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Efficient Pricing in Electricity Markets Real Time Pricing and Deregulating the Electricity Market This Distributional Impacts of Real-time Pricing Rethinking Real Time Electricity Pricing Modern Energy Markets Survey of Utility Real-time Pricing Projects in the U.S. Electricity Pricing in Transition The Hidden Cost of Real Time Electricity Pricing Real Time Pricing for Small Power Producers Demand Response Wealth Transfer from Implementing Real-time Retail Electricity Pricing Real Time Pricing and Deregulating the Electricity Market On the Economics of Real-time Pricing in Low-carbon Electricity Markets High-temperature Refrigerated Warehouse Operation Under Real-time Pricing of Electricity Demand Response Real Time Pricing as a Default Or Optional Service for C & ICustomers Wealth Transfers from Implementing Real-Time Retail Electricity Pricing Electricity Markets Assessing the Impact of Day-ahead Real-time Pricing (DA-RTP) Demand Response on Smart Grid Do Benefits from Dynamic Tariffing Rise? Welfare Effects of Real-time Pricing Under Carbon-tax-induced Variable Renewable Energy Supply Customer Risk from Real-time Retail Electricity Pricing HINRICHS' FUENFJAEHRIGer KATALOG der im DEUTSCHen BUCHHANDEL ERSCHIENENen BUECHER, ZEITSCHRIFTEN, LANDKARTEN. Real-time Pricing and the Cost of Clean Power Reducing the Monthly Electricity Bill Using Real-time Pricing Optimization Is Real-Time Pricing Green? The Environmental Impacts of Electricity Demand Variance Is Real-time Pricing Green? Estimating the Customer-level Demand for Electricity Under Real-time Market Prices Residential End Use Electricity Demand and the Implications for Real Time Pricing in Sweden Flexible demand for electricity and power: Customer Response to Real-time Pricing of Electricity Real-time pricing of electricity on large industrial energy consumers Refrigerated Warehouse Operation Under Real-time Pricing Deregulated Real-time Pricing for the Promotion of Distributed Renewables Transmission Consideration-based Electricity Rates Using Optimal Power Flows Real Time Pricing of Electric Power Customer Response to Day-ahead Wholesale Market Electricity Prices: Case Study of RTP Program Experience in New York Effect of Real-time Electricity Pricing on Renewable Generators and System Emissions Real-time Electricity Pricing in a Deregulated Environment Using Artificial Intelligence The Role of Demand Response in Default Service Pricing An Econometric Analysis of a Real-time Pricing of Electricity Experiment

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Energy has moved to the forefront in terms of societal and economic development. Modern Energy Markets is a comprehensive, economically oriented, exploration of modern electricity networks from production and distribution to deregulation and liberalization processes. Updating previous work by the authors, different aspects are considered resulting in a complete and detailed picture of the systems and characteristics of modern electricity markets. Modern Energy Markets provides clear detail whilst encompassing a broad scope of topics and includes: •A method to model energy production systems including the main characteristics of future demand side management, •Different applications of this model in nuclear and renewable energy scenarios, •An analysis of Real-Time Pricing of electricity and its potential effects across the market, and, •A discussion of the need for regulation in an easily monopolized industry. Engineering and Economics students alike will find that Modern Energy Markets is a succinct and informative resource, as will researchers interested in environmental and energy issues. The inclusion of timely and relevant issues related to economic decision will also be of value to industry and civil officials. One of the most critical concerns that customers have voiced in the debate over real-time retail electricity pricing is that they would be exposed to risk from fluctuations in their electricity cost. The concern seems to be that a customer could find itself consuming a large quantity of power on the day that prices skyrocket and thus receive a monthly bill far larger than it had budgeted for. I analyze the magnitude of this risk, using demand data from 1142 large industrial customers, and then ask how much of this risk can be eliminated through various straightforward financial instruments. I find that very simple hedging strategies can eliminate more than 80% of the bill volatility that would otherwise occur. Far from being complex, mystifying financial instruments that only a Wall Street analyst could love, these are simple forward power purchase contracts, and are already offered to retail customers by a number of fully-regulated utilities that operate real-time pricing programs. I then show that a slightly more sophisticated application of these forward power purchases can significantly enhance their effect on reducing bill volatility. The efficient & reliable functioning of the more than $200 billion electric industry is vital to all Americans. As demonstrated in the 2003 blackout in the Northeast & the 2001 energy crisis in the West, changes in the cost & availability of electricity can have significant impacts on