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Author(s): John L. Neufeld
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# *Price Discrimination and the Adoption of the Electricity Demand Charge*

JOHN L. NEUFELD

Between 1905 and 1915, as state price regulation became widespread, electric utilities in the United States faced severe competition. The primary source of electricity for industry then was not utilities but self-generation by the user in an "isolated plant." The demand-charge rate structure first became widespread during this period. The demand-charge rate structure has been interpreted as a misapplication of the peak-load pricing principle, a view which has made its popularity a puzzle. Instead it was adopted as a sophisticated mechanism which institutionalized profit-maximizing price discrimination given the competition from isolated plants.

The development of the U.S. electric power industry and its pricing policies have often been shaped by the structure of the markets in which it operated. Electric power companies historically faced stiff competition from substitutes for centrally generated electricity. For example, the market for artificial lighting was originally served by gas companies, and Edison's initial pricing policies were based not on his production costs but on the cost to his potential customers of gas lighting.[1] Another competitor to electric utilities, whose importance eclipsed that of gas lighting, was the self-production of energy by an electricity user through the operation of an "isolated plant" on his premises. Isolated plants were long the dominant source of electricity for the industrial class of consumers, whose use of electricity significantly altered American manufacturing.[2] As the movement for state regulation of utility rates developed, from roughly 1905 to 1915, the U.S. electric utility industry organized itself to institutionalize the demand-

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The author is Associate Professor of Economics at the University of North Carolina at Greensboro, Greensboro, NC 27412.

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[1] Charles E. Neil, "Entering the Seventh Decade of Electric Power," Edison Electric Institute (1912), unpaged. Material discussed here appears on the 12th page.

[2] As the electrification of industry increased, more energy was purchased from utilities. The enormous impact of electrification on American industry has been shown by Warren D. Devine, "From Shafts to Wires: Historical Perspective on Electrification," this JOURNAL, 43 (June 1983), pp. 347–72; Richard B. DuBoff, "The Introduction of Electric Power in American Manufacturing," *Economic History Review*, 2nd ser., 20 (Dec. 1967), pp. 509–18; and Arthur G. Woolf, "Electricity, Productivity, and Labor Saving in American Manufacturing, 1900–1929," *Explorations in Economic History*, 21 (Apr. 1984), pp. 176–91.

charge rate structure. Although this rate structure (explained below) had been conceived much earlier, it was only in this period that it came to be widely adopted.

Events surrounding the adoption of the electricity demand-charge rate structure shed light onto the conditions facing the electric power industry in the early part of this century and the way in which it rediscovered and applied principles of price discrimination. The issue is also of interest to economists for another reason. American economists have long advocated time-of-day or other peak-load pricing rate structures for electric utilities, but until very recently such structures have seldom been used.[3] In contrast, demand-charge rate structures became universal for industrial and large commercial customers. A demand-charge rate structure bases a user's bill on his maximum power consumption (known in the early industry as "demand") and on his total energy consumption.[4] Thus this rate structure bases a user's bill on

[3] The first publication by an American economist in this tradition probably was J. M. Clark, "Rates for Public Utilities," *American Economic Review*, 1 (Sept. 1911), pp. 473–87. The usually cited seminal works in the modern literature include M. Boiteux, "La Tarification des Demands en Point: Application de la Theorie de la Vente au Cout Marginal," *Revue Generale de l'Electricite*, 58 (Aug. 1949), pp. 321–40, translated as "Peak-Load Pricing" in *Journal of Business*, 33 (Apr. 1960), pp. 157–79; and P. Steiner, "Peak Loads and Efficient Pricing," *Quarterly Journal of Economics*, 71 (Nov. 1957), pp. 585–610. Econometricians have recently become involved with estimating the benefits from time-of-day rates. See Dennis J. Aigner, "The Welfare Econometrics of Peak-Load Pricing for Electricity," *Journal of Econometrics: Annals 1984–3*, 26 (Sept./Oct. 1984), pp. 1–15.

[4] Energy has a time dimension and is now commonly measured in kilowatt-hours. Power has no time dimension and is measured in kilowatts. One kilowatt-hour of energy can be consumed by using one kilowatt of power for one hour or by using two kilowatts of power for one-half hour. "Demand" is (and was) usually measured not as the maximum instantaneous power used but as the maximum average power used in any 15-minute (or other short time) period. The specific way in which "demand" is charged usually falls into one of two categories: Hopkinson rates and Wright rates. A Hopkinson rate contains an explicit demand charge, for example: demand charge = $2.50 per month per kilowatt of the maximum demand in the month, plus an energy charge of 5 cents per kilowatt-hour used in the month. A Wright rate achieves the same objective through the use of a declining block structure with the size of the high-priced block a function of "demand": 10 cents per kilowatt-hour for electricity used equivalent to or less than 50 hours use per month of the maximum demand; 5 cents per kilowatt-hour for electricity used in excess of the equivalent of 50 hours use per month of the maximum demand. Consider an electricity user whose maximum power consumption in one month is 1 kw and whose energy consumption is 300 kwh. Under a Hopkinson rate, the bill would be calculated as: 1 kw × $2.50 per month (= $2.50) + 300 kwh × $0.05 per kwh (= $15.00) = a total charge of $17.50. Under a Wright rate the calculation would be: (1 kw demand × 50 hours) × $0.10 (= $5.00) + (300 kwh − 50 figured above) × $0.05 (= $12.50) = a total charge of $17.50. Given any Hopkinson rate structure, one can always develop a Wright rate structure which will produce identical bills except in the case of an electricity user whose consumption of energy is so low relative to his maximum power usage that it remains wholly in the initial high-priced block. Actual rate structures sometimes combine features of Hopkinson and Wright rate structures and frequently add other complicating features, such as block pricing. The term "demand-charge rate structure" will be used to refer to any rate structure in which a user's bill is partially a function of his maximum power consumption independent of the time in which the maximum power consumption occurred. The term "demand charge" will be used either interchangeably with "demand-charge rate structure," or, more specifically, to refer to the component of an electricity user's bill which is determined by maximum power consumption. The term

