Mobilizing Demand Side Flexibility through Priority Service-based VPP

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A Smart Grid Vision

"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. "

F.C. Schweppe et al. "HOMEOSTATIC UTILITY CONTROL,"
IEEE Transactions on Power Apparatus and Systems,
Vol. PAS-99, No. 3, *May/June 1980*

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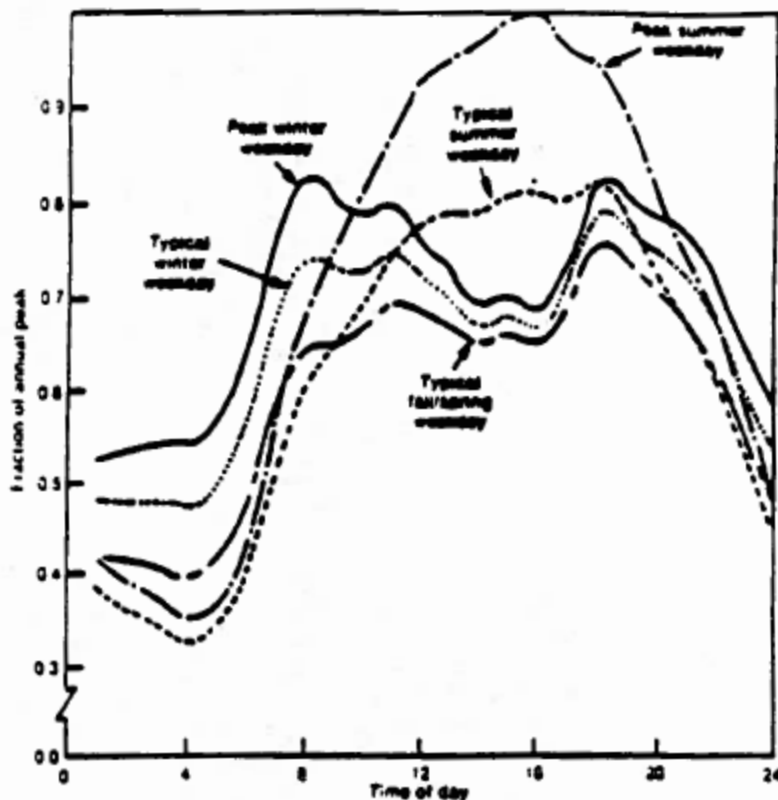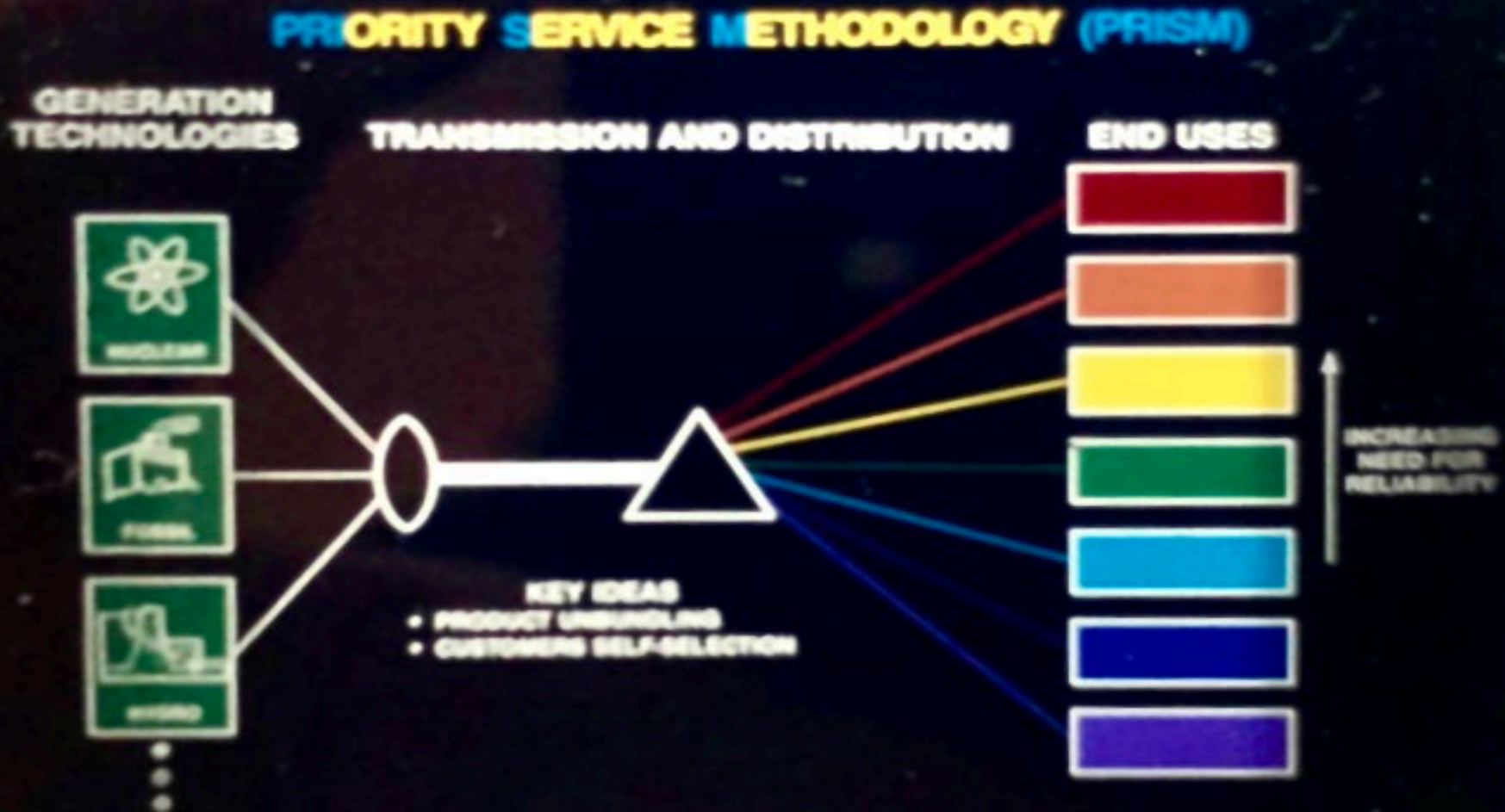
Fig. 1 *Daily Load Shapes for Five Representative Weekdays (North Central Region, 1980). Source: INDUSTRIAL AND COMMERCIAL COGENERATION, Office of Technology Assessment, U.S. Congress (1983), which cites Decision Focus, Inc. (1980).*

