Conservation in an Era of Boom and Bust

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Abstract

This paper describes simulated scenarios for power plant construction in the western United States. The simulations show construction lagging behind the growth in demand, allowing prices to climb to surprisingly high values during the years 2000 and 2001. When construction is completed, new power plants come on line in great number, allowing market prices to fall surprisingly rapidly in the years 2001 and 2002. These results indicate that the restructured electric industry will experience the classic pattern of boom and bust that has been seen in the commodity industries and in capital intensive industries like real estate. The model is then used to simulate the impact of major conservation savings in an era of boom and bust.

Background on Boom and Bust

Many industries have experienced persistent cycles of boom and bust. The cyclical tendency is especially strong in the commodities. A commodity is usually defined as an undifferentiated product, often supplied by many small, independent producers. Examples include mineral products (i.e. aluminum and copper), forest products (i.e. lumber and pulp) and agricultural products (i.e. coffee and cattle). The instability in the commodity industries is costly for each industry, for its customers and for the nations that depend on commodity exports for the bulk of their hard currency.

Cycles of boom and bust also appear in non-commodities, industries dominated by a small number of large producers or industries with highly differentiated products. Examples include aircraft and real estate. Real estate and electric power are similar in many important respects. For example, there are no inventories in these industries to serve as a buffer between producers and consumers. Also, developers in both industries confront significant delays for permitting and for construction. Developers also face high fixed costs which they hope to recover through high capacity utilization.

But real estate and electricity are entirely different in age. Real estate is an industry with a long history of competitive markets and detailed studies. Its history is dominated by a series of exuberant building booms and subsequent busts (Hoyt 1933; DiPasquale and Wheaton 1996). The factors contributing to boom and bust are both physical and psychological. Key physical factors are long capacity lifetimes and significant delays for permitting and construction. Key psychological factors are a focus on external events, inattention to new buildings in the construction pipeline and “herding” behavior (Hoyt 1933, EPRI 2000, Sterman 2000).

The restructured electric industries around the world provide around a decade of history. So far, the lessons are difficult to discern because of frequent changes in market rules and organization. The privatization of the electric system in the United Kingdom (UK) is one of the longer running experiments in the world. The UK experiment is remarkable, in part, for the aggressive investment in new power plants, the so-called "dash for gas” by the distribution companies. But more time is needed to learn from the UK experiment, especially if we are looking for lessons about power plant construction (Ford 2001, Levesque 2001).

Here in the US, we have less experience with restructured electricity markets, but we do have a huge accumulation of power plant proposals, the early sign of a potential boom in construction. An EPRI review of proposed power plants “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).

Warnings of boom and bust are also appearing in the news. A recent article in the New York Times (August 22, 2001) reports on proposals for 350 GW of new capacity that could be on line as early as 2004, said to be enough to boost the nation’s capacity by 50%.The article also reports that many energy experts expect power plant construction to run in boom-and-bust cycles. An earlier article in the Wall Street Journal (July 7, 2000) reports that Duke Energy Corp builds cycles of boom and bust into their own scenario analysis of electricity markets around the world. “There is little doubt there will be over-building. It will happen. The question is when?” says James Donnell, President of Duke’s North American Energy Unit.

Simulating Boom and Bust

Figure 1 shows the opening screen of a computer model to simulate the patterns of power plant construction in the western United States. The model is based on the system dynamics approach which proved useful in two previous modeling studies of power plant construction (Ford 1999, 2001). The model is designed for highly interactive use to promote communication and discussion. The model will be used in this paper to anticipate the impact of conservation savings in an era of boom and bust in power plant construction.

The model represents the loads and resources of the four areas reporting to the Western Systems Co-ordinating Council (WSCC). It assumes that the western market can be represented as a single market with hour by hour prices set by a system operator whose job is to adjust the hourly prices to bring forth the generation to meet the demand. Demand is represented by a user specified load shapes for a 24 hour day, with one typical day for each quarter. Thermal generation is influenced by user-specified forced outage rates and by a fixed shape for the scheduling of planned outages. Hydro generation can vary depending on wet, dry or average conditions. The daily and seasonal shaping factors for hydro generation are specified by the user and tested for plausibility in a separate spreadsheet.

