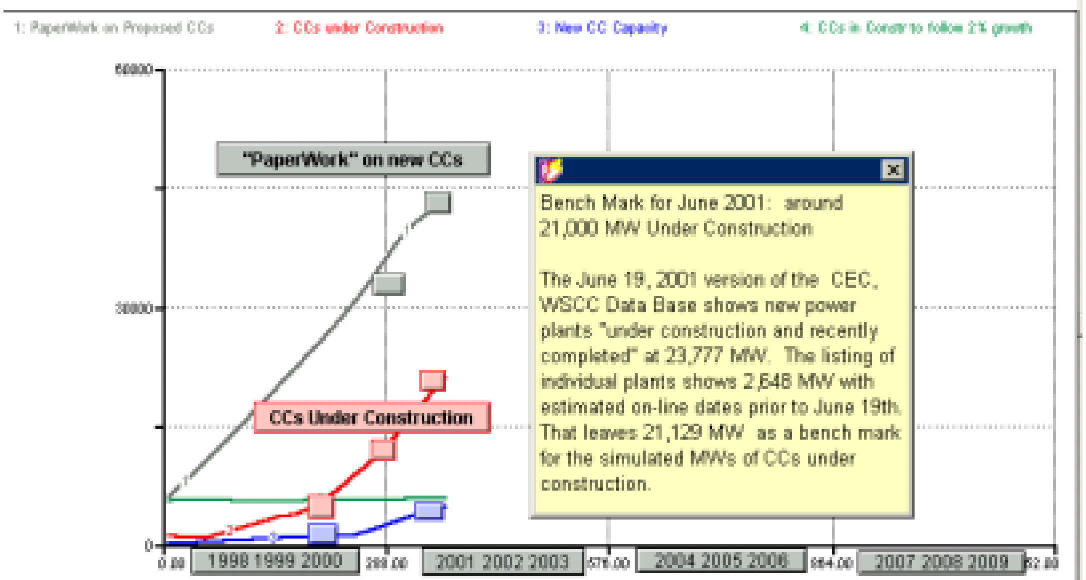

Figure 5. Simulated Construction Over the Past 4 years.

Figure 5 shows that the simulated growth in CCs under construction comes close to all three benchmarks. Figure 5 also shows that the simulated growth in new capacity comes close to the two benchmarks. The fourth variable displayed in Figure 5 shows that around 5,500 MW of CCs would be in construction if investors were building new power plants to expand total generating capacity to keep pace with the 2% annual growth in demand. Figure 5 shows that the simulated construction is well below the 5,500 MW in 1998 and 1999, well above in 2000 and 2001. In other words, the west has experienced under-building in 1998-1999 and over-building in 2000-2001.

The under-building in 1998-1999 is one of the main factors contributing to the severe price spikes in 2000-2001. With a 24-month construction delay, investors would have had to start construction midway through 1998 if they were to bring their plants on line midway through 2000. Perhaps they did not start construction at this time because of "opening market confusion." After all, the California markets did not begin operation until the spring of 1998. On the other hand, one might argue that market rules were evident with the passage of AB 1890 in the summer of 1996. With the rules in place, a rational investor might have looked into future to see highly profitable conditions and started construction midway through 1998. The explanation of the under-building will shape the way one addresses the question of changing California's wholesale market structure for the future. If one attributes the under-building to early market confusion, for example, one might argue that we retain the current market structure and hope the investors will be less confused in the future. On the other hand, if the under-building is attributed to factors that could reappear in the future, we need new market structures.

