5-1-1987

# The Impacts of Alternative Electric Rate Structures for Irrigation: Clay-Union and Union RECs

Donald Taylor
*South Dakota State University*

Ardelle A. Lundeen
*South Dakota State University*

# THE IMPACTS
# of
# ALTERNATIVE ELECTRIC RATE STRUCTURES
# FOR IRRIGATION

## CLAY-UNION AND UNION RECs

by

Donald C. Taylor and Ardelle A. Lundeen
Professors of Economics

Research Report 87-2

May 1987

## ACKNOWLEDGEMENTS

The authors acknowledge with appreciation the privilege, in the process of undertaking this research, to have become acquainted with the three principal officers of the Clay-Union Rural Electric Cooperative (REC): Donald W. Kimball, Manager (also Manager of the Union REC); Dennis Criswell, Member Services and Marketing Director; and Paul Roberts, Business Manager. We thank them for their patience in helping us to understand the process of and some of the many complexities involved in establishing rate structures in the rural electric power industry. We stand in debt to them for what they have taught us.

We also acknowledge with thanks (1) the invaluable services of Todd A. Lone in developing the linear programming model for the research project; (2) the care and competence shown by Todd A. Lone, Lonna V. Walters, and Sandra J. Oswald in running the programming model; (3) the constructive comments on an earlier draft of the manuscript by Thomas L. Dobbs and Larry L. Janssen; and (4) the patience and competence shown by Verna Clark in typing and re-typing the several drafts leading up to this final research report manuscript.

The responsibility for any errors of fact or interpretation in the report

TABLE OF CONTENTS

THE IMPACTS OF ALTERNATIVE ELECTRIC RATE STRUCTURES FOR IRRIGATION
CLAY-UNION AND UNION RECs

TABLE TITLES

FIGURE TITLES

# THE IMPACTS OF ALTERNATIVE ELECTRIC RATE STRUCTURES FOR IRRIGATION CLAY-UNION AND UNION RECs

by
Donald C. Taylor and Ardelle A. Lundeen

## SUMMARY AND CONCLUSIONS

In this research report, the impacts of alternative electric rates and rate structures for irrigation for the Clay-Union and Union rural electric cooperatives (RECs) are evaluated. Consideration is given to both different levels and different forms of electric rate charges.

The alternative electric rate structures are evaluated in terms of the behavior of managers of hypothetical farms designed to represent "typical" irrigator clients served by the two RECs. A linear programming model was developed to portray as fully as possible the technical, institutional, and economic features associated with each representative farm.

The managers of the representative farms are presupposed to be able to make short-term farm enterprise and irrigation adjustments, as well as long-term changes in their irrigation technologies, in response to pre-season declared changes in electric rate structures for irrigation by REC electric power suppliers. The farm enterprise and irrigation technology adjustments considered are the use or non-use of two already-present electric power, high pressure center pivots; the conversion of the already-present center pivots to low pressure and/or diesel power; the purchase of new irrigation systems for use on dryland; water distribution by center pivot sprinklers or gated pipe, surface-irrigation, gravity flows; the irrigation of crops with greater or lesser irrigation requirements than corn; full versus partial irrigation rates; and the renting of additional irrigated and/or non-irrigated land.

The reference point in the linear programming analysis of the representative farms is the 1985 electric rate structure for irrigation in the two RECs. For the Clay-Union REC, the rate structure involves (1) an annual minimum charge per irrigation system of $17.80 per average kilowatt (kW) used, (2) a monthly demand charge of $9.00 per peak kW used during each monthly billing period when an irrigation system is operated, (3) a two-step energy charge, involving 4.2 cents per kilowatt hour (kWh) for the first 100 kWh per average kW per season and 2.6 cents per kWh for all additional kWh, and (4) a load management control option. If the load management option is elected, the monthly demand charges are waived. If the load management option is rejected, a 1.1 cent per kWh credit is received by the irrigator. The Union REC rate structure is similar, except that the annual minimum charge is assessed against nameplate horsepower (HP) rather than against average kWs used and at a rate of $15.40 per HP.

The study's "baseline solutions" involve the modeling of each representative farm with its actual electric rate structure for 1985 under four different situations: irrigators with debt- versus equity-financed new irrigation equipment (to see the impacts of financial leveraging on irrigator behavior) and with 1985 versus 1980 crop prices (to see the impacts of different commodity price levels on irrigator behavior). Attention is given

to expected electric power revenues received by RECs and levels of farm income earned by irrigators with normal precipitation, as well as the estimated range in year-to-year revenue/income associated with unusually heavy and light precipitation.

A series of electric rates and rate structures differing from those in 1985 is examined through linear programming analysis as follows: (1) electric energy (kWh) charges both lesser and greater than those assessed in 1985, which enables the estimation of derived demand functions for electric power to pump irrigation water, (2) greater and lesser "fixed" up-front annual minimum and monthly demand and variable energy (kWh) charges, and (3) differently configured energy (kWh) block rates, namely, single-step, three-step declining, and three-step increasing block rates. Since an examination of the incentives for irrigators to select the load management control option doesn't lend itself to linear programming analysis, this aspect of the study is evaluated via simple budgeting procedures.

**Major findings**

The most important results from the study are summarized as follows.

1. In all eight baseline solutions for the two representative farms, irrigated crop production is profitable. The irrigation systems, ranging in number from two to six per farm, are all electrically powered. All newly purchased irrigation systems involve either low pressure (Clay-Union REC service area) or gated pipe (Union REC service area) irrigation water distribution. Corn is consistently the most common irrigated crop although, in some situations, irrigated soybeans are also profitable. Partial irrigation and rented irrigated land are not profitable in any of the solutions.

2. The impacts of 7% to 38% higher crop prices in 1980 than in 1985 are very substantial. These impacts include greatly increased irrigator profits ($59,000 to $78,000 per irrigator in the baseline solutions), considerably higher direct price elasticities of demand for electricity to pump irrigation water in the upper price ranges of the kWh energy charges, and more extensive irrigation.

3. The impacts of unusual precipitation on RECs are expectedly the opposite of those on irrigators. With the baseline solutions, for example, unusually heavy precipitation results in a $330 to $440 reduction (7% to 10%) in REC electric power revenue per irrigator but a $3,600 to $26,400 increase in irrigator profits. With unusually light precipitation, on the other hand, REC electric power revenues per irrigator are $375 to $500 more, and irrigator profits are $9,500 to $54,000 less. This outcome arises primarily because of a much greater impact of unusual precipitation on irrigators' dryland crop yields and income than on their irrigation electric power payments.

4. In several important respects, rational economic behavior by leveraged irrigators with debt-financed irrigation equipment is quite different from that by irrigators with equity-financed irrigation equipment. For example, irrigators with equity-financed new irrigation equipment generally are more responsive in power use to changes in kWh energy charges in the higher range of electricity prices than are their debt-financing

counterparts. Further, their incomes are much less susceptible to fluctuation when unusual precipitation occurs than are the incomes of their debt-financing counterparts.

5. The direct price elasticities of demand for electricity to pump irrigation water for various segments on the estimated demand functions range from being very inelastic (considerably less than -1.00) at "low" electricity prices to being very elastic (between -1.62 and -12.00) at "high" electricity prices. The 1985 baseline average variable energy charges per kWh of electricity rest within the most inelastic segments of the 20 estimated demand functions. With an increase from the 1985 rates of as little as 1 to 3 cents per kWh, however, irrigators in a majority of the situations examined would have economic incentive to cut back on the level of electricity that they use in pumping irrigation water. Electricity prices would have to rise from 7 to 34 cents per kWh, however, before "typical" irrigators would totally stop using electric power to energize their irrigation systems (with diesel fuel at $0.97 per gallon).

6. The cross demand elasticities for irrigation water (in response to different electric power rates) are much lower than the direct price elasticities of demand for electricity to pump irrigation water. This outcome arises because, as electric power rates increase, diesel powered irrigation systems replace part of the electric powered systems.

7. The "fixed" cost electric power components [plant-related "facilities" and wholesale monthly demand electric power (kW) charges] comprise between 75% and 80% of the total electricity costs for pumping irrigation water. Because of the need for capital assets to eventually be replaced, the relative importance of "fixed" costs does not generally diminish over time. The variable energy (kWh) charges constitute the remaining 20% to 25% of the total electricity costs for irrigation pumping.

8. A possible Clay-Union and Union REC pricing policy to reduce by 75% the annual minimum or monthly demand electric rates, while holding the energy (kWh) charge the same, shows prospects for:

- Either no change or some increase in the amounts of irrigation water pumped and electric power used for pumping irrigation water;
- A 20% to 30% reduction in REC irrigation power revenue; and
- An increase of $1,800 to $3,550 in the return to labor and management for individual irrigator customers.

9. The impacts of modified energy (kWh) block rates on irrigation electric power and water usage are relatively limited. As long as the 1985 "fixed" up-front electric rate components are retained in the rate structure, the impacts of the single-step, three-step declining, and three-step increasing block rates examined (rather than the 1985 two-step declining block rate) on energy and water usage are 1% or less.

10. When the "fixed" up-front electric rate charges are set at zero, more sizeable impacts of modified energy (kWh) block rates on irrigation energy and water use are experienced. The impacts do not conform to a single

pattern, however, as might be hypothesized on the basis of micro production theory (all other things the same). For example, common patterns of increased energy and/or water usage are not associated with more strongly graduated declining block rates (than in the 1985 baseline electric rate structure). Neither are common patterns of decreased energy and/or water usage associated with the three-step increasing energy (kWh) block rate charges.

11. Irrigators who follow the Clay-Union and Union REC load management control program, and do not thereby sustain yield losses, clearly derive economic benefits from the load management option. If only very modest yield losses ( < 2% of normal) would be sustained from following load management, however, irrigators should not follow the load management program.

The Clay-Union and Union REC load management control option provides opportunity for irrigators to voluntarily withdraw from the program at any time they so desire. Results of analysis show that irrigators would be well-advised economically to enter and stay under the load management program as long as irrigation system power interruptions do not create yield-reducing moisture-stress for irrigated crops. For every billing month that irrigators do so, they can avail themselves of waived monthly demand charges. If such stress conditions do arise, however, irrigators would be well-advised to immediately opt out of the load management program, continue to pump irrigation water, and be no worse off economically during that billing month than their all-season load management non-follower counterparts.

**Implications of findings to electric rate pricing policies**

These findings have at least three direct implications to electric rate pricing policies.

1. Current electric rates fall within the most inelastic segments of the estimated direct price demand functions for electricity to pump irrigation water. Increases in the variable energy charge of as little as 1 to 3 cents per kWh would likely lead to some reductions from baseline levels in electric power use by irrigators. Variable energy charge increases of as much as 7 to 34 cents per kWh would have to take place, however, before most current electric power irrigators would totally shift away from electric to diesel power sources (with diesel fuel at $0.97 per gallon).

2. The short-run implications of unusual precipitation on REC revenues are expectedly the opposite of those on irrigator profits. If the negative impacts on irrigators from drought are great enough to force the irrigators out of business, however, both the irrigators and their "parent" RECs stand to lose. Thus, a rate structure that provides for the sharing of risks between RECs and irrigators from unusual precipitation can be expected to be in the best long-term economic interests of both irrigators and RECs.

Two features of the current Clay-Union and Union REC electric rate structures for irrigation provide for the sharing of risks between irrigators and RECs during seasons of unusual precipitation. The spreading of the "fixed" up-front costs over fewer kWhs results in higher average costs per kWh in years of unusually heavy precipitation (and hence limited irrigation pumping). The two-stepped declining energy (kWh) block rate also results in higher average variable energy (kWh) costs with heavy precipitation. Conversely, when precipitation during an irrigation season is unusually light, both features contribute to a below normal overall average cost per kWh for the electric power used by an irrigator.

3. Load management programs to control peak power demands are of definite increasing interest in South Dakota. The central features that make the Clay-Union and Union REC load management option attractive to irrigators are (1) the potential for irrigators to avoid paying monthly demand charges in any month during which 20 hour per day irrigation is adequate to meet the moisture needs of their crops and (2) the possibility for load management followers to opt out of the load management control program (with no greater penalty than to pay the monthly demand charge) whenever they determine that 20 hour per day irrigation would result in yield-reducing moisture-stress. This double-barreled feature of the program contributes to the mutual economic welfare of both the electric power supplier and the electric power user.

## INTRODUCTION

This is the third in a series of five Economics Department reports on a research project, "The Economic Impact of Alternative Electric Rate Structures on Energy and Water Use", sponsored by the South Dakota Agricultural Experiment Station. Supplemental funding for the research was provided by the Western Area Power Administration (WAPA), Golden, Colorado.

The purpose of this third report is to present the empirical results from the study of different electric rates and rate structures for irrigation for the Clay-Union and Union rural electric cooperatives (RECs) in southeastern South Dakota. As a prelude to the presentation of results, abbreviated descriptions of the overall electric rate structure-irrigation research project and the Clay-Union and Union REC representative farm models used in the research are provided.

The initially presented results--termed the "baseline solutions"--are based on the modeling of the representative farms with the actual electric rate structures for irrigation used in 1985 by the Clay-Union and Union RECs. The next group of results shows the impacts of variable energy [kilowatt hour = kWh] charges that are both lower and higher than those assessed in 1985 on the prospective demands for electric power and water for irrigation. The results for three types of alternative rate structure analysis are then presented. These involve greater and lesser "fixed" up-front and variable energy charges, differently configured energy (kWh) block rates, and load management controls. The impacts of unusually heavy and light precipitation on REC power sales and revenues and irrigator profits are also covered.

The other reports in this research report series are as follows:

- No. 1, Enterprise Budgets and Other Data-Sets; Electric Rate Structure-Irrigation Study; Clay-Union, Union, Cherry-Todd, and Cam-Wal RECs;

- No. 2, Mixed Integer Linear Programming Model; Electric Rate Structure-Irrigation Study; Clay-Union, Union, Cherry-Todd, and Cam-Wal RECs;

- No. 4, The Impacts of Alternative Electric Rate Structures for Irrigation, Cherry-Todd REC; and

- No. 5, The Impacts of Alternative Electric Rate Structures for Irrigation, Cam-Wal REC.

A rather "casual" reader can expect to find this third report to stand on its own. Readers with a more serious interest in the empirical findings in this report, however, will find it helpful to consult Reports 1 and 2 for detailed information on the data-sets and modeling used in the study. Where linkages between this and the other reports are particularly strong, references are made parenthetically to pertinent sections from the prior reports.

## OVERVIEW OF THE RESEARCH

About 80% of South Dakota's irrigation pumps are energized by electricity. The high cost and under-utilization of recently developed (coal-based) electric power generation facilities have resulted in increased wholesale costs of electric power and, in turn, in higher electric rates for irrigators and other electric power consumers. Operating within an already financially-stressed agriculture, RECs that supply electricity to irrigators are exploring possible revisions to rate structures offering prospect of more fully meeting the joint needs of themselves and their irrigator clients.

The research results reported in this publication show the impacts of alternative electric rates and rate structures on (1) the demands for power to energize irrigation pumps and for irrigation water and (2) expected levels of irrigator farm income and REC electric power revenue. Included in the analysis is special attention to different levels of commodity prices, debt- versus equity-financed irrigation equipment, and both average income/revenue levels and the estimated range in year-to-year income/revenue associated with unusually heavy and light precipitation.

What represents a "most appropriate" electric rate structure for irrigation for one REC power supplier may not be "most appropriate" for another. A host of rather location-specific factors determines what is "most appropriate". These factors include (1) average amounts of and year-to-year variations in precipitation and solar radiation (as these impact amounts of irrigation water that must be pumped), (2) the lift and source of pumped water, (3) the nature of soils and topography, (4) the spectrum of potentially profitable farm enterprises, (5) the internal financial structure of an REC, (6) the importance of irrigation relative to other sectors in an REC's power sales, and (7) the philosophic positions of an REC's manager and governing board. Taking into account the first four factors, study sites in four different South Dakota RECs were selected for separate study and analysis. In selecting the RECs and study sites within their respective service areas, efforts were made to cover as wide a range as possible of conditions for each of the four factors.

The study sites for the four selected RECs and a brief description of their attributes, relative to the four selection criteria, are as follows (for more details, see pp 3-6 and Figures 1 and 2 in Report 1):

- Clay-Union REC, irrigated area east of Vermillion and south of Route 50 in Clay County,

  *Precipitation--relatively high and stable from year to year,

  *Pump lift--shallow ground water (about 25 ft of lift is common),

  *Soils--light and low-lying, and

  *Farm enterprises--mainly corn and soybeans, but some hog farrowing-finishing, small grains, and alfalfa as well;

- Union REC, irrigated area primarily east of Elk Point and just west of the Big Sioux River, but also extending along the north side of Route 29 north of Elk Point to Route 50, *Precipitation and pump lift--similar to the Clay-Union REC,

*Soils--heavy, with some areas having sufficiently flat topography to permit gated pipe irrigation, and

*Farm enterprises--similar to the Clay-Union REC, except for fewer hog enterprises and more limited alfalfa production;

- Cherry-Todd REC, irrigated area south of a line roughly between St. Francis and Olsonville in Todd County,

*Precipitation--limited,

*Pump lift--deep ground water (about 130 ft of lift is common),

*Soils--light, sandy, well-drained to excessively drained, and

*Farm enterprises--somewhat narrow range, with cow-calf enterprises, corn, alfalfa, and oats being most common; and

- Cam-Wal REC, irrigated area south of Mobridge and just east of the Missouri River in Walworth County,

*Precipitation--lowest of the study sites,

*Pump lift--high lift from the Missouri River, with about 150 ft of lift for the "low-lands" research site and 300 ft of lift for the "bluffs" research site,

*Soils--generally heavy, with an undulating topography, which precludes "low pressure" water distribution, and

*Farm enterprises--cow-calf operations and the widest range of crops for any study site, including corn, alfalfa, small grains, and annual forages (corn silage, sorghum sudan pasture).

In this report, the results from the study for the Clay-Union and Union REC are presented. In Reports 4 and 5, the results for the Cherry-Todd and Cam-Wal RECs are presented. Subsequent publications will cover more generalized findings based on the results for all four RECs. In those publications, the interactions between alternative electric rate structures and the contrasting irrigation environments represented in the four REC service areas will be stressed.

## REPRESENTATIVE FARM MODEL ANALYSIS

To accomplish the purpose of the research, a hypothetical farm was identified to represent "typical" irrigator clients served by each REC. A linear programming model was developed to portray as fully as possible the technical, institutional, and economic features associated with each representative farm (for a detailed description of the model, see Report 2).

**Nature and role of representative farms in the research**

The representative farm models are intended to reflect conditions on typical irrigated farms with above-average management in the Clay-Union and Union REC service areas in 1985. Irrigator farm managers are presupposed to be able to make short-term farm enterprise and irrigation adjustments in response to pre-season declared changes in electric rates and rate structures for irrigation by REC electric power suppliers. They are also presupposed to be able to make changes in irrigation technology (e.g., downgrading irrigation water distribution pressures, shifting from electric to diesel power sources, purchasing new irrigation systems) which have long-term implications to farm resource use. Thus, while the models involve only a single production period, a longer term (7 to 15 years) decision-making planning horizon is envisioned for the managers of the representative farms.

The representative farms are assumed to already be in operation--with specified acreages of land (260 and 440 acres, respectively, of irrigated and non-irrigated cropland for both RECs and an additional 100 acres of pasture for the Clay-Union REC) and generally adequate machinery and equipment, farm buildings, and breeding herds (only for the Clay-Union REC representative farm) to make economic use of the land. The available machinery and equipment includes two electric power, high pressure center pivot systems (for more details on the assumed availability of resources and the constraints on resource use for the representative farms, see pp 19-20 and Tables 25 and 26 in Report 1 and pp 7-8 in Report 2).

**Electric rate structures examined**

In 1985, the electric rate structures for irrigation for both the Clay-Union and Union RECs contained provisions for annual minimum, monthly demand, and two-step declining block rate charges, along with a load management control option. The rate structures are based on annual cost of service studies, as explained in the appendix to this report.

The specific provisions of the **Clay-Union REC** electric rate structure are as follows:

- Annual minimum charge: $17.80 per average kilowatt (kW) used;

- Monthly demand charge: $9.00 per peak kW used during each monthly billing period when an irrigation system is operated:

- Energy charges:

  * First-step, $0.042 per kilowatt hour (kWh) for the first 100 kWh per average kW per season; and

  * Second-step, $0.026 per kWh for all additional kWh;

- Load management control, in which the monthly demand charges are dropped in exchange for an agreement by an irrigator for power to his (her) irrigation systems to be turned off from 5 to 9 pm daily during one or more months of the irrigation season; and

- No load management control, in which irrigation systems are energized without daily interruptions, monthly demand charges are paid, and a $0.011 per kWh (Basin) credit is received by the irrigator.[1]

The **Union REC** in 1985 had the same rate structure as the Clay-Union REC did, except that the annual minimum charge was assessed against nameplate horsepower (HP) rather than against average kW's used[2] and at a rate of $15.40 per HP.