Generation from available capacity is determined by the market price relative to the generators' bids. (If the price exceeds the bid, the unit operates.) The bids are based on the variable costs for the vast majority of the generating units in the WSCC. However, the bids for a user-specified fraction of the older gas units are set far above variable cost. This form of "strategic behavior" has been called "economic withholding." It must be included if the model is to simulate the unusually high prices that have been observed in western markets during the years 2000 and 2001.

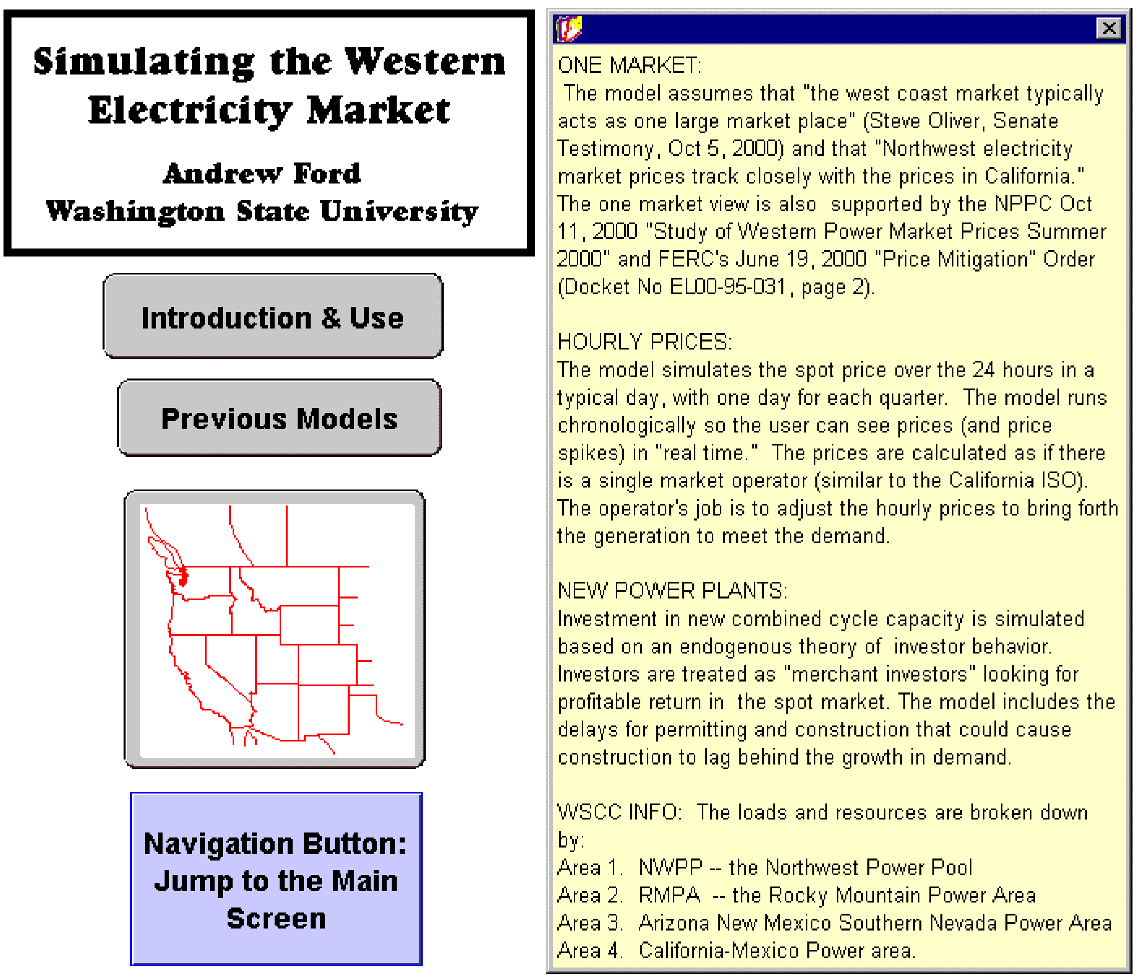

Figure 1. Opening screen of the model of the western electricity market.