the size of his individual peak instead of his level of consumption during the system peak, as would peak-load pricing. This feature has caused it to be interpreted as a misapplication of the principle of peak-load pricing—an interpretation which makes its popularity over time-of-day pricing quite mysterious.[5]

During the last decade of the nineteenth century and the first five years of the twentieth century, a wide-ranging discussion occurred among electric engineers and utility executives concerning the proper basis for pricing electricity. The discussion was international in scope, and most of the original ideas came from Britain. Many, if not all, of the electricity pricing structures which continue to be used and considered today were explored then, and lively exchanges occurred between advocates of demand-charge rate structures and advocates of time-of-day structures.[6] In an address delivered in 1892, the British engineer John Hopkinson became the first of a number of engineers to characterize the electricity demand charge as the correct device to divide a utility's fixed costs among its customers.[7] Hopkinson's analysis demonstrates the importance of the peak load on the total costs of running a power plant, but he made the inferential leap of concluding that it was therefore proper to charge electricity users on the basis of their individual peaks rather than on their consumption during system peaks.

Although modern economic theorists would find flaws in his analysis, as did some of his contemporary colleagues, Hopkinson's proposals suited the industry of his time. In Hopkinson's day artificial lighting consumed almost all of the output of electric utilities.[8] Its relatively high cost led electric lighting to be used almost exclusively in the evening, especially during winter when sunset was early. Under these condi-

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"demand," especially in quoted material, will often refer to the engineering concept of maximum power consumption rather than the usual economic concept. The meaning should be clear from the context.

[5] See, for example Alfred E. Kahn, *The Economics of Regulation* (New York, 1970), vol. 1, pp. 95–96; Ralph K. Davidson, *Price Discrimination in Selling Gas and Electricity* (Baltimore, 1954), pp. 85–86; and W. Arthur Lewis, "The Two-Part Tariff," *Economica*, 8 (Aug. 1941), p. 252.

[6] For more on these early discussions see W. J. Hausman and J. L. Neufeld, "Time-of-Day Pricing in the U.S. Electric Power Industry at the Turn of the Century," *Rand Journal of Economics*, 15 (Spring 1984), pp. 116–26; John L. Neufeld, "The Origin of Electricity Rate Structures—1882 to 1905" (unpublished manuscript, University of North Carolina at Greensboro, 1985).

[7] John Hopkinson, "The Cost of Electric Supply," *Transactions of the Junior Engineering Society*, 3 (1892–1893), pp. 33–46.

[8] In 1897 and 1898 the Commissioner of Labor surveyed electric power companies and received responses from about 31 percent, responsible for 45 percent of the value of all electricity generation. Of those reporting income by type of service (93 percent of respondents), arc lighting accounted for 39 percent of total income and incandescent lighting accounted for 49 percent. A relatively small number of large stations were responsible for much of the non-lighting income. Lighting was the source of over 90 percent of total income for 75 percent of respondents. *Fourteenth Annual Report of the Commissioner of Labor 1899*, House of Representatives, 56th Cong., Document No. 713 (Washington, D.C., 1900).

tions, peaks of individual users were likely to occur simultaneously, making the measure of an individual's maximum power consumption an excellent proxy for his consumption during the system peak. In addition, when Hopkinson gave his address, metering technology was not well developed, and a customer's maximum power consumption was likely to be estimated from the number of connected light bulbs rather than measured with a meter. Indeed, it was common for such estimates to be the sole basis on which electricity was priced. These conditions are consistent with the thesis that the demand-charge rate structure was a second-best form of peak-load pricing, adopted when there was little difference between the time of a system's peak and the time of individual users' peaks, an argument recently put forth by Michael Crew and Paul Kleindorfer.[9] Although plausible, their interpretation is at odds with subsequent events in the industry's history.

Technological progress proceeded rapidly in the early electric industry. Meters capable of measuring maximum power consumption, as well as time-of-day meters, soon became available. The manager of an electric utility in Brighton, England, Arthur Wright, developed the first practical demand meter capable of measuring a user's maximum power consumption. Before the turn of the century he became quite active in promoting Hopkinson's logic, his own version of the demand-charge rate structure, and his meter among U.S. utilities.[10] Those in the United States converted by Arthur Wright include Samuel Insull, the president of Chicago's Commonwealth Edison and one of the most influential executives in the industry. Insull acquired a financial interest in the American rights to Wright's meter patents, and his stature insured that discussions on the demand-charge rate structure were prominent in industry trade meetings.[11]

Despite the prominence of Samuel Insull, demand-charge rate structures did not become widespread until later, after 1906 and before 1917. Thus the adoption of demand-charge rate structures followed their conception by some thirty years, after the industry had altered significantly from the turn of the century. Industrial electricity use, which was largely consumed off the system peak, had become quite important to electric utilities. Although individual peaks of industrial users were the least likely to coincide with the system peak, they were the users most

[9] Michael A. Crew and Paul R. Kleindorfer, *The Economics of Public Utility Regulation* (Cambridge, Mass., 1986), pp. 185–93.