The "baseline" electric rate structures used in the study are the just-described rate structures for 1985 for the two RECs. A series of electric rates and rate structures differing from those in 1985 was then examined, as follows:

- Estimated demand for electric power to pump irrigation water, with electric energy (per kWh) charges both lesser and greater than those assessed in 1985;

- Greater and lesser "fixed" up-front (annual minimum and monthly demand) and variable energy electric rate charges; and

- Differently configured block rates, namely, single-step, three-step declining, and three-step increasing energy (kWh) block rates (in contrast to the 1985 two-step declining rate).

Using the linear programming model, "optimal solutions" for the representative farms with the 1985 electric rate structures were first determined. The results of this analysis show the most profitable farm enterprises and irrigation technologies, the amounts of electric power use and electric power revenue for irrigation pumping, and the return to operator labor and management for each representative farm situation. Most profitable farm plans were then determined for each of the just-described electric rate and rate structure alternatives. The conclusions of the study for all alternatives except those involving load management are based on a comparison of the farm organization, energy use, electric power revenue, and irrigated farm profit features of these various plans. Since an examination of the incentives for irrigators to select the load management control option doesn't lend itself to linear programming analysis, this aspect of the study was evaluated via simple budgeting procedures.

---

[1]The two suppliers of electric power to the East River Electric Power Cooperative--which in turn supplies electric power to the Clay-Union and Union RECs in South Dakota--are the Western Area Power Authority (WAPA) and the Basin Electric Power Cooperative. During 1985 and 1986, Basin Electric granted a $0.02 per kWh credit on all electric power used for irrigation. This credit was passed "down the line" to irrigators. The impact of the Basin credit on irrigators served by the East River Electric Power Cooperative is $0.011 per kWh. The irrigator credit is less than $0.02 per kWh because some of the electric power supplied to East River is from WAPA.

[2]The average kW demand in the Clay-Union REC is reported to be about 85% of the nameplate HP rating for the power unit.

**Irrigation alternatives considered**

Several options are open to irrigators in responding to different electric rates and rate structures. In the study of electric rate structures for irrigation in the Clay-Union and Union RECs, seven irrigation alternatives were considered. The alternatives and the underlying rationale for including each in the study are as follows (for added detail covering these alternatives, see pp 14-16 and Tables 15, 16, and 19 of Report 1 and pp 8-11 of Report 2).

**The use or non-use of two already-present, electric power, high pressure [a pivot pressure of about 75 pounds per square inch (psi)] center pivots.** An important practical question is whether energy prices are so high (relative to commodity price levels) that farmers should no longer use irrigation systems already present on their farms. One objective of the analysis, then, is to determine how high electric power rates can rise before it becomes uneconomic to use electrically powered pumps to lift and distribute irrigation water.[3]

**The conversion of already-present center pivots to low pressure and/or diesel power.** In response to rising electric power rates, irrigators may find it economic to convert their existing irrigation systems to low pressure (in the Clay-Union and Union REC service areas, to about 30 psi) and/or to diesel power sources. The economic question is whether prospective energy savings from low pressure water distribution and/or diesel power will more than offset the annualized costs of converting existing equipment from high to low pressure and/or from electric to diesel energy sources. The representative farm analysis is structured so as to enable a determination of how high electric rates can rise before it becomes economic to downgrade water distribution pressures and/or give up electricity in favor of diesel power for energizing irrigation pumps.

**The purchase of new irrigation systems.** An important practical question is whether electric energy-commodity price and other relationships are such that farmers can afford to expand the area they irrigate through the purchase and use on existing dryland of new irrigation systems. Provision is made in the model for the purchase of several types of irrigation systems, including electric and diesel powered center pivot and gated pipe (the latter for the Union REC only) units.

**Water distribution by center pivot sprinklers or gated pipe, surface-irrigation, gravity flows.** In part of the Union REC service area, soils and topography permit gated pipe, gravity flow water distribution. With gated pipe irrigation systems, the energy pumping costs per acre-inch of water are much less than with sprinkler systems. Counterbalanced against this are larger amounts of irrigation water and irrigation labor that are required with gated pipe than with center pivot irrigation. The representative farm analysis was structured so as to determine whether investments in new center pivot sprinkler systems and/or new gated pipe systems (the latter only in the Union REC service area) would be economic.

---

[3]Unless the already-present electrically powered center pivot systems are converted to diesel power (see the next para), the model requires the payment of the annual minimum charges no matter whether the systems are used or not.

**The irrigation of crops with a greater or lesser irrigation requirement than corn.** The most commonly irrigated crop in the Clay-Union and Union REC service areas is corn. Soybeans are also grown under irrigation in both areas, and in Clay County alfalfa is as well. The irrigation requirement for alfalfa is 70% more than that for corn. The irrigation requirement for soybeans, on the other hand, is slightly less (2-4%) than that for corn. With higher or lower electricity prices for energizing irrigation pumps and different commodity prices, it is conceivable that the relative economics of producing crops with different intensities of irrigation water application could shift.

**Full versus partial irrigation water application rates.** One of the potential adjustments to rising energy prices is to irrigate at a level less than that which meets the full consumptive water requirement of a crop. In the Clay-Union and Union REC representative farm models, two levels of partial irrigation, namely, two-thirds and one-third the full application rate, were permitted. Based on a "textbook" soil moisture-yield production function, yields and production costs were adjusted to correspond with the reduced irrigation levels. The analysis of this option involved determining whether, as electric power rates increase, the reduced pumping and other production costs associated with partial (rather than full) irrigation would be great enough to compensate for the consequent crop yield losses.

**The renting of additional irrigated land.** The final irrigation alternative considered involved determining whether the economics of irrigated crop production with some of the electric rate structure scenarios are sufficiently favorable to justify renting a quarter-section (130 irrigated acres) already serviced with a center pivot system.[4] This alternative is analagous to the irrigation system purchase option, except that this option involves renting rather than purchasing assets and a combined land and irrigation system expansion rather than simply an irrigation system expansion.

**Purchasing new irrigation equipment with debt- versus equity-capital**

Irrigation systems represent multi-period inputs. In economic analysis, the investments required for purchasing them need to be spread out (i.e., amortized) over a number of years. Two types of amortization can be undertaken.

A "financial" type of amortization pertains to debt-financed purchases. The most commonly reported method for debt-financed irrigation system purchases in South Dakota is via a lease-purchase program involving an

---

[4]Provision was also made in the model for renting up to a quarter-section of dryland. The rationale for including the land rental options was to determine the economic feasibility of a possible expansion of irrigation with reduced energy prices and/or increased commodity prices.

A potential limitation in this approach concerns the drawing of conclusions for the macro REC service area (which serves only a fixed land area) based on the analysis of a typical representative farm that is given the option to rent neighboring land. The fact that only dryland is rented in the optimal solutions for both REC representative farms reduces considerably the actual impact of this potential limitation.

initial downpayment (15.5% of the purchase price), six annual payments (15.7% each), and a terminal "buy-out" payment (10%). The debt repayment for converting electric power systems to diesel power is commonly amortized over four years, whereas the smaller investments for converting from high to low pressure water distribution are commonly amortized over two years.

An "economic" type of amortization reflects a longer-term, equity-capital (i.e., farmer-owned capital or savings), economic-profit perspective in which no attention is paid to debt repayment terms. The number of years and interest rate used in this type of amortization reflect a long-term opportunity cost investment perspective of the decision-maker. In this study, the "economic" amortization of investment costs was assumed to extend over 15 years.

Primarily because of a shorter amortization period (7 versus 15 years), but also because of the somewhat higher interest rate implicit in the lease-purchase terms, the annualized "financial" costs of investing in new irrigation systems in the Clay-Union and Union REC service areas are considerably higher (1.5 times as much) than the corresponding annualized "economic" costs (for more detail, see pp 15-16 and Tables 15 in Report 1).[5] These substantial cost differences imply that the most rational behavior of irrigators who purchase new irrigation equipment with equity-capital may be quite different from that for irrigators who have to meet the schedule of debt-repayments associated with recently or newly purchased irrigation equipment financed by debt-capital.

**Commodity price assumptions**

The farm enterprise budgets used in analysis were developed using 1985 input prices, insurance rates, custom rates, wage rates, and capital costs. In most of the alternative electric rate and rate structure scenarios, 1985 commodity prices were also used. To obtain some idea of the impact of different levels of commodity prices, however, in part of the analysis 1980 rather than 1985 crop prices were used. The 1980 prices were higher than those in 1985, ranging in "real" (inflation-adjusted) 1985 terms from being 7% higher for alfalfa to 38% higher for soybeans (Table 1, Report 1).

The commodity prices used in analysis reflect actual market prices for South Dakota as reported by the South Dakota Agricultural Statistical Service and the U.S. Department of Agriculture. It was decided to use actual market prices rather than government program deficiency or loan payment prices because only those irrigators with established acreage and yield bases are eligible to participate in government grain commodity programs. Further, not all irrigators with established acreage and yield bases necessarily participate in government programs. Also, the provisions in government programs in one year frequently differ from those in other years. Since there is no

---

[5]The annualized "financial" ownership costs represent the present value of the series of payments to meet the terms of the lease-purchase agreement--expressed on an annual basis. The annualized "economic" ownership costs represent the present value of a series of payments amortized over 15 years at 11% interest to offset the purchase price of irrigation systems. The payment factors for the annualized "economic" and "financial" ownership costs are 0.14 and 0.21, respectively.

"typical" type of irrigator participation in government programs, our analysis did not reflect participation by irrigators in the 1985 government grain commodity program. Those irrigators with established acreage and yield bases who participated in the government program in 1985, however, did receive higher grain prices than those used in the study's analysis.[6]

**Gross profit maximization**

Solving the linear program representative farm models involved selecting the combination of crop and livestock production enterprises and irrigation technologies that would maximize the farm's "gross profits", where "gross profits" are defined as the surplus of gross revenues over the variable costs of farm production. The variable costs of farm production are those which could be avoided if production were to be stopped. These include out-of-pocket production costs (e.g., for fertilizer, tractor fuel, land rent) and the annualized costs of newly purchased irrigation equipment.

In the results presented in this report, the gross profits determined in the optimal computer-determined solutions for the representative farms were adjusted down to cover the costs of the assumed already-present resources on the farms. The annualized costs associated with the already-present land, farm machinery and equipment, and livestock-related resources for the Clay-Union and Union REC representative farms are $89,000 and $80,000, respectively (see p 20 and Table 26 of Report 1 and pp 6 and 7 of Report 2 for added detail). The resulting "net profit" thereby calculated represents the return to the irrigator's labor and management.

**Unusual precipitation**

In years of unusually heavy precipitation, farmers pump less irrigation water. Other things the same, this impacts REC irrigation revenues negatively, and irrigator profits positively. In years of unusually light precipitation, the implications are the converse. Examining the impacts on REC revenues and irrigator profits of unusually heavy and light precipitation is, therefore, one analytic focal point in the study.

The mean May-September precipitation level over the past 31 years at the Vermillion weather station--which serves as the precipitation reference point for the Clay-Union and Union REC service areas--is 14.3 inches. To determine pertinent levels of unusually heavy and unusually light precipitation to use in analysis, the yearly May-September precipitation amounts were arrayed from smallest to largest. The general procedure for all RECs was to identify an amount exceeded in no more than one to three years out of the 30-34 years for which data were available and to term that an "unusually heavy precipitation"

---

[6]The per-bushel deficiency payments received in 1985 by Clay and Union County participants in the government feed grain program were as follows: corn $0.48, oats $0.29, and wheat $1.08. The acreage set-aside requirements in 1985 were 10% for corn and oats and 30% for wheat.

level.[7] An analagous procedure was followed to determine the "unusually light precipitation" level. Resulting from the application of this general procedure was the identification of 20.0 and 8.6 inches to represent May-September unusually heavy and light precipitation, respectively, for the Clay-Union and Union REC service areas.

It was assumed in analysis that representative farm managers had already made their farm organizational plans and planted their crops based on normally expected precipitation. Selected most profitable solutions for the representative farms which were based on normally expected precipitation, thus, became the reference point for examining the impacts of unusually heavy and light precipitation. The examination was via partial budgeting, with joint attention to:

- The reduced (increased) irrigation system (a) pumping and (b) repair and maintenance costs resulting from reduced (increased) irrigation water application rates;

- The increased (reduced) dryland crop yields; and

- The increased (reduced) costs of drying and storing the increased (reduced) dryland crop production output associated with unusually heavy (light) precipitation (see pp 13-14 and Tables 11 and 12 in Report 1 for added detail).

## BASELINE SOLUTIONS

The "baseline solutions" involve the modeling of the representative farms with the actual electric rate structures for irrigation used by the Clay-Union and Union RECs in 1985 under two different types of situations: irrigators with debt- versus equity-financed new irrigation equipment and with 1985 versus 1980 farm commodity prices. Features common to all eight baseline solutions are first noted. Attention is then given to contrasting results, in turn, for the Union versus Clay-Union REC representative farms, irrigators with debt- versus equity-financed new irrigation equipment, and 1980 versus 1985 commodity prices.

### Common features

In all eight baseline solutions for the two representative farms (Tables 1 and 2), irrigated crop production is profitable. The irrigation systems, ranging in number from two to six per farm, are all electrically powered. All newly purchased irrigation systems involve either low pressure center pivot (Clay-Union REC service area) or gated pipe (Union REC service area) irrigation water distribution. Corn is consistently the most profitable crop, although in some situations soybeans are also profitable.

---

[7]The years of available precipitation data for the different reference point weather stations in the study ranged from 30 to 34. The unusually heavy and light precipitation levels were determined in relation to natural break-points among the one to three years of both heaviest and lightest annual precipitation.

Table 1. Baseline solutions, Clay-Union and Union REC representative farms, irrigators with debt- versus equity-financed new irrigation equiment, 1985 commodity prices[a].

| | Clay-Union REC | | Union REC | |
|---|---|---|---|---|
| | Debt-financing | Equity-financing | Debt-financing | Equity-financing |
| **Resource acquisition** | | | | |
| New irrigation systems purchased | 0 | 3 CP-LP | 1 GP | 3 GP |
| Existing center pivots converted | 0 | 2 CP-LP | 0 | 2 CP-LP |
| Dryland rented (acres) | 160 | 156 | 160 | 160 |
| **Irrigated production** | | | | |
| Corn (acres) | 260 CP-HP | 520 CP-LP | 260 CP-HP<br>160 GP | 260 CP-LP<br>320 GP |
| Soybeans (acres) | 0 | 130 CP-LP | 0 | 160 GP |
| Total acres | 260 | 650 | 420 | 740 |
| Total value of production ($) | 92,040 | 216,155 | 148,680 | 244,795 |
| **Dryland production (acres)** | | | | |
| Corn | 404 | 0 | 290 | 0 |
| Soybeans | 165 | 142 | 150 | 120 |
| Alfalfa | 11 | 44 | 0 | 0 |
| Oats | 20 | 20 | 0 | 0 |
| Total | 600 | 206 | 440 | 120 |
| **Hog farrowing-finishing (brood sows)** | 40 | 40 | 0 | 0 |
| **Electric power used for irrigation** | | | | |
| Total cost ($) | 6,243 | 8,722 | 6,874 | 5,820 |
| Total kWh | 82,053 | 109,353 | 72,555 | 70,119 |
| Average cost per kWh (cents) | 7.6 | 8.0 | 9.5 | 8.3 |
| **Irrigation water used (acre-feet)** | 238 | 594 | 365 | 743 |
| **Return to operator labor and management ($)** | 5,370 | 9,680 | -10,885 | -2,240 |

[a] The names of different irrigation systems are abbreviated as follows: CP = center pivot (electric power), HP = high pressure, LP = low pressure, and GP = gated pipe.

Table 2. Baseline solutions, Clay-Union and Union REC representative farms, irrigators with debt- versus equity-financed new irrigation equipment, 1980 crop prices[a]

| | Clay-Union REC | | Union REC | |
|---|---|---|---|---|
| | Debt-financing | Equity-financing | Debt-financing | Equity-financing |
| **Resource acquisition** | | | | |
| New irrigation systems purchased | 3CP-LP | 4CP-LP | 3 GP | 3 GP |
| Existing center pivots converted | 0 | 2 CP-LP | 2 CP-LP | 2 CP-LP |
| Dryland rented (acres) | 160 | 160 | 160 | 160 |
| **Irrigated production** | | | | |
| Corn (acres) | 260 CP-HP | 130 CP-LP | 260 CP-LP | 260 CP-LP |
| | | | 480 GP | 320 GP |
| Soybeans (acres) | 390 CP-LP | 650 CP-LP | 0 | 160 GP |
| Total acres | 650 | 780 | 740 | 740 |
| Total value of production ($) | 246,620 | 277,720 | 325,230 | 309,210 |
| **Dryland production (acres)** | | | | |
| Corn | 21 | 0 | 0 | 0 |
| Soybeans | 165 | 56 | 120 | 120 |
| Alfalfa | 4 | 4 | 0 | 0 |
| Oats | 20 | 20 | 0 | 0 |
| Total | 210 | 80 | 120 | 120 |
| **Hog farrowing-finishing (brood sows)** | 40 | 40 | 0 | 0 |
| **Electric power used for irrigation** | | | | |
| Total cost ($) | 12,232 | 11,663 | 5,827 | 5,820 |
| Total kWh | 146,708 | 129,708 | 70,566 | 70,119 |
| Average cost per kWh (cents) | 8.3 | 9.0 | 8.3 | 8.3 |
| **Irrigation water used (acre-feet)** | 589 | 704 | 749 | 743 |
| **Return to operator labor and management ($)** | 64,315 | 77,400 | 67,570 | 66,368 |

[a]The names of different irrigation systems are abbreviated as follows: CP = center pivot (electric power), HP = high pressure, LP = low pressure, and GP = gated pipe.

Partial irrigation and rented irrigated land are not profitable in any of the solutions. Rented dryland, however, is profitable in all eight solutions, and in seven of the solutions the maximum permitted area of 160 acres is rented. These results indicate that, under the assumed conditions, farmers can not afford to pay a premium for land serviced with center pivot irrigation systems of as much as $35 per acre (the assumed irrigated and dryland rental rates were $100 and $65 per acre, respectively).

**Union versus Clay-Union RECs**

The extent of irrigation--judged by both the acre-feet of irrigation water applied in all four contrasting model situations and the irrigated acreage in three of the four situations--is greater for the Union than the Clay-Union REC representative farm, especially with 1985 commodity prices. The extent of electric power use for irrigation, however, is less for the Union than the Clay-Union REC farms.

These outcomes arise primarily because the newly purchased irrigation systems for the Clay-Union REC farm all involve relatively energy-intensive center pivots (albeit low pressure units), whereas the newly purchased irrigation systems for the Union REC farm all involve irrigation water-intensive gated pipe units. Gated pipe irrigation does require heavier rates of irrigation water application. It is enough less energy intensive, however, that the efficiency of electric power use for the Union REC farm is considerably higher than that for the Clay-Union REC farm. A further explanation for the lesser electric power usage on the Union REC farm is a 25-30% lower irrigation water application requirement for crops irrigated in the Union versus the Clay-Union REC study areas.

For the Clay-Union REC farm, the maximum number of 40 brood sows in the hog farrowing-finishing enterprise is one component of all four most profitable baseline solutions. Hogs were not considered with the Union REC farm.

**New irrigation equipment purchased with debt- versus equity-capital**

In only one of the four baseline solutions involving debt-financing do the relatively high annualized costs of purchasing new irrigation equipment effectively fail to constrain the expansion of irrigation. This exceptional situation involves the Union REC farm with 1980 crop prices--in which three new gated pipe systems are purchased and the two high pressure center pivots are converted to low pressure. The relatively attractive crop prices of 1980 and the relatively favorable economics of gated pipe irrigation more than compensate for the relatively high cost of debt-financed new irrigation equipment. Because the opportunities for expanding irrigation are essentially exhausted in the Union REC solution involving debt-financed new irrigation equipment, the solution involving the lower cost equity-financed new irrigation equipment differs little from it.

With 1985 commodity prices, a substantial expansion in irrigation (namely, the addition of two or three more irrigation systems) is economic for only irrigators with equity-capital (but not with debt-capital) to finance new irrigation equipment. Both representative farm irrigators with equity-irrigation equipment use more than twice the amount of irrigation water than their counterparts who use debt-capital to finance new irrigation equipment. The corresponding differential for the Clay-Union REC farm with 1980 prices is 20%. Irrigators with equity-financed new irrigation equipment also grow more soybeans under irrigation than their debt-financing counterparts do.