Most projects proposed in the west are combined cycle (CC) units to be fueled by natural gas. We assume that investors are “merchant investors” looking to recover the total costs of a new CC from electricity sold into the spot market. Figure 2 shows the “stocks and flows” to simulate the development process. Applications for permits are based on a user specified goal for proposals under review and in the site bank. The permitting delay is 12 months, and the approved permits may remain in the site bank for ten years before construction is started or the permit expires.

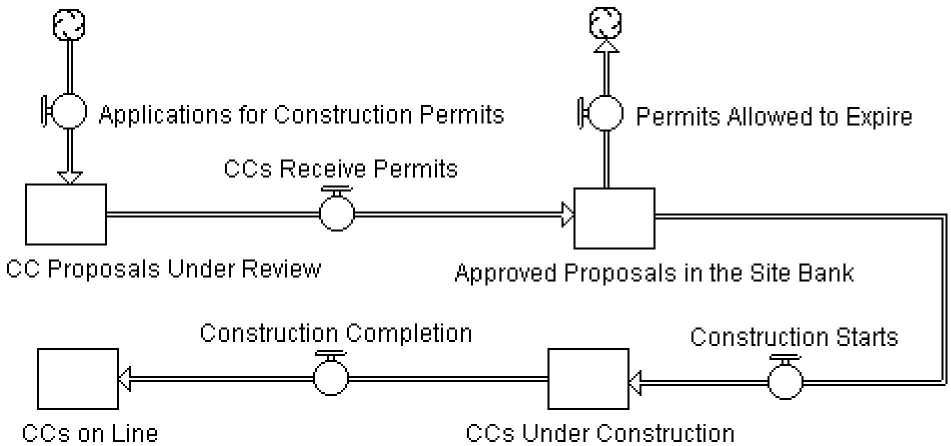

Figure 2. Simulating the development of new combined cycle (CC) units.

The key endogenous variable is “Construction Starts.” The model adopts an explicit theory of investors’ estimates of future profitability. Investors are assumed to follow the trends in demand growth and to estimate the amount of generating capacity that could be in operation in the future. They estimate market prices based on their expectation of the tightness in the future market, and they are inclined to start construction if market prices are estimated to match or exceed the fully levelized cost of a new CC. The new CCs come on line 24 months after construction is initiated, and the new capacity is bid into the market at variable cost.

The Base Case Scenario

Figure 3A shows the simulated development of new CCs (displayed on a scale from 0 to 60,000 MW). The gray curve shows the growth in the “paper work” on new CCs. By early in 2001, there were around 33,000 MW of new CCs in the site bank or under review, as noted by the gray button in Figure 3A. We assume that 33,000 MW is a reasonable estimate of the paper work that developers would like to hold in the future.

Figure 3A shows the MW of CCs under construction by the red curve, and two red buttons are positioned to represent historical values. The red curve passes through the first button in 2000 and just below the second button at the start of 2001. This confirms that the model provides a good match with the construction that has been started to date. The continuation of the red curve into the future shows construction peaking in 2001 at around 19,000 MW. Construction falls to zero by the end of 2003, and a second wave of construction is initiated in 2005, peaking at around 14,000 MW in the year 2007.

The green curve in Figure 3A shows the MW of CCs that would be under construction in a hypothetical situation with investors building exactly the capacity needed to keep pace with 2% annual growth in demand. With a two-year construction delay, the hypothetical construction is around 6,000 MW. The comparison of actual construction and hypothetical construction shows periods of "under building" followed by periods of "over building" in a repeating pattern of damped oscillations.