A Theory of Investor Behavior

The Western Market Model explains the under-building based on market fundamentals that could well reappear in the future, as shown in Figure 6. The model simulates the development process beginning with the application for a construction permit. After 12 months, the developer receives the permit, and the project enters a "site bank". The key decision is whether to start construction. Figure 6 depicts the theory of construction starts with some illustrative numbers from 1998-1999. During these years, natural gas was priced at 2.50 $/mmBTU, and a developer was looking at a fully levelized cost of 31.5 $/mwh for a new CC. In the illustrative example, the investors expect the market to clear at 26 $/mwh, a value which is simply too low for a significant fraction of the developers to begin construction. The model assumes that investors were inclined to wait for expected conditions to improve. With time, demand will grow, expected reserve margins will fall, and expected market prices will rise. When expected market prices are closer to the investors' target for a new CC, they will turn their permits into actual construction projects.

The approach in Figure 6 is simulated continuously over time. That is, investors continuously update their assessments of supply and demand as simulated conditions change over time. If they do start construction, their own construction will shape their assessments in the future. This is an aggregate approach which does not distinguish between the investment decisions by individual companies or between different types of investors, as is done in a previous model (Ford 2001A). Figure 5 demonstrates that this approach succeeds in explaining construction over the historical period. The model explains the under-building in 1998-1999, and it does so without resorting to the argument that investors were inhibited by early market confusion. It also succeeds in explaining the over-building in 2000-2001.