**1980 versus 1985 commodity prices**

The impacts of 7% to 38% higher crop prices in 1980 on the optimal representative farm solutions, especially for the Clay-Union REC farm, are very substantial. Perhaps most importantly, the returns to operator labor and management are no longer negative or only modestly positive. The extent of increase in returns ranges from $59,000 to $78,000 for the four contrasting baseline solutions.

The value of total irrigated crop production with the 1980 crop prices is 1.3 to 2.7 times as much as with 1985 commodity prices. This increase reflects most importantly the direct impacts of the crop price increases, but also in three of the four contrasting situations an expanded irrigated area (from one to three additional irrigated systems with 1980 crop prices). In those three situations, from roughly 1.2 to 2.5 times as much irrigation water is pumped as with the 1985 prices.

In two respects, the responses to the higher 1980 commodity prices differ on the two representative farms. In each case, the Clay-Union REC farm shows responsiveness and the Union REC farm does not. The total kilowatt hours of electric power used for irrigation is roughly 1.2 to 1.8 times more with 1980 than 1985 crop prices for the Clay-Union representative farm--which reflects the purchase and use of three to four additional low pressure center pivot systems on that farm. The Clay-Union REC farm also responds to the relatively greater increase in soybean (38%) than in corn (24%) prices in 1980, through having three to four more center pivots of soybeans in its solutions with 1980 than 1985 commodity prices.

## UNUSUALLY HEAVY OR LIGHT VERSUS NORMAL PRECIPITATION

In the part of the analysis described now, the impacts on the baseline models of unexpected precipitation during the irrigation season are examined. Farmers are assumed to have (1) based their farm plans on normal precipitation levels, (2) planted their crops in the spring, and (3) followed fertilization, plant protection, and other cultural practices in accordance with expected yields based on normal precipitation. As the crop season unfolds, however, precipitation is assumed to depart from the normal and to be either unusually heavy (reaching a level experienced during only 3 to 10 years out of 100 years) or unusually light (again, a 3 to 10 out of a 100 year occurrence).[8] This is presumed to result in reduced (increased) irrigation requirements for irrigated crops and higher (lower) yields for dryland crops.

---

[8] This reflects the one to three year cut-off points for unusually heavy and light precipitation that were identified relative to the 30-34 years of available precipitation data for the reference point weather stations in the study.

For each representative farm with 1985 commodity prices and for both the debt- and equity-financed new irrigation equipment situations, the impacts of unusual precipitation on the amount of irrigation water pumped, the amount of electricity used for pumping irrigation water, the irrigation power revenues received by RECs (which, of course, also represent electric energy costs for irrigation to irrigators), and the return to operator labor and management were determined (Figures 1 and 2). The middle histogram-bars in the figures reflect outcomes with normal precipitation; these are termed 100%-level outcomes. The left histogram-bars reflect outcomes with unusually heavy precipitation, and the right bars outcomes with unusually light precipitation. The percentages shown at the top of the left and right bars indicate the unusually heavy and light precipitation outcome values relative to the respective normal precipitation outcomes.

The findings from this analysis are described first for the unusually heavy precipitation situation and then for the unusually light precipitation situation. Because most of the results differ rather markedly for irrigators with debt- versus equity-financed new irrigation equipment, special attention is given to this dimension in the findings. In instances where the findings for the two REC representative farms differ, the name of the REC farm to which a finding pertains is shown parenthetically.

With unusually heavy precipitation, the decreases in the acre-feet of irrigation water pumped and the kWh of electricity for pumping irrigation water range from 26% (Clay-Union) to 36% (Union). REC irrigation power revenues decrease by $330 to $440 per irrigator, which translate into the following percentage decreases: 5% (Clay-Union) and 6% (Union debt-financing irrigators) or 15% (Union equity-financing irrigators). The impacts of unusually heavy precipitation on the return to irrigator labor and management are much greater. The increased return to irrigators using debt-capital to finance the purchase of new irrigation equipment ranges from $16,800 (Union) to $26,400 (Clay-Union). For equity-financing irrigators, the increases range from $3,600 (Union) to $6,000 (Clay-Union); these differences are less because of fewer dryland acres in the equity-financing optimal farm solutions.

With unusually light precipitation, opposite and somewhat greater impacts on irrigation water and electric power usage, REC revenues, and irrigator profits are realized. The greatest differences are in regard to irrigator profits. The decreases in the return to irrigator labor and management for the Clay-Union REC farm solutions from light precipitation are more than double the corresponding increases from unusually heavy precipitation. Analagous differences for the Union REC farm solutions are substantially greater (involving 3.7- and 4.5-fold rather than 2-fold differences). These outcomes reflect rather modest dryland yield increases from unusually heavy precipitation and more substantial dryland yield decreases from unusually

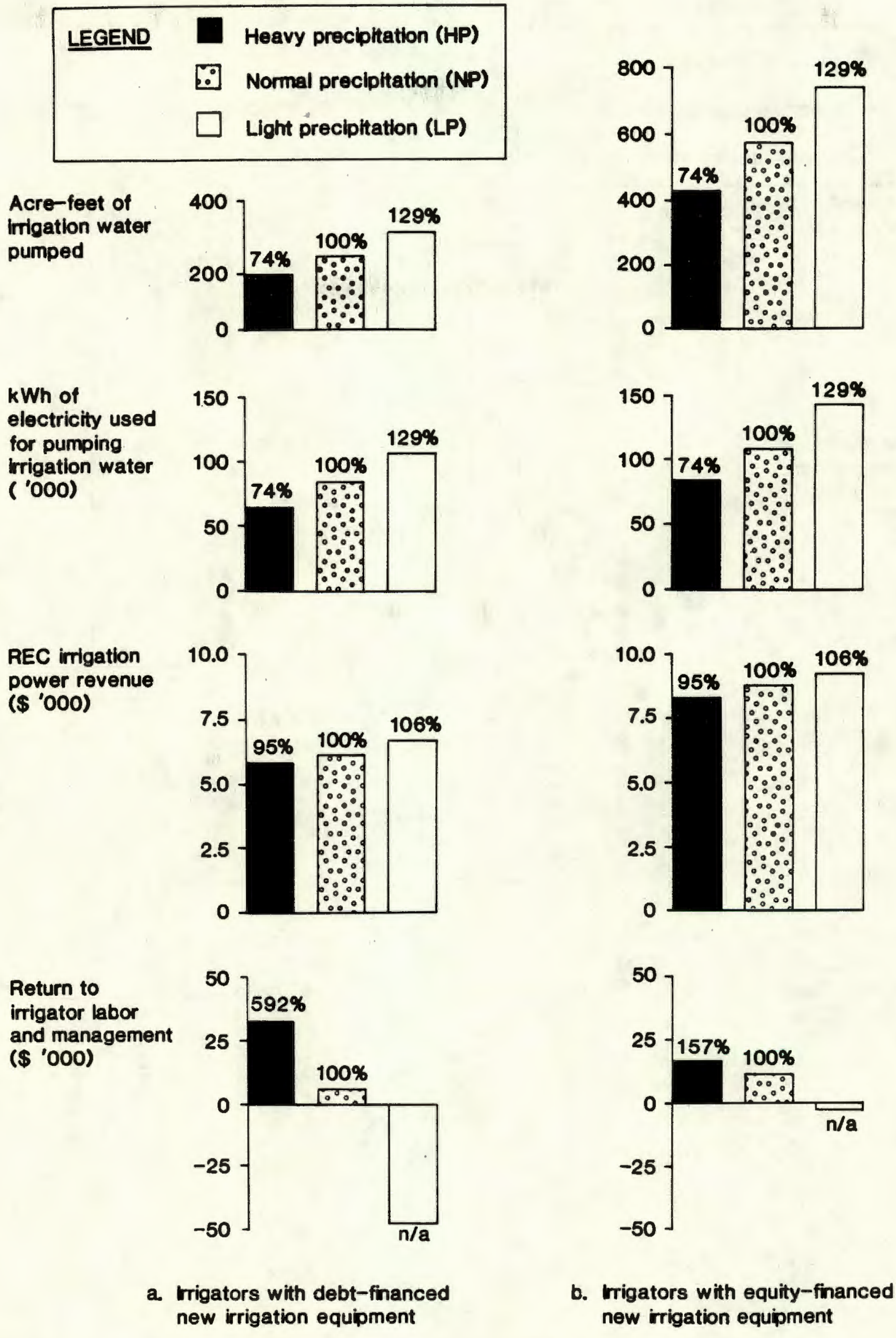



Figure 1. Impacts of unusual precipitation, Clay-Union REC representative farm 1985 baseline solutions, irrigators with debt- versus equity-financed new irrigation equipment.

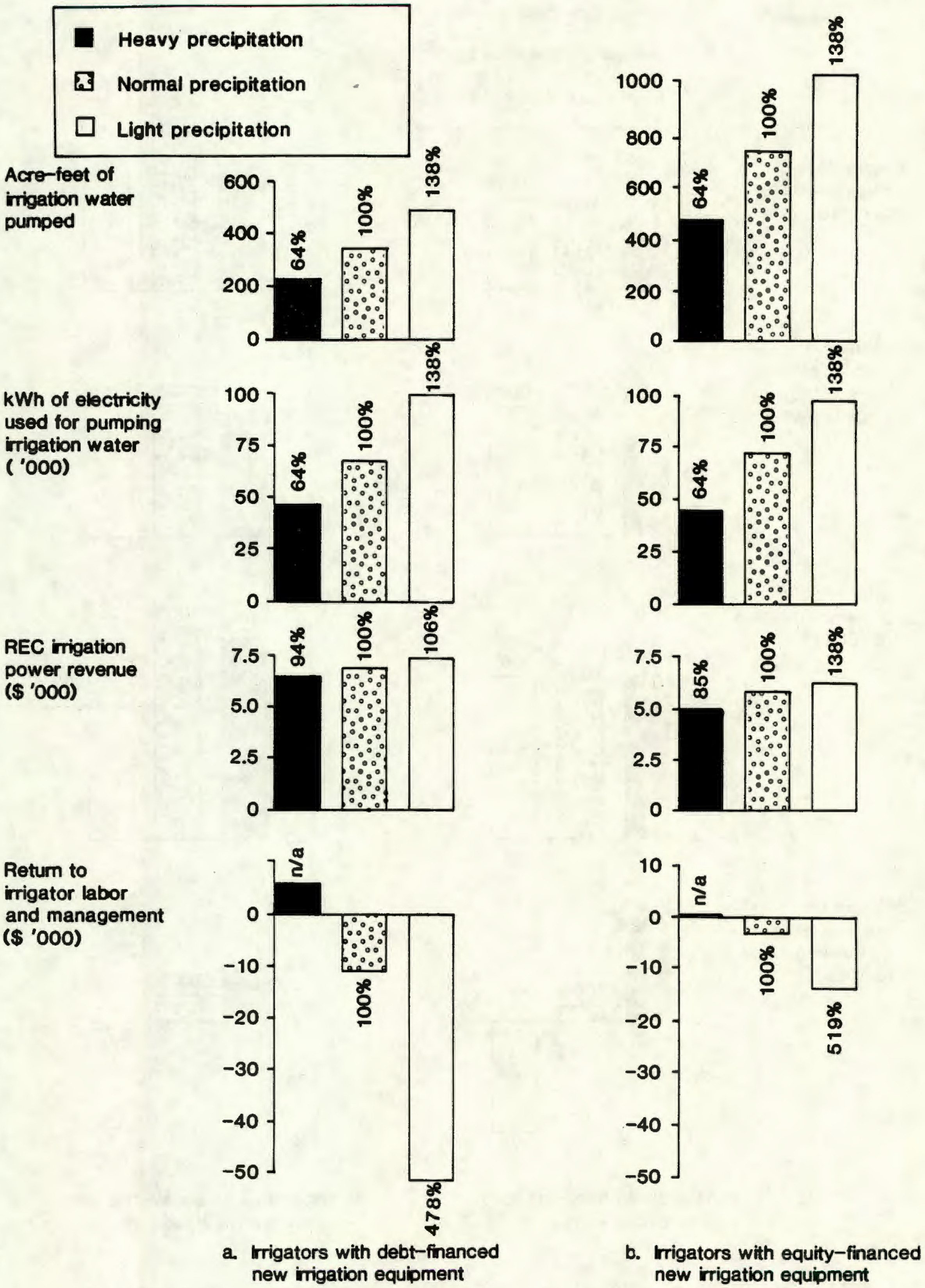



Figure 2. Impacts of unusual precipitation, Union REC representative farm 1985 baseline solutions, irrigators with debt- versus equity-financed new irrigation equipment.

light precipitation.[9]

Irrigators with equity-financed new irrigation equipment pump from 2.0 (Union) to 2.5 (Clay-Union) times as much irrigation water as those with debt-financed equipment. They also experience a much less unstable return to their labor and management when unusual precipitation is experienced. This outcome reflects the much larger acreages of dryland crops in the baseline solutions for irrigators who finance the purchase of new irrigation equipment with debt-capital.

The power usage and REC revenues for irrigators with debt- versus equity-financed irrigation equipment differ between the two REC farms. The Clay-Union REC equity-financing irrigator uses one-third more electric power for pumping irrigation water than his(her) debt-financing counterpart. The analagous difference for the Union REC farm is 3% less. The Clay-Union REC receives about 40% greater electric power revenues from equity-financing than debt-financing irrigators, whereas the Union REC receives 17% to 30% lower revenues from its equity-financing irrigators.

As noted above, the impacts of unusual precipitation on irrigator profits are very substantial. These impacts originate from four sources, as indicated in Tables 3 and 4 for the Clay-Union and Union REC representative farms, respectively. The main finding from this analysis is that the change in electric power payments for irrigation associated with unusual precipitation is relatively small. By far the dominant influence on irrigator profits is that which arises from the impact of unusual precipitation on changes in dryland crop yields.[10] For example, the changes in dryland crop production values for the Clay-Union REC farm are roughly 10 to 160 times as great as the changes in the electric power payments for irrigation. For the Union REC farm, the corresponding "crop production-electric power" cost-multiple is 6 to 100 times.

The ranges in irrigator profits associated with unusually heavy versus unusually light precipitation are much greater for irrigators with debt-financed (Clay-Union $80,550; Union $57,295) than equity-financed (Clay-Union $18,195; Union $12,985) new irrigation equipment. This outcome arises because of fewer dryland crop acres in the equity-financing optimal solutions, and the greater economic volatility generally associated with greater leveraging.

These findings expectedly show the short-term impacts of unusual precipitation on RECs to be the opposite of those on irrigators. If the negative impacts on irrigators from drought are great enough to force irriga-

---

[9]In terms of a "textbook" soil moisture-yield production function, this involves movement from the "normal" soil moisture-yield point along the production function (1) with heavy precipitation toward the function's maximum versus (2) with light precipitation toward the function's inflection point. The slope of the production function toward its maximum is, of course, shallower than toward its inflection point.

[10]Since crop irrigation requirements were adjusted in accordance with the amounts of unusually heavy and light precipitation, irrigated crop yields were assumed to be constant across the three precipitation levels considered in the study.

Table 3. Sources of impact of unusual precipitation on irrigator profits, Clay-Union REC representative farm 1985 baseline solutions, irrigators with debt- versus equity-financed new irrigation equipment.

| Source of change in profits | Change in return to irrigator labor and management associated with unusually heavy precipitation: Dollars | Change in return to irrigator labor and management associated with unusually heavy precipitation: Ratio to electric power payment change[a] | Change in return to irrigator labor and management associated with unusually light precipitation: Dollars | Change in return to irrigator labor and management associated with unusually light precipitation: Ratio to electric power payment change[a] |
|---|---|---|---|---|
| Irrigators with debt-financed new irrigation equipment | | | | |
| Dryland crop production value | +29,373 | 89.0 | -60,848 | 161.4 |
| Irrigation system repair and maintenance | + 459 | 1.4 | - 524 | 1.4 |
| Electric power payment for irrigation | + 330 | 1.0 | - 377 | 1.0 |
| Grain storage and drying | - 3,762 | n/a | + 7,597 | n/a |
| Total | +26,400 | 80.0 | -54,152 | 143.6 |
| Irrigators with equity-financed new irrigation equipment | | | | |
| Dryland crop production value | + 4,693 | 10.6 | -11,142 | 22.1 |
| Irrigation system repair and maintenance | + 1,125 | 2.6 | - 1,286 | 2.6 |
| Electric power payment for irrigation | + 441 | 1.0 | - 504 | 1.0 |
| Grain storage and drying | - 292 | n/a | + 702 | n/a |
| Total | + 5,967 | 13.5 | -12,230 | 24.3 |

[a] These are the ratios of the changes in profits for the respective sources of profit change to the change in the electric power payment for irrigation, e.g., 29,373 ÷ 330 = 89.0 (see the encircled data in the table).

Table 4. Sources of impact of unusual precipitation on irrigator profits, Union REC representative farm 1985 baseline solutions, irrigators with debt- versus equity-financed new irrigation equipment.

| | Change in return to irrigator labor and management associated with unusually heavy precipitation | | Change in return to irrigator labor and management associated with unusually light precipitation | |
|---|---|---|---|---|
| Source of change in profits | Dollars | Ratio to electric power payment change[a] | Dollars | Ratio to electric Power payment change[a] |
| Irrigators with debt-financed new irrigation equipment | | | | |
| Dryland crop production value | +18,140 | 43.8 | -45,014 | 104.2 |
| Irrigation system repair and maintenance | + 604 | 1.5 | - 625 | 1.4 |
| Electric power payment for irrigation | + 414 | 1.0 | - 432 | 1.0 |
| Grain storage and drying | - 2,355 | n/a | + 5,581 | n/a |
| Total | +16,803 | 40.6 | -40,490 | 93.7 |
| Irrigators with equity-financed new irrigation equipment | | | | |
| Dryland crop production value | + 2,467 | 6.2 | - 8,635 | 20.4 |
| Irrigation system repair and maintenance | + 851 | 2.1 | - 879 | 2.1 |
| Electric power payment for irrigation | + 399 | 1.0 | - 423 | 1.0 |
| Grain storage and drying | - 149 | n/a | + 521 | n/a |
| Total | + 3,568 | 8.9 | - 9,416 | 22.3 |

[a]These are the ratios of the changes in profits for the respective profit-sources to the change in the electric power payment for irrigation, e.g., 18,140 ÷ 414 = 43.8 (see the encircled data in the table).

tors out of business, however, both the irrigators and their "parent" RECs stand to lose. Thus, a rate structure that provides for the sharing of risks between RECs and irrigators under circumstances of unusual precipitation can be expected to be in the best long-term economic interests of both irrigators and RECs.

Two features of the current Clay-Union and Union REC electric rate structures for irrigation provide for the sharing of risks between irrigators and RECs during seasons of unusual precipitation. The spreading of the "fixed" up-front costs over fewer kWhs results in higher average costs per kWh in years of unusually heavy precipitation (and hence limited irrigation pumping). The two-stepped declining energy (kWh) block rate also results in higher average variable energy (kWh) costs with heavy precipitation. Conversely, when precipitation during an irrigation season is unusually light, both features contribute to a below normal overall average cost per kWh for the electric power used by an irrigator.

## THE ESTIMATED DEMANDS FOR ELECTRIC POWER AND WATER FOR IRRIGATION

In this section, the impacts of different prices per kWh of electricity on (1) the quantities of electricity used to pump irrigation water and (2) the quantities of irrigation water pumped are presented. For each representative farm situation examined, a series of optimal solutions was determined. The basic reference point for pricing electricity in the models is the 1985 electric rate structure for each REC. To simplify the interpretation of the results of analysis, however, a single- rather than double-step kWh energy charge is used.

In each of the 10 situations examined for each REC farm, starting with a price of 1 cent per kWh, the price of electricity was raised successively by 1 cent per kWh increments--with all other prices and technological coefficients held the same--until the use of electric power to pump irrigation water became uneconomic. Changes in production enterprises, irrigation technologies, quantities of electric power used for pumping irrigation water, and quantities of irrigation water pumped-- as the kWh energy charge is raised--were determined.

Figures 3 and 4 reflect the price of electricity-quantity of electric power results and Figures 5 and 6 reflect the price of electricity-quantity of pumped irrigation water results.[11] In economic terms, the first series of functional relationships is termed the estimated "direct price demand functions for electricity" and the second is termed the estimated "cross price demand functions for irrigation water".

These demand functions are stepped, as is characteristic of any derived demand function estimated with a linear programming model. The dotted portions in the functions represent non-empirically estimated segments between the respective pairs of one cent energy charges for which the empirical estimations were made.

