



Demand Response: An Historical Perspective and Business Models for Load Control Aggregation

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A Smart Grid Vision

- Distribution Automation and Control (DAC) systems have potentially major effects on costs, social impacts, and even on the nature of the power system itself, especially as dispersed storage, generation, and customer interaction become more prevalent.
- Homeostatic Utility Control is an overall concept which tries to maintain an internal equilibrium between supply and demand. Equilibrating forces are obtained over longer time scales (5 minutes and up) by economic principles through an Energy Marketplace using time-varying spot prices.

A Smart Grid Vision

- Faster supply-demand balancing is obtained by employing "governor-type" action on certain types of loads using a Frequency Adaptive Power Energy Rescheduler (FAPER) to assist or even replace conventional turbine-governed systems and spinning reserve.
- Conventional metering is replaced by a Marketing Interface to Customer (MIC) which, in addition to measuring power usage, multiplies that usage by posted price and records total cost.

A Smart Grid Vision

Above excerpted verbatim from the abstract of:
“HOMEOSTATIC UTILITY CONTROL,”
F.C. Schweppe et al
IEEE Transactions on Power Apparatus and Systems,
Vol. PAS-99, No. 3,
May/June 1980 –30 years ago!!!!

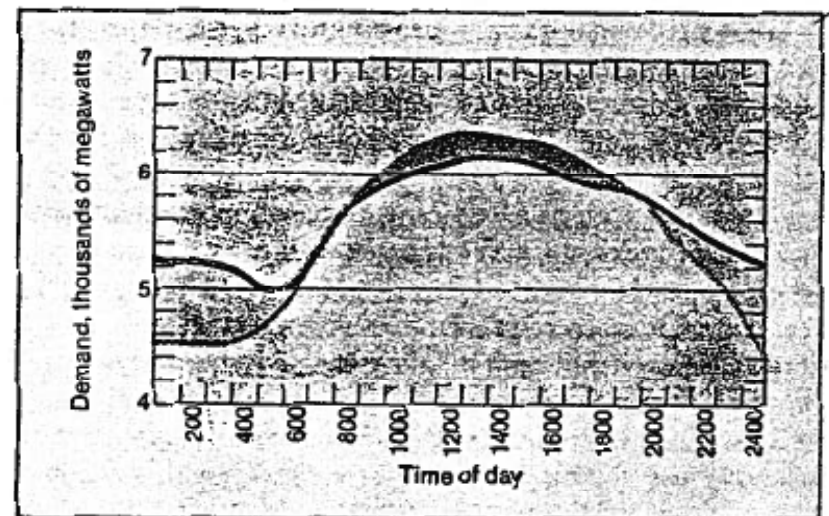
Demand-side load management

The rising cost of peak-demand power means that utilities must encourage customers to manage power usage

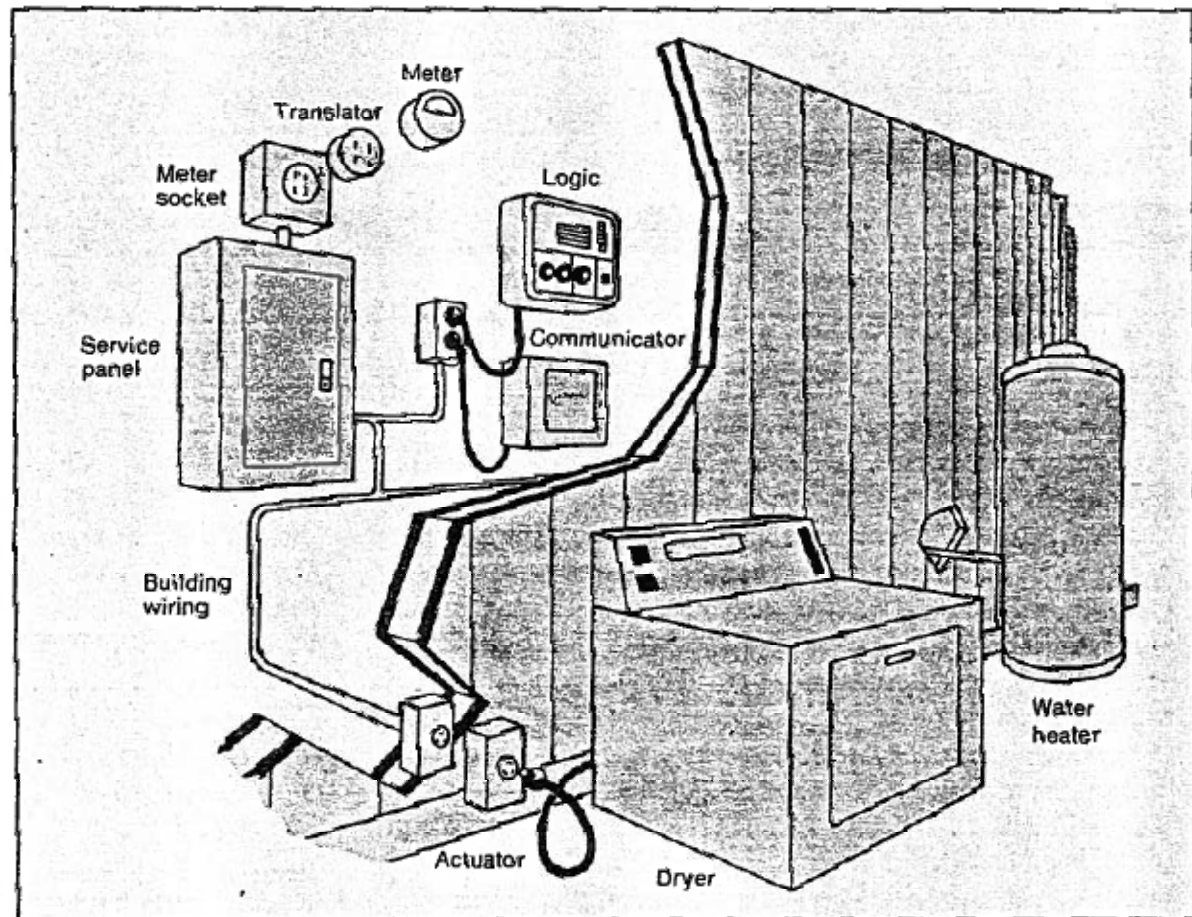
As electricity cost increases, more and more utilities are extending their activities into once-forbidden territory: the customer's side of the meter. In order to increase efficiency and hold the line on costs, they are controlling, directly and indirectly, when and how the electric energy is used—shifting from a

A simple peak/off-peak rate structure requires a two- or three-register meter, each measuring total consumption within a specific time. Weekends as well as nights are usually off-peak periods. Another rate pattern, encompassing multiple cost zones, incorporates peak, off-peak, and shoulder (occurring

Clark W. Gellings
Public Service Electric and Gas Co.



[2] This load-control system for residential and small commercial buildings limits consumption during peak demand periods and is set by the customer according to a rate agreement with the utility. It will prevent appliances such as dryers or water heaters from operating simultaneously if their combined load exceeds the maximum allowed. The translator interprets meter data for the logic circuitry, which controls appliances through the communicator.



FEATURE ARTICLE

Smart Meters and Spot Pricing: Experiments and Potential

ARTHUR H. ROSENFELD, DOUGLAS A. BULLEIT, and ROBERT A. PEDDIE

Abstract — Responsive microprocessor meters are approaching a life-cycle cost that is cheaper than that of electromechanical time-of-use meters, and they are currently being tested in Britain and the U.S. The English residential Credit and Load Management Unit (CALMU) can respond to dynamic prices broadcast by the British Broadcasting Corporation and can in principle turn off individual equipment at prices preselected by the homeowner. In the U.S., a consortium led by Integrated Communication Systems, Inc. (ICS) has started similar experiments, and many "smart houses" are being planned. Responsive meters (and the thermal storage they will

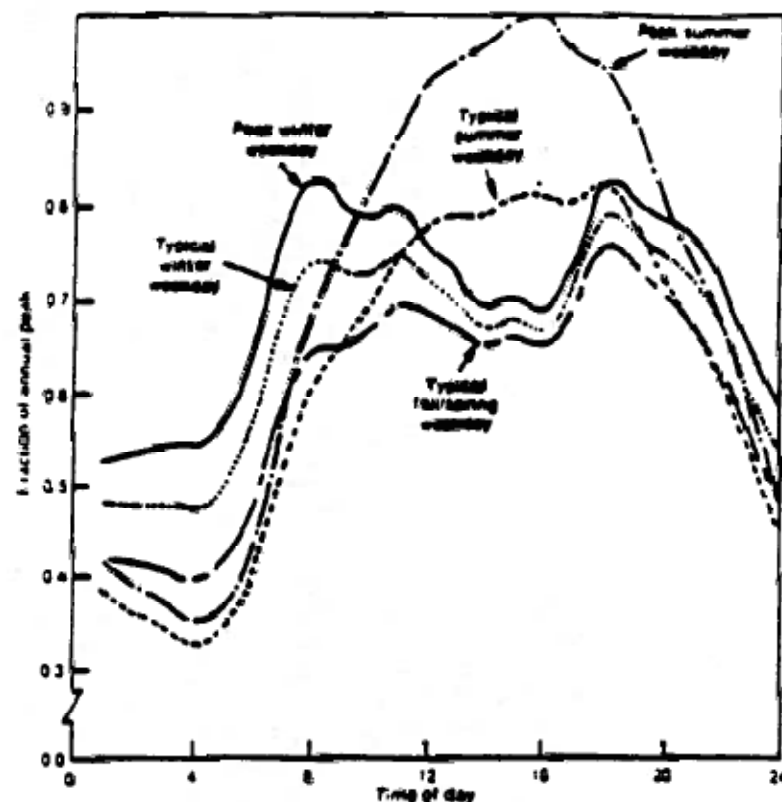
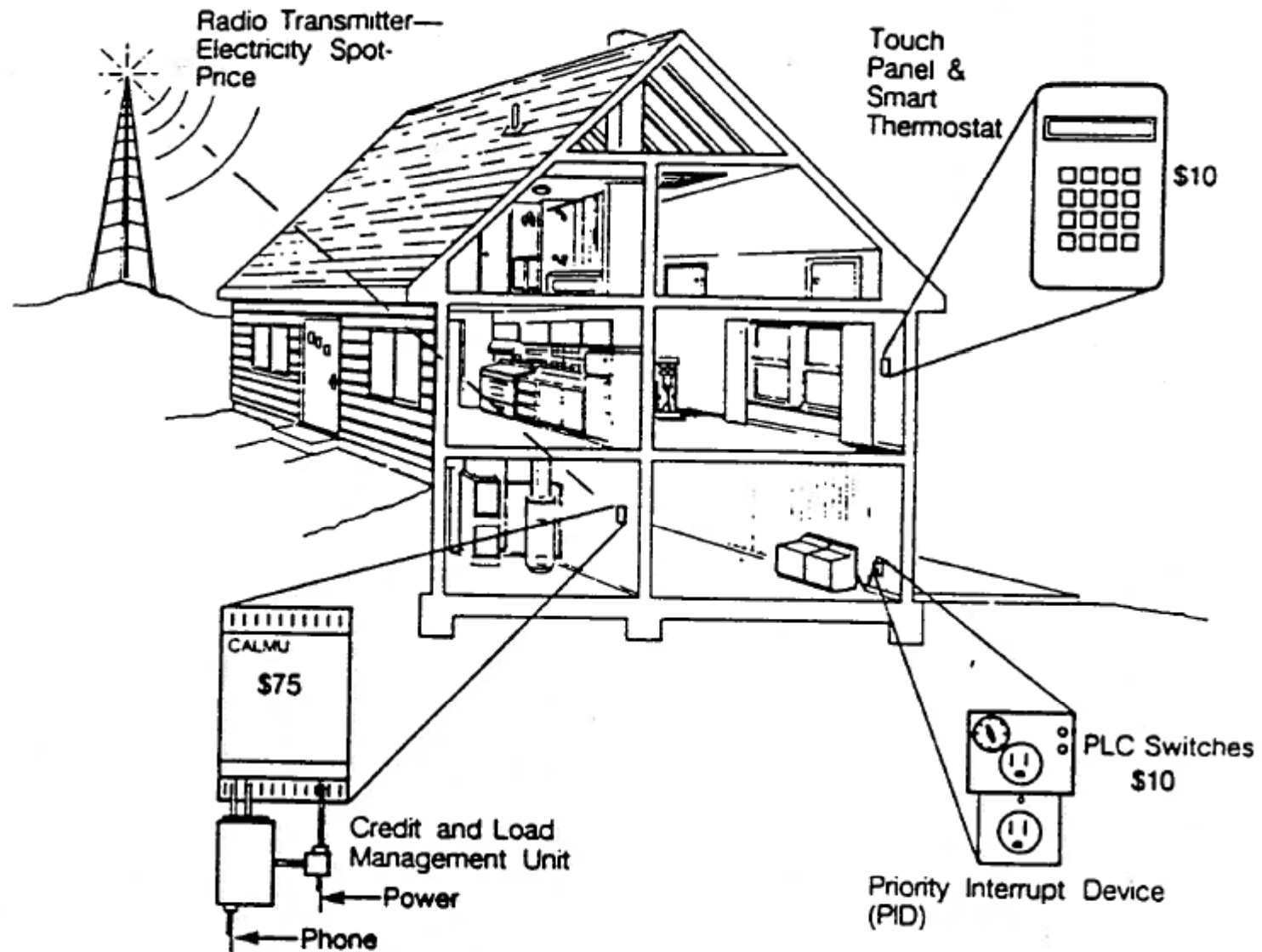


Fig. 1 Daily Load Shapes for Five Representative Weekdays (North Central Region, 1980). Source: INDUSTRIAL AND COMMERCIAL COGENERATION, Office of Technology Assessment, U.S. Congress (1983), which cites Decision Focus, Inc. (1980).

CREDIT & LOAD MANAGEMENT SYSTEM: CALMS



DOCUMENTATION PORTEFEUILLE « DONNÉES TARIFAIRES »

EDF

**Electricité
de France**

**DIRECTION
GÉNÉRALE**

SÉPAC

Division Études Tarifaires

**2, rue Louis-Murat
75008 Paris**

**PRIX APPLICABLES
HORS T.V.A. (18,8 %)
AU 1-02-1987**

Tarif Bleu :

- clients domestiques et agricoles
- clients professionnels

Tarif Vert

Tarif Vert A

Notes : Ne s'applique pas dans les départements et territoires d'Outre-Mer
- Sur décision des collectivités locales, les taxes municipales (de 0 à 8%)
et départementales (0 à 4%) sont applicables sous certaines conditions.

ELECTRIC UTILITY WEEK



An exclusive report on the electric utility industry

June 17, 1985

MASS. DPU RULES BOSTON ED MUST OFFER INTERRUPTIBLE RATES TO ALL CUSTOMERS

Boston Edison must file by Oct. 1 new interruptible rates to be offered to all customers, the Massachusetts Dept. of Public Utilities has ordered. It would be the most extensive set of electric interruptible rates nationwide—as well as the first interruptible electric rates in the state.

All Massachusetts electric utilities will eventually be told to do the same, DPU chairman Paul Levy told *Electric Utility Week*. Declaring that customers should be offered a range of services at a range of prices, DPU told Boston Ed to file a “menu of prices, with the lower prices having longer and more frequent interruptions than the higher prices.”

Interruptions would come at the point where the utility's marginal cost of providing power exceeded the price that the customer had selected, DPU said in its order (Docket 84-194).

Boston Ed would have to provide information on the likely timing, frequency, and duration of interruptions at each price, “so that the customer could make an informed decision. Customers, of course, would still have the option to receive firm service,” said DPU. Boston Edison would offer no immediate comment on the DPU ruling.