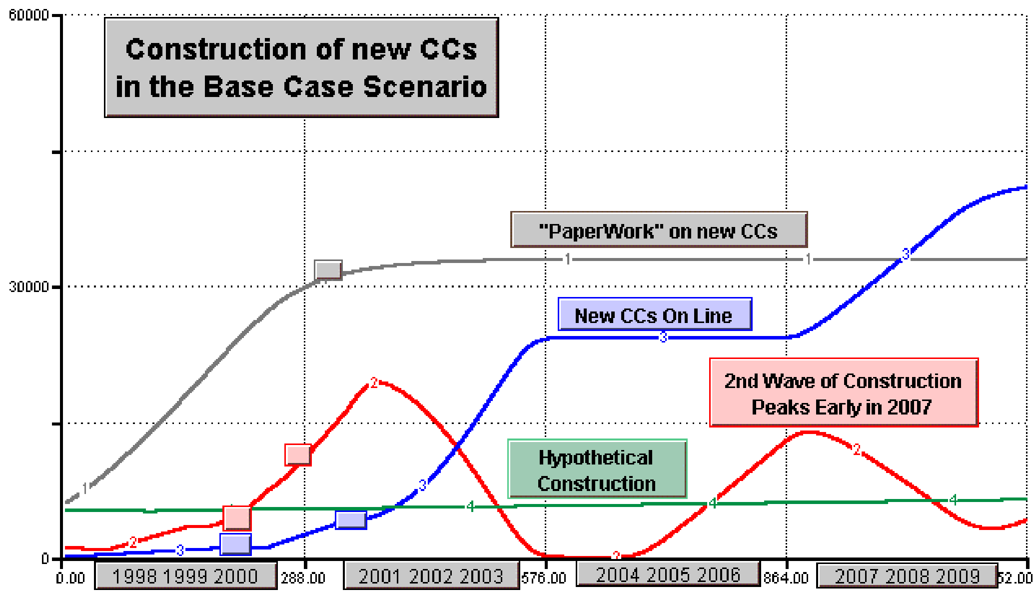

Figure 3A. Power plant construction in the base case scenario.

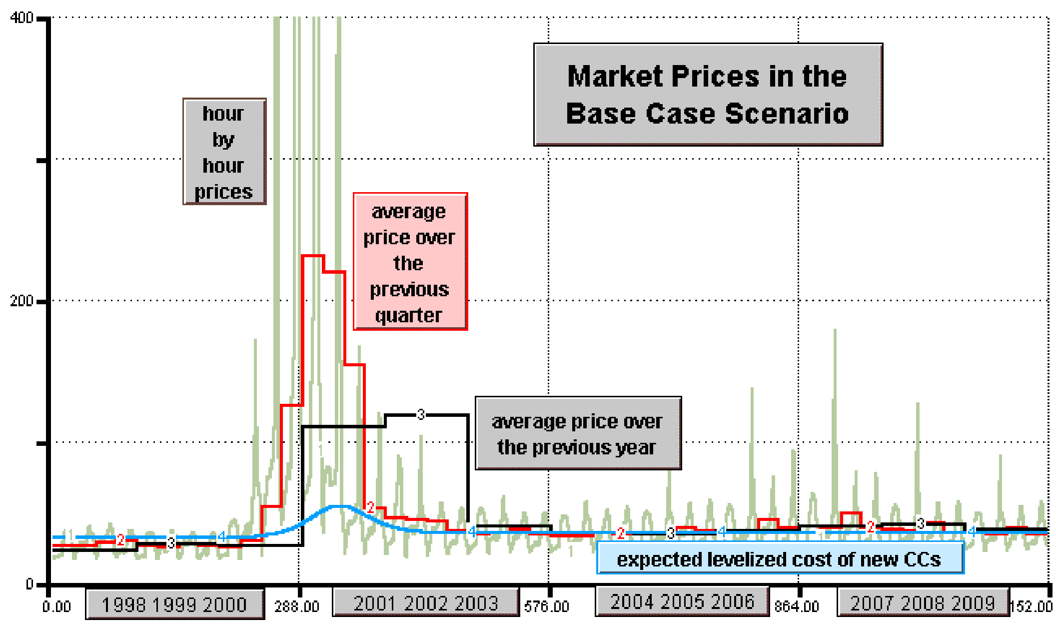

Figure 3B. Market prices in the base case scenario.

Figure 3B shows the market prices (displayed on a scale from 0 to 400 $/mwh) in the base case scenario. Hourly prices are shown in gray; they vary up and down during the 24 hours of a typical day in each quarter. The red curve is updated at the end of each quarter to show the average price observed over the previous year. The black curve is updated at the end of each year. The blue curve puts the market prices in perspective by showing the investors' expectations for the full cost of a new CC.