consumers & the national economy. The Fed. Energy Reg'y. Comm. supports using demand-response programs as part of its effort to develop & oversee competitive electricity markets. This report identifies: (1) the types of demand-response programs currently in use; (2) the benefits of these programs; (3) the barriers to their intro. & expansion; & (4) instances where barriers have been overcome. Also examined the fed. govt.'s participation in these programs through the GSA. Solar and wind power are now cheaper than fossil fuels but are intermittent. The extra supply-side variability implies growing benefits of using real-time retail pricing (RTP). We evaluate the potential gains of RTP using a model that jointly solves investment, supply, storage, and demand to obtain a chronologically detailed dynamic equilibrium for the island of Oahu, Hawai'i. Across a wide range of cost and demand assumptions, we find the gains from RTP in high-renewable systems to exceed those in a conventional fossil system by roughly 6 times to 12 times, markedly lowering the cost of renewable energy integration. There is growing interest in policies, programs and tariffs that encourage customer loads to provide demand response (DR) to help discipline wholesale electricity markets. Proposals at the retail level range from eliminating fixed rate tariffs as the default service for some or all customer groups to reinstituting utility-sponsored load management programs with market-based inducements to curtail. Alternative rate designs include time-of-use (TOU), day-ahead real-time pricing (RTP), critical peak pricing, and even pricing usage at real-time market balancing prices. Some Independent System Operators (ISOs) have implemented their own DR programs whereby load curtailment capabilities are treated as a system resource and are paid an equivalent value. The resulting load reductions from these tariffs and programs provide a variety of benefits, including limiting the ability of suppliers to increase spot and long-term market-clearing prices above competitive levels (Neenan et al., 2002; Boren stein, 2002; Ruff, 2002). Unfortunately, there is little information in the public domain to characterize and quantify how customers actually respond to these alternative dynamic pricing schemes. A few empirical studies of large customer RTP response have shown modest results for most customers, with a few very price-responsive customers providing most of the aggregate response (Herriges et al., 1993; Schwarz et al., 2002). However, these studies examined response to voluntary, two-part RTP programs implemented by utilities in states without retail competition. 1 Furthermore, the researchers had limited information on customer characteristics so they were unable to identify the drivers to price response. In the absence of a compelling characterization of why customers join RTP programs and how they respond to prices, many initiatives to modernize retail electricity rates seem to be stymied. Most electricity customers see electricity rates that are based on average electricity costs and bear little relation to the true production costs of electricity as they vary over time. Demand response is a tariff or program established to motivate changes in electric use by end-use customers in response to changes in the price of electricity over time, or to give incentive payments designed to induce lower electricity use at times of high market prices or when grid reliability is jeopardised. Price-based demand response such as real-time pricing (RTP), critical-peak pricing (CPP) and time-of-use (TOU) tariffs, give customers time-varying rates that reflect the value and cost of electricity in different time periods. Armed with this information, customers tend to use less electricity at times when electricity prices are high. Incentive-based demand response programs pay participating customers to reduce their loads at times requested by the program sponsor, triggered either by a grid reliability problem or high electricity prices. Limited demand response capability exists in the U.S. today. Total demand response and load management capability has fallen by about one-third since 1996 due to diminished utility support and investment. States should consider aggressive implementation of price-based demand response for retail customers as a high priority. This book examines the electricity market benefits and energy efficiency co-ordination corresponding to demand response service. This paper presents estimates of the customer-level demand for electricity by industrial and commercial customers purchasing electricity according to the half-hourly energy prices from the England and Wales (E&W) electricity market. These customers also face the possibility of a demand charge on their electricity consumption during the three half-hour periods that are coincident with E&W system peaks. Although energy charges are largely known by 4 PM the day prior to consumption, a fraction of the energy charge and the identity of the half-hour periods when demand charges occur are only known with certainty ex post of consumption. Four years of data from a Regional Electricity Company (REC) in the United Kingdom is used to quantify the half-hourly customer-level demands under this