Because the kilowatt hour prices are specified in the model runs in integer values and the irrigation crop production activities are specified in the models in 130 acre (for center pivot systems) or 160 acre (for gated pipe systems) units, many of the steps and vertical segments in the estimated demand functions for the individual irrigated farms are rather long. The steps involve changes in the numbers of irrigation systems, the types of irrigation technologies (namely, high or low pressure center pivot or gated pipe water distribution), and the crops irrigated in the most profitable rep-

[11] The figures are presented later in the report--immediately after the points in the text at which the empirical findings portrayed in them are first discussed.

resentative farm solutions with different kWh energy costs.[12]

The real-world aggregate demand functions for all irrigators served by any one REC are much smoother (i.e., more continuous) than the functions reported in Figures 3-6. They are smoother because the economic behavior of every irrigator is not identical and because some irrigators have non-130 acre center pivot fields and non-160 acre gated pipe fields. Nevertheless, it is common practice in applied economic analysis to assume that the general shape of demand functions estimated from the analysis of "typical" individual farms is a reasonable proxy for the general shape of the aggregate demand functions for the real-world situation being examined.

A total of 10 derived demand functions was estimated for each REC representative farm. Ten functions, rather than one, were estimated so as to reflect a variety of different circumstances that either apply in fact or could conceivably apply to different irrigators served by the RECs at one or more points in time. These different circumstances are now briefly noted, along with the pairs of analagous panels in the figures that are compared in drawing conclusions concerning the respective sets of circumstances:

i. Irrigators with **debt- versus equity-financed new irrigation equipment:** Panels "a" versus "b", Panels "c" versus "d", Panels "e" versus "f", and Panels "g" versus "h";

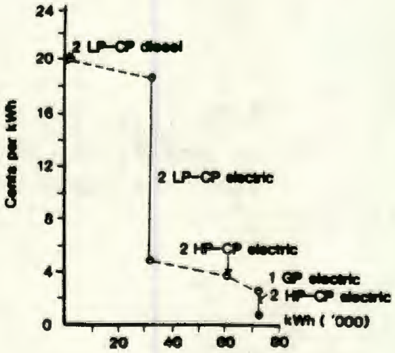
ii. **1985 versus 1980 commodity prices,** to reflect the impact of different levels of commodity prices on the demands for electric power and irrigation water [the 1980 prices which are 7% to 38% higher than the 1985 prices reflect more closely than the 1985 cash market prices (otherwise assumed in the study) the level of prices effectively received by participants in the 1985 government grain commodity program]: Panels "a" versus "c", Panels "b" versus "d", Panels "e" versus "g", Panels "f" versus "h", and Panels "i" versus "j";

iii. **With versus without monthly demand charges,** to reflect the demands for electric power and irrigation water represented by irrigators who do not follow the load management control program versus those who follow the program in all five months of the irrigation season (and therefore do not pay the monthly demand charges in any of the five months): Panels "a" versus "e", Panels "b" versus "f", Panels "c" versus "g", and Panels "d" versus "h"; and

iv. **With versus without annual minimum and monthly demand charges,** to reflect the impact of a possible structural change in the electric rate structure in which the "fixed" up-front charges would be eliminated and electricity payments would be exclusively via an energy (kWh) charge: Panels "a" versus "i" and Panels "c" versus "j".

---

[12] To illustrate, see Panel "a" from Figure 4 which is reproduced to the right. The number and nature (GP = gated pipe, CP = center pivot, HP = high pressure, and LP = low pressure) of irrigation systems (all involving irrigated corn production) are shown for the optimal solutions associated with each vertical segment (single point) in the derived demand function.



In this section, an overview of the results for the 20 estimated demand functions is first provided. Contrasts in the results between the Clay-Union and Union REC representative farms are then presented, followed by the contrasts represented in each of the above four circumstances.

**Estimated direct price demand functions for electricity to pump irrigation water**

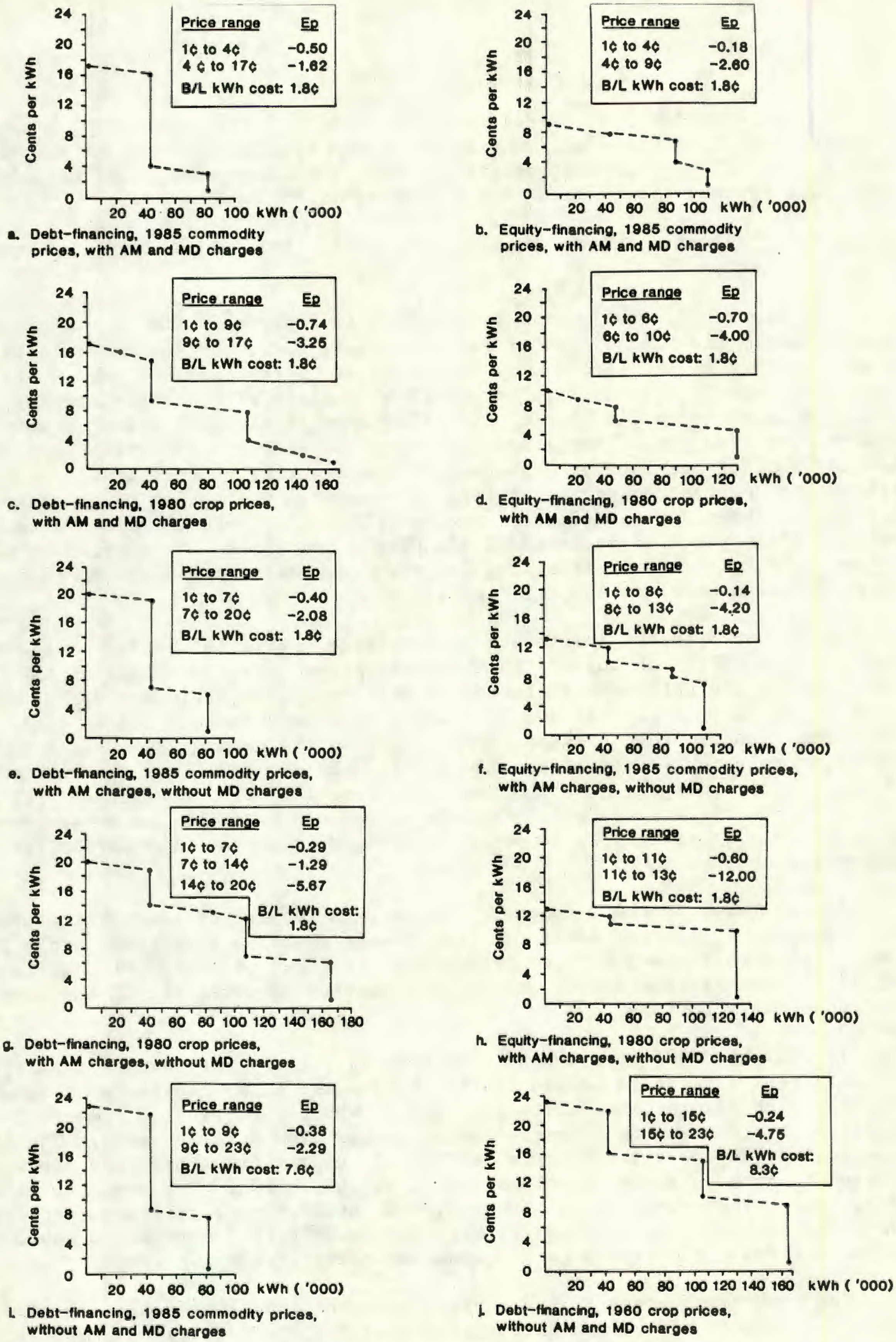
In describing the demand functions in Figures 3 and 4, attention is given to (1) the "endpoints" of the functions, i.e., the amounts of electric power used when (a) electricity is priced at 1 cent per kWh versus (b) the price of electricity is high enough that pumping with water electric power just becomes uneconomic and (2) the direct price elasticities of demand for electricity to pump irrigation water. The direct price elasticities of demand reflect percentage changes in the quantity of electricity used as ratios to corresponding percentage changes in the price of electricity. Because of the discrete nature of the functions, "arc elasticities" were calculated over specified segments of the demand functions. The pertinent price ranges and estimated elasticities for each demand function are shown in the inset for each panel in the two figures.

Also noted in the insets are the average "variable" energy charges per kWh (termed "B/L kWh costs") in the respective baseline solutions that are analagous to the kWh costs reflected in the respective estimated demand functions. In the panels ("i" and "j") which involve "without" annual minimum (AM) and monthly demand (MD) charges, the AM and MD charges in the baseline solutions are allocated across kWhs--in addition to the nominal energy (kWh) charges. By noting the "location" of the average "B/L kWh costs" on the respective demand functions, one can envision the expected type of response by irrigators to possible changes from the 1985 levels for the kWh energy charge.

**An overview of the findings.** The maximum amounts of electricity used for pumping irrigation water (at the lowest electricity prices) range from about 60,000 to 170,000 kWh per irrigator. In eight of the 20 situations examined, these maximum amounts exceed the amounts of power use in the respective baseline solutions.

In the 16 model-runs intended to roughly portray the various conditions of different irrigators served in 1985 by the two RECs (Panels "a" through "h" in each figure), the price per kWh at which electrically powered irrigation systems are no longer economic ranges from 9 to 36 cents. The 1985 baseline average variable costs per kWh of electricity (over and above the "fixed" up-front charges) are less than 2 cents per kWh. The results, therefore, show that--with diesel power priced at $0.97 per gallon--electricity costs would have to rise considerably before "typical" irrigators would totally stop using electric power to energize their irrigation systems.

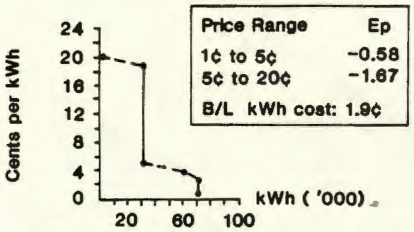
The numbers of steps in the estimated demand functions range from two to six. The direct price elasticities of demand for electricity to pump irrigation water for various segments of the estimated demand functions range from being very inelastic (considerably less than -1.00) at "low" electricity prices to being very elastic (between -1.62 and -12.00) at "high" electricity prices. These elasticity differences have important implications in the



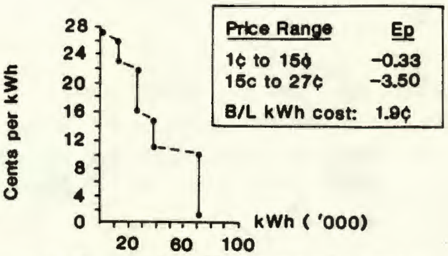

Notes: 1. In the above panel titles, (a) AM = annual minimum and MD = monthly demand at the 1985 baseline rates and (b) "debt-financing" and "equity-financing" mean irrigators who finance new irrigation equipment with debt- and equity-capital, respectively.

2. The "price range" and "$E_p$" inserts show the "direct price elasticities of demand for electricity to pump irrigation water" ($E_p$) for various kWh energy charges (¢ per kWh). The "B/L kWh cost" is the average variable energy charge per kWh in the respective baseline solutions that is analagous to the kWh cost reflected in the respective estimated demand functions.

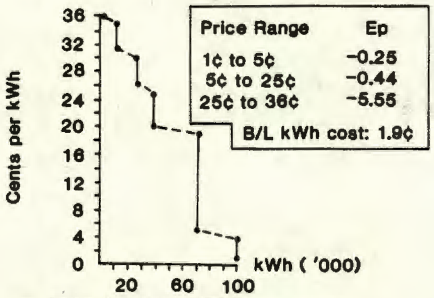
Figure 3. Estimated direct price demand functions for electricity to pump irrigation water, Clay-Union REC representative farm.



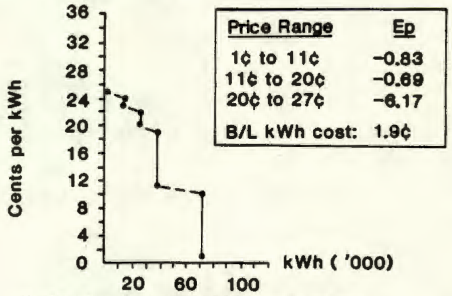

a. Debt-financing, 1985 commodity prices, with AM and MD charges



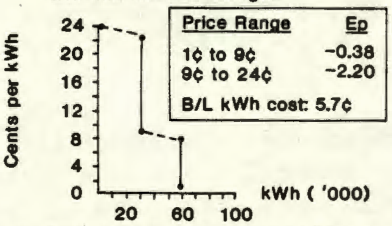

b. Equity-financing, 1985 commodity prices, with AM and MD charges



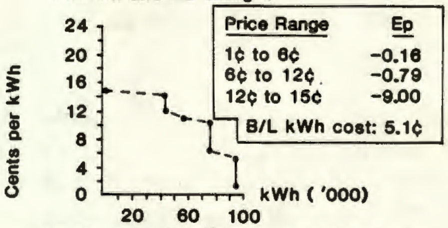

c. Debt-financing, 1980 crop prices, with AM and MD charges



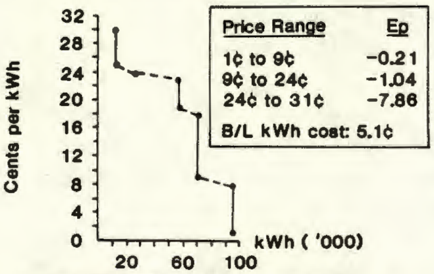

d. Equity-financing, 1980 crop prices, with AM and MD charges



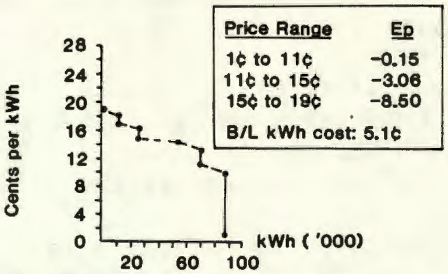

e. Debt-financing, 1985 commodity prices, with AM charges, without MD charges



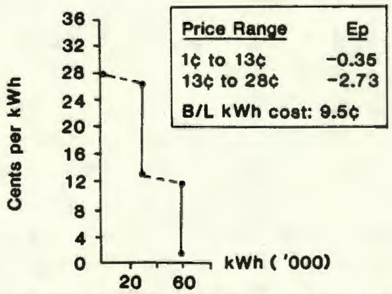

f. Equity-financing, 1985 commodity prices, with AM charges, without MD charges



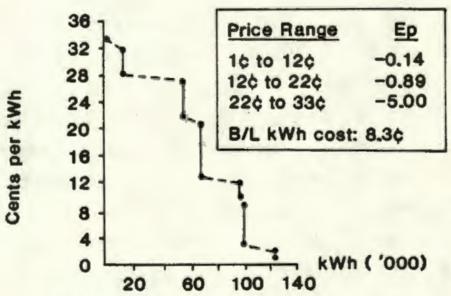

g. Debt-financing, 1980 crop prices, with AM charges, without MD charges




h. Equity-financing, 1980 crop prices, with AM charges, without MD charges




i. Debt-financing, 1985 commodity prices, without AM and MD charges




j. Debt-financing, 1980 crop prices, without AM and MD charges

Notes: 1. In the above panel titles, (a) AM = annual minimum and MD = monthly demand at the 1985 baseline rates and (b) "debt-financing" and "equity-financing" mean irrigators who finance new irrigation equipment with debt- and equity-capital, respectively.

2. The "price range" and "$E_p$" inserts show the "direct price elasticities of demand for electricity to pump irrigation water" ($E_p$) for various kWh energy charges (¢ per kWh). The "B/L kWh cost" is the average variable energy charge per kWh in the respective baseline solutions that is analagous to the kWh cost reflected in the respective estimated demand functions.

Figure 4. Estimated direct price demand functions for electricity to pump irrigation water, Union REC representative farm.

consideration of electric rate policies by RECs. If electric rates are increased over price ranges involving inelastic demand, total electric power revenues can be expected to increase. Conversely, if electric rates are increased over price ranges involving elastic demand, total electric power revenues can be expected to decline.

The 1985 baseline average variable energy charges per kWh of electricity rest within the most inelastic segments of each of the 20 estimated demand functions.[13] The results of this analysis show that with an increase from the 1985 rates of as little as 1 to 3 cents per kWh, however, irrigators in a majority of the situations examined would have economic incentive to cut back on the level of electricity that they use in pumping irrigation water.

**Union versus Clay-Union RECs.** For all ten comparisons, the quantity of electric power used for pumping irrigation water at the lowest electricity prices is greater with the Clay-Union than the Union REC representative farm. The quantity differential ranges from roughly 10,000 kWh to nearly 70,000 kWh per irrigator. Key explanations are the (1) lighter soils and hence 35% to 40% greater crop irrigation requirement and (2) the infeasibility of gated pipe irrigation in the Clay-Union REC study area.

The price at which the use of electricity to energize irrigation pumps becomes uneconomic, on the other hand, is always lower for the Clay-Union REC farm. The "maximum price" differential between the two RECs ranges from 2 to 19 cents per kWh. This outcome arises because the less energy-intensive gated pipe systems in the Union (but not Clay-Union) REC service area are less vulnerable to higher electricity prices than are the pressurized center pivot sprinkler systems in the Clay-Union REC service area.

The direct price elasticities of demand for electricity to pump irrigation water are generally somewhat higher for Union REC irrigators than for Clay-Union REC irrigators. A main underlying reason is the existence of the added gated pipe option in the Union REC service area.

**Irrigators who use debt- versus equity-capital to finance new irrigation equipment.** At "low" electricity prices, there is no simple pattern of irrigators with debt-financed new irrigation equipment using either more or less electricity than their equity-financing counterparts. At "high" electricity prices for seven of the eight paired comparisons, however, the price at which the use of electricity to energize irrigation pumps becomes no longer economic is higher (ranging from 7 cents to 12 cents higher) for the debt- than equity-financing irrigators. On the surface, this outcome might seem surprising. However, the lower annualized costs associated with equity-financed new irrigation equipment apply to the diesel options as well as to the electric options. Since the investment requirements for the diesel options exceed those for the electric options, shifting the assumption in analysis from debt- to equity-financing implies some relative cost advantage to the diesel versus electric options.

---

[13]A technical exception is the Union REC farm with equity-financing, 1980 crop prices, and up-front electric charges. The middle segment of its demand function, which covers a price range of 11 to 20 cents per kWh, has a slightly lower elasticity than its "end" segment covering a price range of 1 to 11 cents per kWh.

In the higher electricity price ranges, the direct price elasticity of demand for electricity to pump irrigation water is higher for equity-financing irrigators. With "low" electricity prices, a generally opposite outcome prevails.

**1980 versus 1985 commodity prices.** With the relatively higher 1980 crop prices, eight of the ten demand functions shift to the right as economic theory (with all other conditions the same) would suggest. In four situations, the entire demand function shifts to the right. In four others, the rightward shift is only in the lower kWh price range. In the other two situations, the failure of the "other things the same" assumption of economic theory to hold gives rise to "unexpected" findings. In one instance, the electrically powered irrigation systems drop out at a lower kWh price with the 1980 crop prices than they do with the lower 1985 commodity prices. In the other instance, less electric energy is used in pumping irrigation water in the lower kWh price range with 1980 than 1985 crop prices. The latter outcome arises because of the substitution of the two center pivots of corn with 1985 prices by soybeans with 1980 prices. Soybeans require slightly less irrigation water than corn and hence, also, less electric power for pumping irrigation water. Finally, in nine of the ten paired comparisons, the direct price elasticities of demand for electricity to pump irrigation water in the upper price ranges of the kWh energy charges are considerably higher with 1980 than 1985 commodity prices.

**Paid versus waived monthly demand charges.** In this analysis, the impact on the derived demand for electric power to pump irrigation water of irrigators choosing to follow load management controls during all five months of the irrigation season is examined. With the Clay-Union REC farm, a clear pattern is shown in the findings. For all four paired comparisons and at "low" kWh prices, load management followers use no more electric power than their non-follower counterparts. The kWh price at which electrically energized irrigation systems become uneconomic is 3 to 4 cents higher for the load management followers.

The outcome for the Union REC farm, however, is quite different. In three of the four paired comparisons, electric power usage at "low" electric prices is greater for load management followers than non-followers. Further, in three of the four paired comparisons, electrically energized irrigation systems become uneconomic at lower kWh prices for load management followers than for non-followers.

The direct price elasticities of demand for electricity to pump irrigation water show a definite pattern of being greater at higher kWh prices for load management followers than for non-followers. At "low" electricity prices on the other hand, no clear patterns of difference are shown.