Figure 3B shows the surprising increase in market prices beginning in the summer of 2000. The hourly prices show pronounced spikes that shoot past the 400 $/mwh scale on the graph. The price cap in the model is based on the cap in the ISO real time market. It was set at 750 $/mwh at the start of the year 2000 and lowered to 500 $/mwh in July. The ISO attempted to lower the cap further in August, but the FERC imposition of a "soft cap" led to a situation where western markets were operating without an effective cap. The average quarterly prices simulated in the model soared to 125 $/mwh in the summer and to 231 $/mwh in the fall. Figure 3B shows that the simulated prices remained high in 2001 (221 $/mwh in the winter and 155 $/mhw in the spring). The high prices in 2000 and 2001 arise from a combination of factors that converged on the west in what has been called the "perfect storm." These include a shocking increase in the price of natural gas, a sudden increases in the price of NOx emissions credits, and major declines in hydro-electric generation in the northwest. The high prices were also caused by the lack of an effective price cap and the lack of timely construction by power plant developers.

These factors account for a substantial part of the price increases shown in Figure 3B, but they do not tell the whole story. The remaining factor is strategic behavior of the generating companies. This is simulated by a user specified block of gas-fired capacity which is subject to economic withholding. This assumption is based on a two-stage comparison with studies by the California ISO. First, withholding is set to zero, and the model's simulated prices are checked against the competitive benchmarks calculated by the ISO. Next, we estimate the fraction of older gas-fired units which are subject to economic withholding, and we compare the model's simulated prices with the actual prices recorded by the California ISO. These tests verify that the model provides credible simulations of market prices under both competitive and actual market conditions observed in the past.

Figure 3B shows the rapid decline in market prices in the summer of 2001. Quarterly prices fall to a level only slightly above the investors' expectations of the fully levelized cost of a new CC. By the year 2003, the quarterly prices are at or below the full cost of a new CC. The base case simulation shows annual prices at around 35 $/mwh during the years 2004 and 2005. Price spikes reappear in 2006 and continue to appear in 2007 and 2008. The spikes cause annual prices to increase to 40 $/mwh in the year 2007 (around 15% higher than the cost of a new CC).

Notice that the price spikes in 2006 and 2007 are much less severe than the spikes shown in 2000 and 2001. There are two reasons for the improved behavior in the second boom. First, the base case does not envision a second coming of the "perfect storm." Rather, we assume that natural gas will be priced at 4 $/mmBTU and that hydro generation will be at values from an average year. These and other assumptions for the future portion of the base case scenario are listed in Table 1.

New Capacity	**Demand**
CCs Capital Cost = 600 $/kw	Initial Demands = WSCC data
CCs Fixed Charge Rate = 14.5 %/yr	Demand Growth = 2 %/yr in all 4 WSCC areas
CCs Heat Rate = 6,800 BTU/kwh	Buy Back Programs = none
CCs Permitting Interval = 12 months	**Market Operations**
CCs Permit Shelf Life = 10 yrs	Adjustment in Demand for A/S = 7%
CCs Construction Interval = 24 months	Capacity Payment = none
CCs Developers Attention to Pipeline = 50%	Economic Withholding = 20% of older gas capacity in CA
New Peakers = none	QFs Shut Down in CA from Credit Crisis = none
New Renewables = none	Price Cap = 200 $/mwh
Existing Capacity	**Fuels and Emissions**
Thermal Capacity = WSCC data	Natural Gas Price in California = 4.00 $/mmBTU
Hydro Capacity = WSCC data	Cost of NOx Emissions Credits = 0 $/mwh
Hydro Generation = average year weather	Coal Price in Southwest = 0.75 $/mmBTU
Retirements = none	Coal Price in Northwest = 1.00 $/mmBTU

Table 1. Assumptions for the long-term portion of the base case scenario.

The second reason for the improved behavior in the second boom is that developers are in a better position to respond when their expectations turn favorable. This is made possible by the large accumulation of approved permits in the site bank after the first boom. Notice that there was less than 30,000 MW of paper work at the start of the first boom, and many of the proposed plants were not yet in the site bank. By the year 2004, however, there is 33,000 MW of paper work, all of which is in the site bank.

The base case simulation indicates that the western electricity markets could well experience the classic pattern of boom and bust that has appeared in commodity and in industries like real estate. The base case provides a point of departure for simulation studies to help us appreciate the wide variety of market dynamics that could appear in the coming decade. For this paper, I use the model to examine the market dynamics in a scenario with 10 GW of retirements. I then consider a scenario with a major conservation program to delivers savings of approximately the same magnitude as the retirements.