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High temperatures trigger control devices

Temperature-activated load controller senses outside air temperature to control customer air-conditioning units. At a 75% duty cycle, the load shed is about 1 kW per unit; few customers complain

The program initiated at Oklahoma Gas & Electric Co to manage its air-conditioning load has been so well accepted by its customers that the company has had to control customer response rather than try to create it. Through the end of June, almost 65,500 control devices were installed on central air-conditioning units, and this is expected to grow to 80,000 by yearend. The system load reduction from the devices installed so far totals 68.7 MW.

Over two-thirds of the devices are Load Levelers—outside-temperature-actuated control devices at the customers' premises that cycle central air-conditioning compressors. They are manufactured by General Electric Co. The remaining 20,000 devices are radio-controlled units installed in the Oklahoma City area about 1981. All new installations will use Load Levelers.

OG&E serves about 550,000 residential customers, roughly half of whom are eligible for participation in the utility's so-called Peaks program, explains Mike Davis, coordinator of load management. Davis points out that the company goal is to install Load Levelers on 75% (about 200,000) of the eligible customers.

Central air-conditioning systems of 2 kVA or more are controlled for three months—June 15 to September 15. In return for allowing the company to exercise this control, residential customers receive a monthly credit of \$2.62 per kVA controlled. For the average customer, this is about \$10/month for July, August, and September. The credit for other customers is \$1.82/kVA.

Principle of operation

The Load Leveler regulates the maximum duty cycle, the percent-on time, of compressors when the outdoor temperature rises to or above a predetermined level. It returns the compressor to normal indoor thermostat control when the outdoor temperature falls below the set point, explains Mike O'Day, sales engi-

neer. Refrigeration & Air Conditioning Control Sales in GE's Appliance Control Dept. The device's operation is based on the principle that a utility's system load curve is temperature-dependent during the summer and winter peak-load periods (Fig 1).

The device operates on a 30-min time base and keeps the compressor on for a specified period of time. Thus, for a 75% duty cycle, O'Day observes, the compressor is on for 22½ minutes and off 7½ minutes. The outside control temperature and duty cycle are preset at the factory, following consultation with the user utility. In OG&E's case, the set points are 95°F and 75% duty cycle. Typically, OG&E's service area experiences about 200 hr/yr at or above 95°F.

Operating the leveler on a 30-min base also assures good humidity control, O'Day points out. As for temperature, he says, studies of typical homes during 75%-duty-cycle control periods shows a rise of 2° to 3°F above normal room

temperatures if the home has a high insulation level and a high unit capacity, and a rise of 3° to 5°F if the home has a low insulation level and a low capacity.

O'Day notes that this temperature rise generally is not objectionable. OG&E's Davis agrees. "Most customers," he says, "report that they can't tell when the control devices are working and when they are not. Needless to say," he adds, "they like the reduction in their electric bills." Davis observes that during tests conducted by OG&E, the use of a 50% duty cycle raised strong customer objections, and this duty cycle was discarded.

Last March, Davis says, a test was made of customer response to the Peaks program. It used TV, radio, newspaper, and direct-mail advertising. During this one-month period, customer requests for installations rose from 3,213 per month to 6,607. As a general rule, he explains, only direct mail to a specific area has been used, to produce an average installation-request rate of 3,000 per month.

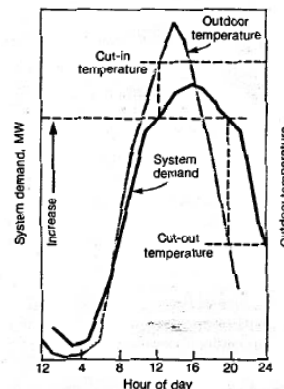
OG&E uses electrical contractors to install the load-control devices. The cost to OG&E is \$25 per device.

Load Levelers have proved to be very reliable and few installation problems have occurred, Davis reports. OG&E does not impose any customer penalty for device removal during the first year of use. With this liberal policy, only 1.6% of the devices have been removed since the start of this program.

Other utilities

The Municipal Electric Systems of Oklahoma (MESO), a statewide municipal association, conducted a feasibility study of load-management systems, says Shane Woolbright, its executive director. He says it recommended that temperature-activated devices be used to control peak loads. As a result, five cities have installed Load Levelers, and he expects 15 to 20 additional cities to follow this lead next year.

The five cities—Burlington, Goltry, Waynoka, Anadarko, and Laverne—use a total of about 500 control devices set at 95°F and operated on a 75% duty cycle, just like OG&E. In fact, says Woolbright, MESO had the benefit of reviewing OG&E's program. The cities hire



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ENERGY MANAGEMENT

Eugene F. Gorzelnik



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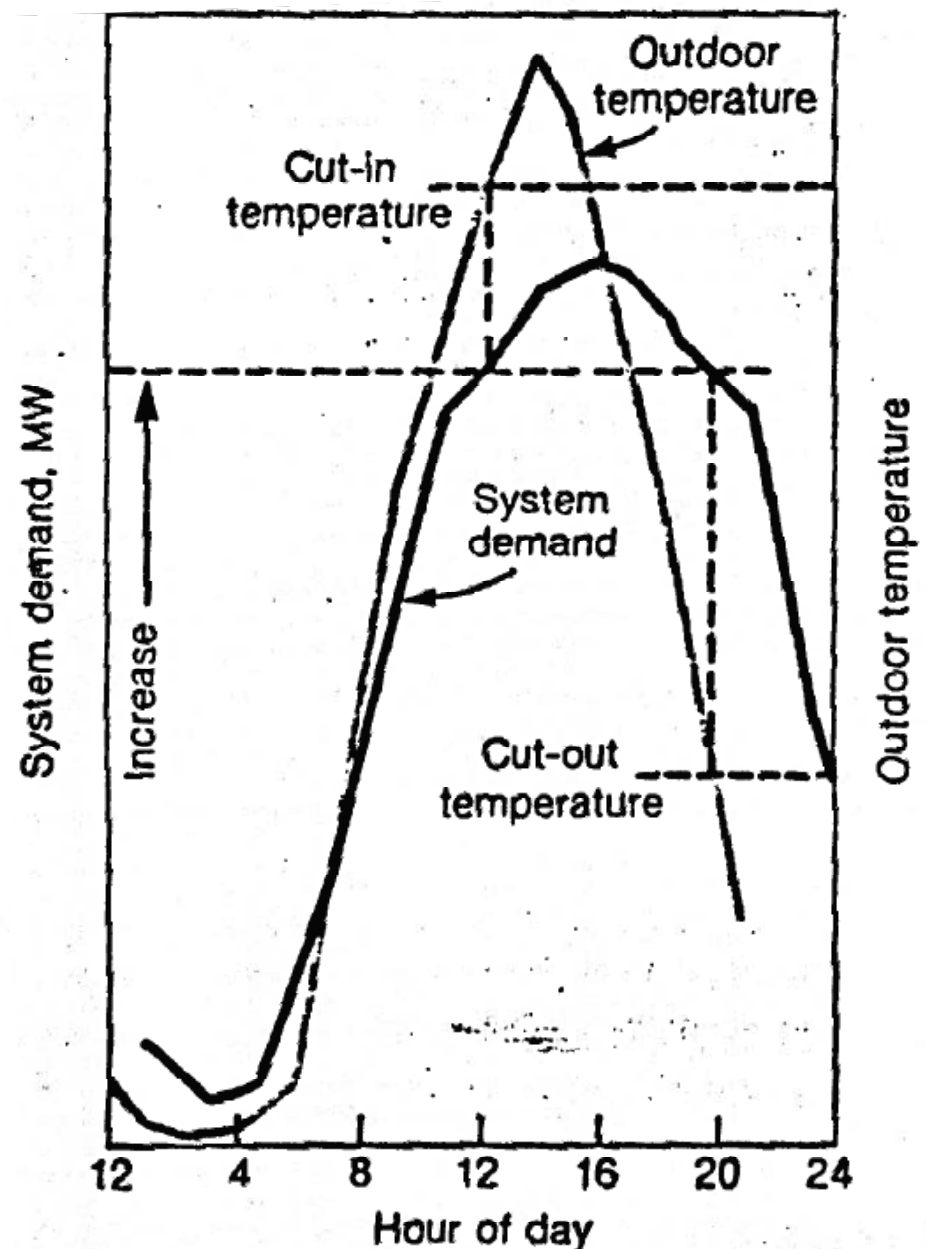
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Electrical World, August 1984

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ENERGY MANAGEMENT

Data link enhances energy, other services

An advanced in-home communications system now being developed and tested in Georgia will provide customers with real-time access to home energy-management services and a test of spot electricity pricing. It also will provide many other in-home electronic services, such as banking, shopping, and security.

Next month, the first of 200 homes in Roswell, Ga., a suburb of Atlanta, will begin field testing of Integrated Communication Systems' (ICS) advanced in-home communication system, called TranstexT. Cornerstone of the ICS system is its ability to improve the efficiency of home-energy consumption, and to give customers greater control over their monthly electric bills.

The system (EW, November 1984, p 12) is characterized as a premium, value-added network that integrates a microcomputer operating system and interactive program language with a digital network protocol, and permits interfacing of voice and data simultaneously over a touch-tone phone, cable, and electric power wiring (Fig 1). It uses common household devices, such as telephones and electrical appliances, to provide customers with new options and better overall control of their environment. TranstexT can also be used to facilitate a wide assortment of in-home information services, such as home banking, electronic shopping, personal security, and educational services.

The utility/data-delivery system is controlled by a "gray box" located adjacent to the electric-service entrance in the home, and connected to the phone and power circuits. The "gray box" contains a backup battery and printed-circuit-board slots, where each of the fundamental service providers plugs in his own PC cards carrying the service-related electronics.

At the center of the TranstexT network is BellSouth's PulseLink data network. PulseLink provides a high-quality data link over existing telephone wires while normal telephone calls are in progress, without interfering with either the voice or data channels.

ICS is a research and development consortium that includes The Southern Co., the holding company for Georgia Power Co., which serves the Roswell area, BellSouth Corp., Westinghouse Electric Co., Control Data Corp., Dow Jones & Co., General Telephone, America District Telegraph, and National Data Corp. The Southern Co. is expected

to invest about \$2.6-million in ICS, and to hold an 18% equity position.

The mission of ICS, Paul Spaduzzi vice president, business development, told a recent Southeastern Electric Exchange marketing meeting, is to accelerate the implementation of ICS nationwide and to differentiate TranstexT from would-be imitators. He added that it will do this by maintaining a superior technical support organization and a strategic business planning group, and creating a commercial infrastructure for local operating consortia (LOC), in which local electric and other utilities, telephone, and cable-TV companies can own and operate TranstexT systems in their respective markets. ICS, he continued, will supply hybrid systems technology and product development to the LOC, and support development of service applications to stimulate demand.

To effect a national implementation of TranstexT, Spaduzzi said, ICS established a participation-development program (PDP), to identify organizations that would like to know more about ICS and its Atlanta field test, and to serve as a forum for more extensive participation in the commercial possibilities. Participation in PDP, he said, allows an organization to monitor the deployment of TranstexT, to obtain significant data on customer perception and usage patterns,

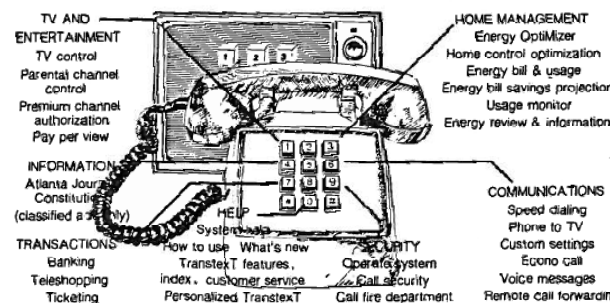
to establish a solid basis for future decisions, and to begin to evolve its own strategies. The fee is \$60,000.

Spot pricing

Georgia Power, says James Callahan, manager of retail market application, has received PSC approval to conduct a two-year spot pricing experiment starting this month. He explains that the price of electricity, which customers in the TranstexT experiment will pay, varies with GP's system lambda—the incremental cost of producing the next kWh. To assist the PSC in making its decision to allow the test, GP supplied it with a 12-month estimate of system lambda.

Under the Variable Spot Price-1 rate approved, customers will be charged a base charge of \$4/month. When the system lambda is under 24 mills/kWh, the price of electricity will be 0.4¢/kWh, plus a fuel-cost adjustment charge. Currently, this charge is about 2¢/kWh, and is not expected to change significantly in the foreseeable future. If system lambda is 24 to 29 mills, the charge will be 3.2¢/kWh plus the fuel charge, and if it is over 29 mills but under 40 mills, it is 9.7¢ plus fuel. Over 40 mills, the critical hours, the charge is 16¢/kWh plus fuel. The critical hours will not exceed 1% of the time.

In picking customers to act as volunteers for the test, Callahan explains, GP set certain mandatory criteria, as well as desirable criteria. All customers, he says, must have electric air conditioning and color TV, and must use over 12,000 kWh/month. Desirable criteria include



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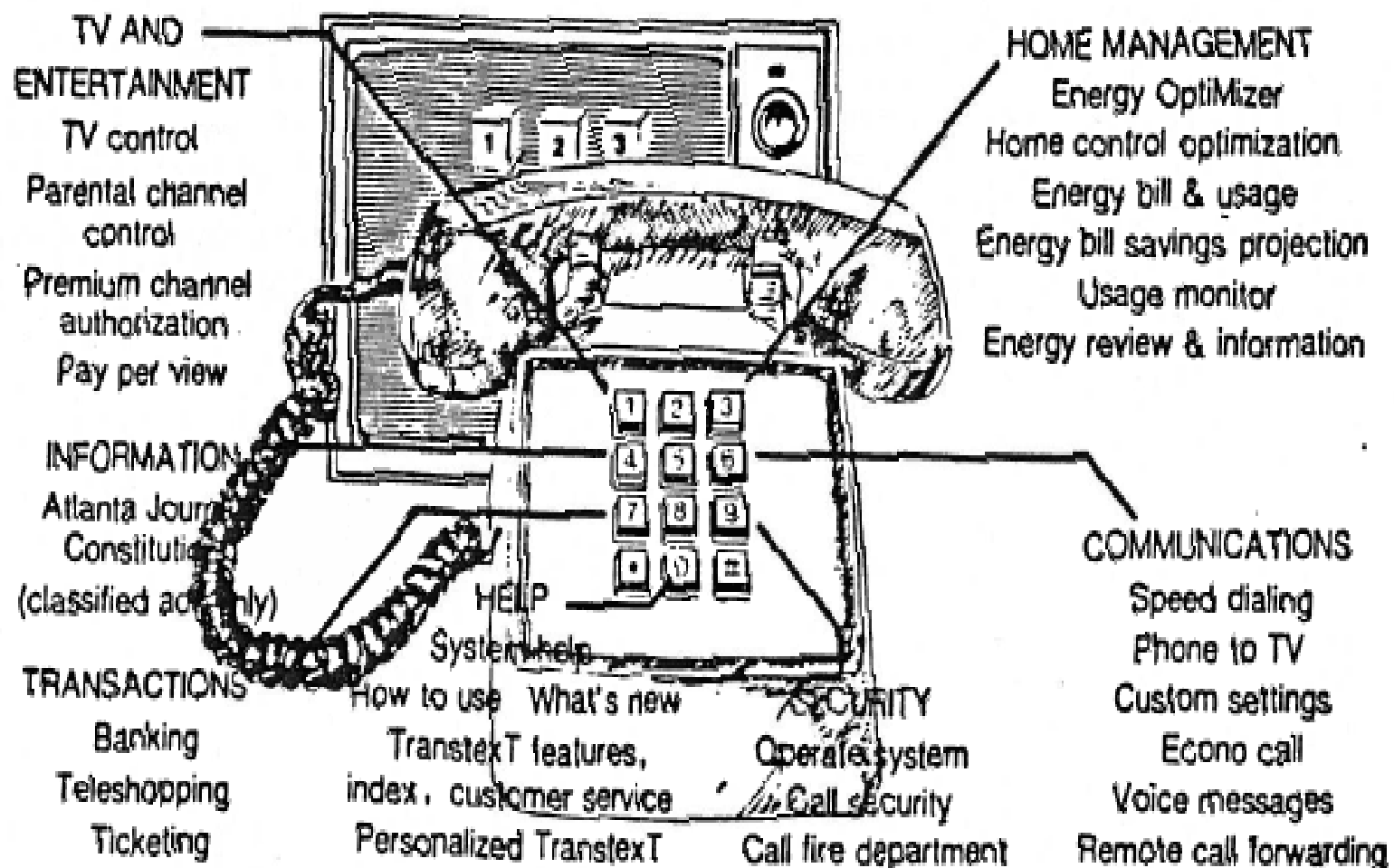
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Electrical World, January 1985



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Electrical World, January 1985

Table 2.1 Pacific Gas and Electric Company Price Schedules

Type	Fixed	Demand		Energy Charge			Limits			Penalty	
	Chg. \$/Mo.	Peak \$/kW	Max	Peak	Shldr Cents/kWh	Offpk	Warn Min.	No.	Dur. Hrs.	1st	2nd \$/kW
Firm Service:											
A1				10.404	10.404	10.404					
A6				24.895	12.447	6.473					
A10	50		2.85	8.658	8.658	8.658					
A11	50	8.10	2.85	12.746	10.197	5.405					
E20	100	8.10	2.85	7.633	7.269	4.264					
Curtailable Service (E20):											
A	290	4.87	2.85	7.631	7.266	4.265	60	15	50	3.11	6.23
B	290	3.04	2.85	7.626	7.261	4.264	30	30	100	4.89	9.79
C	290		2.85	7.494	7.136	4.226	10	45	200	8.45	16.90
Interruptible Service (E20):											
A	300		2.85	6.886	6.557	4.128	60	15	50	11.12	22.24
B	300		2.85	6.392	6.088	4.036	30	30	100	13.34	26.69
C	300		2.85	5.701	5.428	3.908	10	45	200	16.46	32.91



Fishing for
a way to reduce
the cost of
your electric
service?