EPRI PRISM PROJECT

## Team Members: Hung Po Chao (Project Ditector), Shmuel Oren, Stephen Smith, Robert Wilson

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).

Offered to commercial and industrial customers with load > 500KW

Demand Subscription Service (SCE 1980's)
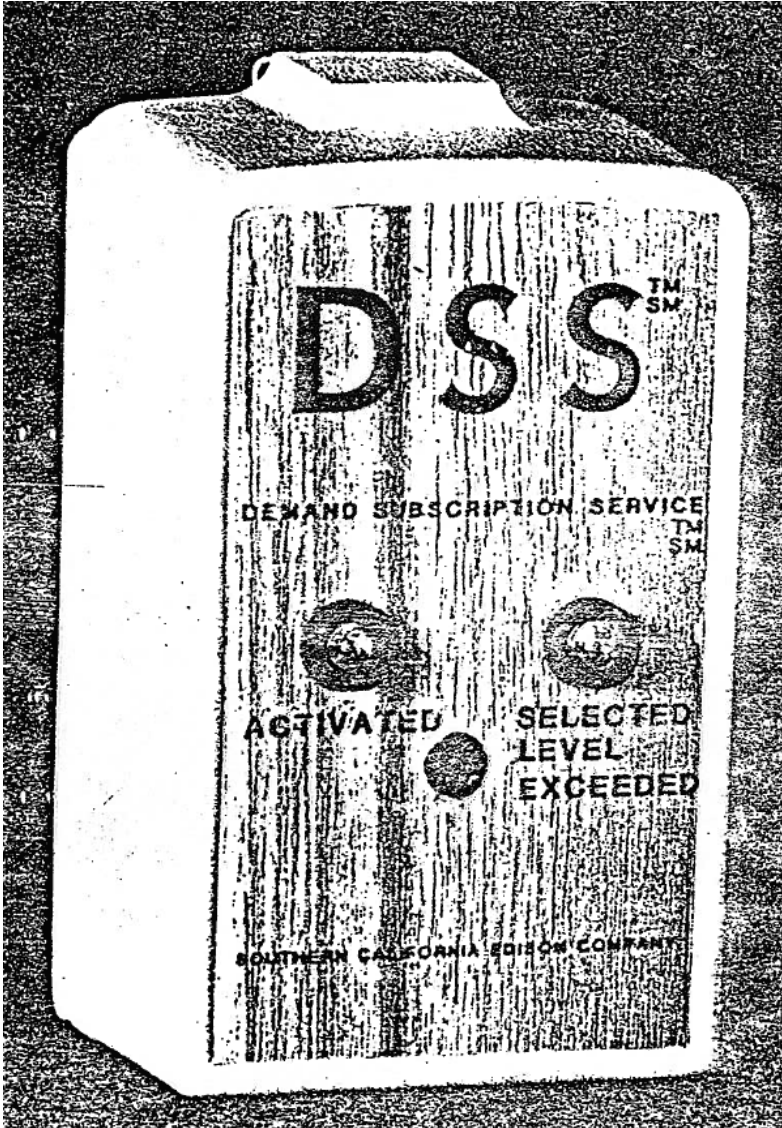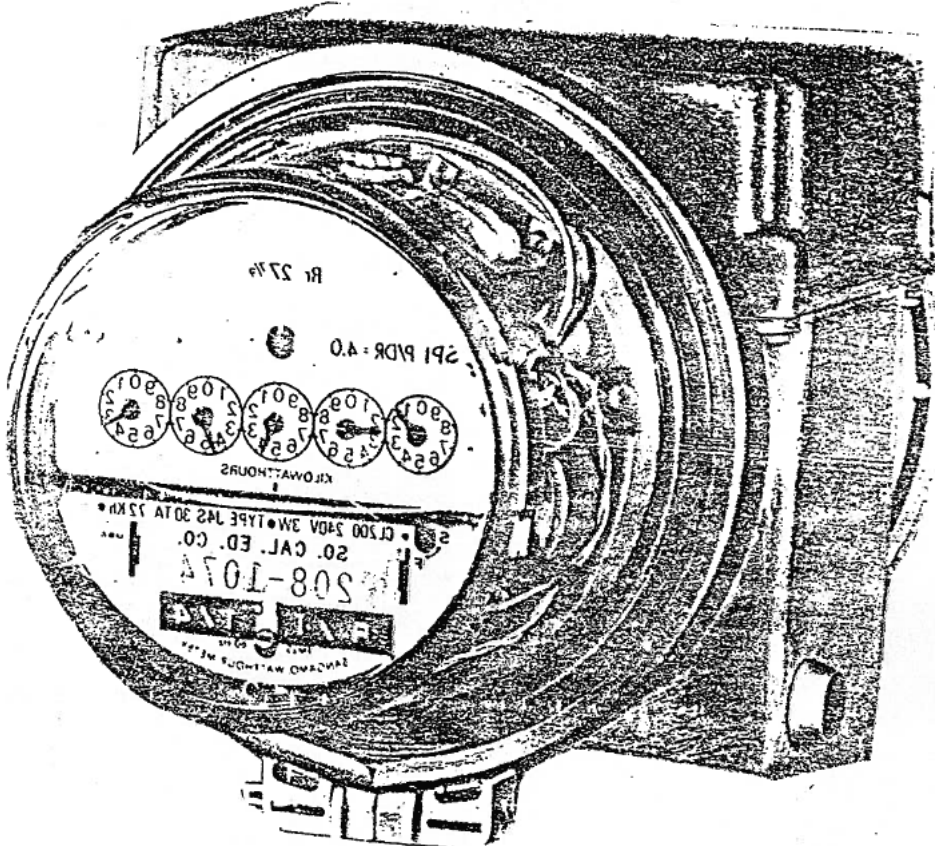
Demand Subscription Service (SCE 1980's)
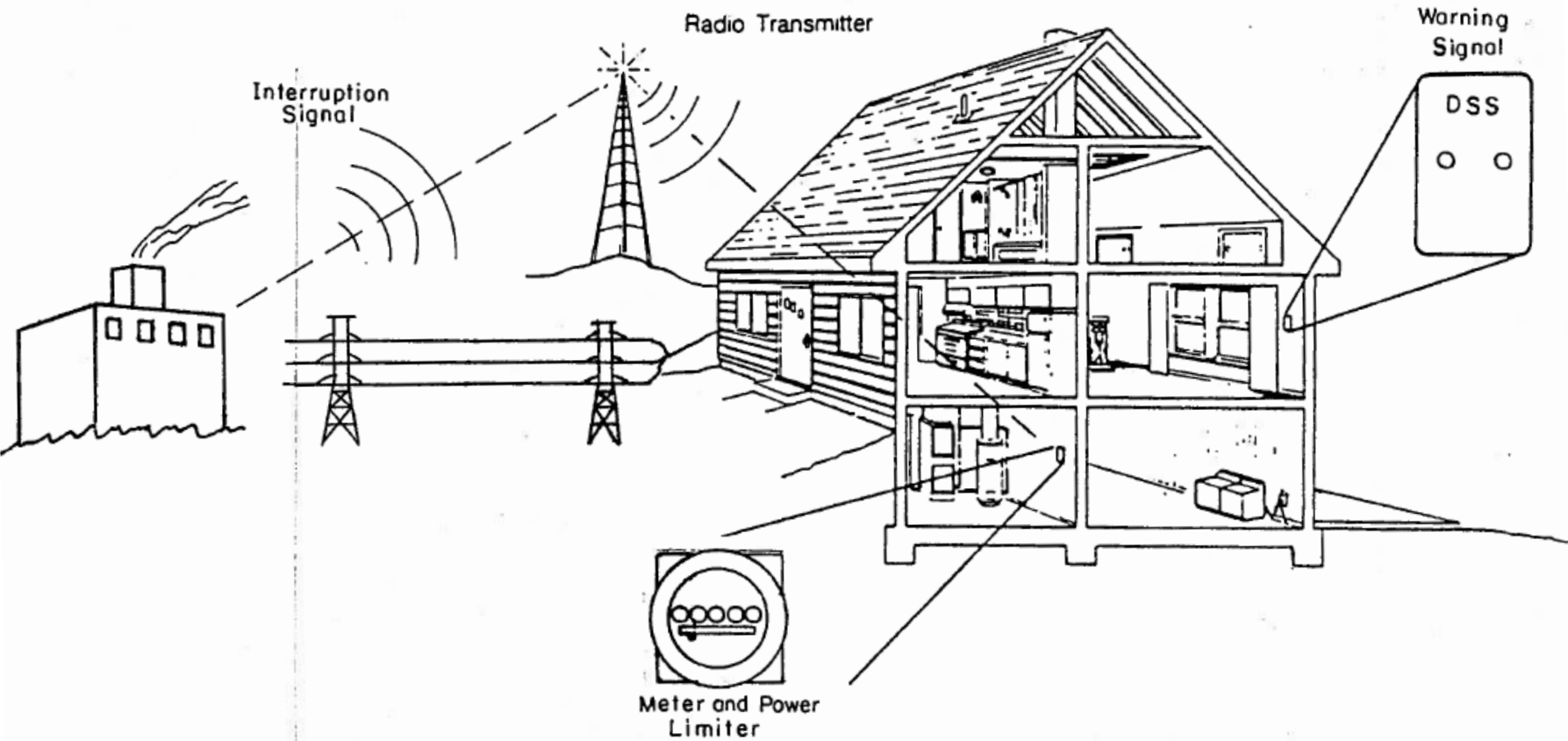
Demand Subscription Service: Radio controlled fuse limits customer's power supply to his subscribed level.

"GET CREDIT FOR TAKING TIME OFF."

YES, I'LL TAKE THE CREDIT.

- -

Put the peel-off address label here.

- -

An Edison representative will phone to make arrangements to install the device. Please be sure to include your home or work phone number below:

(_____) _____ home/work

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

Please complete the following and check appropriate boxes. Tear off and return.

☐ I am an Edison residential customer with electric central air conditioning. Please put me on the new rate schedule D-APS 2 (Air Conditioner Cycling). I have read the brochure information regarding this rate.