real-time pricing program. The econometric model developed and estimated here quantifies the extent of intertemporal substitution in electricity consumption across pricing periods within the day due to changes in all components of day-ahead E&W electricity prices, the level of the demand charge and the probability that a demand charge will be imposed. The results of this modeling framework can be used by distribution companies supplying consumers purchasing electricity according to real-time market prices to construct demand-side bids into a competitive electricity market. The paper closes with several examples of how this might be done Demand response (DR) has been broadly recognized to be an integral component of well-functioning electricity markets, although currently underdeveloped in most regions. Among the various initiatives undertaken to remedy this deficiency, public utility commissions (PUC) and utilities have considered implementing dynamic pricing tariffs, such as real-time pricing (RTP), and other retail pricing mechanisms that communicate an incentive for electricity consumers to reduce their usage during periods of high generation supply costs or system reliability contingencies. Efforts to introduce DR into retail electricity markets confront a range of basic policy issues. First, a fundamental issue in any market context is how to organize the process for developing and implementing DR mechanisms in a manner that facilitates productive participation by affected stakeholder groups. Second, in regions with retail choice, policymakers and stakeholders face the threshold question of whether it is appropriate for utilities to offer a range of dynamic pricing tariffs and DR programs, or just ''plain vanilla'' default service. Although positions on this issue may be based primarily on principle, two empirical questions may have some bearing--namely, what level of price response can be expected through the competitive retail market, and whether establishing RTP as the default service is likely to result in an appreciable level of DR? Third, if utilities are to have a direct role in developing DR, what types of retail pricing mechanisms are most appropriate and likely to have the desired policy impact (e.g., RTP, other dynamic pricing options, DR programs, or some combination)? Given a decision to develop utility RTP tariffs, three basic implementation issues require attention. First, should it be a default or optional tariff, and for which customer classes? Second, what types of tariff design is most appropriate, given prevailing policy objectives, wholesale market structure, ratemaking practices and standards, and customer preferences? Third, if a primary goal for RTP implementation is to induce DR, what types of supplemental activities are warranted to support customer participation and price response (e.g., interval metering deployment, customer education, and technical assistance)? Most US consumers are charged a near-constant retail price for electricity, despite substantial hourly variation in the wholesale market price. This paper evaluates the first program to expose residential consumers to hourly real time pricing (RTP). I find that enrolled households are statistically significantly price elastic and that consumers responded by conserving energy during peak hours, but remarkably did not increase average consumption during off-peak times. Welfare analysis suggests that program households were not sufficiently price elastic to generate efficiency gains that substantially outweigh the estimated costs of the advanced electricity meters required to observe hourly consumption. Although in electricity pricing, congestion pricing, and many other settings, economists' intuition is that prices should be aligned with marginal costs, residential RTP may provide an important real-world example of a situation where this is not currently welfare-enhancing given contracting or information costs. JEL Codes: C93, L51, L94, Q41. Keywords: Real time electricity pricing, energy demand, randomized field experiments. Most electricity customers see electricity rates that are based on average electricity costs and bear little relation to the true production costs of electricity as they vary over time. Demand response is a tariff or program established to motivate changes in electric use by end-use customers in response to changes in the price of electricity over time, or to give incentive payments designed to induce lower electricity use at times of high market prices or when grid reliability is jeopardized. Price-based demand response such as real-time pricing (RTP), critical-peak pricing (CPP) and time-of- This thesis pursues a method to deregulate the electric distribution system and provide support to distributed renewable generation. A locational marginal price is used to determine prices across a distribution network in real-time. The real-time pricing may provide benefits such as a reduced electricity bill, decreased peak demand, and lower emissions. This distribution locational marginal price (D-LMP) determines the cost of electricity at each node in the electrical network. The D-LMP is comprised of the cost of energy, cost of losses, and a renewable energy premium. The renewable premium is an adjustable