[10] Arthur Wright, "Cost of Electricity Supply," *Municipal Electrical Association Proceedings* (London, 1896), pp. 44–67; and Arthur Wright, "Profitable Extensions of Electricity Supply Stations," *Proceedings of the National Electric Light Association, Twentieth Convention* (New York, 1897), pp. 159–89.

[11] Insull mentioned his financial involvement in the Wright patents in a discussion over the relative merits of demand-charge and time-of-day rate structures, *Minutes of the Fourteenth Annual Meeting (19th Convention) of the Association of Edison Illuminating Companies* (Sault Sainte Marie, Michigan, 1898), p. 133.

likely to face demand-charge rate structures. It would be far easier to accept the thesis that demand-charge rate structures were an imperfect form of peak-load pricing had they become widespread earlier or had they been used primarily for residential electricity users, whose peaks coincided with the system peak as late as 1921.[12]

A more satisfactory explanation for the widespread adoption of the demand-charge rate structure can be found in the historical record of discussions occurring within the industry between 1905 and 1915. The onset of state price regulation helped stimulate these discussions because it placed (or threatened to place) the utility industry's operations within a legalistic framework open to public scrutiny and debate, and industry leaders wanted their interests protected from the possible adverse actions of regulatory commissions.[13] Many of the discussions concerned rate structures in general and the demand-charge rate structures in particular. Although the off-peak consumption (and the level of consumption) of industrial users of electricity made them very important to the utility industry, the possibility that these customers would turn to isolated plants for their electricity supply was a serious concern. Under certain conditions, the most profitable way for a utility to price its product for industrial users was to structure rates not on the basis of the utility's cost of production, as peak-load pricing would, but on the basis of factors which would determine the customer's cost of operating an isolated plant, namely his energy consumption and the size of his individual peak.

The usefulness of demand-charge rate structures as an instrument of price discrimination in the face of competition from isolated plants was known within the industry and was accepted by early regulatory commissions as a justification for their use. Historical evidence shows the role of the demand-charge rate structure as an instrument of price discrimination was more important to its widespread adoption than was its role as an imperfect form of peak-load pricing. Other explanations for the popularity of demand-charge rate structures include the suggestion made by Arthur Lewis that their adoption was caused by inadequate metering technology and the suggestion made by I.C.R. Byatt that individuals in the industry favored them because they were unable to understand economic principles.[14] These explanations are unsatisfactory in the light of available historical evidence.

[12] H. E. Eisenmenger, *Central Station Rates in Theory and Practice* (Chicago, 1921), p. 262.

[13] The first commission was established in Massachusetts in 1887. The next commissions were not established until 1907. By 1915, 33 states had established such commissions with 21 established during the period 1911–1913. George J. Stigler and Claire Friedland, "What Can Regulators Regulate? The Case of Electricity," *Journal of Law and Economics*, 5 (Oct. 1962), p. 13.

[14] Lewis, "The Two-Part Tariff"; I. C. R. Byatt, "The Genesis of the Present Pricing System in Electricity Supply," *Oxford Economic Papers*, 15 (1963), pp. 8–18.

ISOLATED PLANTS AND THE STRUCTURE OF UTILITY RATES

Many of the factors affecting the economics of electricity production from isolated plants and from central utilities were similar. The capacity of capital equipment required for generation and distribution was determined by the maximum power, rather than the total energy, the equipment handled. The cost of capital was the major expense of electricity production. The cost of fuel required by the prime mover to generate electricity, however, was directly related to the total electrical energy generated. Although some expenses were related to factors other than total energy generation and maximum power production, most expenses were determined by one or both of these measures of output.

There were also important differences between the two. An isolated plant did not have many of the administrative costs, such as metering and billing, which a utility bore. Isolated plants were usually located near the place of consumption, eliminating transmission costs. Perhaps most importantly, if steam were produced for use in production processes or space heating, an isolated plant could produce electricity as a byproduct. On the other hand, central utilities had two important advantages over isolated plants. First, by using larger generators than any single user could, they benefited from economies of scale. Second, as long as the individual peaks of their customers were not simultaneous, the total generating capacity which the utility required was less than the sum of the generating capacities each user would have required in an isolated plant. Termed "diversity," this advantage was well known to the early electric utility industry. The factors working to the advantage of utilities became more important over time as the size of utilities increased. In the industry's early days, the advantages of isolated plants may have overshadowed those of central utilities, but as growth in the optimal scale of generation led to larger utilities, their advantages came to dominate.[15]

An industrial electricity user choosing between making or buying electricity would certainly compare costs. At an isolated plant costs were a function of the user's total expected energy production and maximum power use. The cost of utility-supplied electricity depended on the utility's rate schedule. Utilities should have responded by offering industrial users a rate structure which maximized the utility's profits. Monopoly power caused profit-maximizing prices to exceed marginal costs, although this does not imply supranormal profits, especially if scale economies caused marginal costs to be below average costs. The profit-maximizing prices quoted to a customer depended on

[15] A table showing maximum available generator size by year is given by Neil, "Entering the Seventh Decade," 5th page. During the period 1879 to 1903 the annual growth rate in maximum generator size was 24.6 percent. From 1904 to 1929 the growth rate was 11.2 percent.

two factors: the marginal cost of serving the customer and the customer's demand elasticity for electricity from the utility, which was in turn affected by the viability of an isolated plant.