Install a device on my air conditioning equipment for the savings option checked below so that I will receive a credit on my bill each month during the 6 summer months.

☐ A—$5.50 credit for each ton of my air conditioner
☐ B—$3.00 credit for each ton of my air conditioner
☐ C—$1.50 credit for each ton of my air conditioner
☐ I am interested but would like additional information about this program.

_____
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.

Economic Paradigms for Product Differentiation in Electricity

- Chao, Hung Po, Shmuel S. Oren, Stephen A. Smith and Robert B. Wilson, "**Multi-Level Demand Subscription Pricing for Electric Power**," *Energy Economics*, (1986) pp. 199-217.

- Oren, Shmuel S., Stephen A. Smith and Robert B. Wilson, "**Multiproduct Pricing for Electric Power**," *Energy Economics*, V. 9, No. 2 (1987), pp. 104-114.

- Chao, H., Wilson, R., " **Priority service: pricing, investment and market organization**" Am. Econ. Rev. 77 (5), 899–916 (1987)

- Chao, Hung Po, Shmuel S. Oren, Stephen A. Smith and Robert B. Wilson, "**Priority Service: Market Structure and Competition**," *The Energy Journal,* Special Issue on Electricity Reliability, V. 9 (1988), pp. 77-104.

- Oren, Shmuel S. and Stephen A. Smith, (Editors) "**Service Opportunities for Electric Utilities: Creating Differentiated Products**," Kluwer Academic Publishers, Boston (1993).
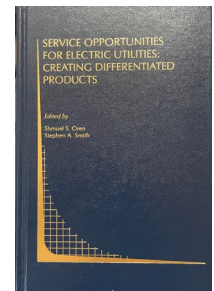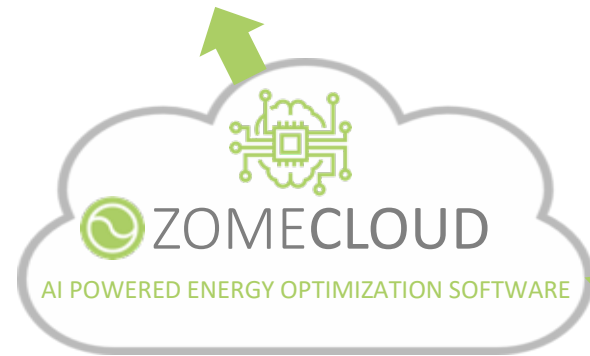
Device Control Paradigm
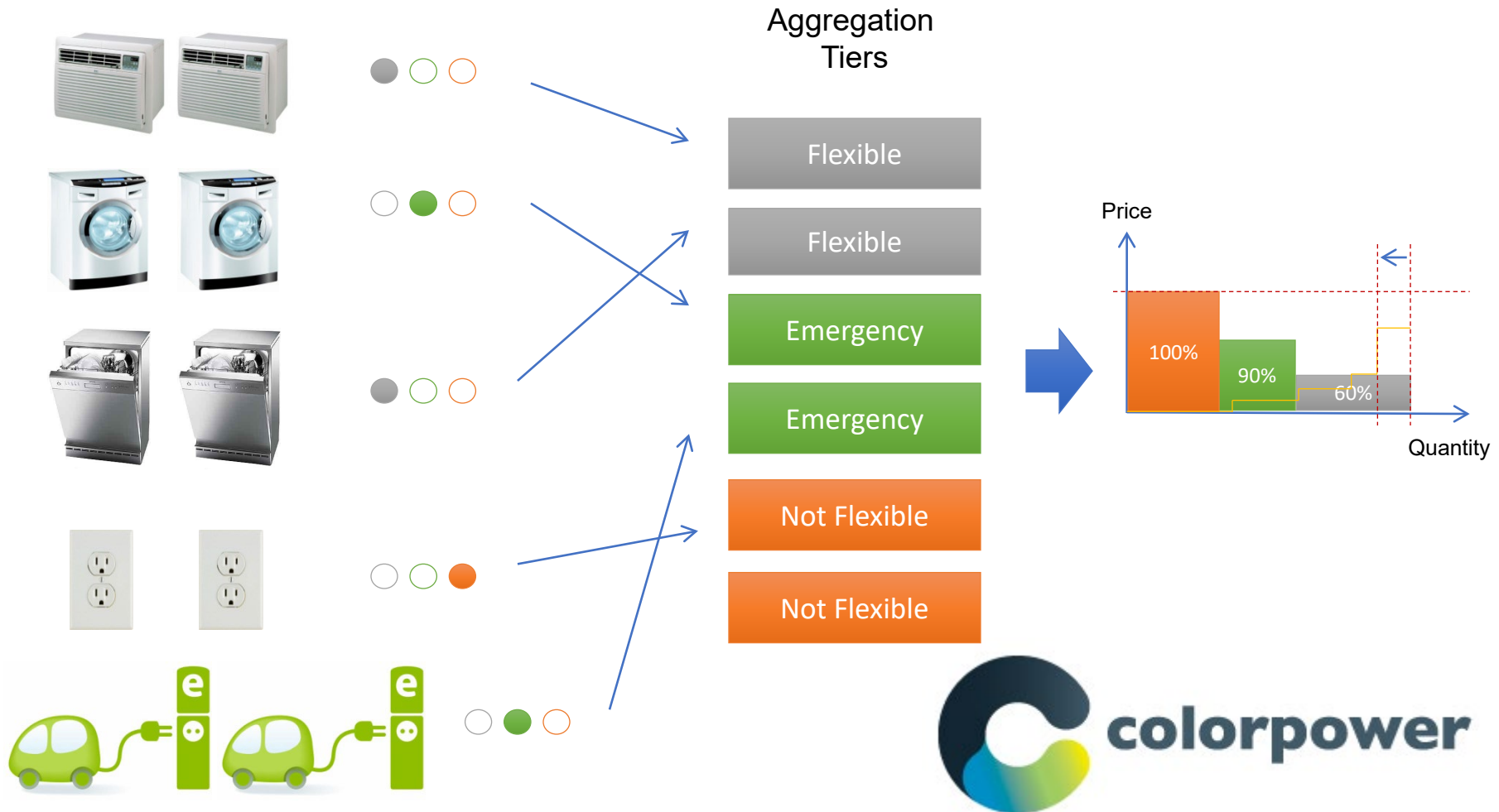
ZOME TECHNOLOGY