function to compensate `green' distributed generation. A D-LMP is derived and formulated from the PJM model, as well as several alternative formulations. The logistics and infrastructure an implementation is briefly discussed. This study also takes advantage of the D-LMP real-time pricing to implement distributed storage technology. A storage schedule optimization is developed using linear programming. Day-ahead LMPs and historical load data are used to determine a predictive optimization. A test bed is created to represent a practical electric distribution system. Historical load, solar, and LMP data are used in the test bed to create a realistic environment. A power flow and tabulation of the D-LMPs was conducted for twelve test cases. The test cases included various penetrations of solar photovoltaics (PV), system networking, and the inclusion of storage technology. Tables of the D-LMPs and network voltages are presented in this work. The final costs are summed and the basic economics are examined. The use of a D-LMP can lower costs across a system when advanced technologies are used. Storage improves system costs, decreases losses, improves system load factor, and bolsters voltage. Solar energy provides many of these same attributes at lower penetrations, but high penetrations have a detrimental effect on the system. System networking also increases these positive effects. The D-LMP has a positive impact on residential customer cost, while greatly increasing the costs for the industrial sector. The D-LMP appears to have many positive impacts on the distribution system but proper cost allocation needs further development. In theory real time pricing ensures more efficient electricity markets than time of use pricing. However, people are prone to habits and regularity, so real time pricing may impose a greater cost of reacting on consumers. In a randomized field experiment we compared the cost of reacting to incentives under these two pricing regimes. We utilized smart-metered hourly power consumption to unobtrusively measure treatment effects. We found that real time pricing reduces consumer surplus from reacting to incentives by half, compared to reacting under a corresponding time of use pricing regime. This suggests a substantial economic value to households of the regularity and predictability provided by time of use pricing. When prices are set properly, they serve as important signals to guide customers to consume the efficient quantity of a good. However, in electricity markets many consumers do not pay prices that reflect the scarcity of power. The true social cost of power varies throughout a typical day; power is usually low cost during off-peak periods in the night but it is high cost during a hot July afternoon. Economists have argued for several decades that consumers should pay a price that varies with the true social cost of power. However, the vast majority of consumers pay a fixed price whether they use power at midnight or noon. This can create a host of economic inefficiencies. Fortunately, this is beginning to change. In many states, including Texas, large commercial and industrial users of electricity pay prices that reflect the social cost of power at the time of consumption. This pricing mechanism is called "real-time pricing" (RTP) in electricity markets. I have access to a unique, new dataset of virtually all 8000 commercial and industrial users in Texas that includes information on both whether they pay real-time prices and their hourly consumption for one year. First, I econometrically estimate the types of commercial and industrial firms that are likely to "sign up" for time-varying prices. Second, I test whether the customers on real-time prices reduce demand substantially in response to higher prices. I find that customers with greater total hourly consumption are more likely to be on real-time pricing. Customers with more "peaky" load profiles are less likely to be on real-time pricing. Customers in south and west Texas have a greater probability of being on RTP than customers in Houston. I also study whether customers on RTP decrease consumption on hot summer days when electricity is scare. These results have important implications for the design of both deregulated electricity markets and policies that seek to increase the amount of electricity generated with renewable sources of energy. We study the distributional impacts of real-time pricing (RTP) in the Spanish electricity market, where RTP was rolled out as the default tariff for a large share of residential customers. We complement aggregate patterns of distributional effects with a novel method for inferring individual households' income using zip code income distributions. We identify three channels for the distributional impacts of RTP: consumption profiles, appliance ownership, and locations. The first channel makes the switch from monthly to hourly prices progressive since high income households consume disproportionately more at peak times when real-time prices are higher. However, in the Spanish context, the other two channels make the switch from annual to monthly prices regressive. In particular, since low income households tend to have more electric heating, they benefit from the price insurance