To determine the profit-maximizing rate structure a utility considered the marginal cost to the utility of supplying service, the total cost to the customer of owning and operating an isolated plant, and the average prices the utility was charging all customers. Three possibilities existed. For some electricity users, the total cost of an isolated plant was less than the utility's marginal cost. A utility could have attracted such users only by the offer of unprofitable rates; no rate structure would have been profit maximizing. This situation was probably common in the very early days of electric power when (as I show later) the majority of all electricity used by industry came from isolated plants. For a second category of electricity user, the high cost of an isolated plant precluded it from consideration. A rate structure of Ramsey prices would have maximized utility profits from them.[16] Peak-load pricing with rates closely tracking (above) marginal cost would have been optimal.

Demand-charge rate structures were the preferred form of rate structure for electricity users in the third category. For them, the cost of operating an isolated plant was greater than the marginal cost to the utility of supply. For customers in this category, however, the cost of operating an isolated plant fell in the gap between the marginal cost to the utility of providing service and the (above-marginal cost) prices the utility generally was charging its customers for such service. Thus in setting prices for these customers, the utility had to take into account competition from isolated plants. Because the marginal cost of supplying them was less than the cost of self-supply, the utility was able to set a price which was high enough to cover marginal cost, thus contributing to profits, yet low enough to make electricity from the utility more attractive than electricity from an isolated plant. The profit-maximizing rate structure had to track the costs of the competition, that is, the costs of operating an isolated plant, not the utility's marginal cost of supply (although prices had to cover marginal cost).

The onset of state rate regulation made it difficult for utilities to determine prices through individual negotiation. Regulation required published rate schedules. A rate schedule which automatically offered lower prices to those for whom the operation of isolated plants was cheaper had to be structured on the factors which determined the cost of isolated plant operation. Those factors are energy consumption and maximum power use, and the demand-charge rate structure is based precisely on them. The individual peaks of these users probably did not

[16] The classic review of Ramsey pricing can be found in William J. Baumol and David Bradford, "Optimal Departures from Marginal Cost Pricing," *American Economic Review*, 60 (June 1970), pp. 265–83.

coincide with the system peak, but this was less important to rate setting than was their cost of using isolated plants. For them demand-charge rates were not a second-best form of peak-load pricing, rather they were the best mechanism for price discrimination.

## THE HISTORICAL RECORD

The early power industry operated on a small scale and originally faced competition from isolated plants even for lighting. Edison's original Pearl Street Station in New York City served an area about a mile square, and in 1904 only fifteen and a half square miles were served by the Edison distribution system, which was still much larger than the Edison systems in other major cities.[17] Detroit's Edison system served only three squares miles, as did Philadelphia's, while other cities had still smaller systems. In addition to his central station business, Edison also operated an Isolated Plant Company which installed as much lighting in the 1880s as did his central station operation.[18] Isolated plants were not only attractive to industrial electricity users, but were also likely to receive serious consideration from hotels and large office buildings. In 1902 the Bureau of the Census conducted a census of central electric light and power stations. Although isolated plants were not canvassed, the report had some interesting comments on them which show the continued access of isolated plants to available scale economies:

> In fact, no statistics of isolated plants are included in this report, which to that extent, therefore falls short of embracing the entire electric light and power industry of the United States. Many of these isolated plants are of a very extensive and important character, being supplied with the most improved apparatus and giving facilities equal to those furnished to populous communities. It is estimated that there are 50,000 of these plants, and that they consume at least half the product in some lines of electric apparatus.[19]

Further evidence on the importance of self-generation can be found by comparing the electrical generation of the entire U.S. electric utility industry with the generation of electricity by industrial, mine, and railway electric power plants (Table 1). This latter group comprised only a portion of all isolated power plants since it excluded isolated plants in institutions, hotels, apartment houses, office buildings, and amusement parks. Nevertheless, the combined output of this subset of isolated power plants exceeded the combined output of the entire utility industry (private and public) as late as 1912 and remained important for many

[17] Neil, "Entering the Seventh Decade," 2nd page.

[18] Harold C. Passer, *The Electrical Manufacturers 1875–1900* (Cambridge, Mass., 1953), pp. 117–21.

[19] U.S. Bureau of the Census, Special Reports, *Central Electric Light and Power-Stations 1902* (Washington, D.C., 1905), p. 3.