Bidding curtailment into
ISO market energy programs

Multi Family Residences
and Commercial Buildings

ZOMEKIT Today:

HVAC control via kitted networked thermostats

Hot Water Heater control via smart on/off adapters

ZOME**CLOUD**

AI POWERED ENERGY OPTIMIZATION SOFTWARE

ZOMEKIT Pilots:

Local **Solar** generation, control, optimization

In-building **Batteries** to store/use energy

Integrated, co-optimizing **EV Chargers**/charging

ZOME**KIT**

SMART BUILDING GATEWAY

1) EASY INSTALL, LOW/NO COST
2) CLIENTS SAVE ENERGY & MONEY
3) AND GET <u>PAID</u> AS A "GRID ASSET"
→ ZOME LINKS BUILDING TO ENERGY MARKETS

The Customer Model

DR customers are represented in aggregate as a continuum of demand increments, each with an expected valuation θ (referred to as type). The aggregate demand curve is the CDF of types scaled to total load capacity N,
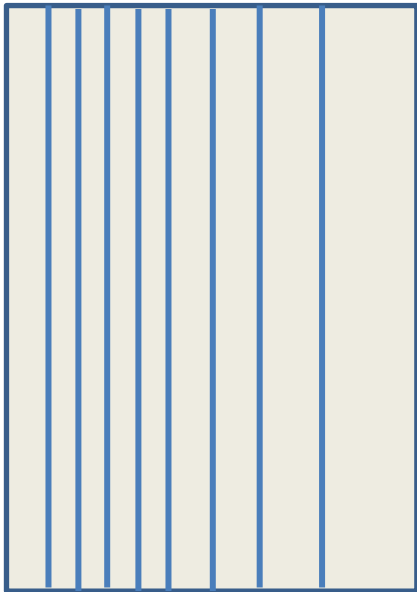
$$D(\theta) = N(1 - F(\theta))$$

Obtain Demand Curves
(shown discretized)

Add curves
Vertically

$N(1 - F(\theta))$

Aggregate demand curve maps a valuation (type) θ to the number of units with expected valuation least θ
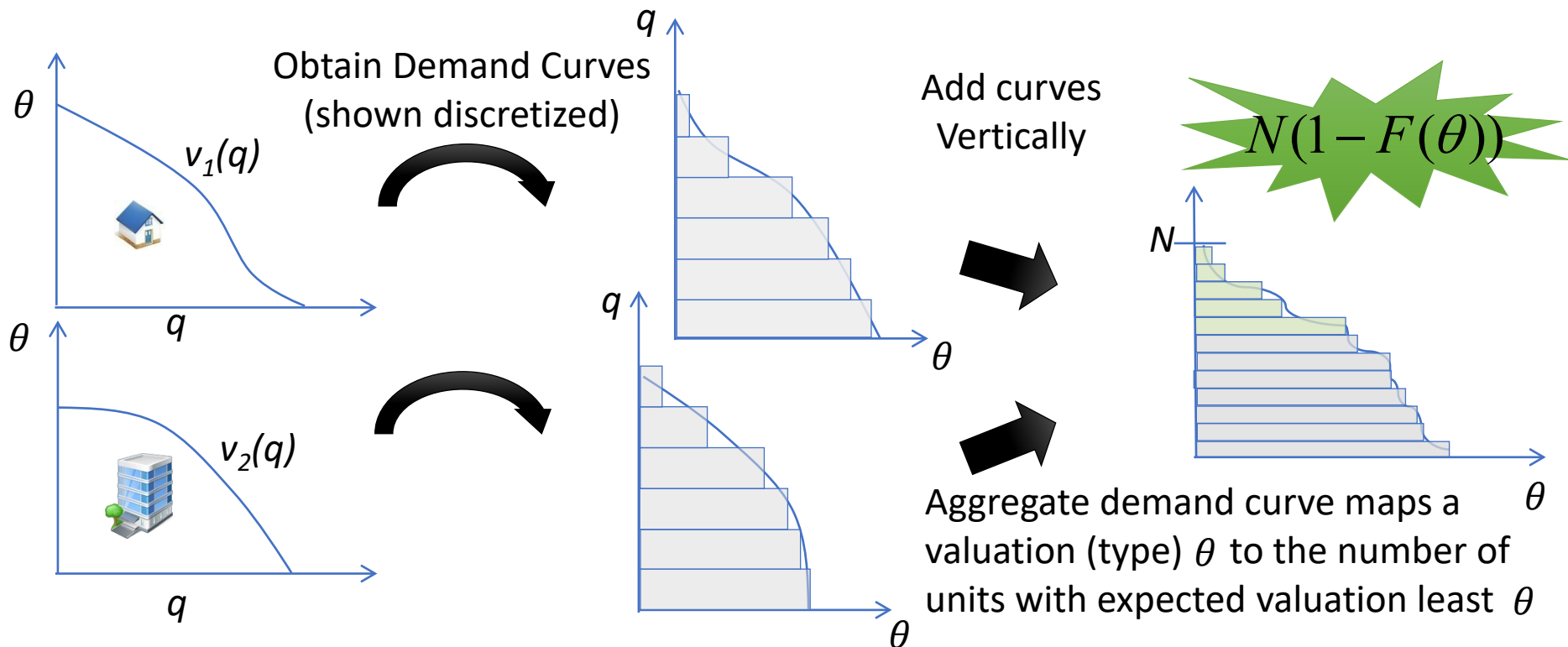
The "Customer" Self-selection Model (for each load segment)