Southern California Edison Company **SCE**



You have the power to reduce the cost of your electric service.

Now, just by agreeing to occasionally reduce your electrical demand, Edison will give you a monthly credit toward your electricity bill — whether you are asked to reduce demand or not!

As a participant in Edison's Interruptible Service Program, you can save up to 60 percent off your on-peak demand charges each month.

By agreeing to reduce all or a portion of your electric load during periods of capacity shortage on Edison's system, you will receive a monthly credit based on how much load you agree to reduce. The more load reduced, the larger the credit. This credit is given every month, whether or not load reductions are requested.

Who can participate?

The program has been designed for large commercial and industrial customers with more than 500 kilowatt (kW) demand. More than 20 such customers currently participate in the program, with interruptible loads ranging from 1000 to 40,000 kilowatts.

Typically, these customers are rock and gravel mining operations, industrial gas producers and steel foundries. However, many types of commercial and industrial operations, ranging from cotton gins to computer centers, can benefit from this program.

How does the program work?

When Edison identifies a need to reduce demand on the system, notification equipment alerts you to the need to reduce your use of electricity to a pre-determined level.

Since automatic switching is *not* done by Edison, you retain full control of your operation. It is up to each program participant to reduce load within 10 minutes to 2 hours, depending on the rate and schedule being used.

If you have on-site emergency or auxiliary generating equipment, you may transfer the load you are reducing to this equipment and maintain isolated service during the period of requested reduction. The effect is the same on the Edison system — demand for electric power is reduced. You would be expected to comply with all air pollution control requirements affecting the installation of auxiliary generating equipment.

When the period of reduction is terminated, participants are notified to return to normal operations. The program is designed to be fail-safe in your favor. If there is a communication failure, the system will automatically terminate the interruption period.

You determine the degree to which you wish to participate in the program. However, if you do not reduce your load to the contracted level, excess demand charges will be assessed ranging from \$20 to \$80 per kW, depending on the number of periods of non-performance.

How your credit is determined.

While the details of each interruptible rate are different, the overall operation of the program is the same for each tariff or schedule. When you agree to reduce load to a pre-determined level at Edison's request, you receive a monthly credit based on your monthly maximum on-peak period demand value.

The following chart outlines available schedules and rates:

Interruptible Schedules

Monthly Billing Credits	I-2	I-3	I-4
10-minute rate	\$3.10/kW	\$1.50/kW	\$1.00/kW
30-minute rate	2.60/kW	1.00/kW	.50/kW
2-hour rate	—	.50/kW	.00/kW
Additional if interrupted during month		3.00/kW	2.50/kW

The number of periods of interruption will not exceed an average of 15 times or 180 hours per calendar year over a five-year period (except for Schedule I-4, which is for one year).

Conversion to this service does require a one-time fee of approximately \$15,000 to cover telecommunications and load monitoring equipment needed to implement the service. You may pay this fee directly or, in most cases, apply credits earned through the program toward the fee.

As an example, using Schedule I-2 on the 30-minute rate from the chart, if your monthly on-peak demand is 1,500 kW and you agree to reduce demand to 500 kW within 30 minutes of being requested to do so, that 1,000 kW of interruptible load would earn a monthly credit of \$2,600 (1,000 kW x \$2.60/kW). Applying this credit toward the equipment connection charge would make the payback period only 5.7 months.

Is this program right for you?

Before you volunteer for the Interruptible Service Program, you should estimate your costs associated with an interruption. Will product be lost? Will a service you provide be interrupted? Can you reduce load in time? Will you have to pay employees who are not being productive?

In addition, you need to consider if this program is to your advantage. If you can shift operations with heavy electrical load to mid- or off-peak periods, your savings may be greater than savings from the Interruptible Service Program. Perhaps one of Edison's air conditioner cycling or other load management programs would be more beneficial to your operation.

How do you learn more?

An Edison energy services representative will be happy to discuss

Interruptible Schedules

Monthly

Billing Credits

	I-2	I-3	I-4
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Offered to commercial and industrial customers with load > 500KW

Best time to contact me is: _____ a.m./p.m.

Signature of owner/manager, if approval needed.

“Read this. I’d like to see you get up to \$165 just by signing up for Air Conditioner Cycling.”

—George Burns

If you have central air conditioning, you can save money on your summer electric bills by participating in the Air Conditioner Cycling Program.

This program helps slow the growing demand for new power plants. When business and industry are in full production and residential customers are using electrical appliances and air conditioners, the demand

for electricity reaches peak levels. Air Conditioner Cycling helps manage the growth of peaks and reduces the need to build new power plants.

Here’s how the program works.

By choosing to participate in the new Air Conditioner Cycling Program, you’ll get a credit toward your

THERE ARE THREE SAVINGS OPTIONS.		EXAMPLES*		TOTAL SAVINGS OVER 6 SUMMER MONTHS.			
SAVINGS OPTION	MONTHLY SAVINGS FOR EACH TON OF A/C	2.5-TON UNIT	3-TON UNIT	3.5-TON UNIT	4-TON UNIT	4.5-TON UNIT	5-TON UNIT
A—off full time cycling is in effect	\$5.50	\$82.50	\$99	\$115.50	\$132	\$148.50	\$165
B—off 10 min. out of each 15 min. period	\$3.00	\$45	\$54	\$63	\$72	\$81	\$90
C—off 7½ min. out of each 15 min. period	\$1.50	\$22.50	\$27	\$31.50	\$36	\$40.50	\$45

*Any size electric central air conditioner or heat pump in good working condition qualifies for this program.

AIR CONDITIONER CYCLING PROGRAM

Background

- **Experimental Programs**
 - **Automatic Powershift, Residential 1977-1981**
 - **Automatic Powershift, Commercial/Industrial 1979-1981**

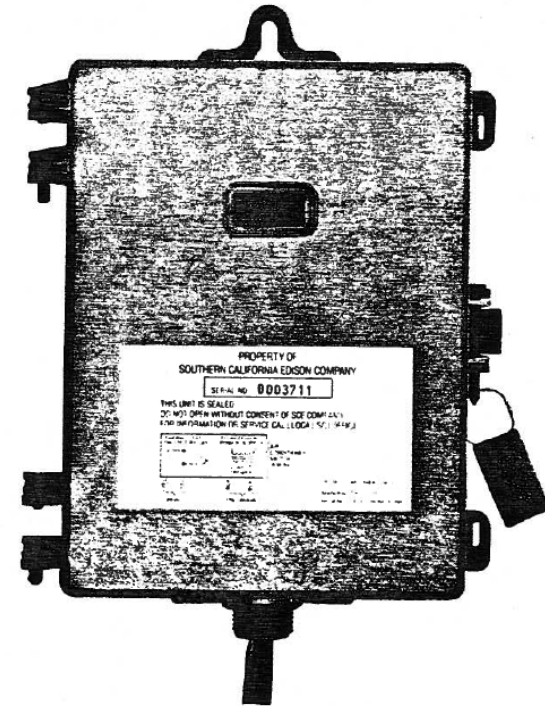
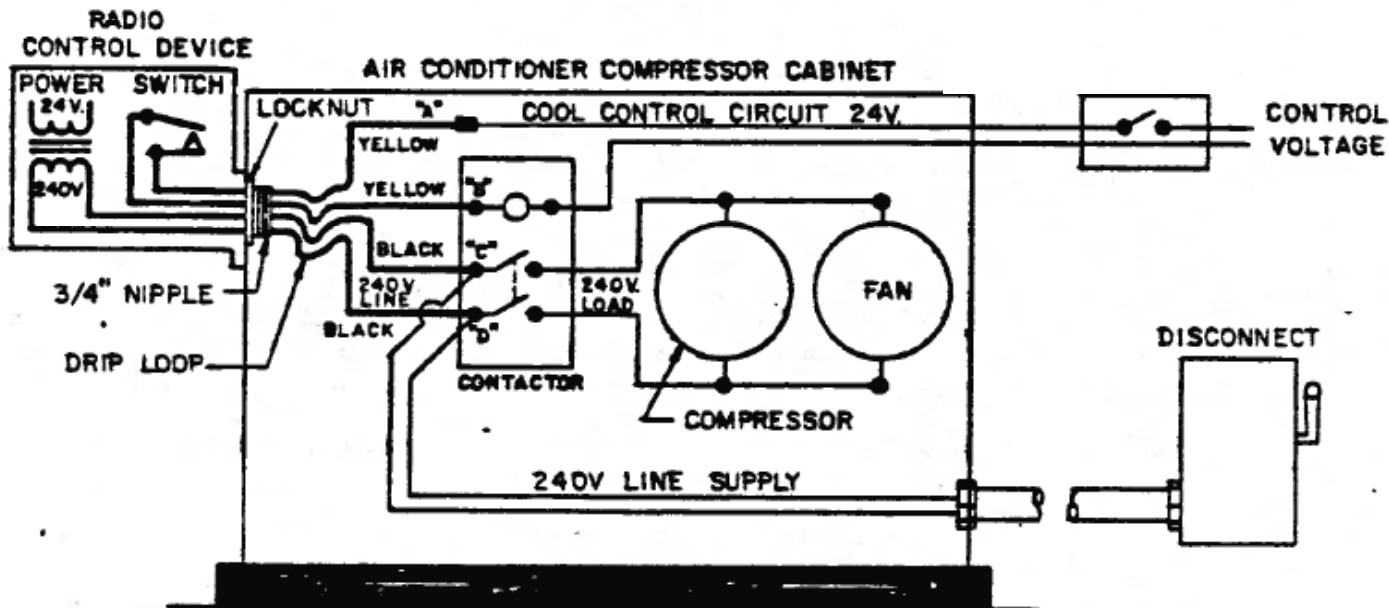
Objectives

- **Reduce Demand During System Capacity Shortage**
- **Established As A Part Of Our Resource Plan**
- **130 MW By Year End 1984**
 - **Residential = 114 MW**
 - **Commercial/Industrial = 16 MW**

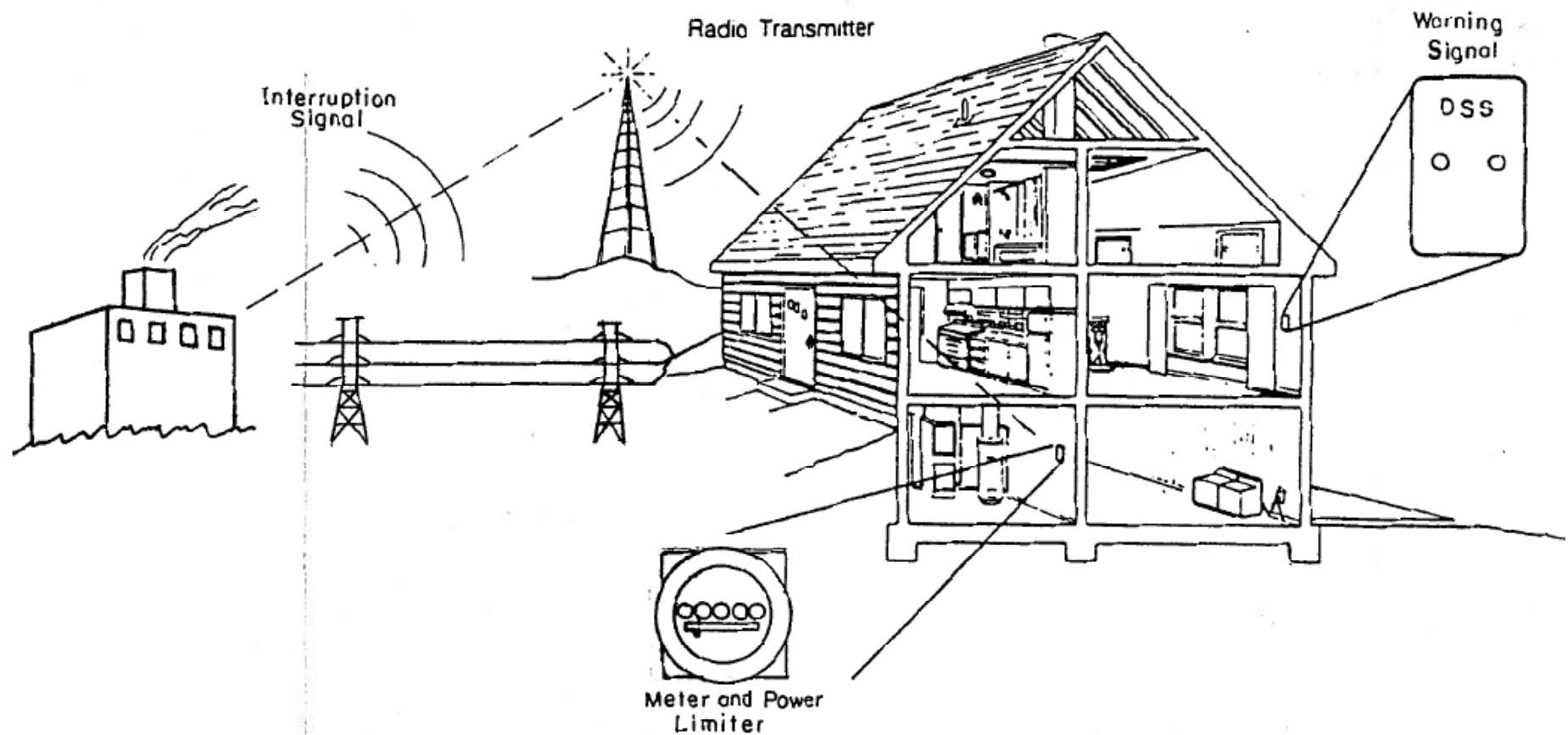
Scope

- **Voluntary Program**
- **Various Strategies And Rate Incentives (attached)**
- **Goal - Install 65,000 Devices By Year End 1984.**

LOAD MANAGEMENT CONTROL DEVICE



Demand Subscription Service



Demand Subscription Service: Radio controlled fuse limits customer's power supply to his subscribed level.