TABLE 1
ELECTRICITY PRODUCTION IN THE UNITED STATES BY OWNERSHIP OF GENERATORS FOR SELECTED YEARS
(in gigawatt-hours)

| | (1) Total Electric Utility Industry | (2) Total Industrial, Mine and Railway Electrical Power Plants | (3) Percent of Total 100 × (2) / [(1) + (2)] |
|---|---|---|---|
| 1902 | 2,507 gwh | 3,462 gwh | 58% |
| 1907 | 5,862 | 8,259 | 58 |
| 1912 | 11,569 | 13,183 | 53 |
| 1917 | 25,438 | 17,991 | 41 |
| 1920 | 39,405 | 17,154 | 30 |
| 1925 | 61,451 | 23,215 | 27 |
| 1930 | 91,112 | 23,525 | 21 |
| 1940 | 141,837 | 38,070 | 21 |
| 1950 | 329,141 | 59,533 | 15 |
| 1960 | 755,374 | 88,814 | 11 |
| 1970 | 1,531,609 | 108,162 | 7 |

*Source:* Edison Electric Institute, *Historical Statistics of the Electric Utility Industry* (New York, 1974), p. 21.

years after. The significance of self-generation to the important industrial class of electricity users can be seen from the proportion of total electric horsepower powered from self-generation (Table 2). Again, self-generated power dominated utility-generated power until after 1914 and remained as much as half of utility-generated power in 1929.

Interest in the relative advantages of electricity provided by utilities and by isolated plants stimulated considerable discussion in trade journals and at professional meetings. Both American and British

TABLE 2
ELECTRIC MOTOR POWER USED IN U.S. MANUFACTURING BY SOURCE OF ELECTRICITY
(horsepower)

| | (1) Purchased Energy | (2) Self-Generated Energy | (3) Percent of Total 100 × (2) / [(1) + (2)] |
|---|---|---|---|
| 1899 | 182,562 hp | 310,374 hp | 63% |
| 1904 | 441,589 | 1,150,886 | 72 |
| 1909 | 1,749,031 | 3,068,109 | 64 |
| 1914 | 3,884,724 | 4,938,530 | 56 |
| 1919 | 9,284,499 | 6,969,203 | 43 |
| 1923 | 13,365,663 | 8,821,551 | 40 |
| 1925 | 15,868,828 | 10,254,745 | 39 |
| 1927 | 19,132,310 | 11,219,979 | 37 |
| 1929 | 22,775,664 | 12,376,376 | 35 |

*Source: U.S. Census of Manufactures: 1929* (Washington, D.C., 1933), p. 112.

journals published articles discussing which was the more economical.[20] Interesting isolated plant installations were described in some detail.[21] Back-to-back papers advocating each source of supply were presented at engineering meetings attended by industrial electricity users.[22]

The connections among price discrimination, utility rate structures, and the use of isolated plants were realized quite early. In 1900 an important leader of the early electric utility industry characterized the competition in a way that shows the frustration it occasioned: "Isolated plants have proved active competitors and a thorn in the flesh for more reasons than one. Of all forms of competition I like this one least. Bad methods of charging have cultivated the isolated plant to an appalling extent.[23] The role of the demand-charge rate structure as a tool of price discrimination which tracked the cost to a customer of using an isolated plant was clearly recognized in an editorial in *Electrical World* in 1915:

> [Demand-charge rate structures] make it extremely easy, by a combination of a demand charge with an energy charge, to arrange a discount curve possessing almost any characteristic required to meet the exigencies of local service. If, for example, there are in any territory a considerable number of large consumers—isolated plants let us say—who can be served only at a rate which would be ruinous if extended to all customers, it is perfectly possible to devise a combination demand and service rate which shall meet the requirement of charging what the traffic will bear with respect to this particular group without extending unjustifiably great discounts to others. The same general device, in one form or another, has therefore become very widely used as giving rise to perhaps the maximum flexibility in producing a general discount curve suitable for meeting the conditions that may arise under almost any circumstances.[24]

As the movement for state rate regulation grew, political attention focussed on the operation of electric power companies, and state legislatures moved to strip power companies of the ability to engage in price discrimination at all.[25] Those whose interests lay in the use of isolated plants were most likely to favor such restrictions. In 1913 an association of manufacturers of machinery for isolated plants formed

[20] Two of many are: R. S. Hale, "Isolated Plant vs. Central Stations Supply of Electricity: A Suggestion for Obtaining Estimates of Costs on a Competitive Basis," *Electrical World and Engineer*, 42 (Sept. 5, 1903), pp. 383–84; H. S. Knowlton, "The Central Station and the Isolated Plant," *Cassier's Magazine*, 32 (Aug. 1907), pp. 359–63.

[21] "Electrical Plant in the Newark Free Public Library," *Electrical World and Engineer*, 42 (Aug. 15, 1903), pp. 271–72.

[22] Charles T. Main, "Central Stations versus Isolated Plants for Textile Mills," pp. 205–17; and R. S. Hale, "The Supply of Electrical Power for Industrial Establishments from Central Stations," pp. 219–27; also discussion, pp. 977–1009, all from *Proceedings of the Joint Meeting of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers* (Feb. 16, 1910).

[23] Henry L. Doherty, "Equitable, Uniform, and Competitive Rates," *Proceedings of the National Electric Light Association, Twenty-third Convention* (New York, 1900), p. 305.

[24] "Principles of Rate-Making," an editorial, *Electrical World*, 65 (Apr. 17, 1915), p. 971.