- "Customer" values a unit of consumption at θ and faces retail rate p^R
  - ➡ "Outside option" utility = $(\theta - p^R.)^+$ (forgo contract)
- Aggregator offers payment $t(\theta)$ per kW to load type θ for the right to curtail with probability $1 - r(\theta)$
- Customers are risk-neutral so
  - ➡ Utility with contract= $r(\theta) \cdot (\theta - p^R)^+ + t(\theta)$
- θ is private information, revealed through self-selection of $(t(\theta), r(\theta))$ from a manue of options $(t(r), r)$ Offered by the aggragator (Revelation Principle)
- Customer self-selection must satisfy incentive compatibility (IC) and Individual rationality (IR)

Demand Backed Reserves Obligations (DBRO)
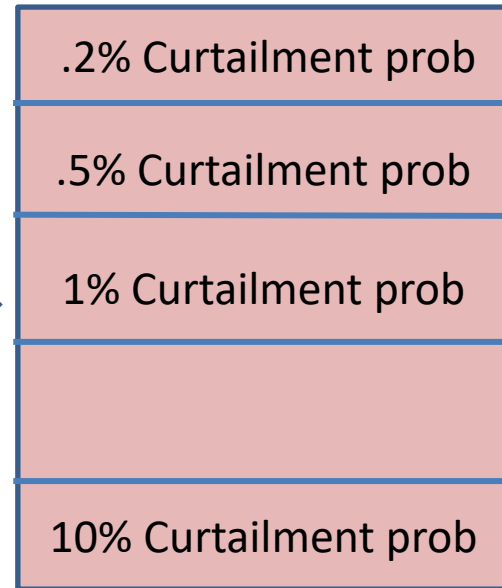
Portfolio of uncertain supply resources

Supply shortfall assigned to curtailable demand in priority order

Priority trunches of curtailable loads

.2% Curtailment prob

.5% Curtailment prob

1% Curtailment prob

10% Curtailment prob

Priority trunches priced to induce desired distribution of demand reserves

Analogy to CDO (but without the default correlation)

PERFORM—Performance-based **E**nergy **R**esource
Feedback, **O**ptimization, and **R**isk **M**anagement

FEDERAL ENERGY REGULATORY COMMISSION
Fact Sheet

September 17, 2020

News Media Contact:
Craig Cano, mediadl@ferc.gov
Docket No. RM18-9-000

FERC Order No. 2222: A New Day for Distributed Energy Resources

FERC Order No. 2222 will help usher in the electric grid of the future and promote competition in electric markets by removing the barriers preventing distributed energy resources (DERs) from competing on a level playing field in the organized capacity, energy and ancillary services markets run by regional grid operators.

DERs are small-scale power generation or storage technologies (typically from 1 kW to 10,000 kW) that can provide an alternative to or an enhancement of the traditional electric power system. These can be located on an electric utility's distribution system, a subsystem of the utility's distribution system or behind a customer meter. They may include electric storage, intermittent generation, distributed generation, demand response, energy efficiency, thermal storage or electric vehicles and their charging equipment.

This rule allows several sources of distributed electricity to aggregate in order to satisfy minimum size and performance requirements that each may not be able to meet individually.

Co-Winner 2020 Nobel Prize in Economics

CEO Energy Trading Analytics

CEO ZOME Energy Networks

Robert Wilson · Shmuel Oren · Hung Po Chao · Alex Papalexopoulos

PERFORM—**P**erformance-based **E**nergy **R**esource **F**eedback, **O**ptimization, and **R**isk **M**anagement