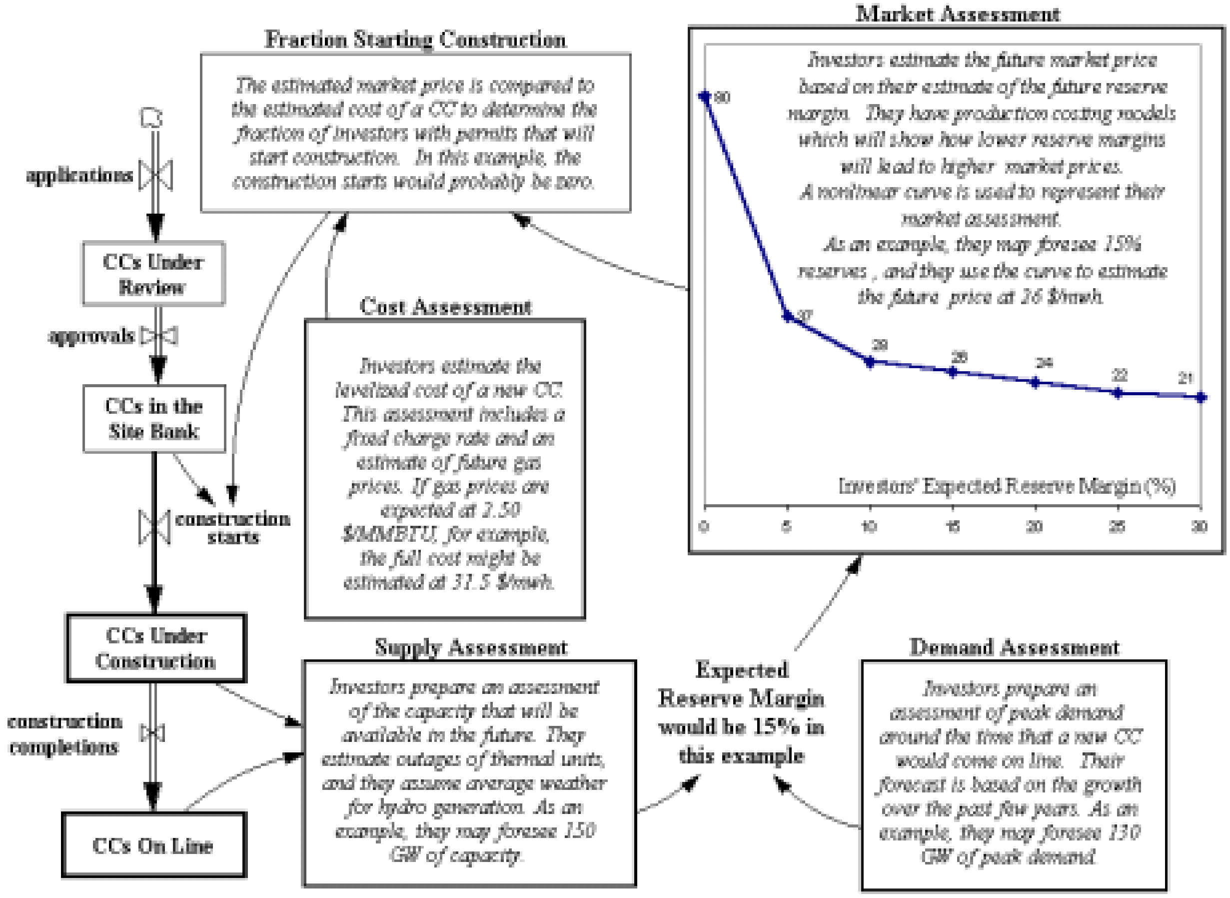

Figure 6. The Theory of Investor Behavior Implemented in the Western Market Model.

The Business As Usual Scenario

Several of the model inputs were adjusted from year to year during the historical period. For example, the price of natural gas increased rapidly in 2000 and early 2001 before declining midway through 2001. These variations are helpful during the historical period because they improve the comparison with historical prices. However, as we extend the simulations into the future, it makes sense to adopt relatively constant assumptions in the interest of clarity. For example, I assume that hydro generation will be based on average runoff and natural gas will cost 4 $/mmBTU in California. Although there are many older power plants in the west, there are no retirements of existing capacity in the business as usual scenario. The new capacity will come from private investment in the CCs. There are no investments by the California Power Authority, but I do include Bonneville's commitment to 530 MW of wind capacity in the northwest. The scenario assumes that a price cap will remain in place and that economic withholding will remain at the values found useful in explaining historical prices. There are no capacity payments; no real-time pricing programs; and retail rates are frozen.