DEMAND SUBSCRIPTION SERVICETM_{SM}

To Restore Your Electrical Service You Should:

- 1.** Immediately turn off or unplug all electrical appliances and devices which may create a hazard if they are restored to service without supervision.
(Examples: electric irons, mixers, fans, workshop equipment and other such household appliances.)
- 2.** Turn off a sufficient number of electrical appliances and devices to reduce your demand for electricity to your Level of Service.
- 3.** Push the "Reset" button which is located on bottom left side of your Demand Subscription Service Device.

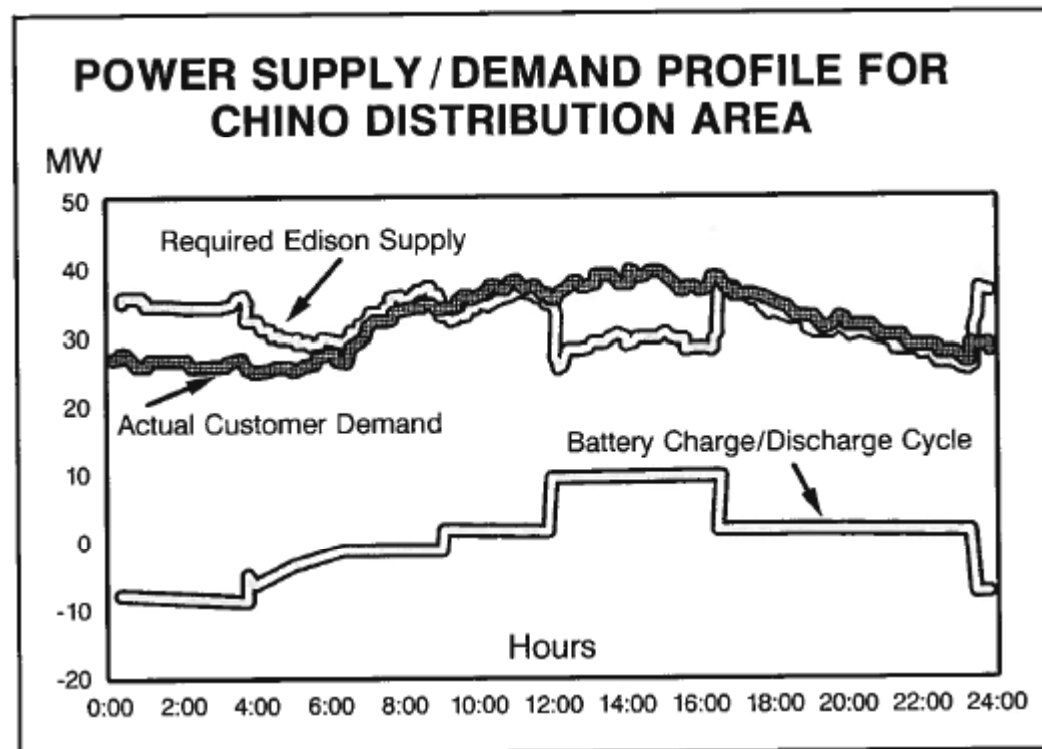
If you are unable to restore your electrical service, or if you experience any difficulties with your Demand Subscription Service Device, call _____ and identify yourself as a Demand Subscription Service Customer.

Southern California Edison

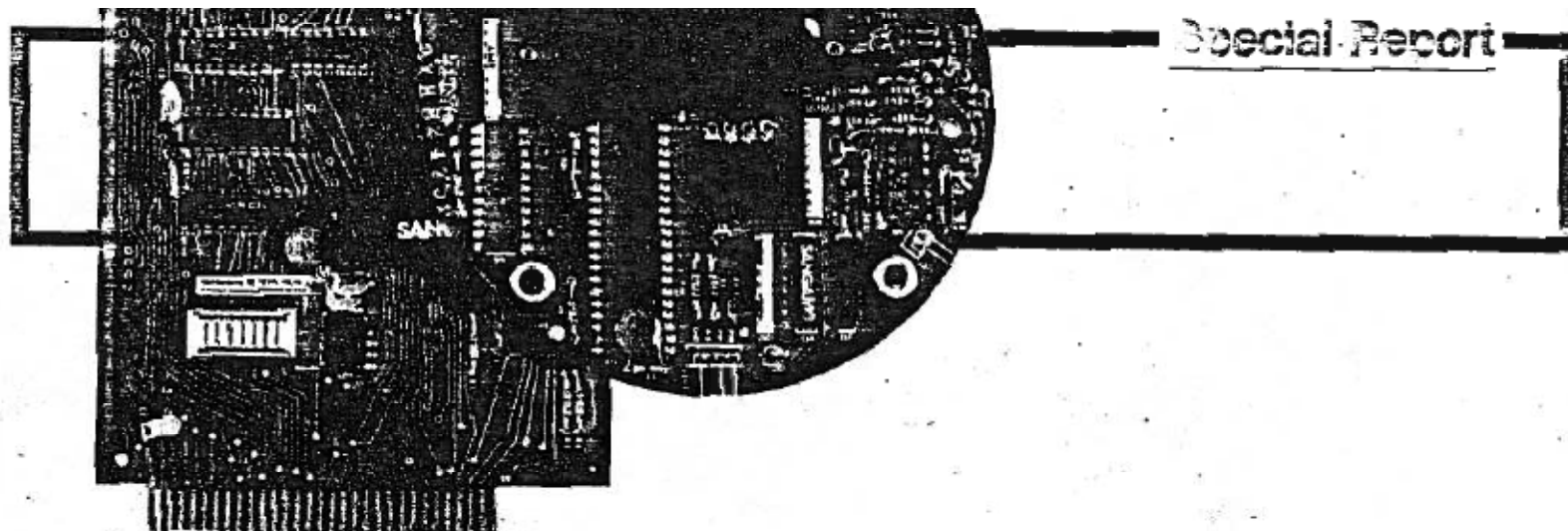


The World's Largest Battery Energy Storage Facility Now On Line

The 10 MW/40 MWh Chino Battery Energy Storage Facility has been completed and its two-year demonstration test plan has begun. Already, the plant has achieved its full power rating and has helped to lighten Edison's peak load.



Southern California Edison, Research Newsletter, 4th Quarter, 1988



Electronic meter carves a niche for itself

By Eugene F. Gorzelnik, Senior Editor

The explosion in the knowledge and availability of electronic devices in all areas of human endeavor in the 1960s and 1970s has triggered signifi-

This report is limited to examining the forces that have been and are shaping the face of the electric meters of today and tomorrow, and the direction in

measures and integrates the current and voltage, including any waveform distortions caused by harmonics that a conventional meter can miss, and stores the

Electrical World, January 1983

NetComm — Origins, Progress, Plans for the Future

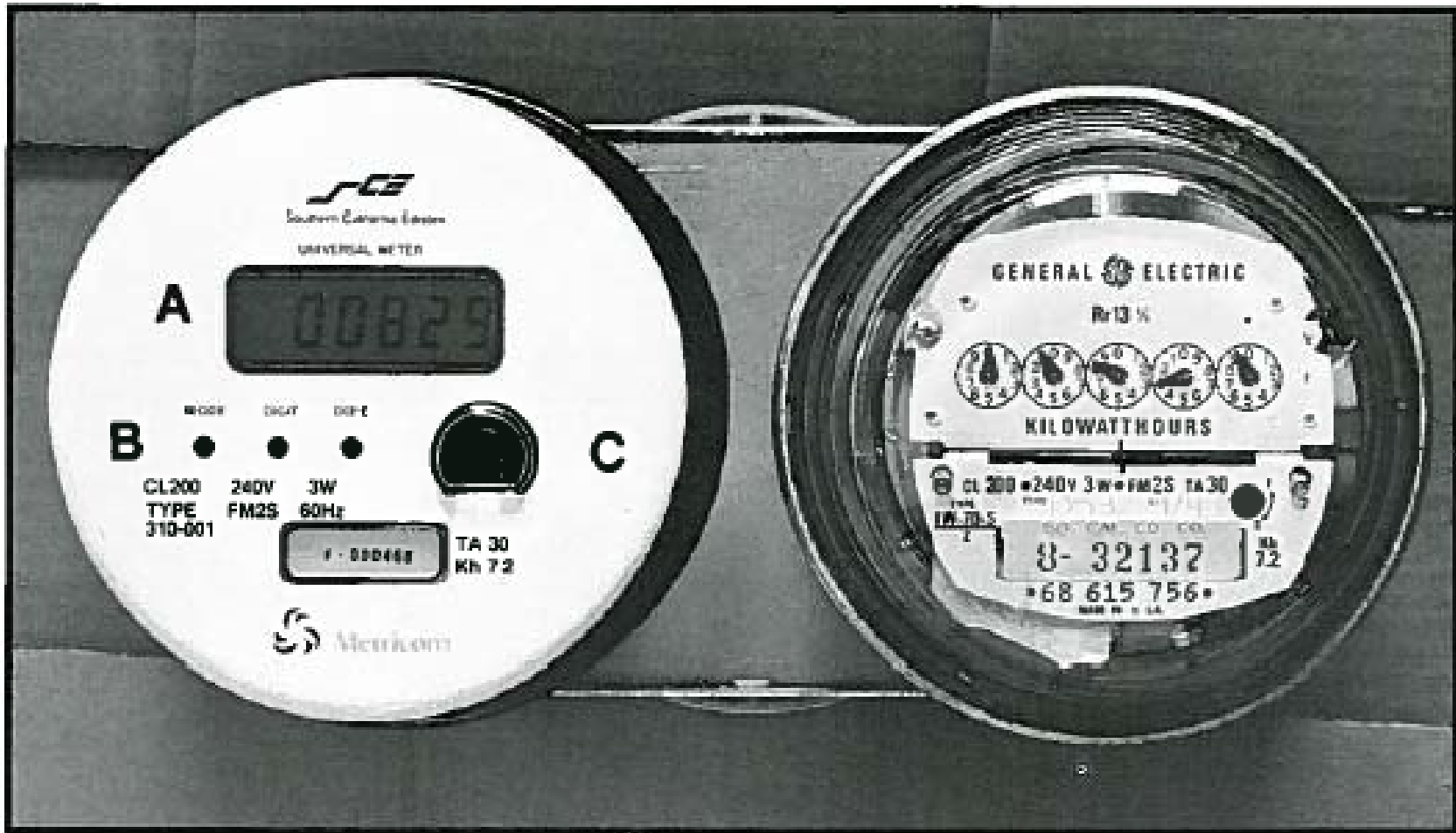
This special issue of *Research Newsletter* is entirely devoted to **NetComm**, a high-priority project of Southern California Edison's Research Division. NetComm links customers' electronic meters to utility computers via a network of high-frequency radios to perform a variety of metering, monitoring, and diagnostic functions. NetComm's two-way communication capabilities will allow Edison to offer a more cost-sensitive rate structure and will allow the customers to make price-conscious choices regarding electrical consumption. NetComm's innovative technology is currently undergoing field testing in Edison's Valencia District with future applications planned for the 1990s.

The NetComm (for **Net**work **Comm**unications) Project began in the fall of 1986 when Southern California Edison's Research Division received an unsolicited proposal from a start-up Silicon Valley electronics firm called Metricom, Inc. (Figure 1). That proposal held the potential to deliver three important system improvements that Edison had long sought: accurate electronic meters, time-of-use rates through two-way communication with the customers, and the ability to perform a number of distribution automation functions.

The NetComm project was conceived as an ambitious undertaking. Its potential effects on improving the quality of customer services and distribution automation are far reaching. Ultimately the NetComm system will consist of new all-electronic meters, new distribution sensors and control devices, and one or more computers



Continued on Page 2



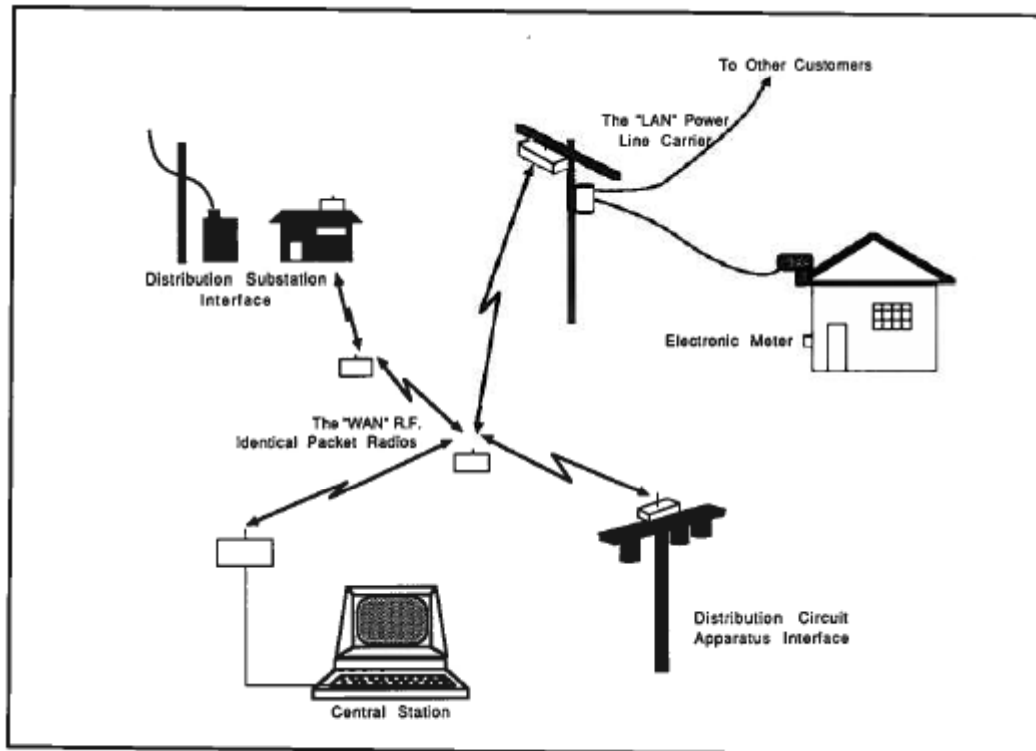
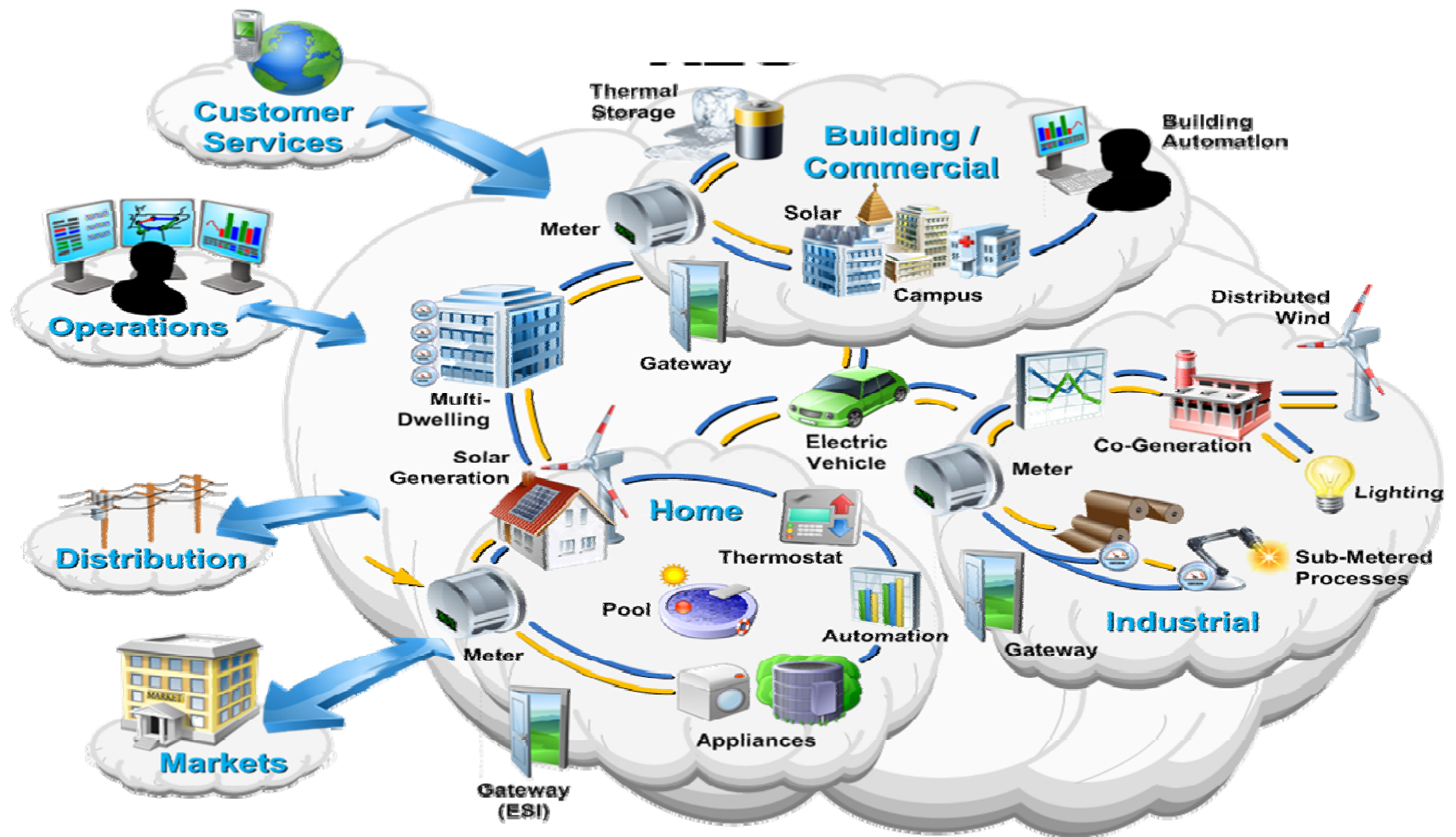


FIGURE 3: This schematic of NetComm's sophisticated communication capabilities shows how various control, monitoring, and communication functions can be performed from central or field locations.