PROJECT DESCRIPTIONS
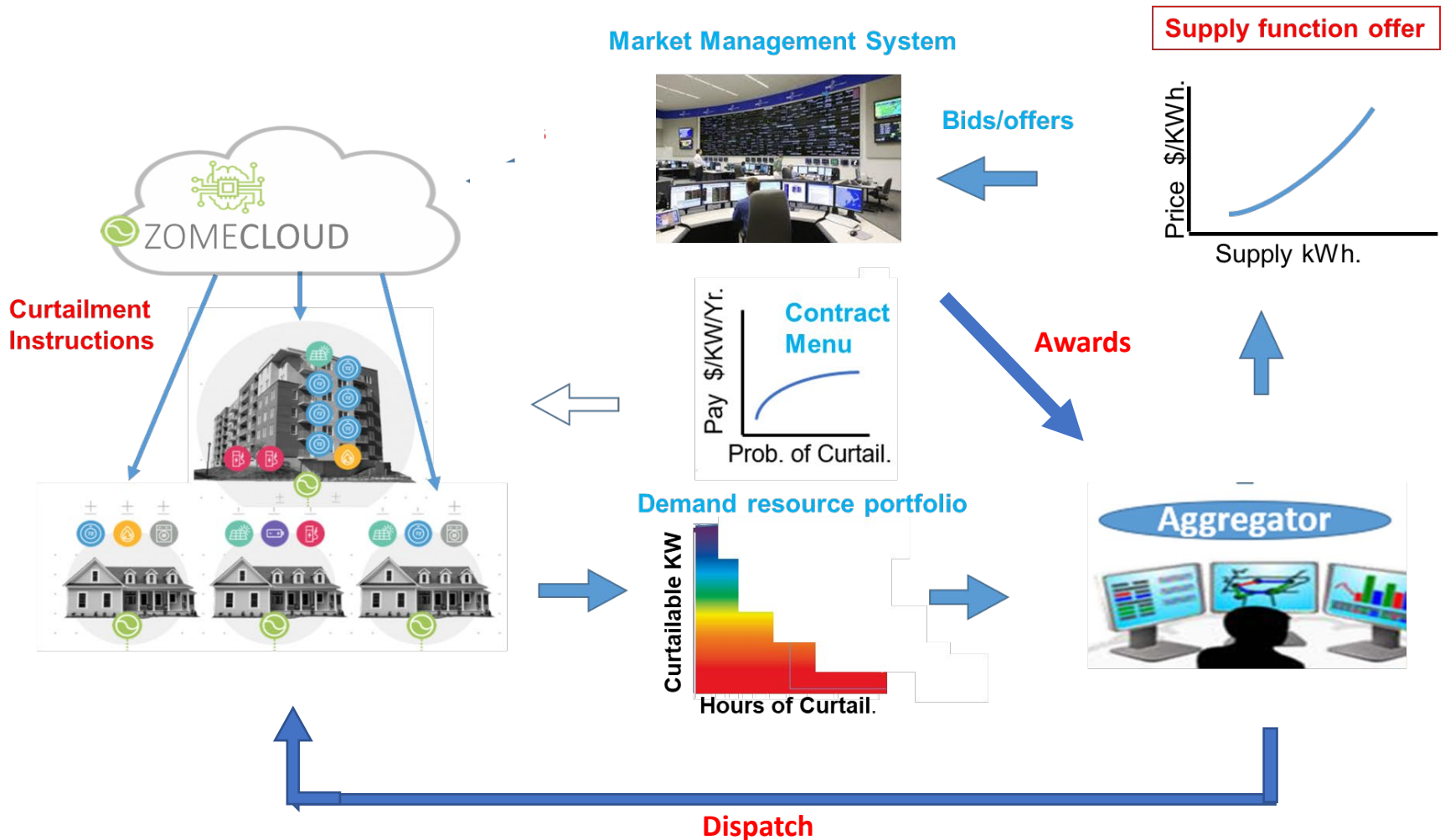
Energy Trading Analytics, LLC – Phoenixville, PA
Stochastic Market Auction Redesigned Trading System (SMARTS) - $3,360,000

The proposed effort is to develop a novel, state-of-the-art stochastic redesign for wholesale real-time energy and reserve markets coupled with intelligent energy-portfolio risk management tools that enable consumers to prioritize their flexible demand assets (such as air conditioners, water heaters, energy storage) to offer their flexibility into markets as demand reserves. This project will evaluate the risk and performance of the proposed market trading system and conduct simulation and pre-pilot tests to demonstrate the approach in the world's largest wholesale electricity market, PJM Interconnection. The redesigned market trading system will advance price-responsive risk management, foster robust decentralized decision making for real-time operations and operational planning under uncertainty, and attract innovation and investment opportunities.
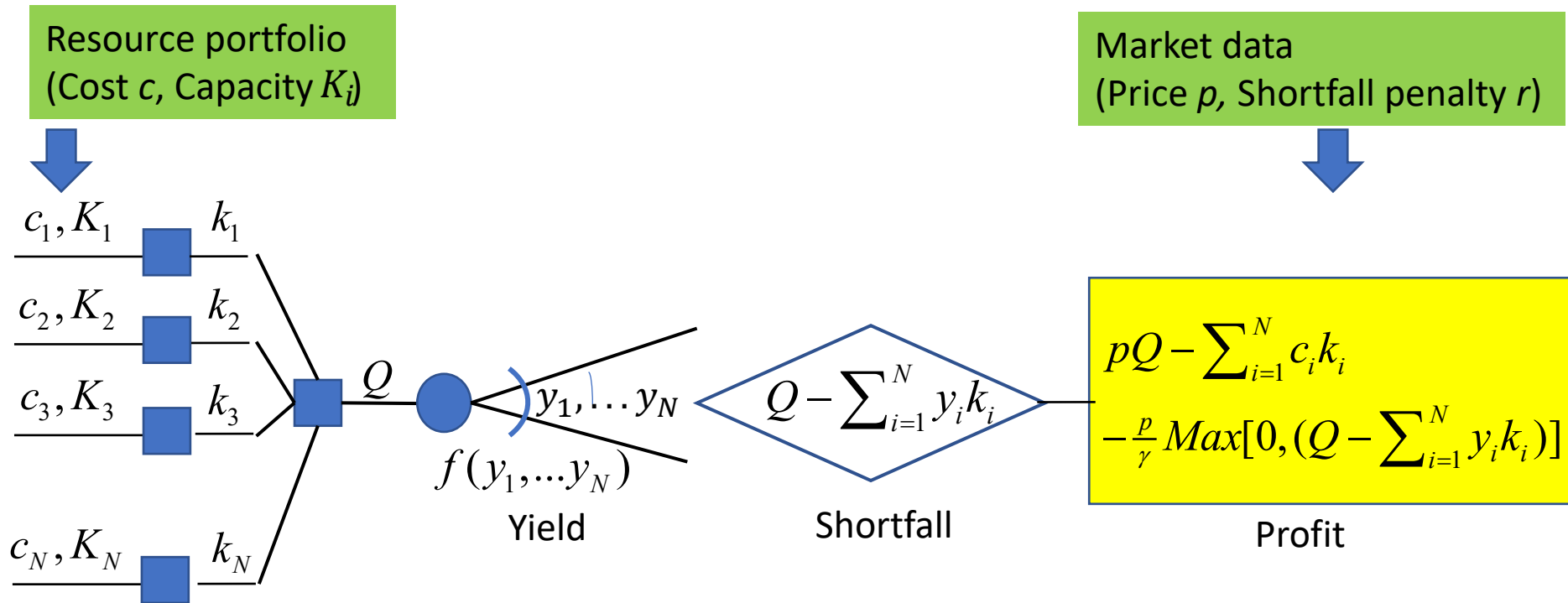
ARPA E PERFORM – SMARTS Project