Figure 7 shows the simulated construction in the business as usual scenario. The scenario envisions that investors will wish to maintain the paperwork at the amount accumulated over the past few years. The total paperwork remains at approximately 45,000 MW from 2002 through 2009. This is a combination of projects under review as well as projects in the site bank. As permits are granted, the bulk of the paperwork will be in the site bank. The construction curve in Figure 7 shows that CCs under construction peaks near the end of 2001. From this point forward, construction completions are greater than construction starts, and the total MW of CCs under construction declines. This simulation suggests that we are now at the crest of the current building boom. As the construction is completed during 2002 and 2003, installed CC capacity will grow to around 27,000 MW by the start of 2004. Figure 7 shows a second wave of construction beginning in 2006 and peaking near the end of 2007.

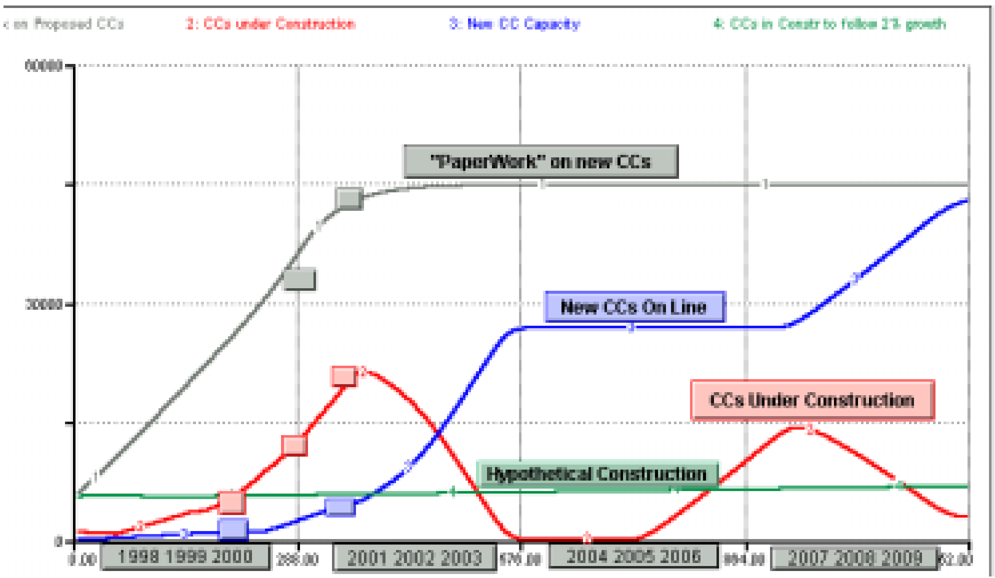

Figure 7. Simulated Construction in the Business As Usual Scenario.