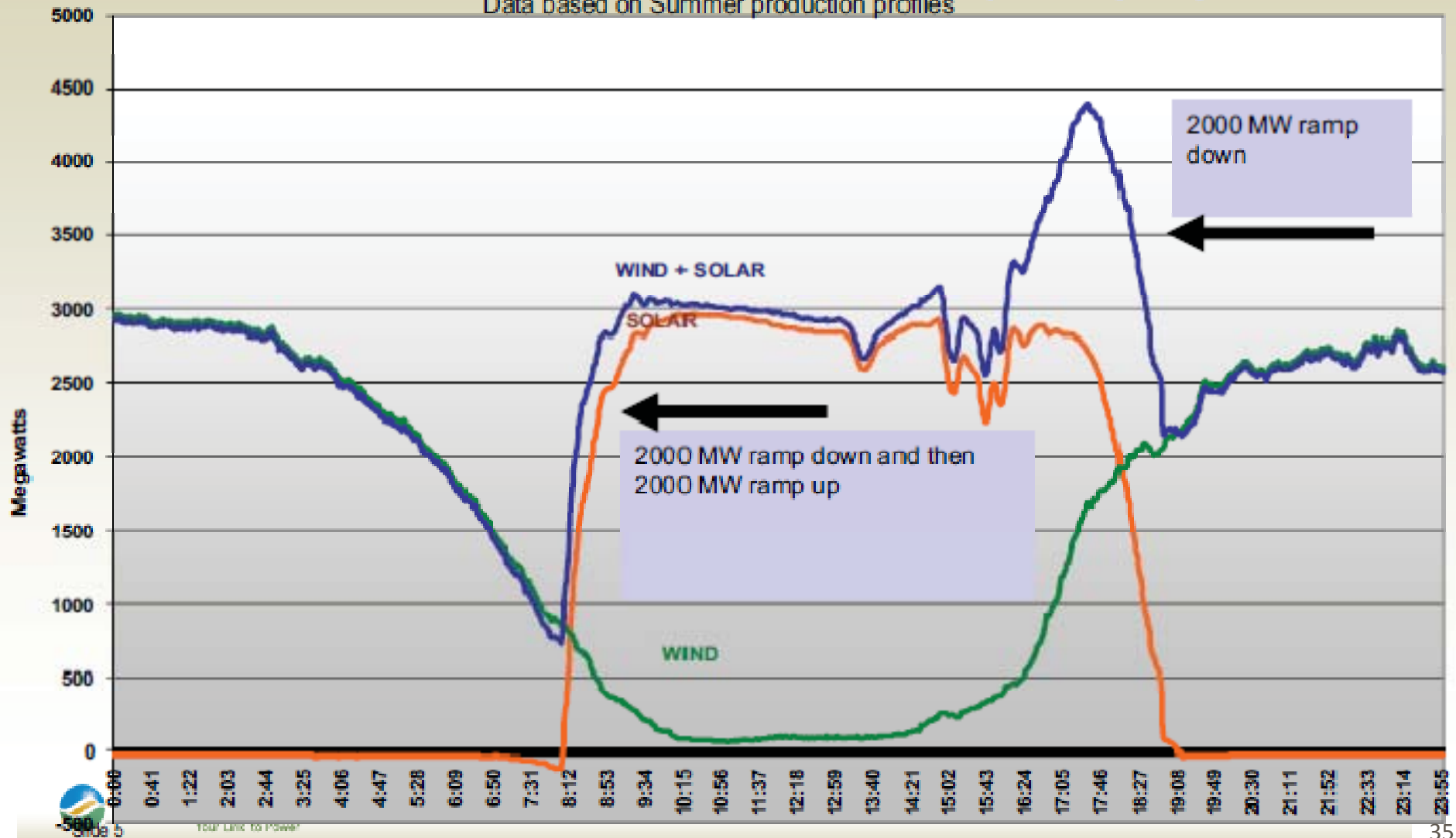
Future Electricity System



Example of ramping challenges at ~20% RPS

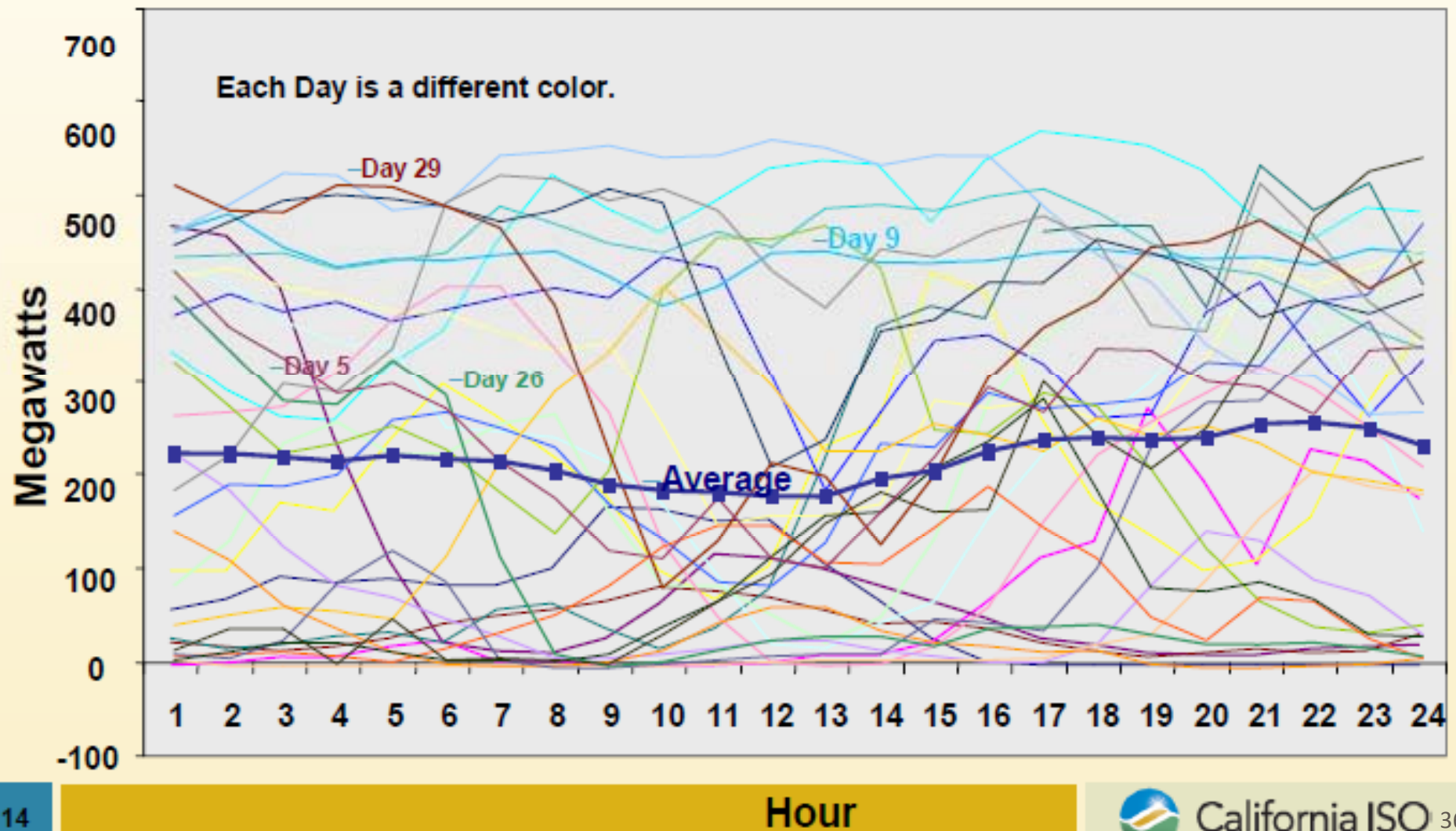
4000 MW SOLAR and 6000 MW WIND Nameplate Capacity

Data based on Summer production profiles



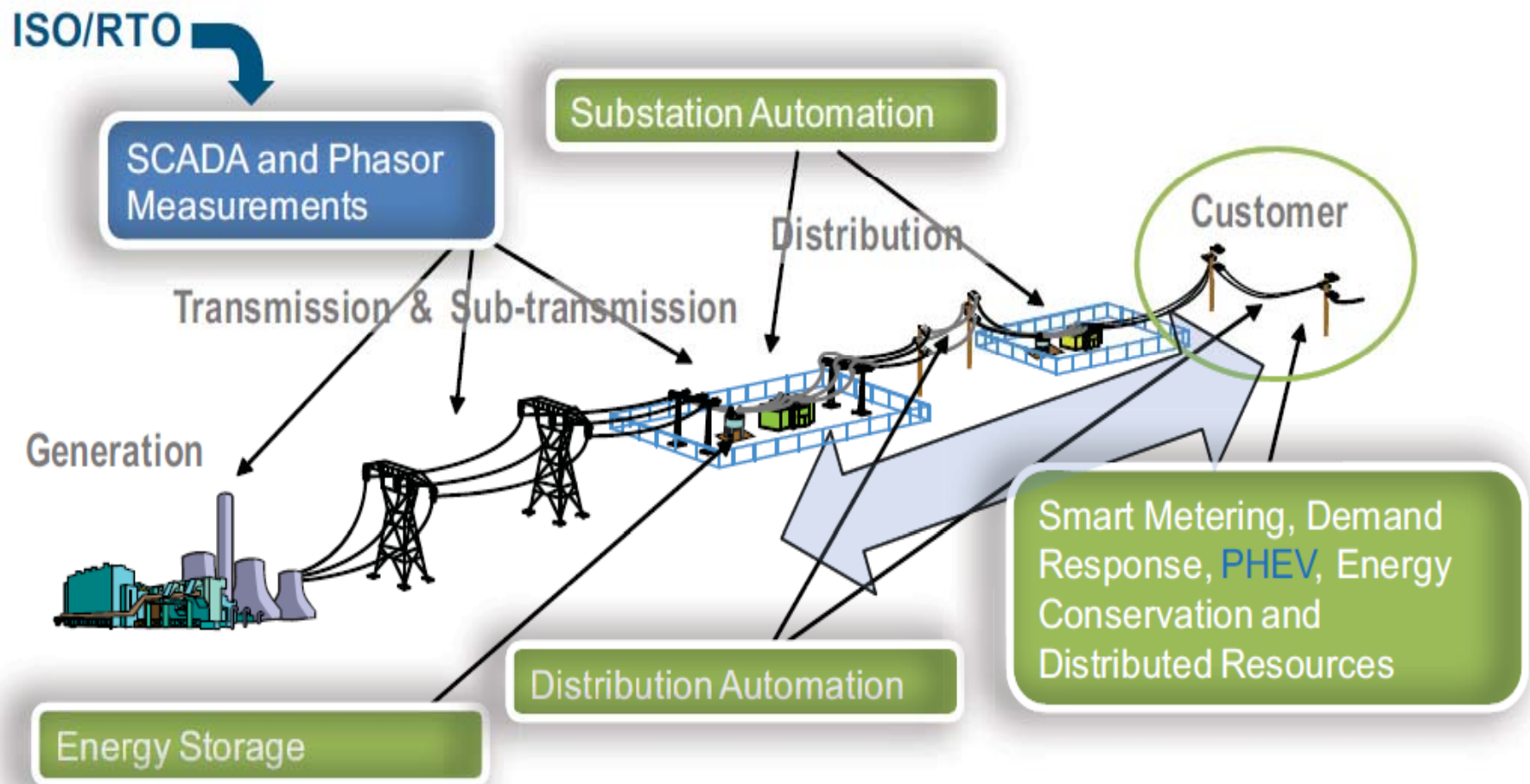
Tehachapi Wind Generation in April – 2005

Could you predict the energy production for this wind park either day-ahead or 5 hours in advance?



Making the Grid Smart

Two-Way Communication and Control



General Observations About Demand Response

- ❑ While today's metering and control technology is cheaper, technology was never a barrier to implementation of demand response
- ❑ The focus has been (as now) on demonstration of capability, rather than on developing a business model that will facilitate implementation.
- ❑ The key elements to making demand response a reality are:
 - A regulatory framework
 - Institutional structure
 - A sustainable business model that will incentivize customer choice at the retail level

Economic *Paradigms for Demand Response*

- ❑ Provide real time prices to retail customers
 - Politically objectionable
 - Customers do not like and are not used to price uncertainty
 - While RT price response can be automated it still puts the burden on the customer
 - Treating electricity as a commodity works well at wholesale level but retail customers would rather think of electricity as a service
- ❑ Provide quality differentiated service based on contracted load control options.
 - Quality differentiated service and optional price plans are common in other service industries (air transportation, cell phone, insurance)
 - Customers have experience with choosing between alternative service contracts
 - Customers prefer uncertainty in service rather than uncertain prices

The Challenge

- ❑ Need Business model and economic paradigm for a utility or third party aggregator to bridge the gap between wholesale commodity market and retail service
- ❑ Aggregated retail load control can be bid into the wholesale markets for balance energy and ancillary services.
 - Load control through direct device control (thermostats, airconditioners, water heaters, EV battery charge)
 - Intrusive
 - Faster response enables higher valued products (e.g. regulation)
 - Or control of power through the meter with customer dynamic control of allocation to devices in the home.