Managing Delivery Risk
(Revenue Management Approach)

Resource portfolio
(Cost c, Capacity K_i)

Market data
(Price p, Shortfall penalty r)

c_1, K_1 k_1

c_2, K_2 k_2

c_3, K_3 k_3

Q

c_N, K_N k_N

$y_1, \ldots y_N$

$f(y_1, \ldots y_N)$

Yield

$Q - \sum_{i=1}^{N} y_i k_i$

Shortfall

$pQ - \sum_{i=1}^{N} c_i k_i$

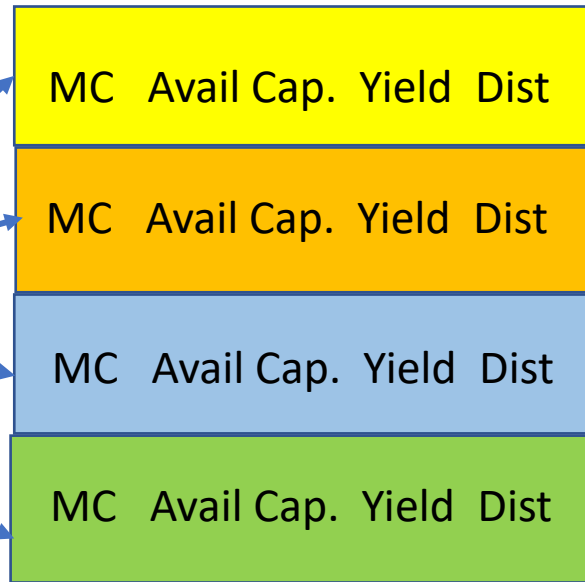$- \frac{p}{\gamma} Max[0, (Q - \sum_{i=1}^{N} y_i k_i)]$

Profit

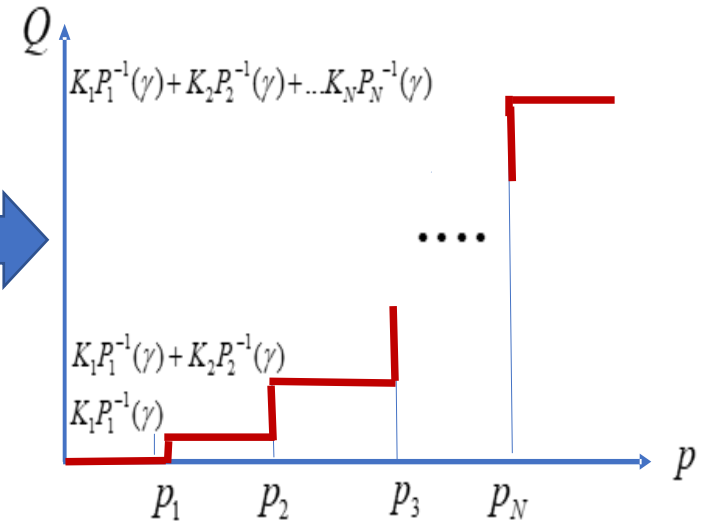# Risk-controlled VPP Supply Function Based on Curtailed Tiered Capacities and Offline Energy Yield Estimation

Resources

Tiered Priority Trunches
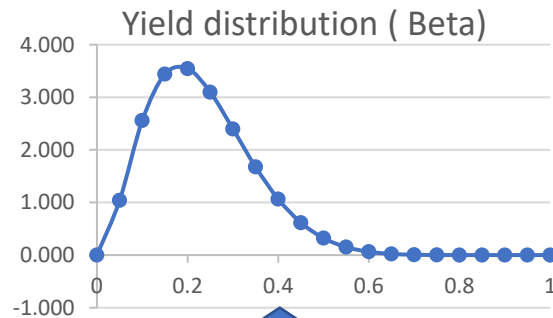
| MC | Avail Cap. | Yield | Dist |

| MC | Avail Cap. | Yield | Dist |

| MC | Avail Cap. | Yield | Dist |

| MC | Avail Cap. | Yield | Dist |

Supply Function
(Offered Energy/Clearing Price)

$$K_1 P_1^{-1}(\gamma) + K_2 P_2^{-1}(\gamma) + \dots K_N P_N^{-1}(\gamma)$$

$$K_1 P_1^{-1}(\gamma) + K_2 P_2^{-1}(\gamma)$$

$$K_1 P_1^{-1}(\gamma)$$

$p_1 \quad p_2 \quad p_3 \quad p_N$

Shortfall Probability

Yield distribution (Beta)

Offline Sampling

Conditioning: Device, Time, Temp, Location

STAY TUNED!!!