The scenario suggests that we are currently in the midst of a building boom with the actual construction well above the hypothetical construction. This over-building situation continues until midway through 2003. For the next three years, however, the scenario envisions construction below the levels needed to keep pace with demand. This lull in construction arises when investors again arrive at pessimistic market assessments (similar to the assessment depicted in Figure 6). During this interval, investors are reluctant to start construction, even though they hold a huge number of approved permits. Investors hold off on construction starts until 2006 – 2007.

Figure 8 shows market prices in the business as usual scenario, with the vertical scale running from 0 to 400 $/mwh as in the previous display. The simulation indicates that hourly variations for typical days in 2002 and 2003 would be much smaller than the variations in 2001. Figure 8 shows the quarterly prices continue to decline during the interval from 2002 to 2004. The construction boom allows for much lower prices for the interval from 2002 to 2005. The average in 2002, for example, is 39 $/mwh. By 2003, the average annual price is down to 34 $/mwh. At this level, the annual price is slightly below the investors' expected cost of a new CC.

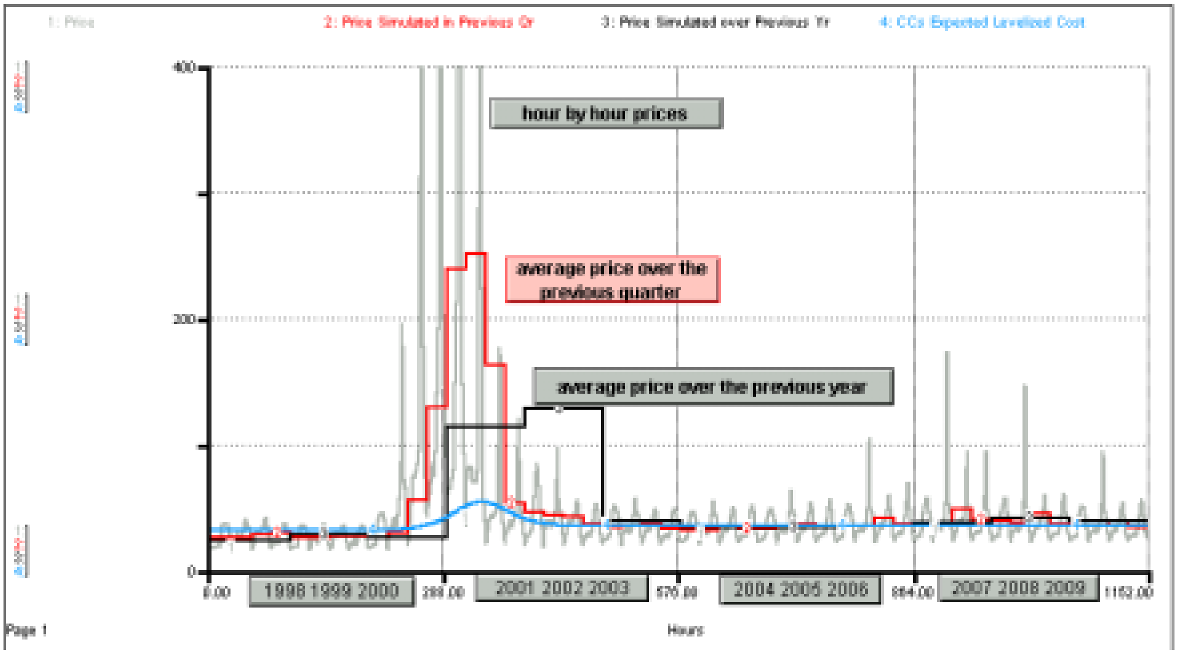

Figure 8. Simulated Prices in the Business as Usual Scenario

An important result from the business as usual simulation is the reappearance of price spikes in the years 2006 and 2007. The spike in 2006 exceeds 100 $/mwh; the spike in 2007 is around 175 $/mwh. These contribute to an increase in the quarterly and annual prices. In 2007, for example, the average annual price is 41 $/mwh, somewhat above the investors' expected cost of 35 $/mwh for a new CC. The magnitude of these price spikes is much lower than the spikes during 2000 and 2001, but their timing is similar. The spikes in 2000 and 2001 appeared in the midst of a large building boom, just prior to the majority of the new CCs completing construction. The spikes in 2006 and 2007 appear in the midst of the second building boom, just prior to the next major increase in installed capacity. The building boom allows reserve margins to climb above 7% during the interval from 2002 to 2006. By 2007, however, reserve margins have returned to the low levels that would force the system operator to declare alerts.

Commentary

The "Business As Usual" scenario suggests that the western system will not provide the reserve margins said to be necessary for a reliable system. Reserves would dip below 15% even during 2003 and 2004, the years immediately after the completion of the first wave of construction. By 2007 and 2008, reserve margins are back at unreliable levels, reminiscent of the situation in 2000 and 2001. Construction would appear in repeated waves of boom and bust. We see that price spikes could reappear as soon as 2006 and 2007. These spikes are much less severe than the spikes in 2000 and 2001. The improved behavior arises because the scenario does not envision a replay of the "perfect storm." For example, gas prices do not skyrocket in 2006 like they did in 2000.

Also, hydro generation does not decline in the years 2006 and 2007, like it did in 2000 and 2001. These assumptions mask the underlying deterioration of the supply-demand balance that occurs during the lull in construction.

Figure 9 shows a variation in the opening scenario to unmask the difficult conditions that could emerge within the next decade. The new simulation assumes that the northwest could experience a "dry year" in 2007 and that the price cap is lifted at the start of 2004. (We might envision the cap would be eliminated because those who oppose price caps would win adherents to their view during the previous two years, years of low prices and declining construction.) Figure 9 shows hourly prices spiking "off the chart" in the year 2007. Quarterly prices would climb to around 200 $/mwh, and the average annual price for 2007 would jump to 146 $/mwh, a value which exceeds the annual prices seen in either 2000 or 2001. Reserve margins (not shown here) would decline to levels lower than the simulated reserves in the years 2000 and 2001.