[25] "Central-Station Rates Discussed at Boston," *Electrical World*, 57 (Mar. 9, 1911), p. 604; William H. Winslow, "Rate Making for Central Stations," *Electrical World*, 63 (Jan. 3, 1914), pp. 12–13.

under the name "Uniform Electric Rate Association" for the apparent purpose of preventing or ending the practice by central stations of granting lower prices to those who might otherwise have used isolated plants. The association obtained and published as a pamphlet an opinion by Louis D. Brandeis on the legality of that practice.[26] Brandeis took the position that rate differentials were justifiable if they could be shown to be cost based, but that differentials based solely on differences in the characteristics of demand (including the feasibility of using isolated plants) were not legal. The publication of Brandeis's opinion was followed in *Electrical World* by a series of over twenty letters to the editor on the issue of uniform rates.[27]

Responsibility for defending the industry's interests in the rate structure controversy was taken by the leading industry trade group, the National Electric Light Association (NELA), forerunner of the modern Edison Electric Institute. The NELA aimed to forge a common methodology among utilities for structuring rates. In 1910 the NELA formed a special committee on "Rate Research" so that the various companies could have "far more uniform methods of making rates and more uniform rates than exist in the country to-day."[28] In its first report, the committee argued that it was important for the NELA, rather than regulatory commissions or the courts, to take the initiative in formulating rate structures. The committee noted then and later, with satisfaction, that commissions and courts had avoided dealing with the issue of rate structures. The committee opened an office in Chicago and published (for several decades) a weekly periodical, *Rate Research*, which reprinted many of the most important papers on demand-charge rate structures written before the turn of the century, and reported on and abstracted all news which affected electric rates and regulation, especially regulatory commission opinions. In its second annual report, issued in 1912, the committee provided standard forms for utilities to use in presenting their rates to customers and regulators. In addition, the committee unanimously recommended that demand-charge rates be used for large business users of electricity but reported disagreement over whether such rates were appropriate for those with lower consumption.[29] No justifications for these positions were provided in the report.

The controversy over rates centered on the issue of price discrimina-

[26] Louis D. Brandeis, "Central Station Rates, Legal Opinion of Louis D. Brandeis," abstracted and quoted in *Rate Research*, 4 (Oct. 15, 1913), pp. 35–38, and (Oct. 22, 1913), pp. 51–54.

[27] These letters appeared in the letters to the editor section of *Electrical World* from October 25, 1913 to July 31, 1915.

[28] *Proceedings of the National Electric Light Association, Thirty-Fourth Convention* (New York, 1911), p. 290.

[29] "Report of the Rate Research Committee," *Proceedings of the National Electric Light Association, Thirty-Fifth Convention* (New York, 1912), pp. 184–229.

tion. Could different rates be justified only when the costs of serving customers varied (the "cost-of-service" basis), or was it also desirable or acceptable to charge different rates to customers varying only in demand characteristics (the "value-of-service" basis)?[30] The opponents of value of service were concerned about the exploitation of monopoly power in the pursuit of profit maximization and criticized the practice of customers being charged different rates when there were no apparent differences in the conditions of supply. Proponents of the value-of-service approach came to the position that cost of service was the appropriate basis for setting a utility's total earnings, but that value of service was appropriate in determining the share of those earnings to be borne by each customer. They argued that it was better for all of the utility's customers if new customers could be induced to take central station supply, rather than self-generate, as long as the price charged those customers exceeded marginal costs, permitting some contribution to overhead costs. Thus the objective of rate design was to provide the largest possible service at the lowest possible cost to all, a position consistent with social welfare given the existence of large economies of scale within the utility industry.

In its 1914 report to the National Electric Light Association, the Rate Research Committee strongly advocated value of service as the primary basis for structuring rates.[31] The committee specifically defined value of service as the amount which an electricity user would have to pay to obtain an equivalent or substitute means of service, and noted that the concept had proven most acceptable to regulatory commissions when used to meet the competition from isolated plants.[32] The committee's comments regarding the use of demand-charge rate structures are revealing:

> In the case of large customers, the value of the service to the customer clearly depends on the amount for which he could make the same service for himself, because if the rate asked is notably higher than this amount, the customer may put in his own plant. The value of the service to the customer depends on what it would cost him to make it himself, and this cost clearly depends in part on the size of plant that he would need. The size of plant that he would need is determined by his maximum demand and necessary reserve. . . .
>
> The demand is at least a rough measure of this cost, and is therefore a test of the value to the buyer.[33]

The committee also considered and expressed its disapproval of

[30] These discussions paralleled to a remarkable extent earlier discussions on rate structures within the railway industry, although surprisingly little reference was made to the case of railways by those in the electric power industry. D. Phillip Locklin, "The Literature on Railway Rate Theory," *Quarterly Journal of Economics*, 47 (Feb. 1933), pp. 167–230.

[31] "Report of the Rate Research Committee and Discussion," *Proceedings of the National Electric Light Association, Thirty-Seventh Convention* (New York, 1914), pp. 59–116.

[32] Ibid., pp. 63, 70.