provided by time-invariant prices during winter, when prices are higher and more volatile. Given that price differences are greater across months than within months, the regressive effect dominates in our application. Using counterfactual experiments, we find that RTP makes low income households particularly vulnerable to adverse price shocks during winter. In the future, the wider adoption of enabling technologies (including storage and demand response devices) by the high income groups might worsen the distributional impacts of RTP. Our findings should allow to design an equitable real-time pricing system while retaining its efficiency properties. Demand side flexibility is the ability of power consumers to reduce their demand in periods of peak load, possibly shifting demand to other periods. The organisation for the Nordic energy regulators, NordREG, has ordered this study to explore demand side flexibility in a Nordic perspective. The study contains a literature survey of demand side flexibility and assess the potential for, and benefit of demand side flexibility. Based on the survey, the report highlights implementation barriers and possible contributions from to reducing these barriers. Existing barriers are e.g lack of ICT, automation services, smart meters and real-time prices. The greatest potential for demand side flexibility in the Nordics is within residential space heating. The value of demand side flexibility is uncertain, but may be 1–2 billion SEK per year. In the foreseeable future, with the full deployment of Advanced Metering Infrastructure (AMI) in electric grid systems in the US, the Day-Ahead Real-Time Pricing (DA-RTP) demand response program would get technical support for its large-scale implementation. So, it is necessary to evaluate the impact of DA-RTP on the future smart grid. This thesis assesses the impact of DA-RTP on a smart grid by modifying three Scenarios based on standard IEEE 30-bus test system. The system costs and stability of the three Scenarios are quantified by tools of Optimal Power Flow (OPF) and Transient Stability (TS). The results show, at a steady state operating point, DA-RTP saves system cost and lowers energy loss. At a transient operating point, with an integration of DA-RTP, the smart grid system improves stabilities of rotor angle and field voltage, as well as, reducing real and reactive power generation oscillation. These assessment results indicate DA-RTP benefits the future smart grid by efficiently reducing the system operating cost and increasing the stability performance. Real-time pricing of electricity may result in major efficiency improvements in the consumption and production of electric power. It can be realized by using current microelectronic technology to implement a dynamic power marketplace, with low entrance barriers and adaptive pricing reflecting the marginal costs of generation. A complex and interrelated set of technical, political, economic, and regulatory questions surround the notion of real-time pricing of electricity. They are briefly outlined in this paper. A current bibliography of material relevant to these studies is also included. (Author). Real-time retail pricing (RTP) of electricity, in which the retail price is allowed to vary with very little time delay in response to changes in the marginal cost of generation, offers expected short-run and long-run benefits at the societal level. While the effects of RTP on most market participants have been examined previously, its effects on a) renewable generator revenues and b) power sector emissions are not well understood. This thesis presents a counterfactual model of the new England wholesale power market, including within-hour consumer price response, to analyze revenues under RTP for four renewable test cases and emissions of CO2, SO2, and NOx. Assuming a moderate consumer price-response (e = -0.3), I find that revenues for both wind and solar cases will decrease by about 3%, a smaller loss than that expected by the generation sector as a whole (~ 6%) or by peak generators (~ 55%). In the same scenario, RTP is expected to decrease emissions of CO2, SO2, and NOx by 2-3% in the short-run. These results are qualitatively robust across a range of elasticities and other input parameters. A discussion of the political barriers to RTP highlights interest group pressure from peak generators and the framing of gains and losses for consumers. These barriers are likely to attract significant policymaker attention in RTP discussions, but the results of my empirical analysis show the need to also consider how RTP may interfere with the ability to achieve other policy objectives, including promoting renewable energy and reducing emissions. Real-time pricing (RTP) of electricity would improve allocative efficiency and limit wholesalers' market power. Conventional wisdom claims that RTP provides additional environmental benefits. This paper argues that RTP will reduce the variance, both within- and across-days, in the quantity of electricity demanded. We estimate the short-run impacts of this reduction on SO2, NOx, and CO2 emissions. Reducing variance decreases emissions in regions where peak demand is met more by oil-fired capacity than by hydropower, such as the Mid-Atlantic. However, reducing