**Zero versus 1985 levels of up-front electric rate charges.** This analysis involves further attention to changes in the form of electric rate charges. The structural change involves eliminating both types of up-front (annual minimum and monthly demand) charges. As a consequence, the total payment for electric power for irrigation is assumed to be assessed through the single-step energy charge.

In three of the four paired comparisons, the electric power demand functions are vertically displaced upward roughly to the extent of the per-kWh cost equivalent of the up-front charges [e.g., in Figure 3, Panels "i" versus "a", by about 5.8 cents (7.6 cents - 1.8 cents)]. These outcomes imply only a limited impact on irrigation use from the structural change in electric power rates. In the fourth situation (Union REC farm, debt-financing, 1980 crop prices), however, the structural change in electric power rates does impact the nature of the demand for power (e.g., with zero up-front charges, electrically powered irrigation systems become non-economic at even lower electric power rates than when the up-front charges are included in the electric rate structure assessed against farmers).

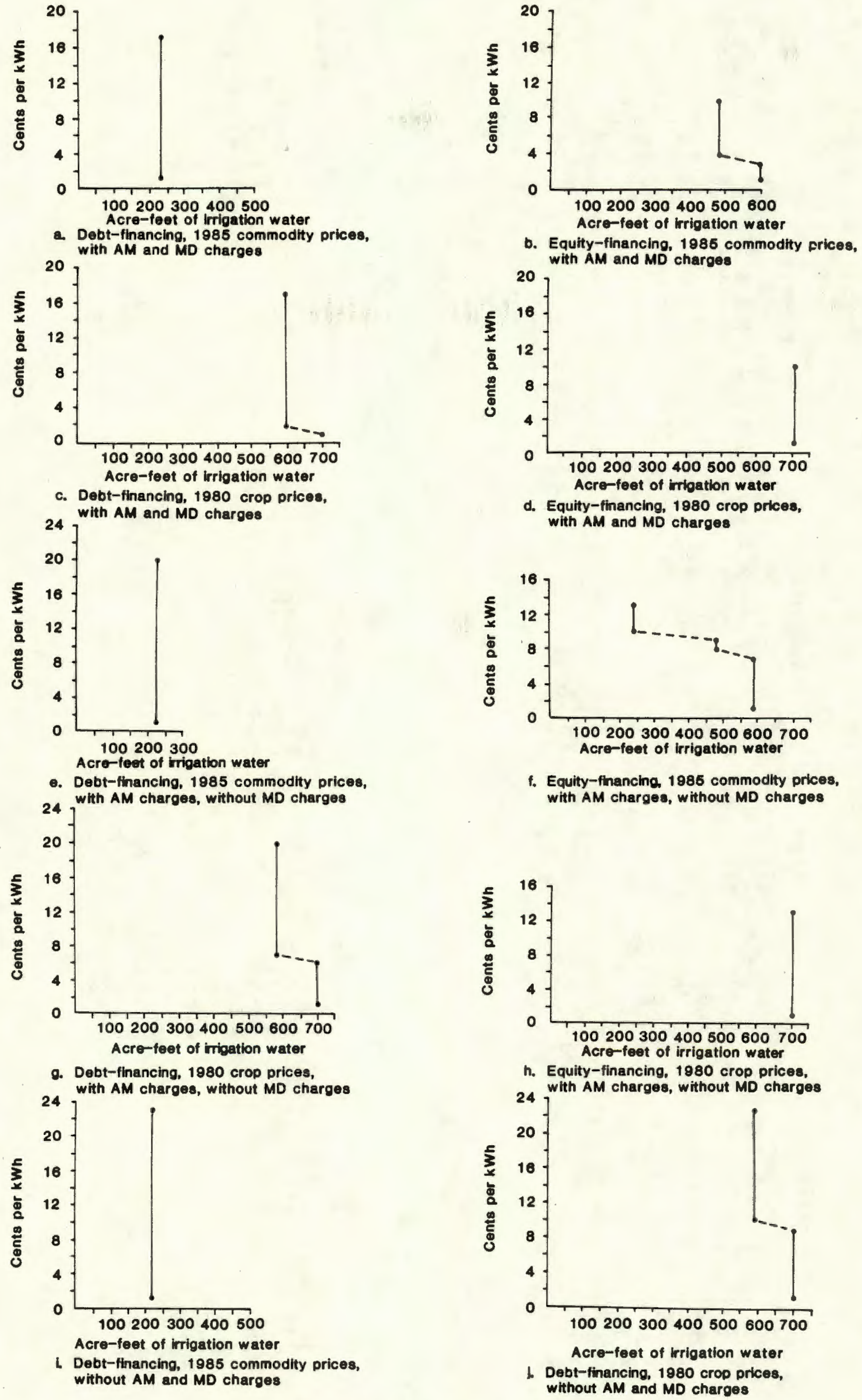
The impacts of eliminating both up-front electric rate charges on the direct price elasticities of demand for electricity to pump irrigation water are generally the same as indicated above with only the monthly demand charge being eliminated. However, the extents of elasticity differential with both up-front charges eliminated are generally less than those when only the monthly demand charge is eliminated. For one of the four paired comparisons involving the elimination of both up-front charges, an opposite outcome prevails.

Based on the findings from these last two sections, two types of overall conclusions can be drawn. Eliminating altogether one or both of the up-front electric rate charges does not lead to one common type of impact on the nature of demand for electricity to pump irrigation water. In some instances, the nature of demand is impacted little. In others, the nature of the derived demand for electric power is impacted, but with no uniform pattern. Second, eliminating altogether one or both of the up-front electric rate charges generally leads irrigators to show a more elastic demand for electricity to pump irrigation water at higher kWh prices.

**Estimated cross price demand functions for irrigation water**

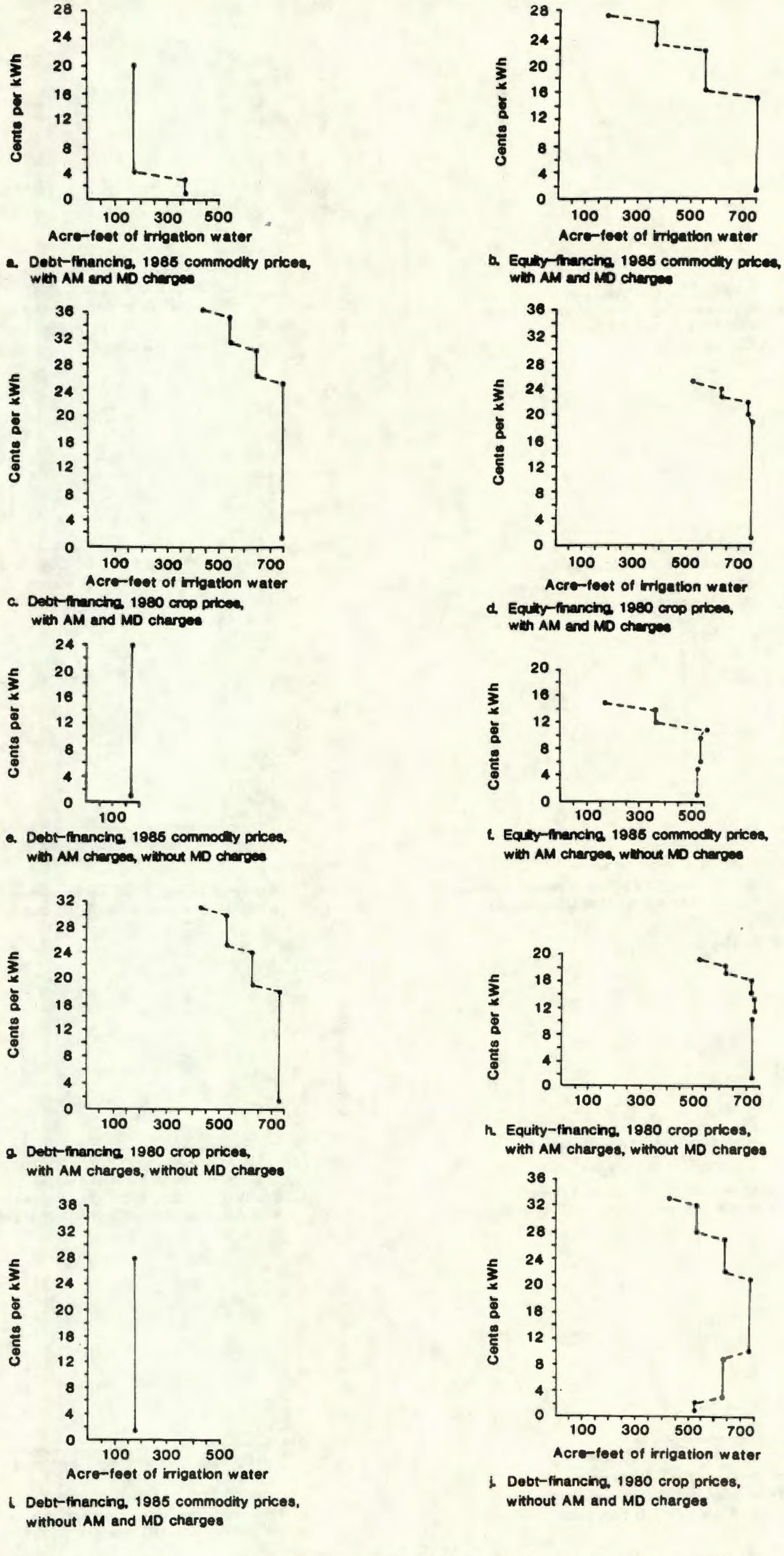
At the lowest electric power rates, the amounts of irrigation water pumped per irrigation season per irrigator range from about 175 acre-feet to 750 acre-feet (Figures 5 and 6). At electricity prices at which electrically powered irrigation systems are no longer economic, irrigation water--ranging from about 175 acre-feet to 700 acre-feet per irrigator--continues to be pumped.

This outcome arises because, as electric power rates increase, diesel powered irrigation systems tend to replace the electric powered systems. In 7 of the 20 situations examined, the substitution of diesel for electric power is complete, i.e., the estimated cross demand functions for irrigation water are perfectly inelastic--showing that whenever an electrically powered system drops out it is replaced by a diesel powered system. As electric power rates rise in the other 13 situations, the scale of irrigation drops off some, with diesel systems replacing only part of the electric systems that had been economic at lower electric power rates (and, in some instances, with diesel sprinkler systems replacing gated pipe systems for which water is lifted by electrically energized pumps).




Note: In the above panel titles, (a) AM = annual minimum and MD = monthly demand and (b) "debt-financing" and "equity-financing" mean irrigators who finance new irrigation equipment with debt- and equity-capital, respectively.

Figure 5. Estimated cross price demand functions for irrigation water, Clay-Union REC representative farm.




a. Debt-financing, 1985 commodity prices, with AM and MD charges

b. Equity-financing, 1985 commodity prices, with AM and MD charges

c. Debt-financing, 1980 crop prices, with AM and MD charges

d. Equity-financing, 1980 crop prices, with AM and MD charges

e. Debt-financing, 1985 commodity prices, with AM charges, without MD charges

f. Equity-financing, 1985 commodity prices, with AM charges, without MD charges

g. Debt-financing, 1980 crop prices, with AM charges, without MD charges

h. Equity-financing, 1980 crop prices, with AM charges, without MD charges

i. Debt-financing, 1985 commodity prices, without AM and MD charges

j. Debt-financing, 1980 crop prices, without AM and MD charges

Note: In the above panel titles, (a) AM = annual minimum and MD = monthly demand and (b) "debt-financing" mean irrigators who finance new irrigation equipment with debt- and equity-capital, respectively.

Figure 6. Estimated cross price demand functions for irrigation water, Union REC representative farm.

Three of the 10 cross demand functions for irrigation water for the Union REC farm have "atypical" backward bending (upward sloping) segments. This outcome arises from increased kWh prices at the low end of the kWh price spectrum that result in water-intensive gated pipe systems replacing center pivot systems, with a result that the amounts of irrigation water pumped increase. Then, at higher kWh prices, center pivot diesel systems replace the gated pipe systems and hence the amounts of irrigation water pumped decrease.

The responsiveness of irrigation water pumping to rising electric power rates is generally much greater for the Union REC representative farm than for the Clay-Union REC farm. This outcome arises because of the added gated pipe surface irrigation option on the Union REC farm.

For six of eight paired comparisons, the cross demand functions for irrigation water are shifted farther to the right for equity- than debt-financing irrigators. In five of the eight situations, the demand functions for equity-financing irrigators have more steps than do those for debt-financing irrigators. Further, for nine of the ten comparable situations, the cross demand functions for irrigation water are shifted farther to the right for irrigators with 1980 crop prices than with the lower 1985 commodity prices.

## RATE STRUCTURE ANALYSIS

In the prior demand analysis, greater attention is given to changes in the level of charge than to the form of charge for electricity. In this section, relatively more explicit attention is given to the form of electric rate charge. The impacts on irrigators and the RECs of different levels of up-front (annual minimum and monthly demand) and energy (kWh) charges, differently configured energy (kWh) block rates, and load management controls are each examined in turn.

### Different levels of "fixed" up-front and variable energy electric rate charges

Rural electric cooperatives are faced with high fixed costs that derive directly from their substantial investments in electric power transmission and physical plant facilities and indirectly via the cost structure for the wholesale power which they purchase that embodies the high fixed cost of coal-based electric generation facilities. The appendix to this report shows, for example, that 38% of the Clay-Union REC's operating costs for irrigation are plant-related "facilities" charges, 46% are demand charges, and only 15% are variable energy (kWh) charges. In this study's Clay-Union and Union REC representative farm baseline solutions, the "fixed" up-front electric charges account for between 75% and 80% of the irrigators' total electric power payments for irrigation (Table 5).[14]

In years of unusually great precipitation and/or widespread participation of irrigators in acreage set-aside government commodity programs, irrigation pumping may drop off greatly. To guard against electric power revenue shortfalls in such circumstances, most RECs adopt electric pricing policies that result in the passing on of their "fixed" costs to their customers in the form of "fixed" up-front electric rate charges.

Some irrigators object to having to make large "fixed" up-front payments for their electrically powered irrigation systems. They would prefer that a larger proportion of their irrigation electric power payments be in the form of energy (kWh) charges. They place particular value on being able to exercise direct control over the amount of their irrigation electric power bills--through determining when and for how long during the irrigation season charges should be assessed against their irrigation systems. Further, some irrigators believe that many of the REC fixed cost facilities are already paid off and, therefore, that they should not have to continue to bear large up-front electricity payments.[15]

The cost of service investment analysis outlined in the appendix shows (1) the relatively large proportions of REC operating costs that are "fixed" and (2) the extended numbers of years over which capital assets are depreciated. Once those depreciation periods are exhausted, the capital assets usually have to be replaced, which sets in motion new series of even higher dollar rates of depreciation (because of inflation) for the RECs.

Although large proportions of REC operating costs are "fixed", the "fixed" costs do not generally diminish over time, and irrigators served by the Clay-Union and Union RECs are reported to be generally accepting of the current structure of charges for irrigation pumping power, the impacts of pricing electricity through varying proportions of "fixed" up-front and variable energy (kWh) charges are examined. The rationale for undertaking this analysis is partly scientific curiosity and partly to generate information that could be used in responding to the concerns of irrigators who would strongly prefer to pay for electric power via rate structures with a higher proportion of variable to fixed charges.

---

[14]The annual minimum charge for an irrigation system is "fixed" in that an irrigator must pay it regardless of whether or not he operates the system. After the expiration of the initial contract period between an irrigator and an REC, however, irrigation systems can be "pulled out" without the irrigator having a continuing obligation to meet the annual minimum payment on the system.

The monthly demand charge is "fixed" in a different regard. This charge can be avoided totally if an irrigation system is not activated during a monthly billing period. But an irrigator must pay it in full if the irrigation system is used for even "one moment" during the monthly billing period.

[15]The periods specified in contracts between irrigators and RECs are generally much shorter than the average length of time over which an REC's various capital assets are depreciated.

Table 5. "Fixed" up-front versus variable energy charges, Clay-Union and Union REC representative farm baseline solutions, irrigators with debt- versus equity-financed new irrigation equipment, 1985 and 1980 crop prices.

| | Clay-Union REC | | | | Union REC | | | |
|---|---|---|---|---|---|---|---|---|
| | Debt-financing | | Equity-financing | | Debt-financing | | Equity-financing | |
| | Dollars | Percent | Dollars | Percent | Dollars | Percent | Dollars | Percent |
| Solutions with 1985 commodity prices | | | | | | | | |
| Annual minimum charges | 2,355 | 37.7 | 3,175 | 36.4 | 2,749 | 40.0 | 2,263 | 38.9 |
| Monthly demand charges | 2,381 | 38.2 | 3,531 | 40.5 | 2,734 | 39.8 | 2,250 | 38.7 |
| Sub-total of up-front charges | (4,736) | (75.9) | (6,706) | (76.9) | (5,483) | (79.8) | (4,513) | (77.6) |
| Energy charges | 1,507 | 24.1 | 2,016 | 23.1 | 1,391 | 20.2 | 1,307 | 22.4 |
| Total electric power charges | 6,243 | 100.0 | 8,722 | 100.0 | 6,874 | 100.0 | 5,820 | 100.0 |
| Solutions with 1980 crop prices | | | | | | | | |
| Annual minimum charges | 4,259 | 34.8 | 3,810 | 32.7 | 2,263 | 38.8 | 2,263 | 38.9 |
| Monthly demand charges | 5,269 | 43.1 | 5,457 | 46.8 | 2,250 | 38.6 | 2,250 | 38.7 |
| Sub-total of up-front charges | (9,528) | (77.9) | (9,267) | (79.5) | (4,513) | (77.4) | (4,513) | (77.6) |
| Energy charges | 2,704 | 22.1 | 2,396 | 20.5 | 1,314 | 22.6 | 1,307 | 22.4 |
| Total electric power charges | 12,232 | 100.0 | 11,663 | 100.0 | 5,827 | 100.0 | 5,820 | 100.0 |

In exploring this issue, the impacts of both increasing and decreasing one-at-a-time each of the annual minimum, monthly demand, and energy charges are determined. All other prices (including only 1985 commodity prices) and the technological coefficients are held the same in analysis. The "increased" electric rates are set at double their respective 1985 baseline levels. The "decreased" electric rates are set at 25% of their baseline levels (i.e., at 75% less than their respective 1985 baseline levels). Optimal solutions for each of the representative farms are determined with each of these alternate electric rate structures.

The results of this analysis for the Clay-Union and Union REC representative farms are presented in Figures 7 and 8. The histogram-bars that reflect results from the baseline solutions with 1985 electric power rates are described as showing 100%-level outcomes. The three histogram-bars to the left of the center baseline bars reflect outcomes for the respective one-at-a-time doubling in price for the three electric rate components, and the bars to the right of center reflect outcomes for the 75% reduced electric rate charges.

**Acre-inches of irrigation water pumped.** The one-at-a-time increased and decreased up-front and energy charges have essentially no impact on irrigation pumping in three of the four representative farm situations examined. The exceptional situation involves the Union REC debt-financing situation. In this case, a doubling of either the annual minimum or monthly demand charge leads to a 53% reduction in irrigation pumping, whereas a decrease to 25% of the baseline rates for either of these two types of charges leads to a 53% increase in irrigation pumping. These results arise from the elimination of a gated pipe system with the increased up-front charges and the addition of an extra gated pipe system with the decreased up-front charges.

**Electricity for pumping irrigation water.** Patterns of change in irrigation pumping power are only loosely related to changes in irrigation pumping. This outcome arises because (1) the irrigation technology options considered in the model involve various intensities of energy and water use and (2) the optimal solutions reflect a sensitivity to these and other differences in the various options considered.

For the Clay-Union REC farm, the irrigation power pumping requirement is the same for the solutions involving one-at-a-time reduced electric rate charges as for the 1985 baseline solutions. The solutions involving one-at-a-time increased electric rate charges, however, involve 20% (equity-financing of new irrigation equipment) to 46% (debt-financing) less irrigation pumping power being used.

For Union REC farm irrigators with equity-financed new irrigation equipment, increased or reduced up-front and energy charges have essentially no impact on the irrigation power pumping requirement. Union REC farm irrigators with debt-financed irrigation equipment, however, respond differently to one-at-a-time changes in up-front charges. Power usage drops by 56% when either the annual minimum or monthly demand charge is increased (two high pressure center pivots are converted to low pressure and one gated pipe system drops out), and increases by 18% when either of the up-front charges is decreased (an extra gated pipe system is added).