PRIORITY SERVICE METHODS

PRISM

ELECTRIC POWER RESEARCH INSTITUTE

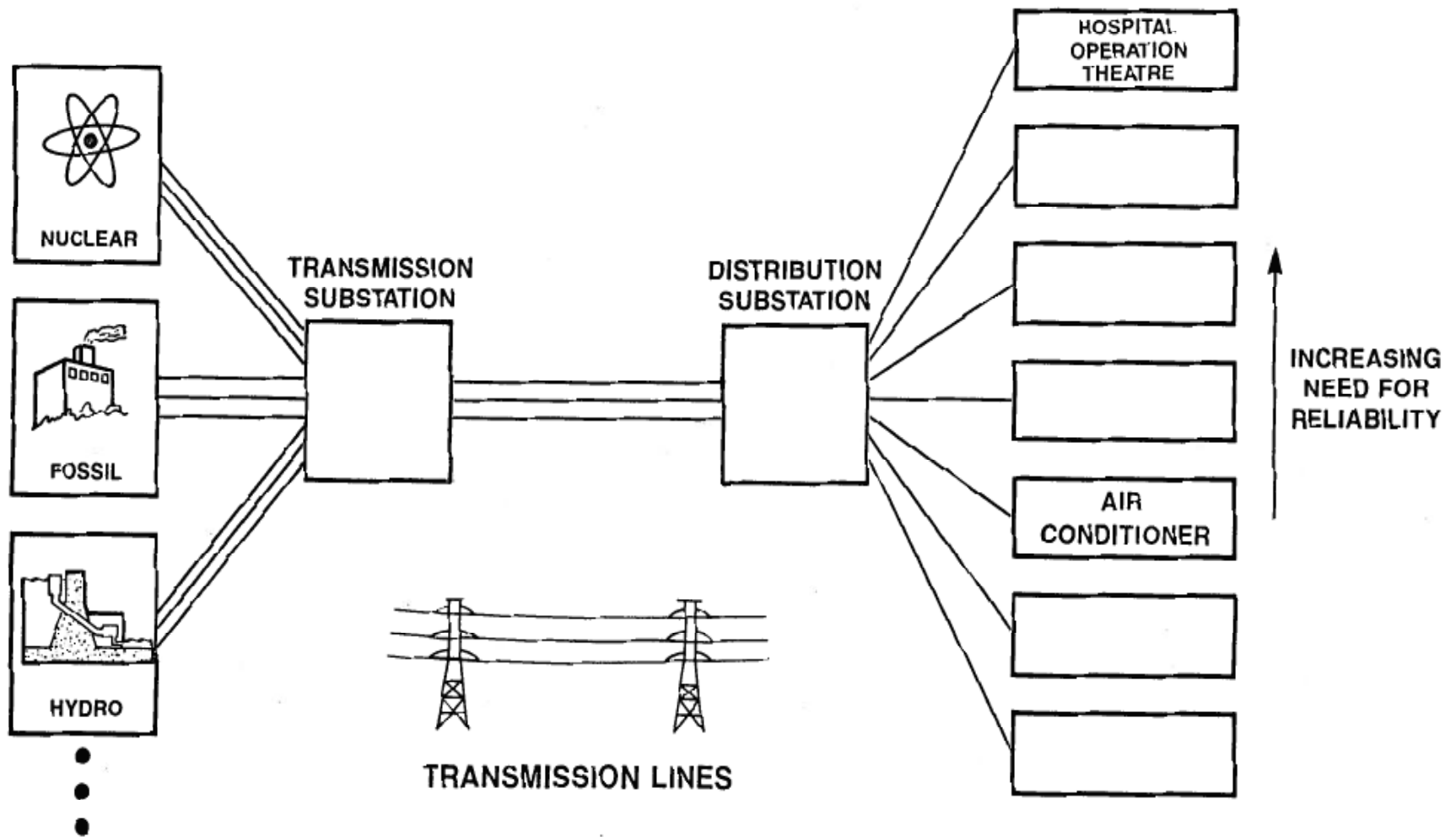
1982-1990

AN OVERVIEW OF THE ELECTRIC POWER SYSTEM

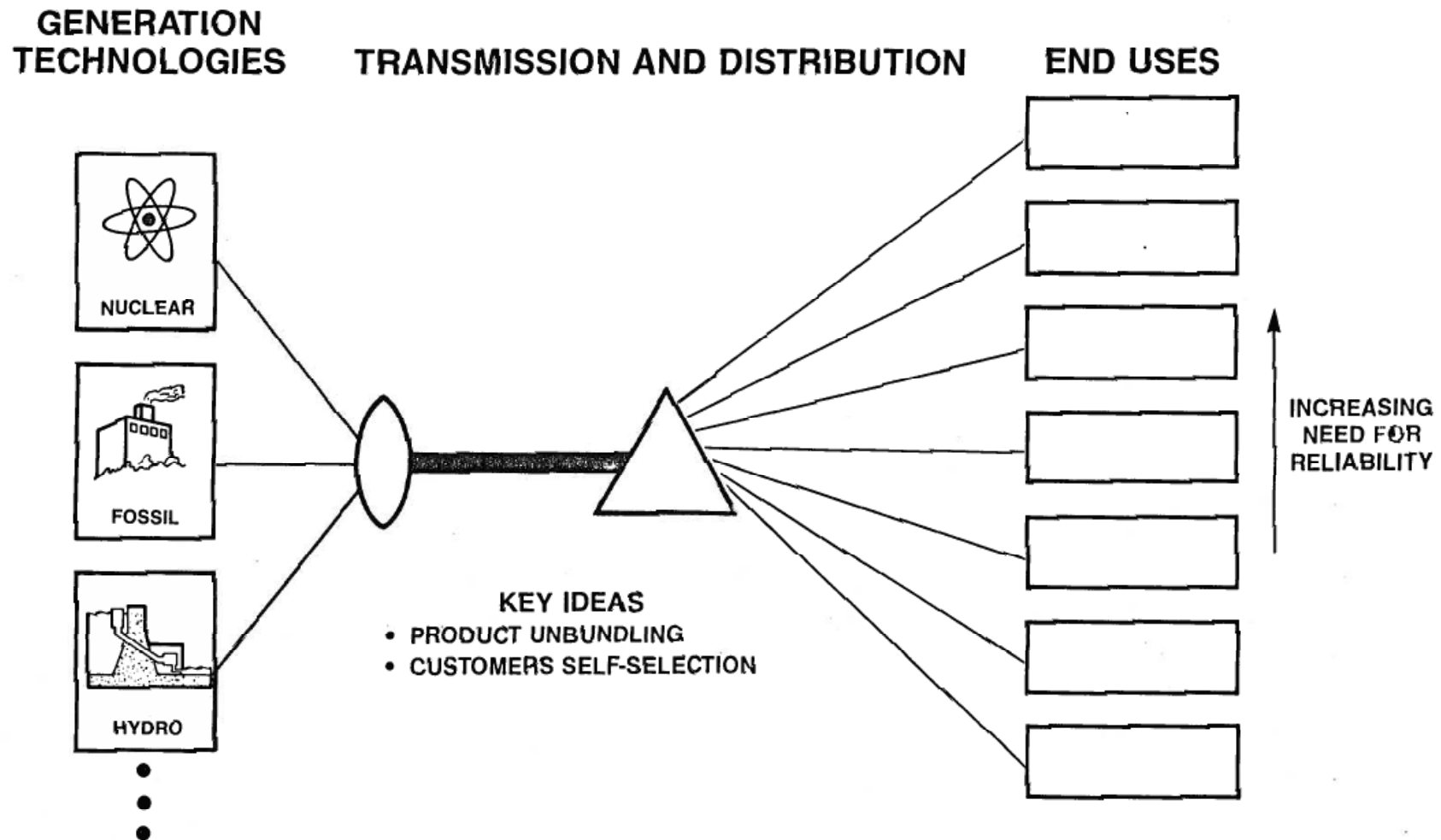
GENERATION TECHNOLOGIES

TRANSMISSION AND DISTRIBUTION

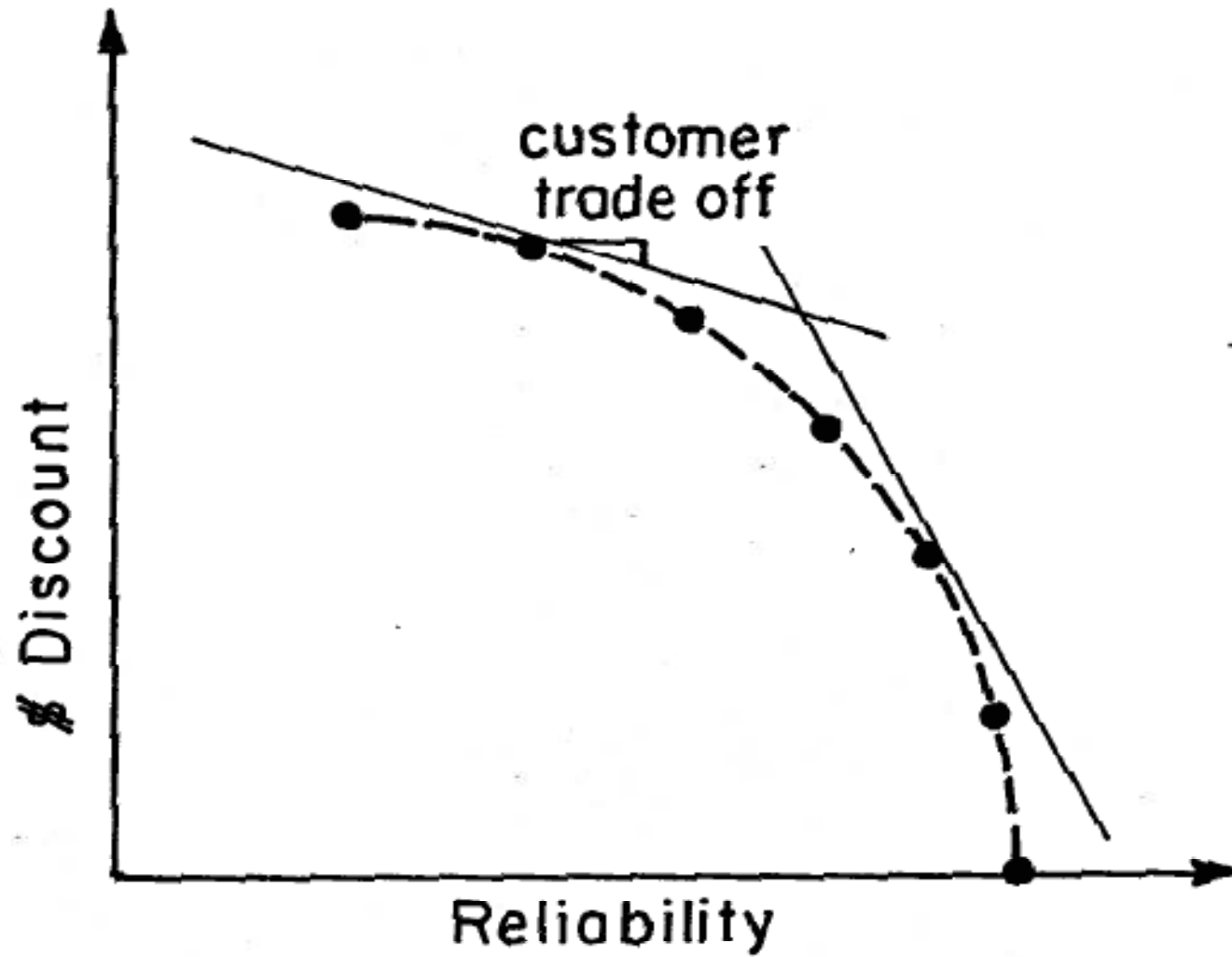
END USES



PRIORITY SERVICE METHODOLOGY (PRISM)



PRICE MENU



KEY FEATURES OF METHODOLOGY

- **Market segmentation
(explicit consideration of preference diversity)**
 - **Product differentiation
(based on supply cost and value of service)**
 - **“Menus” of service contracts that induce efficient
matching of products and applications through
customers’ selections**
 - **Customers preferences revealed through their choices**
-

EPRI7762

EPRI



December 1991

Innovators

with EPRI technology

Café Niagara

Seasonal Entrées*	Fixe Prix
VIPP Day Ahead	\$15.25
VIPP Same Day	\$ 6.00
VIPP Short Notice	\$ 3.00

Includes Choice of Service Size (kW)

*Subject to Availability And Seasonal
Market Prices

All Major Customer
Accounts Accepted

Priority Service

House Spécialités	Prix
TOU	As Posted
HIPP	At Market Prix*

Special Tableside Services
Available

*Prices Change Daily; Ask Your
Server

Your Patronage
is Our Gratitude

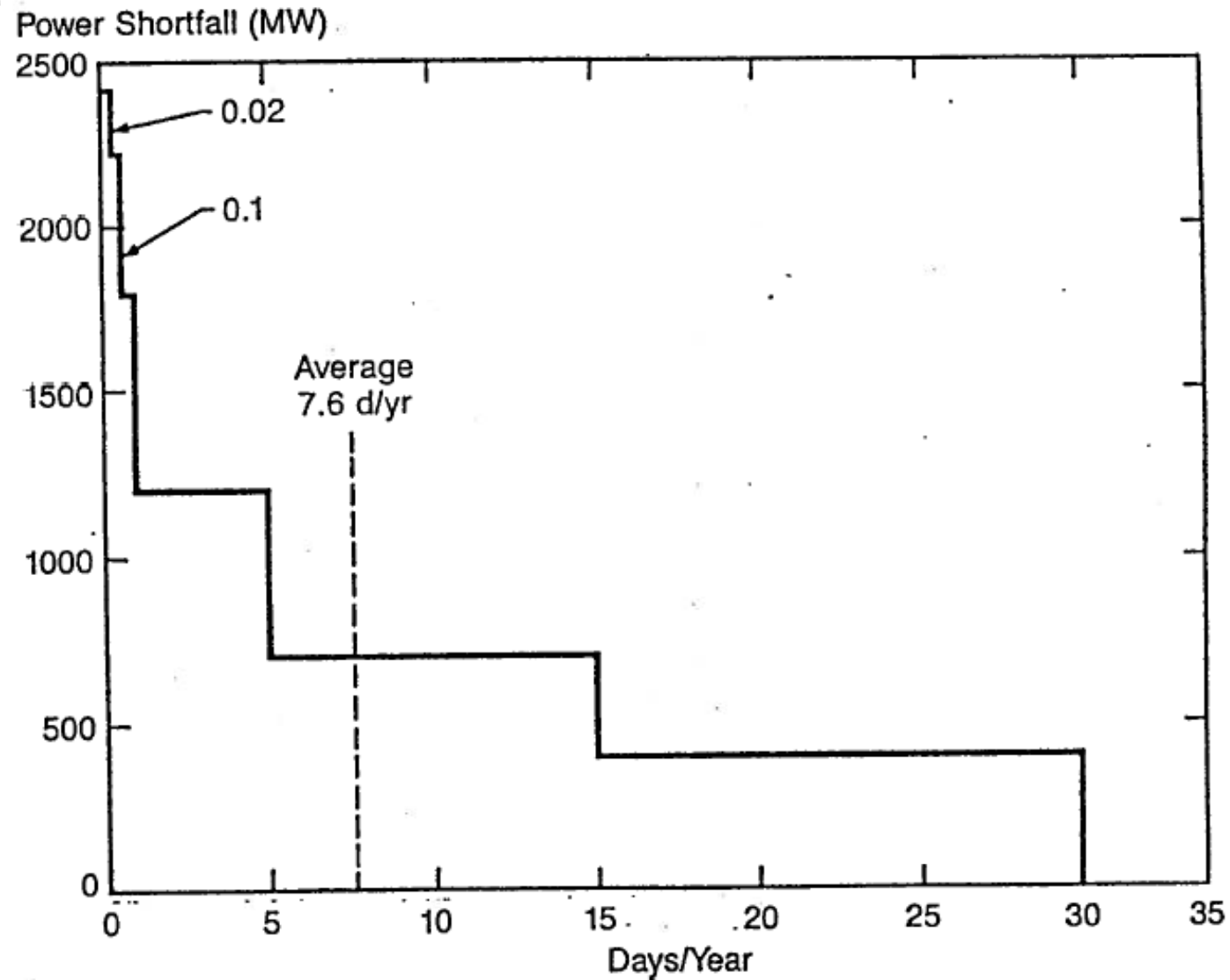
*EPRI/UTILITY
COLLABORATION
IMPROVES BOTH
SYSTEM RELIABILITY
AND CUSTOMER
SATISFACTION*

"The challenge was to make curtailable service more attractive to subscribers and more cost effective for Niagara Mohawk. The solution was to offer customers more choices with appropriate incentives."