variance increases emissions in more US regions, namely those with more hydropower like the West. The effects are relatively small. Dynamic retail electricity pricing, especially real-time pricing (RTP), has been widely heralded as a panacea for providing much-needed demand response in electricity markets. However, in designing default service for competitive retail markets, demand response often appears to be an afterthought. But that may be changing as states that initiated customer choice in the past 5-7 years reach an important juncture in retail market design. Most states with retail choice established an initial transitional period, during which utilities were required to offer a default or ''standard offer'' generation service, often at a capped or otherwise administratively-determined rate. Many retail choice states have reached, or are nearing, the end of their transitional period and several states have adopted an RTP-type default service for large commercial and industrial (C & I) customers. Are these initiatives motivated by the desire to induce greater demand response, or is RTP being called upon to serve a different role in competitive markets? Surprisingly, we found that in most cases, the primary reason for adopting RTP as the default service was not to encourage demand response, but rather to advance policy objectives related to the development of competitive retail markets. However, we also find that, if efforts are made in its design and implementation, default RTP service can also provide a solid foundation for developing price responsive demand, creating an important link between wholesale and retail market transactions. This paper, which draws from a lengthier report, describes the experience to date with default RTP in the U.S., identifying findings related to its actual and potential role as an instrument for cultivating price responsive demand [1]. For each of the five states currently with default RTP, we conducted a detailed review of the regulatory proceedings leading to its adoption. To further understand the intentions and expectations of those involved in its design and implementation, we also interviewed regulatory staff and utilities in each state, as well as eight of the most prominent competitive retail suppliers operating in these markets which, together, comprised about 60-65% of competitive C & I sales in the U.S. in 2004 [2]. Adoption of real-time electricity pricing -- retail prices that vary hourly to reflect changing wholesale prices -- removes existing cross-subsidies to those customers that consume disproportionately more when wholesale prices are highest. If their losses are substantial, these customers are likely to oppose RTP initiatives unless there is a supplemental program to offset their loss. Using data on a random sample of 636 industrial and commercial customers in southern California, I show that RTP adoption would result in significant transfers compared to a flat-rate tariff. When compared to the time-of-use rates (simple peak/offpeak tariffs) that these customers already face, however, the transfers drop by nearly half; even under the more extreme price volatility scenario that I examine, 90% of customers would see changes of between a 9% bill reduction and a 14% bill increase. Though customer price responsiveness reduces the loss incurred by those with high-cost demand profiles, I also demonstrate that this offsetting effect is unlikely to be large enough for most customers with costly demand patterns to completely offset their lost cross-subsidy. The analysis suggests that adoption of real-time pricing may be difficult without a supplemental program that compensates the customers who are made worse off by the change. I discuss how "two-part RTP" programs, which allow customers to purchase a baseline quantity at regulated TOU rates, can reduce the transfers associated with adoption of RTP. Real-time pricing (RTP) of electricity would improve allocative efficiency and limit wholesalers' market power. Conventional wisdom claims that RTP provides additional environmental benefits. This paper argues that RTP will reduce the variance, both within- and across-days, in the quantity of electricity demanded. 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Electricity Pricing In Transition is written to address the new issues facing utilities, retailers, regulators, and customers in the changing electricity market. It is organized into five sections. Section I deals with the new restructured organization that has emerged from yesterday's vertically integrated, regulated monopoly company. Section II deals with issues in competitive pricing. Section III reviews the role of demand response and product design in today's chaotic marketplace. Given the single importance of California's energy crisis and the fact that it will be studied for years to come, Section IV is devoted to studying the lessons learned from this crisis. The final section of the book deals with markets and regulations. This book will provide practitioners with guidance on how to avoid the major pitfalls in pricing electricity while the market is in transition by drawing upon the insights and lessons learned from the experience of others that are documented in this book.