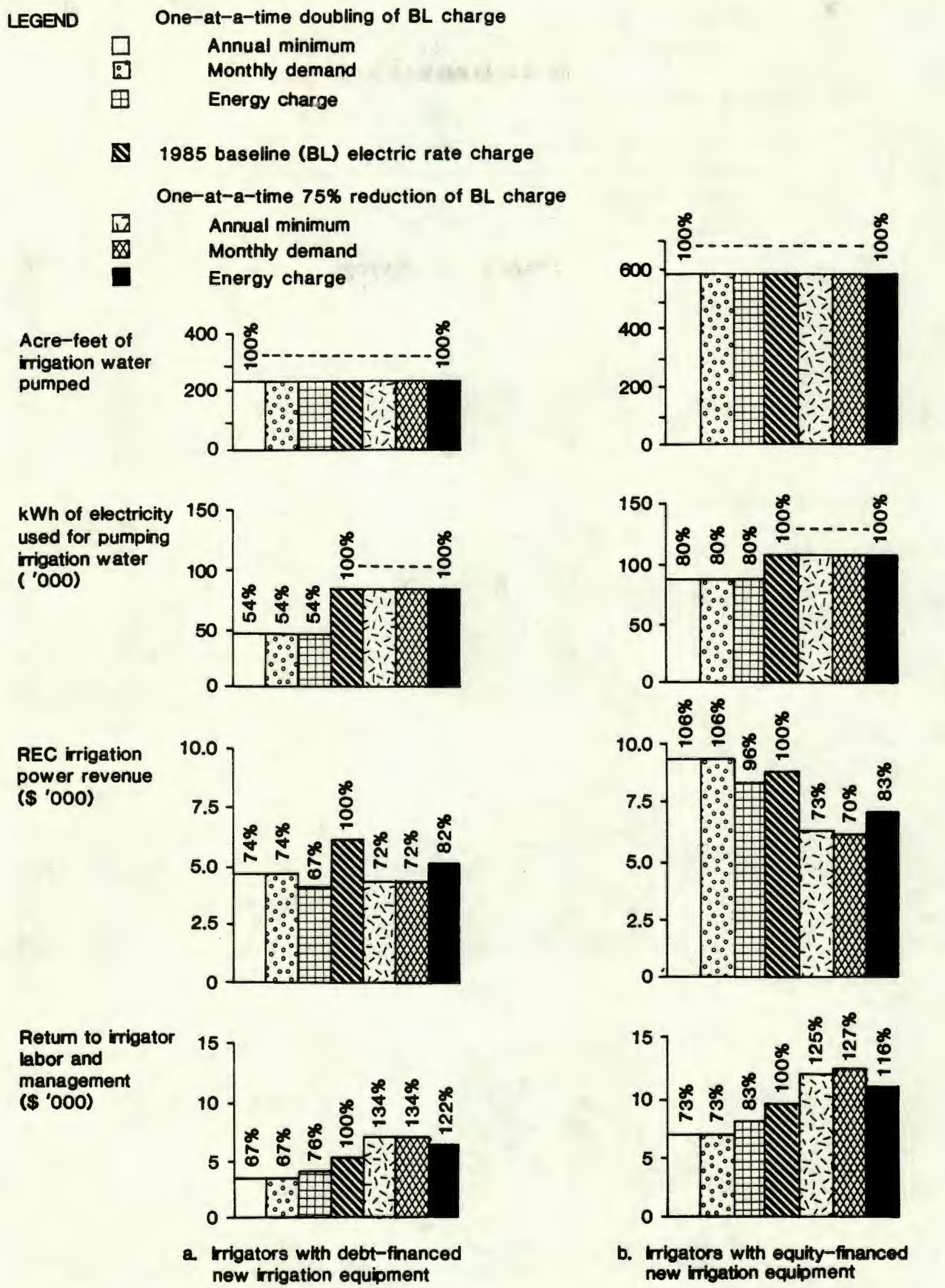



Figure 7. Impacts of one-at-a-time increased and decreased "fixed" up-front (AM = annual minimum and MD = monthly demand) and variable (EC = energy charge) electric rate charges, Clay-Union REC representative farm, irrigators with debt- versus equity-financed new irrigation equipment, 1985 commodity prices.

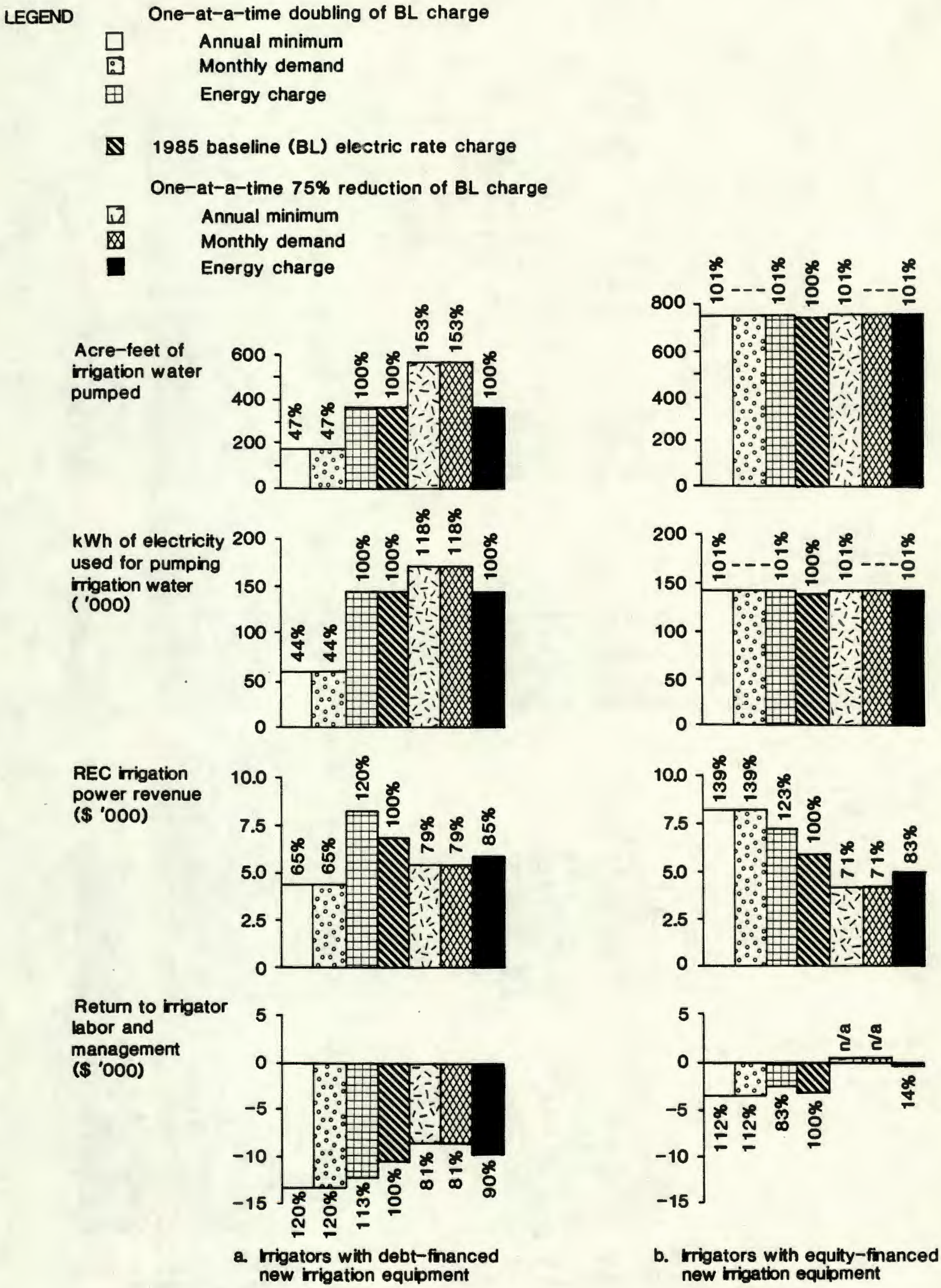



Figure 8. Impacts of one-at-a-time increased and decreased "fixed" up-front (AM = annual minimum and MD = monthly demand) and variable (EC = energy charge) electric rate charges, Union REC representative farm, irrigators with debt- versus equity-financed new irrigation equipment, 1985 commodity prices.

**REC irrigation power revenue.** A one-at-a-time doubling in the individual electric rate charges leads to just as many instances of a decrease, as of an increase, in REC irrigation power revenue. Each instance of a one-at-a-time reduction in the individual electric rate charges, however, involves a reduction in REC irrigation power revenue. The impacts of comparable one-at-a-time changes in electric rate charges in each situation are much more similar between the annual minimum and monthly demand rates than between either up-front charge and the energy charge.

Reducing energy charges to 25% of the baseline rate results in a 15% to 18% reduction in REC irrigation power revenue. Reducing either annual minimum or monthly demand charges to 25% of their respective baseline rates results in a 20% to 30% reduction in REC irrigation power.

**Return to irrigator labor and management.** The pattern of impacts on irrigator profits from one-at-a-time increased and decreased electric power rates is rather clear. In 11 of the 12 situations involving increased electric power rates, profits are impacted negatively. In all 12 situations involving decreased electric power rates, profits are impacted positively. The negative profit impacts range from roughly $375 to $2,650, whereas the positive profit impacts range from roughly $1,800 to $3,550.

The final focus of analysis in this section is on a very practical consideration to REC management. What if an REC were to decrease its annual minimum or monthly demand charges and then unusually heavy precipitation were to be experienced? To what extent would REC revenues become vulnerable from such a policy decision on rates and such a natural circumstance?

To investigate this question, differences in REC revenues (and irrigator profits) in circumstances with normal versus unusually heavy precipitation--under assumed one-at-a-time 75% reductions in annual minimum and monthly demand charges--are examined. The normal precipitation circumstances are those just described in this section. The budgeting of the impacts of unusually heavy precipitation is based on the assumptions and procedures used for examining this phenomenon in the above section entitled "unusually heavy or light versus normal precipitation."

The findings from this analysis for the two REC representative farms are presented in Table 6. Separate attention is given to irrigators with debt- versus equity-financed new irrigation equipment. The main finding from this analysis is the following. If RECs were to reduce by 75% one or the other of their up-front electric rate charges and then their irrigator clients were to experience unusually heavy precipitation, the REC revenues from electric power would be reduced by $330 to $485 per irrigator. These reductions amount to 7% to 10% of the respective REC revenues with normal precipitation.

In response to the unusually heavy precipitation, irrigators with debt-financed new irrigation equipment would realize added profits ranging from nearly $10,000 to over $26,000. The corresponding impacts on profits for irrigators with equity-financed new irrigation equipment are less, but nevertheless substantial (roughly $3,500 to $7,000 per irrigator).

Because RECs are not permitted by federal law to carry forward positive margins from one year to another, even a 7% to 10% unexpected reduction in

Table 6. Selected impacts of unusually heavy precipitation when annual minimum and monthly demand charges are reduced one-at-a-time to 25% of their respective levels in 1985, irrigators with debt-financed versus equity-financed new irrigation equipment, Clay-Union and Union REC representative farms.

| | Clay-Union REC representative farm | | Union REC representative farm | |
|---|---|---|---|---|
| | Annual minimum charge | Monthly demand charge | Annual minimum charge | Monthly demand charge |
| **Irrigators with debt-financed new irrigation equipment** | | | | |
| Impacts on REC revenues | | | | |
| Dollar decrease per irrigator | 330 | 330 | 485 | 485 |
| Dollar decrease as a percent of the revenue with normal precipitation | 7.4 | 7.4 | 8.9 | 8.9 |
| Impacts on irrigator profits | | | | |
| Dollar increase per irrigator | 26,515 | 26,515 | 9,895 | 9,895 |
| Dollar profits per irrigator with normal precipitation | 7,170 | 7,185 | -8,805 | -8,820 |
| **Irrigators with equity-financed new irrigation equipment** | | | | |
| Impacts on REC revenues | | | | |
| Dollar decrease per irrigator | 441 | 441 | 400 | 400 |
| Dollar decrease as a percent of the revenue with normal precipitation | 7.0 | 7.3 | 9.7 | 9.6 |
| Impacts on irrigator profits | | | | |
| Dollar increase per irrigator | 6,895 | 6,895 | 3,570 | 3,570 |
| Dollar profits per irrigator with normal precipitation | 12,065 | 12,335 | 230 | 220 |

REC revenue in a particular year would somehow have to be covered in that same year. The prior analysis shows that if the REC revenue shortfall occurred as a result of unusually heavy precipitation, irrigators with dryland would derive substantial economic benefits from the added precipitation. In principle, an after-season rate adjustment mechanism could be created to transfer enough of that precipitation benefit to the REC to meet its fixed cost obligations--in exchange for a concession by the REC to irrigators for part of the burden of the electric payment for irrigation to be shifted from "fixed" up-front to variable energy (kWh) charges. From three standpoints, however, such a pricing policy would probably be ill-advised.

1. The more complex a rate pricing policy, the greater the difficulties in administering the policy. Administrative encumberances could be expected to arise in (a) ensuring that all irrigators would know about and clearly understand the after-season rate adjustment provision, (b) arriving at a common agreement between individual irrigators and the REC on whether (and, if so, how much) precipitation during the irrigation season is unusually great, and (c) collecting the additional electric payments after the irrigation pumping season ends. In addition, special pricing features for one electric rate class (electric power consuming sector) not shared by other rate classes can be expected to lead to possible customer discontent and misunderstanding.

2. Such a rate adjustment policy would do nothing to compensate for REC revenue shortfalls that could arise from non-precipitation based reductions in irrigation pumping, e.g., from acreage set-aside government commodity programs.

3. Perhaps most significant and as indicated above, two features of the current electric rate structure already provide for the sharing of risks between irrigators and RECs during seasons of unusual irrigation pumping. The spreading of the "fixed" up-front costs over fewer kWhs results in higher average costs per kWh in years of unusually little pumping. The two-stepped declining energy (kWh) block rate also results in higher average variable kWh costs with limited irrigation pumping. Conversely, when irrigation pumping during an irrigation season is unusually great, both features contribute to a below-normal overall average cost per kWh for the electric power used by an irrigator.

**Differently configured energy (kWh) charge block rates**

The 1985 Clay-Union and Union REC electric rate structures for irrigation provide for a two-step variable energy (kWh) charge--in addition to "fixed" up-front annual minimum and monthly demand charges. In the analysis of differently configured energy (kWh) block rates, attention is given to a single-step energy charge and to three-step declining and three-step increasing energy block rates. The "fixed" up-front electric charges are specified in some models at 1985 levels and in others at zero levels. The primary purpose of this analysis is to determine if differently configured energy block rates, in combination with different policies regarding the assessment of "fixed" up-front electric rate charges, would provide incentive for either greater or lesser electric power and water usage in irrigation.

The heights of the steps (i.e., the levels of the prices for the various steps) and the lengths of the steps (i.e., the numbers of kWhs covered by each bounded step) in the alternative block rate structures were determined as follows. The alternative energy block rate prices were specified relative to the average costs per kWh in the respective baseline solutions (call them **AC**). These **AC** values became (1) the single-step block rate prices and (2) the middle-step prices in the three-step block rate models (Table 7). The first and the third-step prices were arbitrarily set at 90% more and 90% less than the respective **AC** values. In the increasing three-step block rate models, the first and third-step declining block rate charges are interchanged.

The first-step energy (kWh) charge in the 1985 electric rate structure applies to the first 100 kWh per average kW per season. Since the average kW per season differ for high pressure center pivot, low pressure center pivot, and gated pipe water distribution, the amounts of power covered by the first bounded step for these irrigation technologies are 6,300 kWh, 3,360 kWh, and 1,680 kWh, respectively.

The lengths of the blocks in the three-step block rate analysis for the debt- and equity-financing Clay-Union and Union REC representative farms were determined in relation to the average kWh power usages per irrigation system in the respective baseline solutions (call them **BL**). By arbitrarily dividing each **BL** by three, the kWh designated for coverage with each of the first- and second-steps in the three-step block rate models were determined to be as follows:

-Clay-Union REC debt-financing irrigator: 13,675 kWh;

-Clay-Union REC equity-financing irrigator: 7,290 kWh;

-Union REC debt-financing irrigator: 8,060 kWh; and

-Union REC equity-financing irrigator: 4,675 kWh.

The results of the alternative energy block rate analysis are presented in Figures 9 and 10. The first histogram-bar in each panel represents the baseline solution result. The other histogram-bars represent the results for the alternative block rate models as follows:

- Second and third bars: single-step models;

- Fourth and fifth bars: three-step declining block rate models; and

- Sixth and seventh bars: three-step increasing block rate models.

The "fixed" up-front electric charges were set at the 1985 levels in the models underlying the first, second, fourth, and sixth bars and were eliminated in the models underlying the third, fifth, and seventh bars.

As long as the 1985 "fixed" up-front components are retained in the electric rate structures, no modified energy block rate structure has any significant (more than 1%) impact on irrigation electric power or water usage for either REC representative farm. This is shown by the values for the even numbered bars in the top two panel-tiers of Figures 9 and 10 differing from those for the baseline-bars by no more than 1%.

Table 7. Differently configured variable energy (kWH) block rate charges assumed in analysis, Clay-Union and Union REC representative farms.

| Block rate model | Level of charge (cents per kWh) | | | | | |
|---|---|---|---|---|---|---|
| | Clay-Union REC representative farm | | | Union REC representative farm | | |
| | First-step | Second-step | Third-step | First-step | Second-step | Third-step |
| Baseline two-step[a] | | | | | | |
| Debt-financing | 3.26 | 1.58 | n/a | 3.26 | 1.58 | n/a |
| Equity-financing | 3.26 | 1.58 | n/a | 3.26 | 1.58 | n/a |
| Single-step | | | | | | |
| 1985 up-front charges | | | | | | |
| Debt-financing | 1.84 | n/a | n/a | 1.92 | n/a | n/a |
| Equity-financing | 1.84 | n/a | n/a | 1.86 | n/a | n/a |
| Zero up-front charges | | | | | | |
| Debt-financing | 7.61 | n/a | n/a | 9.47 | n/a | n/a |
| Equity-financing | 7.98 | n/a | n/a | 8.30 | n/a | n/a |
| Three-step declining block | | | | | | |
| 1985 up-front charges | | | | | | |
| Debt-financing | 3.50 | 1.84 | 0.18 | 3.65 | 1.92 | 0.19 |
| Equity-financing | 3.50 | 1.84 | 0.18 | 3.53 | 1.86 | 0.19 |
| Zero up-front charges | | | | | | |
| Debt-financing | 14.46 | 7.61 | 0.76 | 17.99 | 9.47 | 0.95 |
| Equity-financing | 15.16 | 7.98 | 0.80 | 15.77 | 8.30 | 0.83 |
| Three-step increasing block | | | | | | |
| 1985 up-front charges | | | | | | |
| Debt-financing | 0.18 | 1.84 | 3.50 | 0.19 | 1.92 | 3.65 |
| Equity-financing | 0.18 | 1.84 | 3.50 | 0.19 | 1.86 | 3.53 |
| Zero up-front charges | | | | | | |
| Debt-financing | 0.76 | 7.61 | 14.46 | 0.95 | 9.47 | 17.99 |
| Equity-financing | 0.80 | 7.98 | 15.16 | 0.83 | 8.30 | 15.77 |

[a]The baseline block rate charges reflect the basic 4.2 and 2.6 cent per kWh two-step energy charges, adjusted down by the 1.1 cent per kWh Basin credit and adjusted up by an assumed 5% interest time money cost.