The Retirements Scenario

The second scenario assumes that 8 GW of gas-fired units in California and 2 GW of coal-fired units in the northwest will be retired over the interval from 2003 to 2006. These are modest retirements, amounting to 27% of the older gas units in California and 12% of the coal units in the northwest. Nevertheless, the loss of 10 GW of existing capacity should be sufficient to alter the market dynamics considerably from the base case scenario.

The model assumes that developers observe the retirements as they occur, but they do not attempt to guess the retirements that may appear in the future. As the retirements take place, developers adjust their expectations for future generating capacity and come to view the western system as a “tighter” system in the future. These adjustments change their expectations for future market prices, and they change the timing of construction starts.

Figure 4A shows the new pattern of power plant construction with the 10 GW of retirements. The second wave of construction now begins in 2004, almost immediately after the end of the first building boom. The peak in construction appears at the end of 2005 with around 21,000 MW under construction.

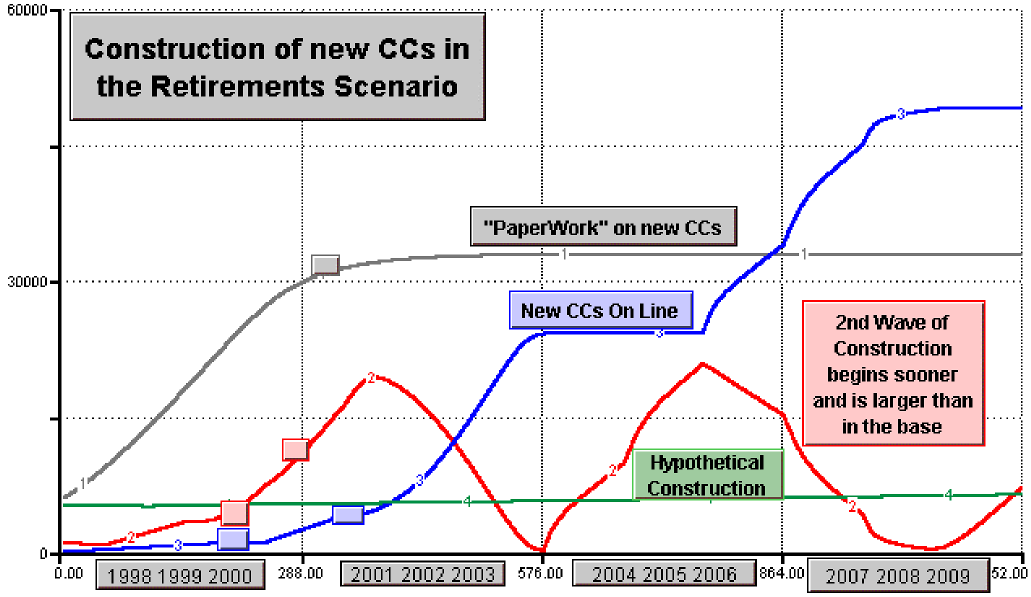

Figure 4A. Power plant construction in the retirements scenario.