[33] Ibid., p. 88.

time-differentiated rates. Although such rates, according to the committee, did reflect differences in the costs of providing service, "unless this happens to coincide with a difference of value to the buyer, they are undesirable."[34] Despite the concern felt by some members of the NELA, regulatory commissions proved to be sympathetic to the value-of-service principle and to the demand-charge rate structure. L. R. Nash, in a book written in 1933, discussed the role of cost of service and value of service in terms which are virtually the same as those advocated by the Rate Research Committee in its 1914 report. Rates for large customers, according to Nash, were commonly based on value of service, defined as the cost to the user of providing such service to himself.[35] Nash cited several rulings from state commissions in support of this position. An interesting example of an early (1909) Massachusetts regulatory commission ruling which dealt with the issues of value of service and demand-charge rate structures was published in *Rate Research* in 1912:

> . . . there is a considerable number [of customers], both actual and possible, who may readily supply themselves with light or obtain power from some other source. . . . If the company is to supply them, it is subject to the ordinary rules of business competition—it must meet prices established by conditions which it does not create and cannot control, or not do the business. . . .
>
> . . . The demand system, whatever its faults in determining the individual's cost to the company, has at least the merit of recognizing the most essential elements determining the probable cost to the individual of supplying himself, and therefore operates to fit the price which the company must make to get his business, to his actual condition.[36]

Discussions within the industry between 1905 and 1915 show an appreciation for the use of the demand-charge rate structure as a tool of price discrimination in the face of competition from isolated plants. To accept price discrimination in the face of isolated plants as the cause of the widespread use of demand-charge rate structures requires evidence that their use first became widespread during that time period.

## DATING THE ADOPTION OF DEMAND-CHARGE RATE STRUCTURES

Completely satisfactory data on the form of rate structures used by utilities in the United States are not available for years prior to 1917. In 1917 the NELA Rate Research Committee began publication of an annual series of reports giving detailed information on the rates and rate structures used by electric utilities in all major cities in the United States. Before 1917, tables showing the rates charged by different utilities were occasionally constructed. Unfortunately, the primary

[34] Ibid., pp. 86–87.
[35] L. R. Nash, *Public Utility Rate Structures* (New York, 1933), p. 321.
[36] "Electric Rates—Massachusetts," *Rate Research*, 2 (Oct. 23, 1912), pp. 52–53.

purpose of those tables was to permit comparisons of the average level of rates among utilities rather than to provide details on the structure of rates. Indeed, until the work of the NELA Rate Research Committee, the terms used to describe features of electricity rate structures lacked uniformity. Despite these shortcomings, evidence for the years 1897 and 1906 strongly suggests that demand-charge rate structures were not widely used in those years. By contrast, the demand-charge rate structure was ubiquitous by 1917.

One of the earliest sources of information about rates charged by electric utilities in the United States was a paper presented by J. W. Lieb at a convention of the Association of Edison Illuminating Companies in 1897.[37] Lieb discussed extensively the variety of rate structures then known, including a number of demand-charge structures. His examples of actual utility rate structures were all European. He described one form of demand-charge rate structure as "being extensively used in Europe and America," in which the price per kilowatt-hour was discounted as a function of total energy consumption and maximum power consumption.[38] Lieb also provided a set of tables, however, showing the rates charged by Edison companies in twelve major American cities for incandescent, arc, and power service. The demand-charge feature was present in only five of the twelve cities' incandescent contracts, and in only three of the cities' power contracts. If his table reflects a greater use of demand-charge rate structures for lighting, that is consistent with the use of demand-charge rates as a form of peak-load pricing. Their use, however, did not dominate other rate structures.

In 1906, the National Electric Light Association published a confidential report on rates for electric service.[39] The report gives a table listing rates by city for 1,183 American cities and a small number of foreign cities. The table devotes columns for each city to business incandescent lights, residence lights, arc lights, and power service. For the three types of lighting service, there are separate entries for each city for flat rate (non-metered) service and metered service. For power service there are separate entries for rates based on horsepower and rates based on kilowatt-hours. Remarks for each city are also given which occasionally provide detailed information about rate structures. Despite the detail of this table, significant information may have been lost. In a number of cases, the table entries clearly describe demand-charge rate structures. In many cases, however the table entries indicate that charges or discounts were based on a "sliding scale," an

[37] J. W. Lieb, Jr., "Methods of Charging for Current," *Minutes of the Thirteenth Meeting of the Association of Edison Illuminating Companies* (Niagara Falls, 1897), pp. 59–79.

[38] Ibid., p. 68.

[39] *The National Electric Light Association's Report of Rates for Commercial Lighting and Power Service* (New York, 1906).

ambiguous term which may indicate that a demand-charge rate structure was used.[40] In many other cases, several prices are given for a kilowatt-hour without explanation. It is likely that the rate structure granted discounts for large energy consumption alone, but the possibility that "demand" was a factor cannot be dismissed.

A number of cities were described in the 1906 report as having "Wright" demand rates, but no cities were described as having "Hopkinson" rates, a ubiquitous rate structure designation in 1917. Publication of the 1906 report preceded the creation of the NELA Rate Research Committee and the publication of *Rate Research*. The greater use of the Hopkinson structure in 1917 may well reflect the success of the committee's efforts to reeducate the industry about the theoretical rate structure work which had been performed before the turn of the century.