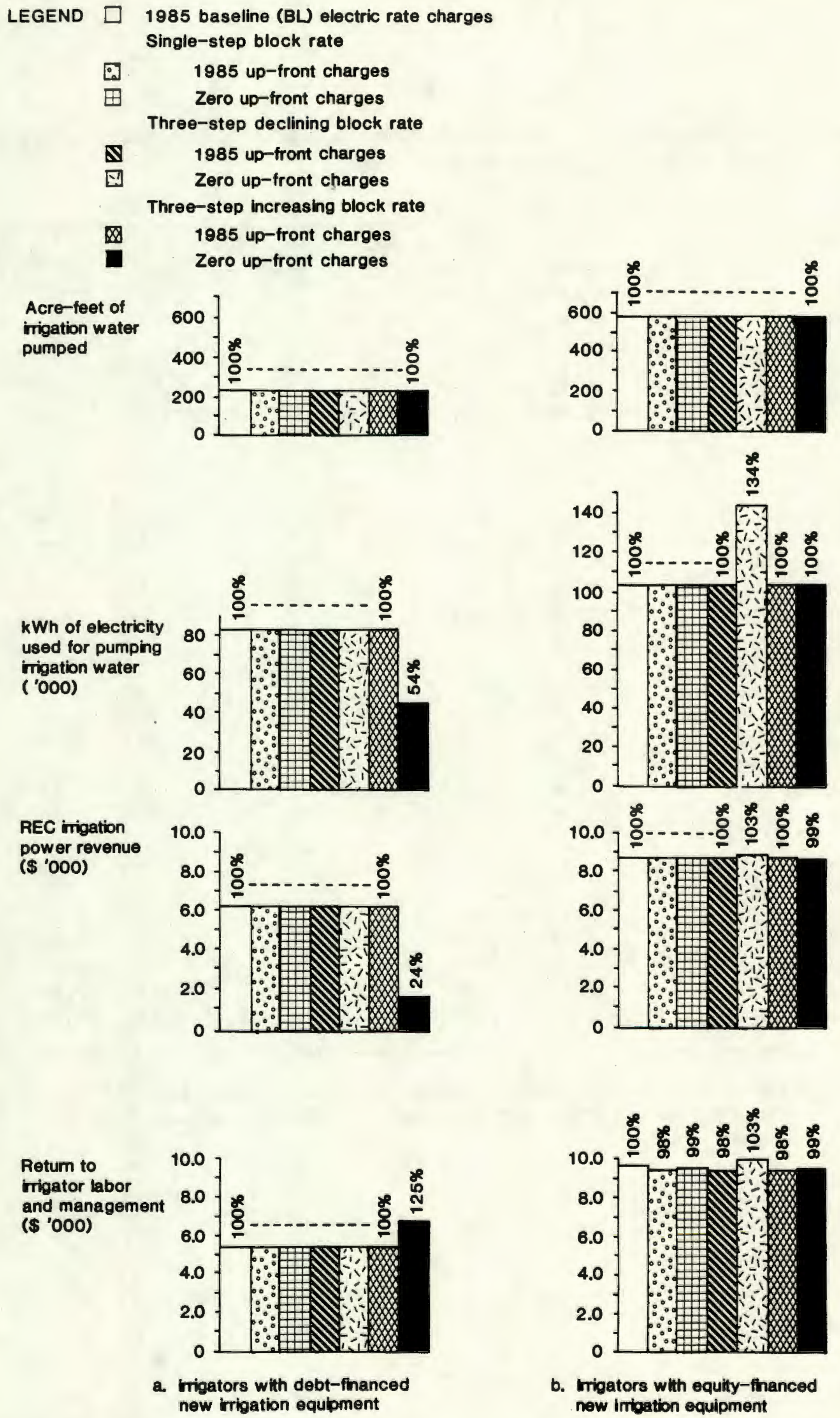



Figure 9. Impacts of differently configured energy (kWh) block rate charges, Clay-Union REC representative farm, irrigators with debt- versus equity-financed new irrigation equipment.

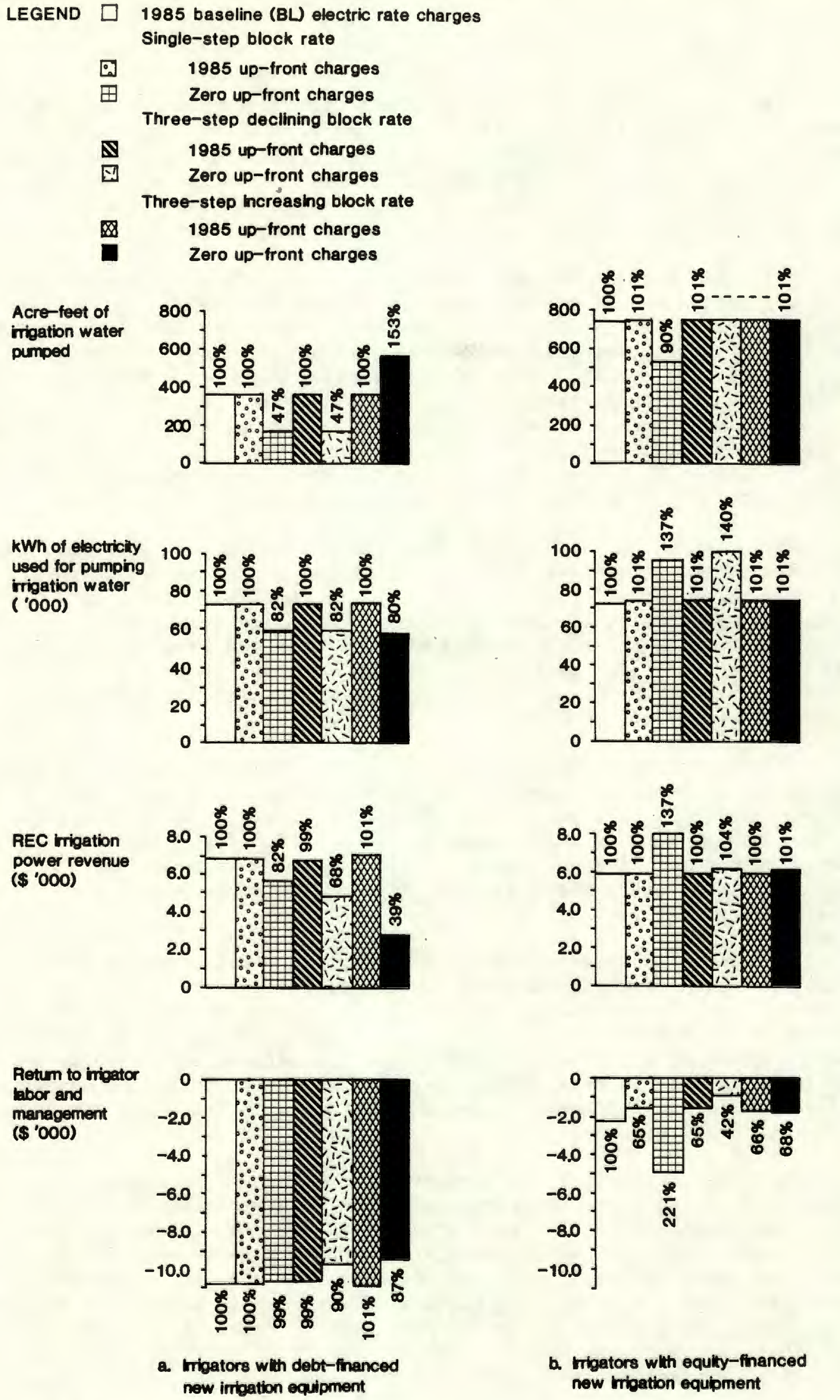



Figure 10. Impacts of differently configured energy (kWh) block rate charges, Union REC representative farm, irrigators with debt- versus equity-financed new irrigation equipment.

When the "fixed" up-front electric charge components are set at zero, however, some differences arise in irrigation electric power and water usage with the modified variable block rate structures versus the respective baseline rate structures--especially for the Union REC representative farm. The directions of impact for the leveraged Union REC debt-financing irrigator are the opposite of those for the Union REC equity-financing irrigator.

For the Union REC debt-financing irrigator, the impacts on electric energy use of the single-step and the three-step declining block rates and the three-step increasing block rate are all essentially the same, namely, 18% to 20% less power usage. In the first two situations, irrigation water pumping is cut by 53%. With the increasing block rate structure, however, irrigation pumping increases by 53%. The reduced power and water usage with the single-step and three-step declining block rates arises from the dropping out of a gated pipe system that is in the baseline solution. With the three-step increasing block rate, two rather than one gated pipe system and two low rather than high pressure center pivots are under corn production.

For the Union REC equity-financing irrigator, on the other hand, the single-step and three-step declining block rates provide incentive for 37% to 40% more power usage. The added power usage (but reduced irrigation pumping) with the single-step block rate arises from the irrigation of (1) six rather than (2) two low pressure center pivots of corn and three gated pipe systems as in the baseline solution. The added power usage with the three-step declining block rate is associated with two high pressure rather than two low pressure center privots of corn.

The Clay-Union REC representative farm is almost totally unresponsive in irrigation energy and water use to the modified energy (kWh) block rate structures. The only exceptions are (1) a 46% reduction in power use with a three-step increasing block rate and zero "fixed" up-front charges for the debt-financing irrigator and (2) a 34% increase in power use with a three-step declining block rate and zero "fixed" up-front charges for the equity-financing irrigator.

In instances of more than a 1% change in electric power usage, REC irrigation power revenues (irrigator payments for power to energize their irrigation pumps) vary directly with the changes in electric power usage. In instances of reduced power usage, the percentage reduction in REC irrigation power revenue is equal to or greater than the percent reduction in power use. In instances of increased power usage, on the other hand, the percentage increase in irrigation power increase is equal to or less than the percent increase in power use.

For the Clay-Union REC representative farm, the returns to irrigator labor and management, with one exception, are impacted by no more than 3% with the different block rate structures. The one exception is a 25% increase in irrigator profit associated with the three-step increasing block rate and zero "fixed" up-front electric rate charges. For the Union REC debt-financing irrigator, the pattern of outcomes is similar to that for the Clay-Union REC representative farm (negative, rather than positive, returns are involved with the Union REC farm, however). For the Union REC equity-financing irrigator, the impacts on the return to labor and management are positive for each of the modified electric rate structures except one (single-step block rate with no "fixed" up-front electric rate charges).

The two principal findings from the analysis of differently configured energy (kWh) block rates are the following.

1. The impacts of modified energy block rates on irrigation electric power and water usage are relatively limited. As long as the 1985 "fixed" up-front electric rate components are retained in the rate structures, for example, the impacts of the single-step, three-step declining, and three-step increasing block rates (rather than the 1985 two-step declining block rate) on energy and water usage are 1% or less.

2. When the "fixed" up-front electric rate charges are set at zero, more sizeable impacts of modified energy block rates on irrigation energy and water use are experienced. The impacts do not conform to a single pattern, however, as might be hypothesized on the basis of simple micro production theory (all other things the same). For example, common patterns of increased energy and/or water usage are not associated with more strongly graduated declining block rates (than in the 1985 baseline electric rate structure). Neither are common patterns of decreased energy and/or water usage associated with the three-step increasing energy (kWh) block rate charges.

**Load management controls**

As indicated above, the Clay-Union and Union RECs in 1985 offered a load management option to their irrigator clients. Monthly demand charges were waived during any month of the irrigation season when irrigators would agree for the power to their irrigation systems to be turned off daily between 5 and 9 pm.[16] If irrigators did not elect the load management option, they were entitled to receive a 1.1 cent per kWh Basic credit for all electric power used.

**All-season following of load management controls.** In our initial microeconomic analysis of load management, we assume that an irrigator would opt either to follow load management throughout the entire irrigation season or not at all during the irrigation season. Thus, in this part of the analysis, no attention is given to the possibility of an irrigator opting into and out

[16] In the following analyses, no account is given to the time and inconvenience associated with irrigators having to reactivate their irrigation systems following the daily 5 to 9 pm shut-downs of their systems. This simplified analytic procedure was adopted, not because of a view that such time and inconvenience is of no consequence, but because of wide variations among irrigators in (1) the amounts of time required to reactivate their systems and (2) the value that they place on such added time and inconvenience.

Incidentally, in 1986, provisions for the load management option were changed so that the 5 to 9 pm power interruptions were made only on those days during the irrigation season when the RECs were experiencing a peaking in their power demand.

of load management controls depending on whether an irrigated crop is experiencing moisture stress.

In this analysis, a two-part budgeting procedure is followed. In the first part, the electric power related benefits and costs of load management are determined. In the second part, attention is given to possible yield losses from following load management.

The electric power related benefits from following load management are represented by the potentially waived monthly demand charges (Table 8). The magnitudes of these benefits for the various crops and irrigation technologies are calculated taking into account the monthly demand charges for the different irrigation technologies (Table 20, Report 1) and the monthly durations of the irrigation season for the different crops (Table 10, Report 1).

The costs of following load management are represented by the aggregate amount of the foregone Basin credit to which load management non-followers are entitled. These costs reflect the cross-product of:

- The irrigation application rates (inches) for the respective crops and REC service areas (Table 10, Report 1);

- The acres per irrigation system, namely, 130 for center pivot and 160 for gated pipe systems;

- The kilowatt hour requirement per acre-inch of irrigation water pumped, namely, 28.69, 15.35, and 5.59 for high pressure center pivot, low pressure center pivot, and gated pipe water distribution, respectively (p 19, Report 1); and

- The per-unit Basin credit of $0.011 per kWh.

By subtracting the electric power related costs from the electric power related benefits, the net electric power benefits from following load management throughout the duration of the irrigation season are determined. These net benefits per irrigation system range from $181 for gated pipe irrigated corn in Union County to $2,200 for high pressure center pivot irrigated alfalfa in Clay County. Since the net electric power related benefits are positive for all combinations of crops and types of irrigation, irrigators in the Clay-Union and Union REC service areas could have derived in 1985 a clear economic electric power related net benefit from following the load management option.

If by following the load management option, however, the yield of an irrigated crop would be adversely affected, further analysis would be required. Yield reductions can be expected if (1) irrigated crops are experiencing moisture-related stress and (2) the supply of irrigation water is interrupted because of load management controls.

The second budgeting component, therefore, involves determining the break-even yield losses that irrigators can afford to sustain from following load management throughout the duration of the irrigation season (Table 9). To do this, the net electric power related benefits per irrigation system are

Table 8. The electric power related benefits and costs of following load management throughout the duration of the irrigation season by crop and type of irrigation, Clay-Union and Union REC representative farms, 1985.[a]

| | Type of irrigation | | |
|---|---|---|---|
| | Center pivot | | Gated pipe |
| | High pressure | Low pressure | |
| | (dollars per irrigation system) | | |
| Clay-Union REC | | | |
| Corn | | | |
| Benefit | 1,190 | 642 | ↑ |
| Cost | 451 | 241 | |
| Net benefit | 739 | 401 | |
| Soybeans | | | |
| Benefit | 1,785 | 963 | not |
| Cost | 443 | 237 | appli- |
| Net benefit | 1,342 | 726 | cable |
| Alfalfa | | | |
| Benefit | 2,975 | 1,605 | |
| Cost | 775 | 415 | |
| Net benefit | 2,200 | 1,190 | ↓ |
| Union REC | | | |
| Corn | | | |
| Benefit | 1,206 | 642 | 322 |
| Cost | 328 | 176 | 141 |
| Net benefit | 878 | 466 | 181 |
| Soybeans | | | |
| Benefit | 1,206 | 642 | 322 |
| Cost | 316 | 169 | 137 |
| Net benefit | 890 | 473 | 185 |

[a]The electric power related benefit from following load management is represented by the value of the monthly demand charges that are waived as a result of an irrigator electing to follow the load management option. The electric power related cost from following load management is represented by the amount of the foregone Basin credit to which load management non-followers are entitled.

Table 9. Break-even per-acre yield losses that farmers can afford to sustain from following load management throughout the duration of the irrigation season, by crop and type of irrigation, Clay-Union and Union REC representative farms, 1985.

| | Type of irrigation | | |
|---|---|---|---|
| | Center pivot | | Gated pipe |
| | High pressure | Low pressure | |
| Clay-Union REC | | | |
| Corn (bu) | 2.4 | 1.3 | n/a |
| Soybeans (bu) | 2.0 | 1.1 | n/a |
| Alfalfa (ton) | 0.38 | 0.20 | n/a |
| Union REC | | | |
| Corn (bu) | 2.9 | 1.5 | 0.5 |
| Soybeans (bu) | 1.3 | 0.7 | 0.2 |

divided by (a) the acres per irrigation system and (b) the 1985 per-unit crop prices (Table 1, Report 1).

For high pressure center pivot irrigators, the break-even per-acre yield losses are no greater than 3 bu for corn, 2 bu for soybeans, and 0.38 ton for alfalfa. These break-even losses are about 2.0%, 4.3%, and 6.9%, respectively, of the average expected yields with normal precipitation for corn, soybeans, and alfalfa (Tables 2 and 4, Report 1). Thus, high pressure, center pivot irrigators who anticipate a yield reduction from daily interruptions in irrigation throughout the irrigation season from 5 to 9 pm equal to or greater than these amounts are ill-advised economically to follow the load management option. With lesser or no anticipated yield losses, irrigators can expect to benefit from following the load management option.

For low pressure center pivot and gated pipe irrigators, the maximum tolerable yield losses from all-season load management are considerably less than those for high pressure center pivot irrigators. The reduced margin for loss arises primarily because of the lesser electric power requirement per acre-inch of irrigation water pumped for these types of systems.

**Selective month-by-month following of load management controls.** In the preceding analysis, following load management was treated as a seasonal "all or none" proposition. The Clay-Union and Union REC load management option, however, provides for the possibility of load management followers to stop following the load management option at any time during any month that an irrigator desires to.

In this section, the possibility of an irrigator following load management selectively month-by-month is contrasted with the possibility of an irrigator not opting to follow load management. The contrast is illustrated with high and low pressure center pivot (HP-CP and LP-CP) irrigated soybeans in the Clay-Union REC service area.

The benefits and costs of following load management are analyzed month-by-month, taking into account pertinent technical and economic data (Table 10). The monthly demand charges associated with HP-CP and LP-CP irrigated production in the Clay-Union REC service area are $595 and $321, respectively (Col 2). The monthly gross irrigation water applications for Clay-Union soybeans are as shown in Col 3. The amounts of the associated monthly foregone Basin credits are shown in Col 4. The net monthly benefits from following load management (Col 5) are converted to break-even yield losses as shown in Col's 6 and 7.

The monthly break-even yield losses vary inversely with the amounts of monthly irrigation applications. Further, the monthly break-even yield losses are about 85% more with HP than LP water distribution. The maximum monthly break-even yield loss for soybeans (HP water distribution in September), however, is only 53 lb per acre (1.8% of the yield with normal precipitation).

Being able to manage irrigation water so as to avoid a minimum level of moisture-stress leading to anything less than a 1.8% yield loss during a particular month is an unrealistic management objective for any irrigator. The conclusion of this analysis, therefore, is clear. An irrigator following

Table 10. Technical and economic data for assessing the advisability of an irrigator selectively following load management month-by-month, center pivot irrigated soybeans, Clay-Union REC study area, 1985.

| Water distribution pressure and month during the irrigation season | Monthly electric power related benefits and costs per center pivot from following load management | | | | Break-even monthly soybean yield losses that an irrigator could afford to sustain from following load management | |
|---|---|---|---|---|---|---|
| | Benefit: waived monthly demand charges($)[a] | Cost: foregone Basin credit | | Net monthly benefit($)[d] | | |
| | | Gross irrigation application (inches)[b] | Amount of foregone Basin credit($)[c] | | Pounds per acre[e] | Percent of normal yield[f] |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| High pressure (HP) | | | | | | |
| July | 595 | 5.5 | 226 | 369 | 33 | 1.1 |
| August | 595 | 5.1 | 209 | 386 | 35 | 1.2 |
| September | 595 | 0.2 | 8 | 587 | 53 | 1.8 |
| Season total | 1,785 | 10.8 | 443 | 1,342 | 121 | 4.2 |
| Low pressure (LP) | | | | | | |
| July | 321 | 5.5 | 121 | 200 | 18 | 0.6 |
| August | 321 | 5.1 | 112 | 209 | 19 | 0.7 |
| September | 321 | 0.2 | 4 | 317 | 28 | 1.0 |
| Season total | 963 | 10.8 | 237 | 726 | 65 | 2.3 |

[a]From Table 20, Report 1.
[b]From Table 10, Report 1.
[c]The monthly foregone Basin credits are represented by the cross-product of (1) the respective monthly gross irrigation applications; (2) 130 acres per center pivot; (3) 28.69 and 15.35 kWh per acre-inch of irrigation water pumped for HP and LP water distribution, respectively; and (4) the Basin credit of $0.011 per kWh.
[d]The net monthly benefits represent the difference between the Col 2 and Col 4 values for the respective months.
[e]The monthly pounds per acre yield losses represent the respective net monthly electric power related benefits per center pivot divided by (1) 130 acres per center pivot and (2) the 1985 price of soybeans of $0.0857 per pound ($5.14 per bu).
[f]The irrigated soybean yield in the Clay-Union REC study area is 48 bu per acre.

load management who anticipates that a continued 5 to 9 pm interruption in irrigation during any particular month would begin to place his irrigated crop under any yield-reducing moisture-stress should straightaway "break the seal", and opt out of load management control for the remainder of that monthly billing period.[17]

Does the fact that the load management option is so sensitive to possible yield losses imply that irrigators should stay away from load management control programs? Depending on the provisions of a particular load management control program, the answer could be yes or no. The stipulations of the Clay-Union and Union REC load management control option, however, provide clear economic incentive for irrigators to opt for load control in all months except those in which power interruptions would result in yield-reducing moisture-stress. This can be seen from the following.