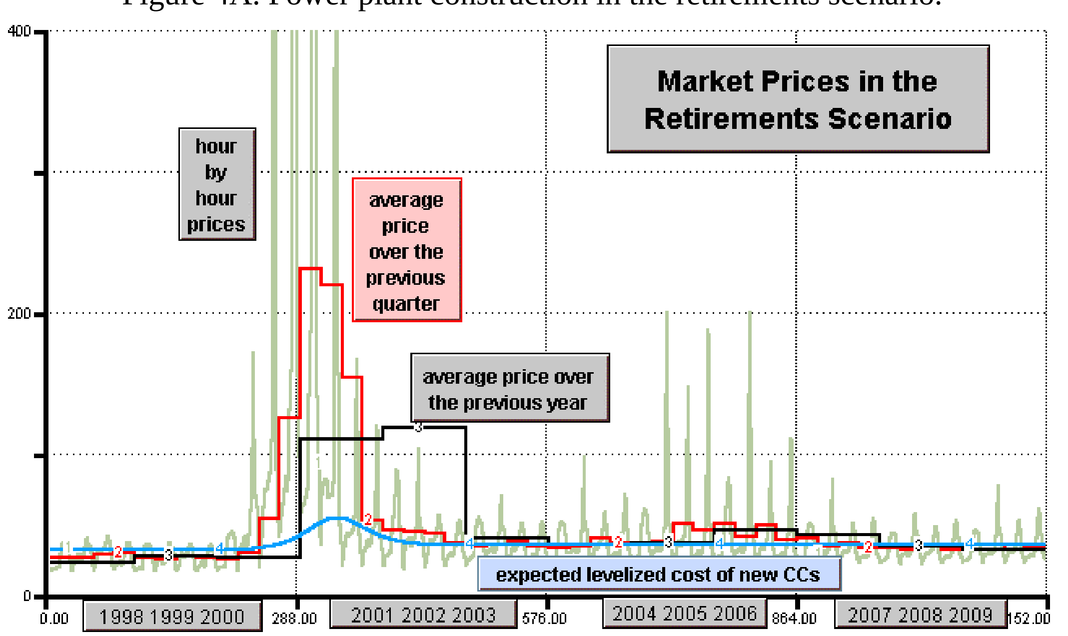

Figure 4B. Market prices in the retirements scenario.

Figure 4B shows the market prices in the scenario with 10 GW of retirements. The new simulation shows that price spikes are more numerous and more pronounced than in the base case. The first spike appears in 2004. Some of the spikes in 2005 are hitting the 200 $/mwh price cap. These spikes cause the average annual price for 2005 to reach 46 $/mwh, 31 % above the full cost of a new CC. By the year 2007, the second wave of construction allows the prices to decline to levels at or below the full cost of a new CC.

The Conservation Scenario

The impact of conservation programs is illustrated in a simulation with efficiency programs implemented during the four year interval from 2002 to 2005. To keep the scenario simple, I assume that the programs are sufficient to cut the annual growth in demand in each of the four WSCC areas from 2% to 0%. The total savings in peak demand is around 12,000 MW by the end of the program. Developers are assumed to observe the reduction in demand, but they do not attempt to guess conservation savings for the future. As the savings take effect, developers adjust their expectations. Figure 5A shows that these changes cause the second wave of construction to be delayed until the year 2007.

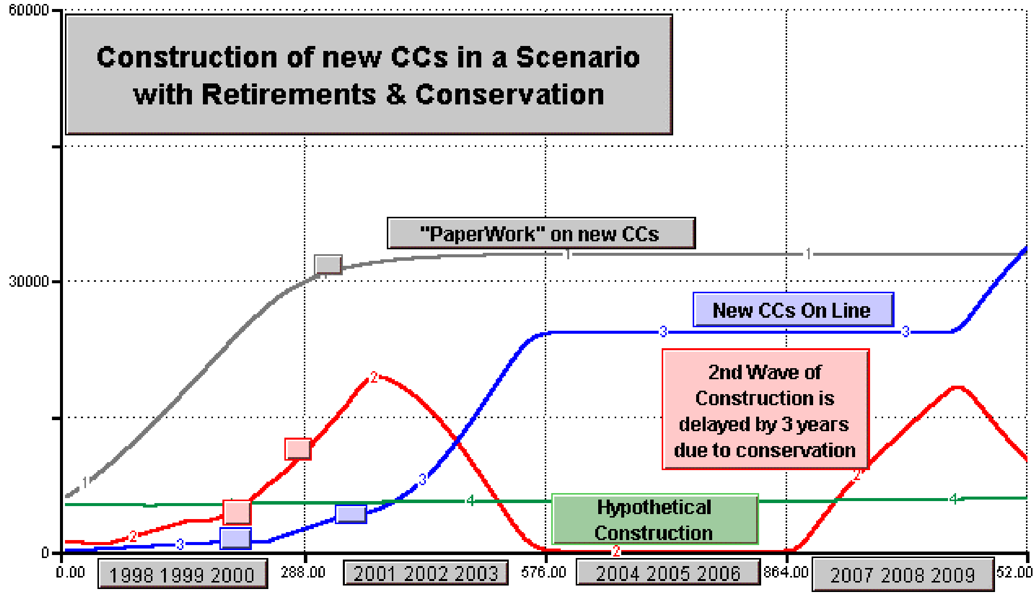

Figure 5A. Power plant construction in the third scenario.