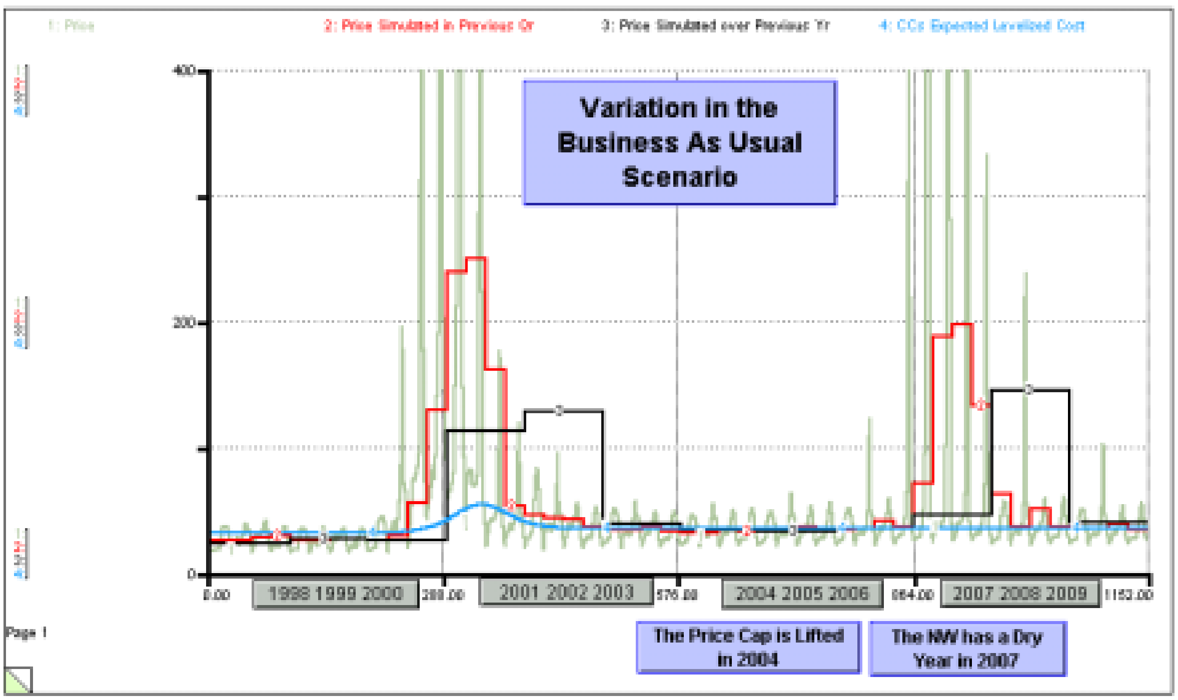

Figure 9. Market Prices in a Variation of the Business As Usual Scenario.

Lessons from the California Crisis

The purpose of the special issue of the Journal of Industry, Competition and Trade is to draw lessons from the California crisis; this article looks at the western wholesale markets to provide a longer-term perspective on the problems that have appeared in California. Figure 9 gives the key result by dramatizing the wholesale market volatility that may appear in a system prone to a boom and bust pattern of construction. The simulation reveals that the western system could be "one dry year away" from a repeat of the crisis conditions that appeared in the years 2000 and 2001. If we do not implement fundamental changes in the structure of wholesale markets, we run the risk of exposing the west to another round of price spikes and rolling blackouts.

This risk is explained in more detail in a discussion paper (Ford 2001B) prepared for a California Energy Commission workshop in November of 2001. The paper argues that wholesale markets could be improved if private investors receive an additional incentive in the form of a fixed capacity payment. On the other hand, we might turn to the California Power Authority to make the investments that will be needed in the future. However, if the Power Authority is to deliver on its mission of guaranteeing a reliable electricity supply, is should be prepared for a large and permanent commitment. The discussion paper also considers demand-side interventions. It argues that removing the legislative freeze on retail rates does not lead to long-term improvements in wholesale market performance. The more effective approach on the demand side is to implement programs to allow selected retail customers to respond to wholesale prices in real-time.

Transferability of Results

Electric systems in the rest of the USA have different markets and different mixes of resources from those in the west. The PJM system in the eastern USA, for example, includes a market for installed capacity (the ICAP market) as well as the market for electric energy. Also, the PJM system is much less dependent on hydro-generation, so it is not exposed to the "dry-year" and "wet-year" variations that are so important in the western USA. Other countries engaged in restructuring have different markets and resources as well. Their planners are looking to California for lessons. For example, should they expect private developers in their system to build new power plants in waves of boom and bust? If so, should they consider adding incentives to promote more timely construction?

These are complicated questions might be addressed with a comprehensive simulation approach, like the Western Market Model explained here. As a first step (short of full-fledged model development), planners might gain an initial appreciation of the potential for under-building by repeating the step by step assessment depicted in Figure 6. Planners may conduct the market assessment based on their own version of power plant costs and their own estimates of future prices of natural gas. Planners would used their own version of the non-linear market assessment curve, which could be generated from conventional production costing models. If the assessment leads to the same under-building situation depicted in Figure 6, planners should brace themselves for construction to appear in waves of boom and bust.

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