■ **Jeff Wicks**

General Manager-Marketing
Niagara Mohawk Power Corporation

Supply Shortage Profile Or Aggregator's Wholesale Offers Profile



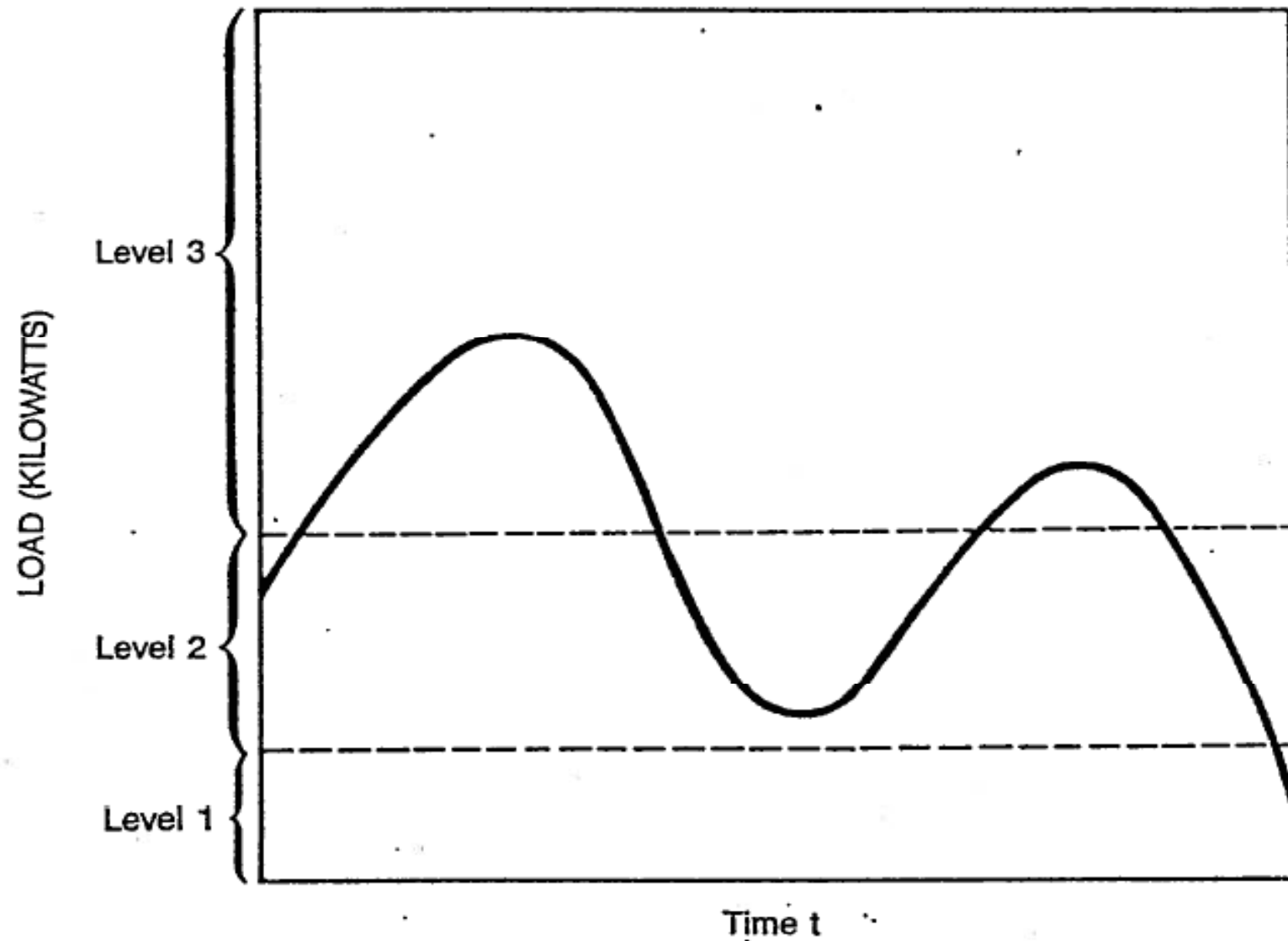
THE AVAILABLE SERVICE RELIABILITY OPTIONS

Menu of Service Options

	<i>Average Number of Days/Year Interrupted</i>					
	<i>0.02</i>	<i>0.1</i>	<i>1</i>	<i>5</i>	<i>15</i>	<i>30</i>
Demand charge (\$/kW/yr)	84	72	48	30	12	0

- Each customer type minimizes service charge + expected interruption cost
 - Menu prices are designed to induce appropriate customer selections
-

Stratification of Demand into Service Priorities



ILLUSTRATIVE EXAMPLE OF BENEFITS OF RELIABILITY BASED PRICING
Profile of Demands (MW) and Interruption Costs

		<i>Customer Type</i>								<i>Total MW</i>	<i>Interruption Cost (\$/kW)</i>
		<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>		
<i>MW of Demand</i>	{	100	—	—	100	—	—	—	—	200	200
		—	—	100	100	100	100	—	—	400	50
		100	100	100	—	—	100	100	100	600	10
		—	100	—	100	100	—	100	100	500	3
		—	100	100	—	—	100	—	100	400	1
		100	—	—	—	100	—	100	—	300	0.5

Only the last two columns characterizing the shortage cost histogram in the population are needed for price menu design

BASIS FOR SELECTING PREFERRED SERVICE OPTION
Minimize (service charge + expected interruption cost)/kW

	<i>Expected No. of Interruptions per Year</i>					
	<i>0.02</i>	<i>0.1</i>	<i>1</i>	<i>5</i>	<i>15</i>	<i>30</i>
\$ Cost/kW interrupted						
200	88	92	248	1030	3012	6000
50	85	77	98	280	762	1500
10	84.2	73	58	98	162	300
3	84.1	72.3	51	45	57	90
1	84.0	72.1	49	35	27	30
0.50	84.0	72.05	48.5	32.5	19.5	15
Customers' selections						

THE DISTRIBUTION OF CUSTOMERS' RELIABILITY SELECTIONS (matches deliverable service reliability)

Interruption cost \$/kW interrupted	200	50	10	3	1	0.5
Interruptions per year selected	0.02	0.1	1	5	15	30
Total MW selecting that level	200	400	600	500	400	300
Interruptible MW at that frequency	2400	2200	1800	1200	700	300

COMPARING TOTAL CUSTOMER COSTS WITH & WITHOUT SERVICE RELIABILITY DIFFERENTIATION

With Random Outages (\$ millions)

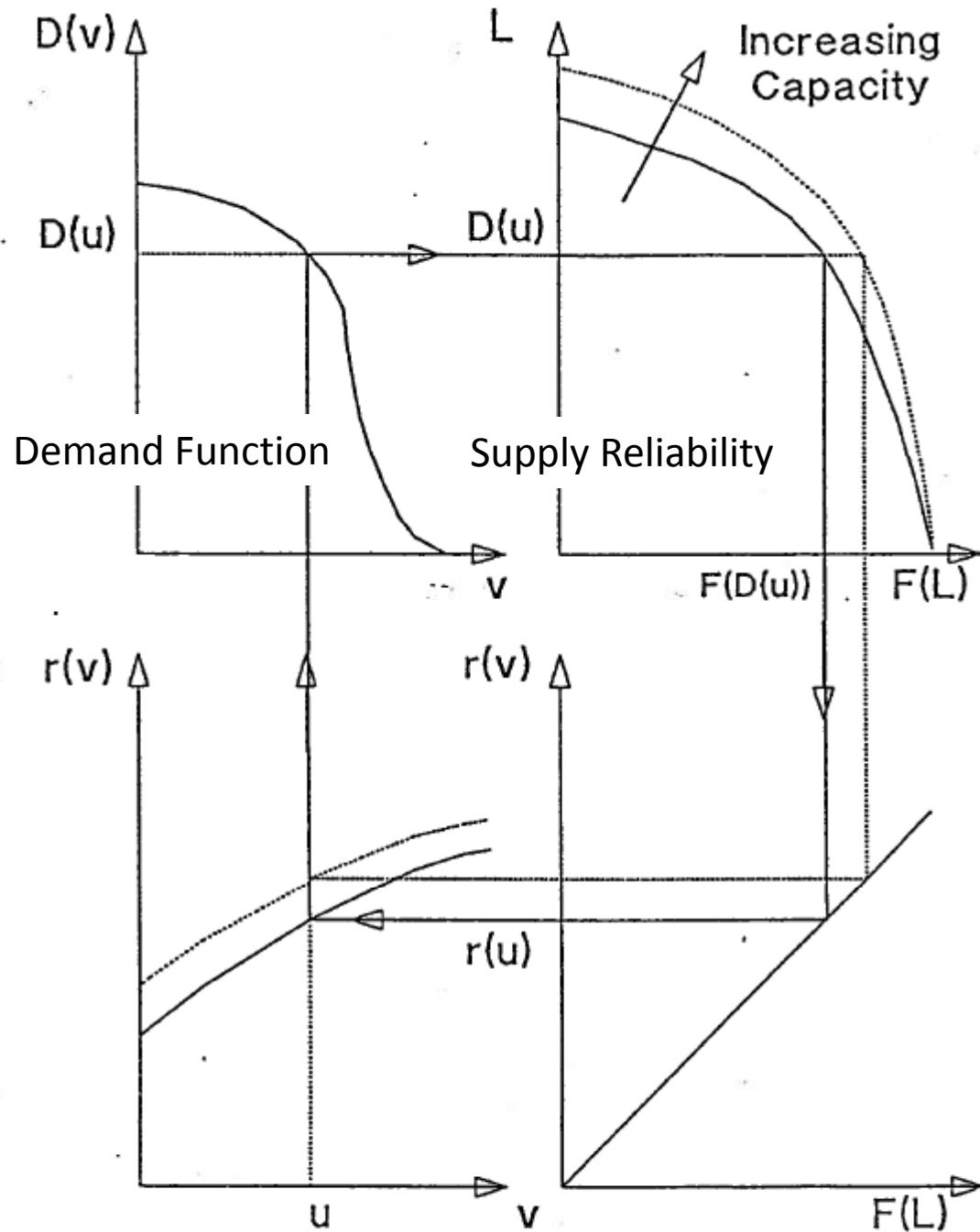
	<i>Customer Type</i>							
	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>
Charge/yr	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
Shortage (cost/yr)	160.0	10.6	46.4	192.3	40.7	46.4	10.3	10.6
Total (cost/yr)	171.8	22.4	58.1	204.1	52.4	58.1	22.0	22.4

With Service Reliability Menu (\$ millions)

	<i>Customer Type</i>							
	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>
Charge/yr	13.2	9.0	13.2	18.6	10.2	13.2	7.8	9.0
Shortage (cost/yr)	2.9	4.0	3.0	2.4	3.5	3.0	4.0	4.0
Total (cost/yr)	16.1	13.0	16.2	21.0	13.7	16.2	11.8	13.0

Determining the Supply Probability $r(v)$ Under Efficient Rationing

$r(v)$ = Probability of supply assigned to a MW with valuation v/hr .



Deriving the Optimal Price Menu

Find a price function $p(r)$ such that

$$r(v) = \underset{r}{\operatorname{Arg Max}} \{r \cdot v - p(r)\}$$

Self –Selection conditions:

Efficient Rationing Condition:

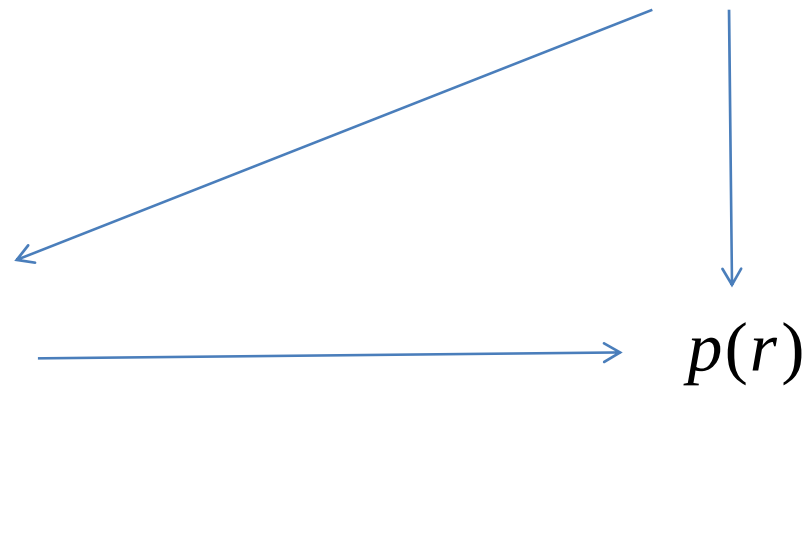
$$\frac{dp}{dr} = v$$

$$v \cdot r - p(r) \geq 0$$

$$dp(v) = v \cdot dr(v)$$

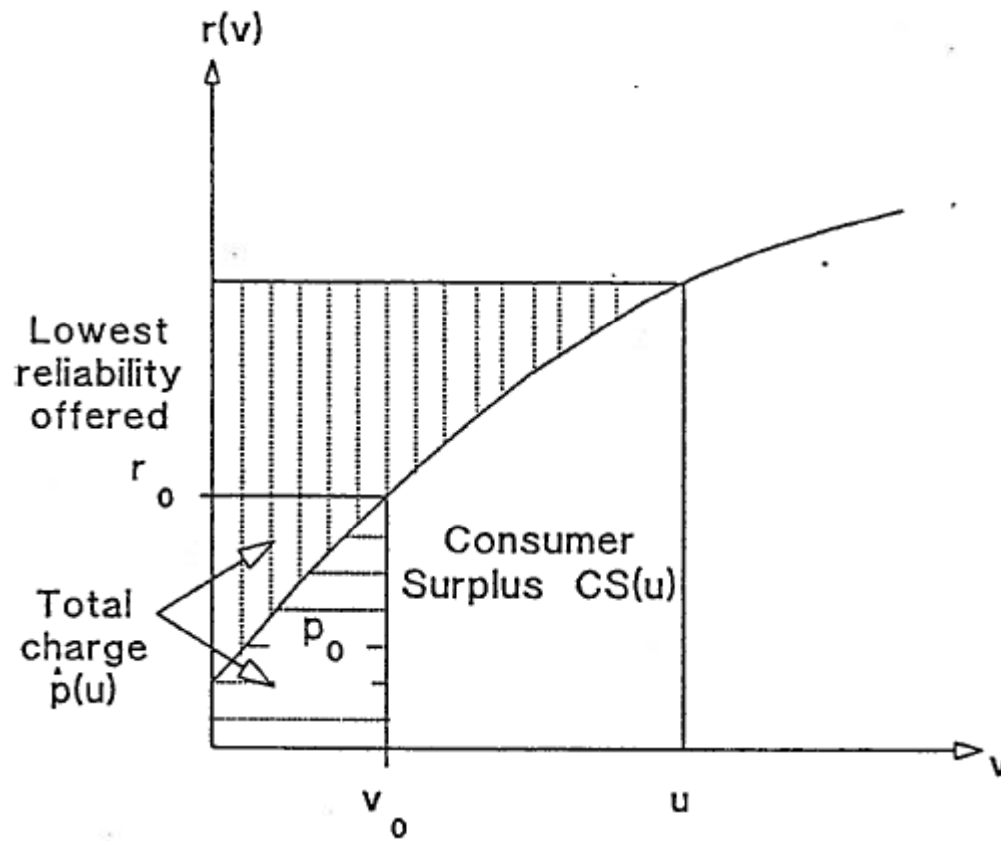
$$p(v) = p_0 + \int_0^v u dr(u)$$

$$r(v) = F(D(v))$$

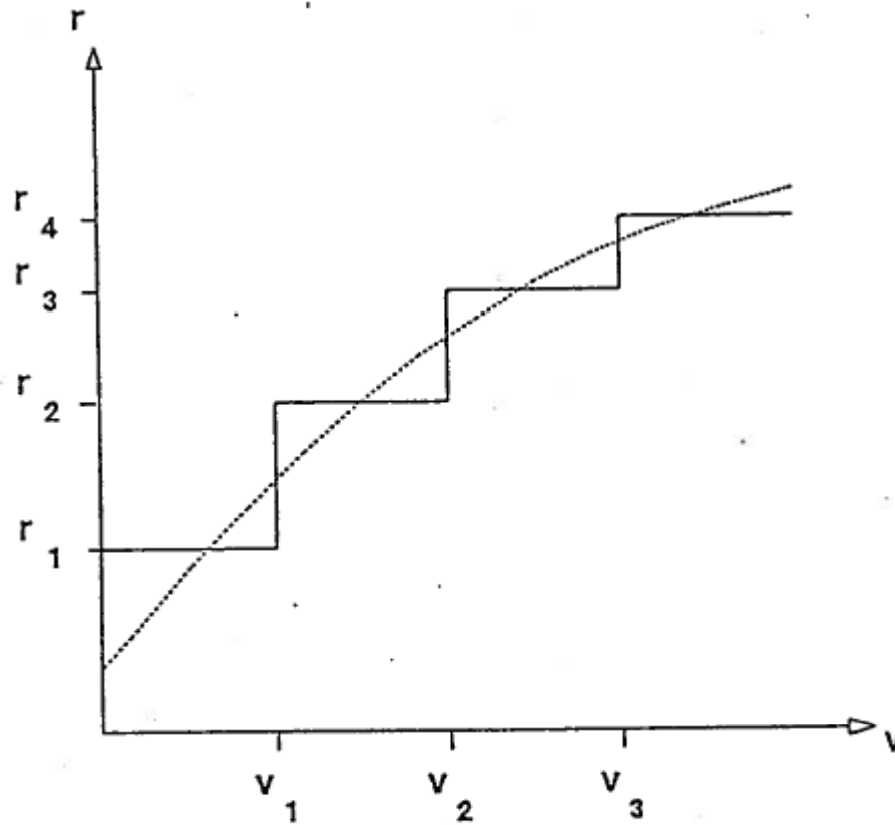


Free parameter determining the minimum valuation served

Graphical Illustration of Pricing Formula



Discrete Approximation



Efficiency losses of discretization $\sim O(1/N^2)$

THE IMPLEMENTATION OF PRIORITY SERVICE CAN TAKE SEVERAL ORGANIZATIONAL FORMS

Demand subscription

- Frequency of interruption

Priority insurance

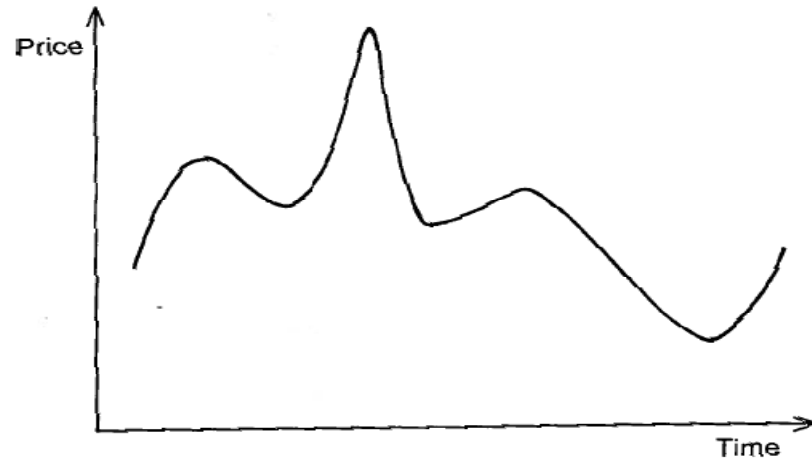
- Interruption compensation

- Priority points

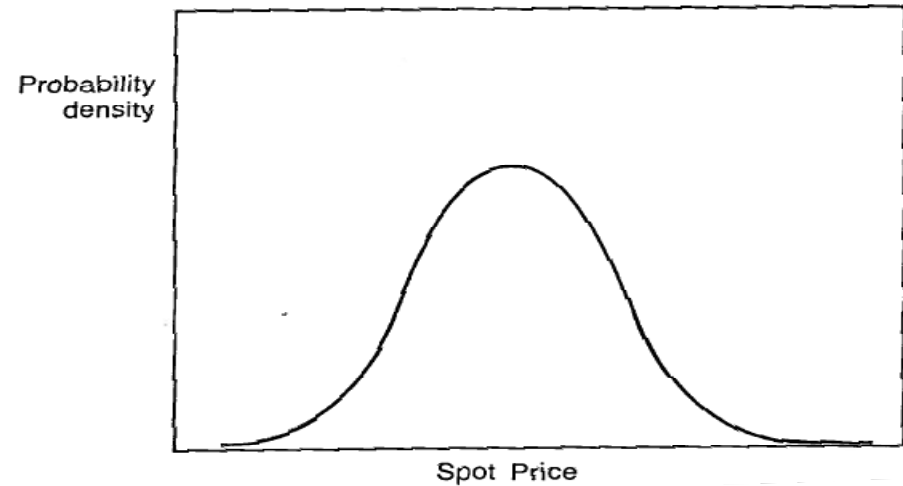
- Rank order of service
-

Relationship between Priority Service and RT price response

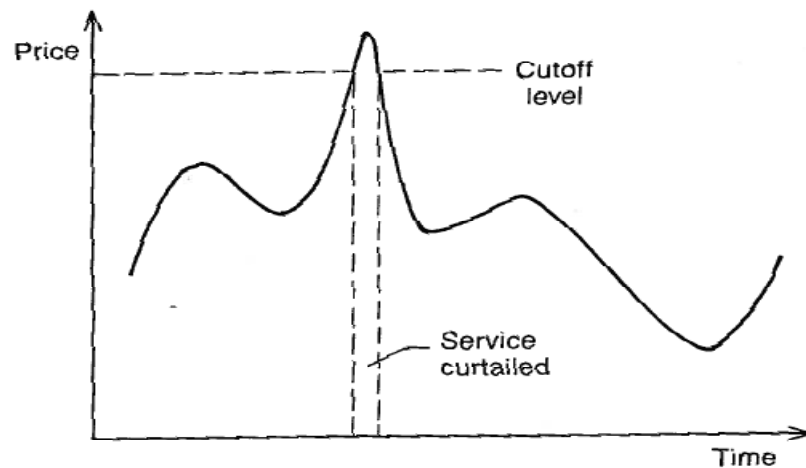
SPOT PRICES ARE REVISED CONTINUOUSLY



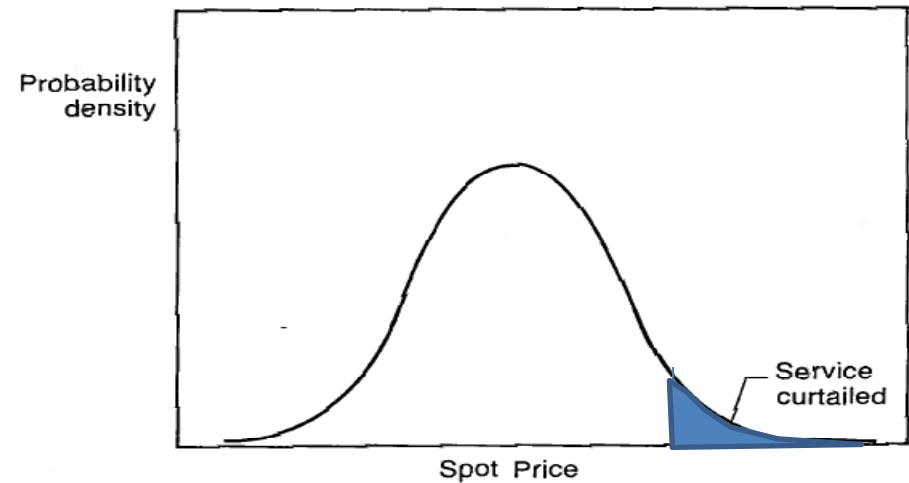
SPOT PRICES ARE RANDOM



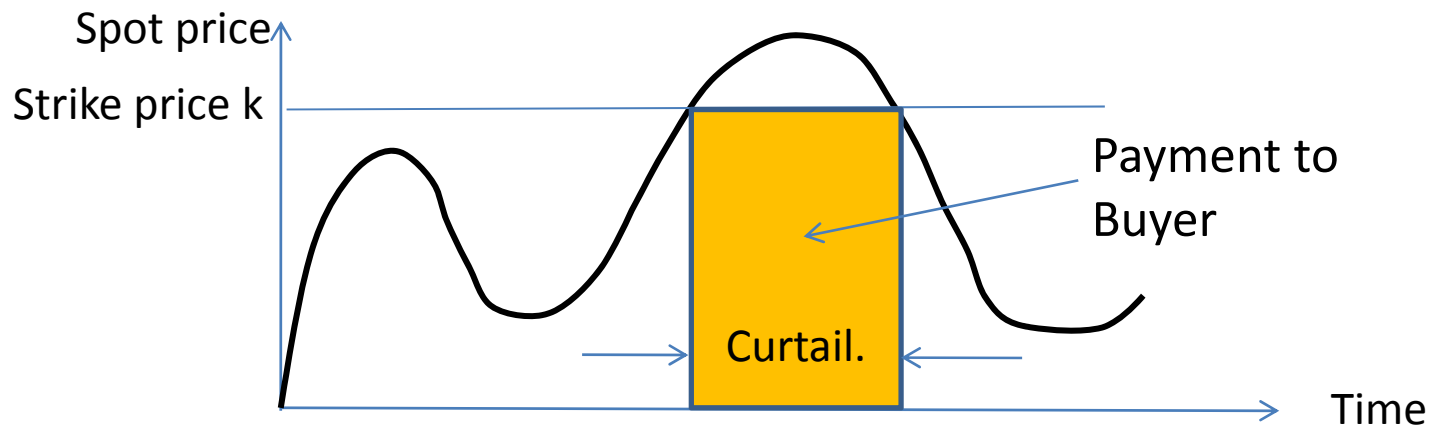
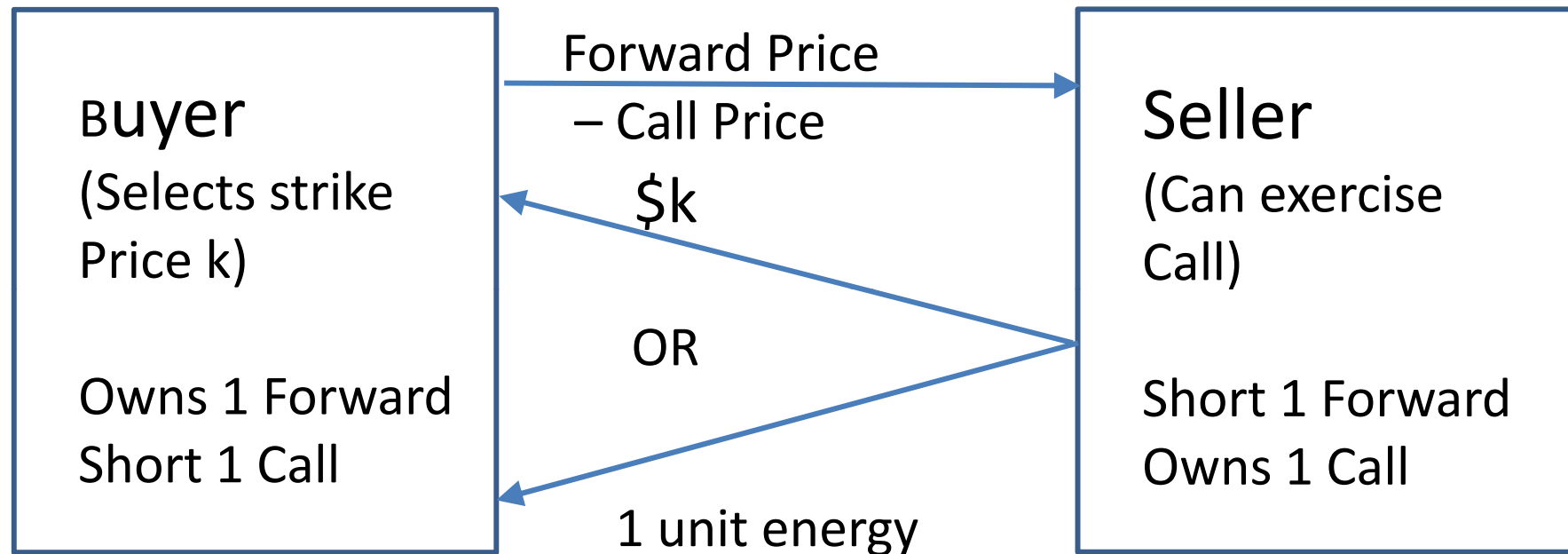
PRIORITY SERVICE VS SPOT PRICING



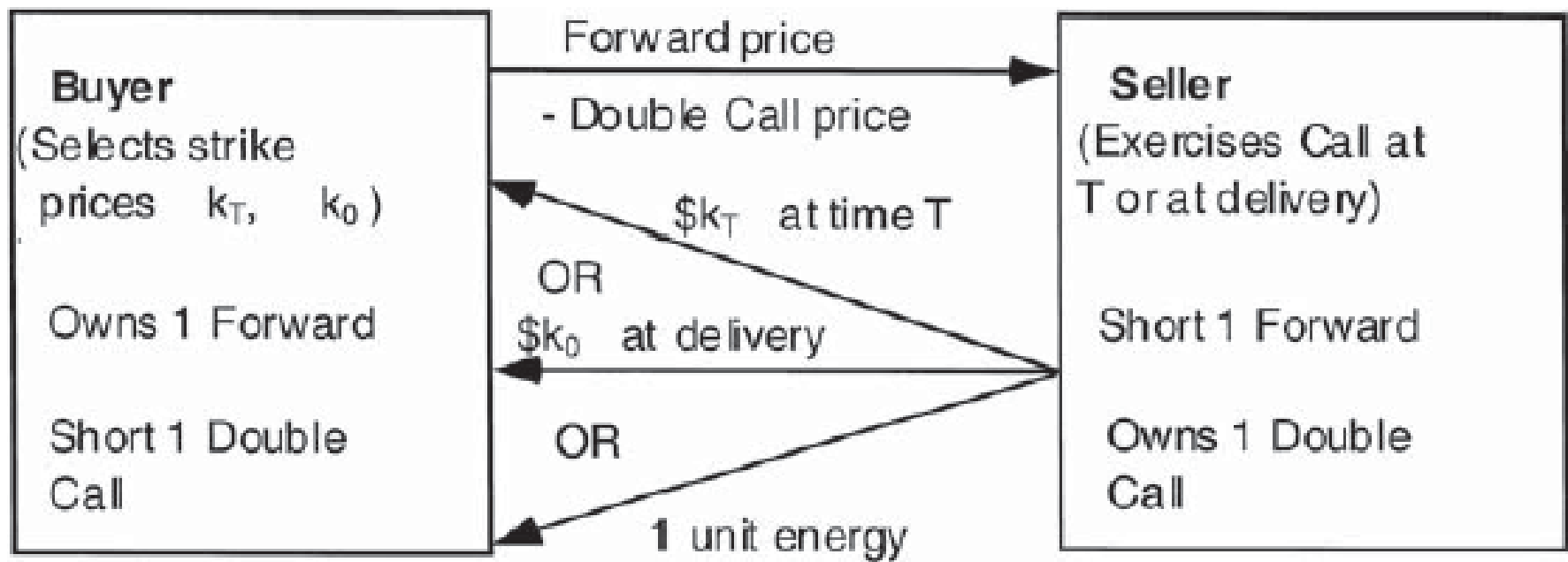
PRIORITY SERVICE IS CLOSELY RELATED TO SPOT PRICING



Modeling Interruptible Service Contract as a Callable Forward Contract (strike price determines priority)



Modeling Interruptible Service Contracts with early notification option as a Double-Callable Forward Contract





This is like deja vu all over again.

-- Yogi Berra