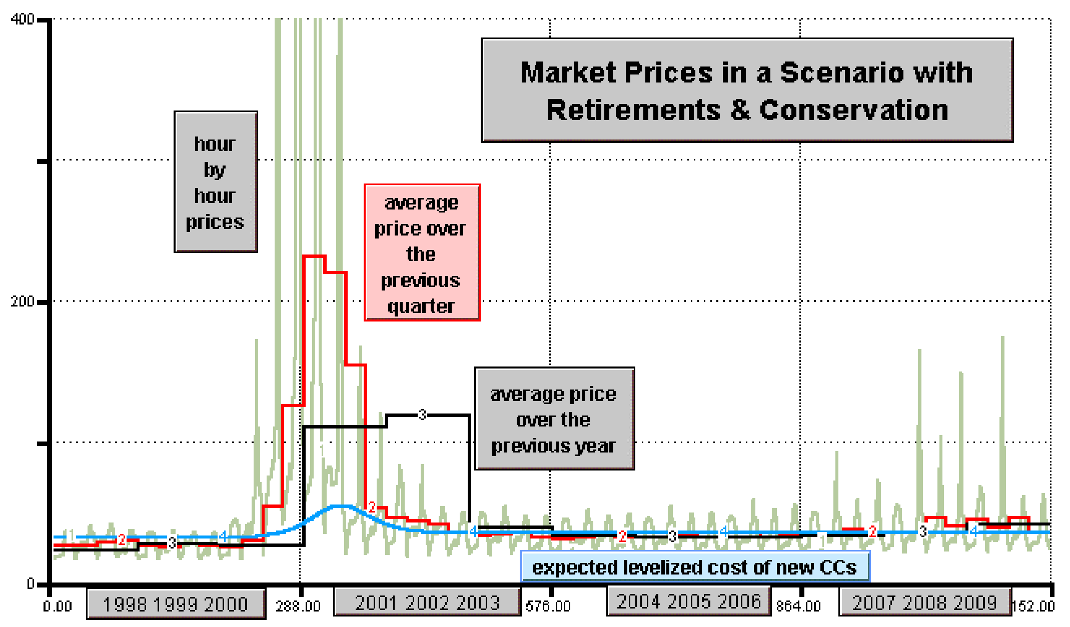

Figure 5B. Market prices in the third scenario.

The hypothetical construction in Figure 5A is displayed at the constant amount needed to keep pace with 2% annual growth in demand. In this scenario, however, we should envision the hypothetical construction dropping to zero during the years 2002-2005, the interval when growth is eliminated through conservation savings.

Figure 5B shows the price implications of the third scenario. The conservation savings allow prices to remain at or below the full cost of a new CC until the year 2007. By this time, the market has returned to tighter conditions and price spikes reappear. The spikes are less severe than in the previous scenario. Notice, for example, that the spikes in Figure 5B remain below the 200 $/mwh cap. The average annual price in 2008 is simulated at 41 $/mwh, around 17% higher than the full cost of a new CC.

Concluding Remarks

The comparison of Figures 4 and 5 shows some of the challenges of evaluating conservation in an era of boom and bust. These simulations reveal that conservation savings would lead to a somewhat different timing of the booms in construction and the appearance of price spikes.. But the conservation programs simulated in this paper do not eliminate the fundamental dynamics of boom and bust.

The comparison of Figures 4 and 5 also reveals the challenge of summarizing the benefits of traditional conservation programs. In this simple case, a 12 GW program is implemented in 2002 to 2005. The simulations indicate that average annual prices would be reduced over the interval from 2002 to 2006. But the program leads to higher annual prices in the years 2007 and 2008 (and the higher prices are likely to continue a few years into the future).

To conclude this simple example, let's look at the wholesale price benefits over the interval from 2002 until 2008. The average annual reduction in spot market prices turns out to be 2.85 $/mwh over this seven-year interval. If this improvement is spread over approximately 110,000 aMW of sales, the annual benefits would be approximately $2.75 billion; the total benefits would be just over $19 billion.

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