Despite the shortcomings of the 1906 report, it gives the clear impression that demand-charge rate structures were not widely used. Indeed, had utilities offered the number of complex rate structures in 1906 which they were to have in 1917 and later, it is doubtful such a simple table could have been constructed. Of all the U.S. cities in the report, over 95 percent had residential lighting rates, and 91 percent used metered rates for residential lighting. Of those using metered rates, only about 9 percent of the cities reported use of "sliding scales" or demand charges. Similarly, 98 percent reported business incandescent rates, and 92 percent used metered rates. Only about 10 percent of the metered rates were clearly demand-charge rates or "sliding scale" rates. Rates for power were less common; only 69 percent of the cities in the report had such rates listed. Of those with power rates, only about 11 percent had structures which contained demand charges or "sliding scales." Although in use, the demand-charge rate structure was not dominant, and it was not primarily being used for industrial customers.

In 1917 the Rate Research Committee published the first volume in an annual survey of electricity rates. The volume contained information for 161 U.S. cities with populations above 40,000.[41] Each rate structure for each utility is described in detail, making it possible to reliably determine the extent to which demand-charge rate structures were used. Most utilities used several rate structures, up to sixteen, and the average was approximately seven. Rate structures were quite idiosyncratic, and many customers were given the option of choosing among several rate structures.

In a number of cities more than one utility provided electric service,

[40] Generally the term sliding scale indicated that discounts on energy costs were given those with larger consumption, as would be the case under a declining block rate schedule. Presumably this term might also have been used for a "Wright" demand-charge rate structure, or a similar rate structure. See fn. 4 for an explanation of the Wright rate structure.

[41] Rate Research Committee, *NELA Rate Book and Supplement* (Chicago, 1917).

TABLE 3
PERCENT OF U.S. CITIES USING CERTAIN ELECTRICITY RATE STRUCTURES

| | User Class | | | |
|---|---|---|---|---|
| | Residential Lighting | Business or Commercial Lighting | Power | Industrial, Wholesale or Primary Service |
| Percent of cities with rates for this class | 98.1% | 97.5% | 93.8% | 75.2% |
| Of cities with rates for this class, percent using | | | | |
| Demand charge rate structures only | 26.6 | 35.7 | 35.1 | 73.6 |
| Nondemand charge structures only | 60.8 | 51.0 | 15.9 | 8.3 |
| Both demand charge and other rate structures | 12.7 | 13.4 | 49.0 | 18.2 |

*Note:* Cities are those with populations above 40,000.
*Source:* Compiled by the author from Rate Research Committee, National Electric Light Association, *NELA Rate Book and Supplements: 1917* (Chicago, 1917).

but competing utilities usually offered identical rates. Twenty-one cities had multiple utilities with different rates. I have taken the rates of the utility first listed as representative.

Table 3 categorizes rate structures based on title and listed applicability as given in the 1917 report and abbreviates the information given in that report. Some rate structures were placed in two categories; for example, "wholesale power" was placed in both the power and the industrial categories and "general lighting" was categorized as both residential and commercial lighting. Rate structures apparently intended for restricted use, such as heating and cooking and electric-car battery charging, were not categorized.

Demand-charge rate structures appear to have been more common for all classes of service in 1917 than they were in 1906 or in 1897, owing, perhaps, to improved metering technology, although this difference could merely reflect inadequacies of the earlier data. By 1917, however, demand-charge rates structures were least used for residential lighting and were most used for power and industrial service. Demand-charge rate structures were used for power service in 84 percent of the cities with that rate class; nearly 92 percent of cities with industrial rates used demand-charge rate structures for that service. This pattern is consistent with the hypothesis that demand-charge rate structures were most likely to be offered those for whom self-generation of electricity was most attractive, rather than those for whom maximum power consumption was a good proxy for consumption during the system peak.

## CONCLUSION

Despite long advocacy by economists, time-of-day or other forms of peak-load pricing have not been widely used by American electric utilities. Instead, utilities have traditionally used demand-charge rate structures for large industrial users of electricity. These rate structures have often been viewed as a misapplication of the principles of peak-load pricing, which has made their popularity puzzling. Rationales for their widespread use have explained them as a "second-best" form of peak-load pricing, adopted when an individual electricity user's peak was likely to occur at the same time as the system peak and when metering technology was in its infancy. These explanations are plausible descriptions of the electric power industry before the turn of the century, when time-of-day and demand-charge rate structures were developed. The evidence indicates, however, that demand-charge rate structures did not become widespread until after 1906, and they were used primarily for industrial electricity users, whose maximum power consumption was least likely to coincide with system peaks.

A better explanation is found in the historical record of the industry. In the period roughly between 1906 and 1915, the industry faced the onset of state price regulation. Anxious to protect rate structures from outside legal challenge, the leading industry trade group organized to develop unanimity on the form of and justification for electricity rate structures. It was during this period that the demand-charge rate structure became widespread, and it was justified not as a form of peak-load pricing but as an instrument of price discrimination designed to reduce the price of electricity for those for whom the self-generation of electricity in isolated plants was an alternative to the purchase of electricity from electric utilities. Utilities responded to the serious competitive threat posed by isolated plants by using a rate structure which based prices not on the factors determining the utility's production costs but on the factors which would determine the cost of alternative supply. The cost of electricity from an isolated plant depended on the user's maximum power consumption and total energy consumption, and the demand-charge rate structure made the cost of electricity from a utility also dependent on these same factors. The persistence of the demand-charge rate structure after isolated plants ceased to pose a competitive threat to utilities is interesting, and makes it a modern relic of the economic conditions faced by electric utilities in an earlier time.