An irrigator who rejects load management controls thereby "earns the right" to pump irrigation water 24 hours a day, every day of the month. As a consequence, he/she "automatically" has to pay the monthly demand charge for every month in the irrigation season.

An irrigator who opts for load management controls can pump irrigation water for 20 out of every 24 hours a day every day of the month, with no consequential liability for paying monthly demand charges. As long as pumping 20 hours per day is adequate to meet the moisture-needs of an irrigated crop, the irrigator is clearly better off than his "load management rejection" counterpart because he has had a well watered irrigated crop without having had to pay any monthly demand charges.

If yield-reducing moisture-stress should arise with the limited 20 hour per day pumping in a particular month, however, the irrigator can immediately opt out of the load management control program and pump 24 hours a day. He thereby becomes no worse off, regarding the payment of the monthly demand charge, than his "load management rejection" counterpart in that month. In all months during the irrigation season when 20 hours per day of pumping is adequate, on the other hand, the load management follower gains economically as he avails himself of the waived monthly demand charges.

Thus, the central features that make the Clay-Union and Union REC load management option attractive to irrigators are (1) the potential for irrigators to avoid paying monthly demand charges in any month during which 20 hour per day irrigation is adequate to meet the mositure needs of their crops and (2) the possibility for a load management followers to opt out of the load management control program (with no greater penalty than to pay the monthly demand charge) whenever they determine that 20 hour per day irrigation would result in yield-reducing moisture-stress. This double-barreled feature of the program contributes to the mutual economic welfare of both the electric power supplier and the electric power user.

[17]Although the illustration is developed for irrigated soybeans in the Clay-Union REC service area, the conclusion for Clay-Union soybeans applies also to each of the irrigated crops in both the Clay-Union REC service areas. The next most likely "candidate" for a large break-even percentage yield loss is alfalfa in May in which the irrigation water application rate is 2.1 inches. The break-even yield loss for it, however, is only 1.6%.

## LIMITATIONS OF THE STUDY

The analytic model employed in this study, as with any other study, fails to accommodate all pertinent features of the real-world environment being studied. Those features believed to be the most limiting in this regard are the following.

The actual farmer decision-making process is only crudely incorporated into the MILP model. The only farmer managerial objective explicitly considered in the model is the maximization of revenues over and above the variable costs of farm production. No attention is given to other potentially quantifiable objectives (regarding, for example, cash-flow management and risk management) and less quantifiable objectives (e.g., preferences regarding family involvement with the farm, farmer involvement in the home, leisure time). Neither is attention given to the investment credit (prevailing in 1985) and tax deduction dimensions of irrigation investments nor the possible participation of irrigators in government grain commodity programs.

The model covers only a single production period; yet, many decisions are made by farmers within the context of several production periods. Crops are considered individually; yet, some farmers plan cropping patterns with rotational considerations in mind. Specific assumptions (e.g., center pivots that cover only 130 acres and gated pipe systems that cover only 160 acres of land each, land and labor resource availabilities, insurance rates, commodity storage and marketing practices) may apply to some farms, but certainly not to all farms. The same is true for the assumed crop and livestock production coefficients and irrigation technologies. Because of these limitations, the findings from the study—while based on the soundest analytic procedures that we could find and further develop—should not be interpreted as absolutely definitive.

We also realize that the applicability of the findings from the study to individual RECs depends importantly on the cost structures and governing philosophies of each REC. We hope that this report and others prepared through this research project will provide some useful insights to RECs as they deal with the inherently multi-faceted and complex task of formulating electric rate pricing policies for irrigation.

## APPENDIX

### THE BASES FOR ESTABLISHING ELECTRIC RATE STRUCTURES CLAY-UNION REC[18]

The purpose of this appendix is to provide an overview of the underlying philosophy and procedures that the Clay-Union REC uses in establishing its electric rates and rate structures for irrigation and other "rate classes" (electric power consuming sectors).

The Clay-Union REC has five rate classes, namely, single phase (mainly residential, accounting for 68.4% of REC revenue), large power (loads in excess of 50 kVa of transformer capacity, 22.1% of revenue), irrigation (both single and three-phase, 6.8% of revenue), commercial three-phase (up to 50 kVa, 1.5% of revenues), and street lights (0.2% of revenue). To the maximum extent possible, the REC establishes electric rate structures which result in each rate class being fully self-supporting. In other words, deliberate efforts are exercised to keep one rate class from subsidizing another.

In this appendix, attention is given to (1) the cost of service investment analysis, undertaken annually by the Clay-Union REC, that represents the "analytic backbone" for the establishment of the REC's electric rate structure, (2) the process for and results from assigning the REC operating costs to the various rate classes, and (3) the linkage between those cost assignments and the development of the Clay-Union REC electric rate structure for irrigation for 1985.

**Cost of service investment analysis**

A Cost of Service Study plays a key role in decisions on the electric rate structure determined for each rate class. In the process of undertaking the cost of service study, the costs of the REC's total electric plant are allocated across the various rate classes. Both the fixed costs associated with the REC's total electric plant investment and the variable operating costs--except the wholesale costs of purchased electric power--are allocated in accordance with the results of the cost of service investment analysis.

The cost of service methodology used by the Clay-Union REC is based on the "minimum practical mile of line" concept. The "minimum" investment costs per mile for (1) poles, towers, fixtures, and overhead conductors and (2) underground conductors and devices are determined. These per-mile costs are multiplied by the respective mileages of overhead and underground transmission lines owned by the REC. The resulting "minimum practical mile of line" investment costs are termed as "customer" distribution plant costs. The differences between the total actual distribution plant investment costs and the "customer"

---

[18] The sources of this appendix are a paper entitled The Modified Colorado Concept, Cost of Service Study, Clay-Union and Union RECs, presented at Rate Seminar-Cost of Service, Madison, South Dakota, April 30, 1985 and several discussions during 1986 and 1987 between the authors and the Manager of Clay-Union REC and two of the REC senior staff.

costs are termed "capacity" distribution plant costs. The "capacity" costs represent plant investment to meet electric load requirements in excess of "minimal" quantities of power and energy.[19]

The end-of-year depreciated inventory values for each component of the distribution plant investment are allocated in accordance with the above-described respective "customer-capacity" investment ratios.[20] The subsequently determined overall customer-capacity investment ratio for the entire distribution plant is then used to allocate (1) the end-of-year depreciated inventory value for the REC "general plant" (office buildings and equipment) and (2) selected operating expenses, namely, distribution facility operation and maintenance costs, depreciation on investment (over 35 years for lines, transformers, and buildings and 2 to 15 years for trucks, tools, and office equipment), taxes, and interest on long-term debt. The other non-purchased electric power operating expenses are allocated as follows. Meter reading, billing, and collection (termed "customer accounting") costs and "sales" costs are assigned totally to the "customer" category of expense. The administration and general office expense is allocated in accordance with the overall customer-capacity ratio for all other operating expenses.

**Assignment of the REC operating costs to the various rate classes**

The REC operating costs--inclusive of wholesale purchased electric power--can be portrayed in each of three contexts. The first two types of portrayal, namely, according to accounting line item and type of electric cost, can be prepared on the basis of the results of a cost of service investment analysis and information on the wholesale purchased power costs. The third type of portrayal reflects the assignment of the REC operating costs to the various rate classes.

In this section, the total operating expenses for the 1985 Cost of Service Study for the Clay-Union REC are presented and discussed. They are initially shown by accounting line item and type of electric cost. The procedures for assigning these costs to the various rate classes and the results of using the procedure are then indicated.

Of the total operating expenses reported in the 1985 Cost of Service Study for the Clay-Union REC, about 66% are accounted for by the electric power that the REC purchases from the East River Electric Power Cooperative in Madison (Appendix Table 1). The total demand charge is 50% greater than the total energy charge. Of the non-purchased electric power costs, the largest are for administration and general office (9.9% of the total operating costs), interest on

---

[19]The investment in line transformers is handled in a somewhat analagous way. The investment cost per "minimum size" transformer is multiplied by the actual number of transformers owned by the REC to determine the "customer" assigned transformer costs. The difference between the total actual REC investment in transformers and the "customer" cost is termed the "capacity" component of the total transformer investment.

[20]The investments in "services", "meters", and "installations on consumer premises" are assigned totally to the "customer" component of the distribution plant costs.

investment (8.0%), distribution facility operations and maintenance (7.1%), and depreciation on investment (5.9%).

The REC total operating expenses presented in Appendix Table 1 are shown, by type of electric cost, in Appendix Table 2. The demand charge represents about 38% of the total, the energy charge 25%, the customer charge 21%, and the capacity charge 16%. The procedures used for allocating these charges among the various rate classes are now discussed.

The total REC demand, capacity, and energy charges are allocated to the various rate classes on the basis of the following:

- Demand: the contribution of each rate class to the total kilowatt (kW) demand (coincidental) placed on the East River Power Cooperative through the purchase of electric power by the Clay-Union REC:

- Capacity: the contribution to the seasonal non-coincidental peak demand of each rate class; and

- Energy: the actual kilowatt hour (kWh) usage by each rate class.

The allocation of the total customer charge among rate classes is according to five individual components: minimum mile of line (52% of the customer costs), administration and general office (29%), billing and collections (12%), meters and service entrance (6%), and meter reading (1%). These costs are allocated among rate classes on the basis of the following:

- Mininmum mile of line: in direct proportion to the number of customers in each rate class;

- Administration and general office: in direct proportion to the revenues earned by each rate class;

- Meter reading: the actual average costs of reading meters for the respective rate classes; and

- Other cost components: via two different weighted proportions of customer numbers.

Using these procedures, the Clay-Union REC operating costs are assigned to rate classes as shown in Appendix Table 3. A generally similar pattern is shown in the relative (percentage) breakdowns among the four type-of-electric-cost categories for the various rate classes. The main exceptions to the general pattern are (1) a much above-average relative importance of demand (kW) charges for the irrigation and large power rate classes, which arises because of extreme unevenness in the demand for power from month to month within the year for each of these rate classes, and (2) a much below-average relative importance of customer charges for the large power rate class, which arises directly from the "definition" of that rate class.

Further insights on inter-comparisons among rate classes can be derived from the average allocated costs for the various rate classes shown in Appendix Table 4. In the first part of this table are the average cost data, as reported directly in the 1985 Cost of Service Study for the Clay-Union REC. The demand

Appendix Table 1. Clay-Union REC operating expenses, by accounting line item.[a]

| Expense category | Dollars | Percent |
|---|---|---|
| Purchased electric power | | |
| Demand charge | 1,406,961 | 37.9 |
| Energy charge | 939,777 | 25.3 |
| Capacity charge | 111,367 | 3.0 |
| Sub-total | (2,458,105) | (66.2) |
| Other operating expenses | | |
| Administration and general office | 365,640 | 9.9 |
| Interest on investment | 297,640 | 8.0 |
| Distribution facility operations and maintenance | 264,050 | 7.1 |
| Depreciation on investment | 219,600 | 5.9 |
| Customer accounting and sales | 100,830 | 2.7 |
| Taxes | 5,060 | 0.2 |
| Sub-total | (1,252,820) | (33.8) |
| GRAND TOTAL | 3,710,925 | 100.0 |

Source: 1985 Cost of Service Study, p 12.

[a]In addition to these operating expenses, the REC is required to provide for "margins" (ranging from 0.5 to 1.5 times as much as their interest costs). These margins become capital credits that are assigned back—over 15 to 20 years—to cooperative members in proportion to their patronage of the cooperative.

Appendix Table 2. Clay-Union REC operating expenses, by type of electric cost.

| Expense category | Dollars | Percent |
|---|---|---|
| Demand charge | 1,406,961 | 37.9 |
| Energy charge | 939,777 | 25.3 |
| Customer charge | 760,046 | 20.5 |
| Capacity charge | 600,796 | 16.2 |
| Street lights | 3,345 | 0.1 |
| Total | 3,710,925 | 100.0 |

Source: 1985 Cost of Service Study, p. 12.

Appendix Table 3. The Clay-Union REC assignment of operating costs to rate classes.[a]

| | Single phase | | Large power | | Irrigation | | Commercial three phase | | Total[b] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dollars | Percent | Dollars | Percent | Dollars | Percent | Dollars | Percent | Dollars | Percent |
| Electric energy costs | | | | | | | | | | |
| Demand (kW) charge | 780,863 | 30.7 | 476,960 | 58.2 | 116,778 | 46.4 | 30,953 | 34.1 | 1,406,961 | 37.9 |
| Energy (kWh) charge | 680,398 | 26.8 | 192,654 | 23.5 | 38,531 | 15.3 | 26,314 | 29.0 | 939,777 | 25.4 |
| Sub-total | (1,461,261) | ( 57.5) | (669,614) | ( 81.7) | (155,309) | ( 61.7) | (57,267) | ( 63.1) | (2,346,738) | ( 63.3) |
| Plant-related costs | | | | | | | | | | |
| Customer charges | 688,398 | 27.1 | 16,610 | 2.0 | 38,579 | 15.4 | 16,145 | 17.7 | 760,046 | 20.5 |
| Capacity charges | 391,118 | 15.4 | 133,377 | 16.3 | 57,676 | 22.9 | 17,423 | 19.2 | 600,796 | 16.2 |
| Sub-total | (1,079,516) | ( 42.5) | (149,987) | ( 18.3) | (96,255) | ( 38.3) | (33,568) | ( 36.9) | (1,360,842) | ( 36.7) |
| GRAND TOTAL | 2,540,777 | 100.0 | 819,601 | 100.0 | 251,564 | 100.0 | 90,835 | 100.0 | 3,710,925 | 100.0 |

Source: 1985 Cost of Service Study, p. 7.

[a] The actually-used assigned operating costs for establishing the electric rate structures for the various rate classes differ slightly (about 1%) from the "Grand Totals" shown below. Adjustments are first made for gross revenue taxes, current margins, deferred margins, and other limited purposes.

[b] The total column includes, in addition to the costs for the four rate clases shown in the table, $3,345 of street light-relate costs.

(kW) and energy (kWh) charges are very similar among rate classes. The plant-related costs per customer are expectedly below-average for the numerous (2,647) single phase customers and above-average for the customers constituting the other rate classes (only 35 to 87 customers per rate class).

The point of greatest difference among rate classes, however, concerns the capacity charge. This charge per kWh of power use for irrigation is 2.3 times as great as the average for all rate classes for the RECs (2.89 versus 1.26 cents per kWh). This cost phenomenon arises because of a disproportionately large contribution of irrigation to the REC's seasonal non-coincidental peak demand for electric power.

In the second part of Appendix Table 4, the data for the various rate classes are standardized across the type-of-electric-cost categories on the basis of average per kWh costs. In other words, no matter what the nature of the type of electric cost, the total expense for it is divided by the kWh use projected in the 1985 Cost of Service Study for the respective rate classes.

The most striking contrast shown is a 60% above-average cost for the electric power used for irrigation (12.6 versus 7.8 cents per kWh). The overall electric cost per kWh for irrigation is high because the demand charge per kWh for irrigation is twice the average (5.85 versus 2.96 cents per kWh) and the plant-related costs are 70% above-average (4.82 versus 2.86 cents per kWh). These above-average costs for irrigation reflect (1) above-average electric distribution plant costs associated with the relative remoteness of location for irrigators and (2) the relatively limited volume of kWh usage compared to the peak kW demand requirement associated with irrigation pumping that is "energy-intensive", on the one hand, and limited to only a small part of the year, on the other hand. The latter feature precludes the spreading of fixed annual customer and capacity charges across large numbers of kWhs.

**Establishment of the electric rate structure for irrigation**

The electric rate structure for irrigation for the Clay-Union REC has evolved from year to year during the 1980s based on (1) reviews of experience with prior rate structures by the management and governing board of the REC and (2) preferences expressed by irrigators concerning possible changes in electric rate structures. These changes involve both the nature of the electric rate structure and the within-season timing of payments for the customer and capacity (or "facilities") charge.

For example, several years ago the entire facilities charge for Clay-Union REC irrigators was due at the beginning of the irrigation season. A change was then made that permitted the facilities charge to be paid at the end of the season, with provision for the potential offsetting of part of an irrigator's facilities charge by his energy (kWh) charge.

More recently, in response to a quite commonly held preference by irrigators, two changes were made. To simplify understanding by irrigators of the rationale for the electric rate structure for irrigation, a decision was made to (1) load the entire REC facilities charge into the "annual minimum" charge and (2) essentially pass through to irrigators the wholesale demand (kW) and energy (kWh) charges paid to the East River Cooperative, along with necessary margins.

Appendix Table 4. Clay-Union REC, average allocated costs, by rate class.

| | Single-phase | Large power | Irrigation | Commercial three phase | All rates classes |
|---|---|---|---|---|---|
| Average cost | | | | | |
| Electric energy | | | | | |
| Demand ($ per kW) | 10.52 | 10.55 | 10.53 | 10.46 | 10.65 |
| Energy (cents per kWh) | 1.95 | 1.95 | 1.93 | 1.99 | 1.97 |
| Plant-related | | | | | |
| Customer ($ per year) | 257.08 | 470.80 | 438.56 | 380.10 | 270.09 |
| Capacity (cents per kWh) | 1.12 | 1.35 | 2.89 | 1.32 | 1.26 |
| Standardized average per-kWh cost (cents) | | | | | |
| Electric energy | | | | | |
| Demand | 2.24 | 4.84 | 5.85 | 2.34 | 2.96 |
| Energy | 1.95 | 1.95 | 1.93 | 1.99 | 1.97 |
| Sub-total | ( 4.19) | ( 6.79) | ( 7.78) | ( 4.33) | ( 4.93) |
| Plant-related | | | | | |
| Customer | 1.97 | 0.17 | 1.93 | 1.22 | 1.60 |
| Capacity | 1.12 | 1.35 | 2.89 | 1.32 | 1.26 |
| Sub-total | ( 3.09) | ( 1.52) | ( 4.82) | ( 2.54) | ( 2.86) |
| GRAND TOTAL | 7.28 | 8.31 | 12.60 | 6.87 | 7.79 |

Source: Adapted from 1985 Cost of Services Study, pp. 3-7 and 11.

The second change was to allow the annual minimum payment to be paid in three equal installments on July 15th, August 15th, and September 15th.

Within this guiding perspective, we now examine the linkage between the above assignment of REC operating costs to the irrigation rate class and the electric rate structure for irrigation that was established in 1985.

1. The **annual minimum** payment represents the dollar charge per average kW for each irrigation service. It covers the full REC facilities (plant-related customer and capacity) charge for irrigation, which in the 1985 Cost of Service Study is $38,155 + $57,033 = $95,188.[21] The total horsepower represented by the electric motors energizing the pumps of the REC's irrigators in 1985 is 6,000, which is equivalent to 5,348 kW. Through dividing $95,188 by 5,348, the annual minimum of $17.80 per average kW is determined.

2. The **monthly demand** payment charge assessed against irrigators is directly linked with the wholesale monthly demand payment from the Clay-Union REC to the East River Power Cooperative.[22] The total wholesale monthly demand payment for irrigation in the 1985 Cost of Service Study is $115,460. The total kW demand over the irrigation season for the 87 irrigators is 10,960. The quotient associated with these two figures is $10.53 per kW.

The actual monthly demand payment in the 1985 rate structure for irrigation is $9.00 per kW per month. A demand charge somewhat less than $10.53 per kW per month was chosen for an interim period, to reduce the magnitude of one-time adjustment from the prior year's charge of $7.80 per kW per month.

3. The **energy** (kWh) payment for irrigation is also directly linked with the wholesale energy (kWh) charge from the Clay-Union REC to East River.[23] The total energy allocation for irrigation in the 1985 Cost of Service Study of $38,100 was divided by the projected kWh usage of 1,975,000 to obtain an average cost of 1.93 cents per kWh for irrigation energy.

The energy (kWh) charge in the 1985 electric rate structure for irrigation is two-stepped, with the costs for the first 100 kWh per kW per season at 4.2 cents per kWh and all additional kWh at 2.6 cents per kWh. These rates are higher than 1.93 cents per kWh to offset the $1.50 per kW shortfall in the monthly demand charge and provide a "cushion" to meet the "margin" requirement of the REC. The energy (kWh) charge is two-stepped, rather than single-stepped, to facilitate the meeting of the monthly demand shortfall, on the one hand, and encourage greater electric power usage, on the other.

---

[21]These figures and those that follow are taken from Appendix Table 3, with slight modifications to conform with the first footnote to the table. The monthly demand (kWh) and energy (kWh) costs emerging from the Cost of Service Study are also shown in Appendix Table 5.

[22]In principle, the monthly demand charge represents the payment for the electric power generation and transmission facilities required to meet an REC's electric power supply needs at any given time.

[23]In principle, the energy charge--based on kWh of consumption--represents the payment for the resources used in generating electricity.