Energy Infrastructure
Strategic Planning ◆ Project Development

Demand Response Enabling Technologies

from the Building Side of the Meter

Peter M. Schwartz, Principal

Workshop - June 4, 2003

Peter Schwartz & Associates

Setting the Context

- Establish electric market characteristics:
  - Energy-efficiency market potential ***[How much gold is there?]***
  - Electric demand, consumption & energy intensity by market segment & end use ***[Where can you mine the gold cost-effectively?]***
- California statewide electric supply and demand balance ***[Establishing the gold's value]***
- How do you create dynamic, demand-responsive buildings? ***[Mining the gold]***
- What are barriers to a demand-responsive market? ***[What's blocking the gold mining?]***

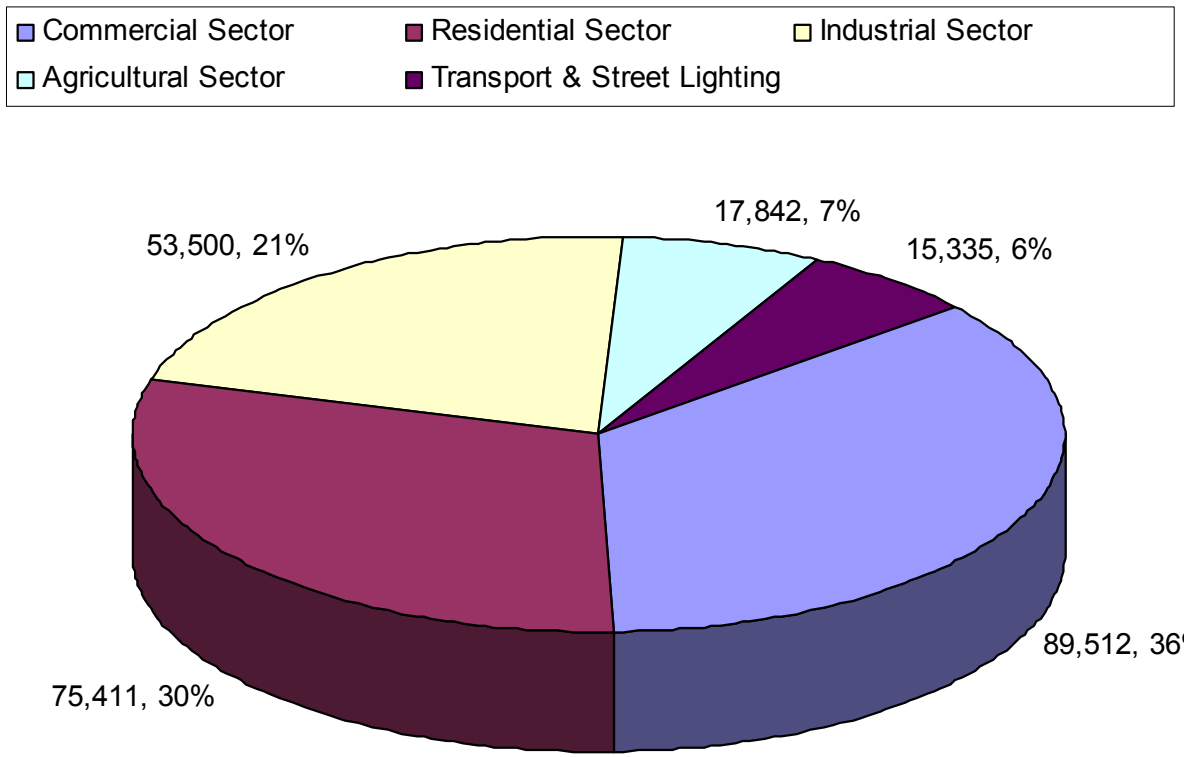
Energy Infrastructure
Strategic Planning ◆ Project Development

How Much Gold is There?

Peter Schwartz & Associates

1999 California Electricity Consumption (GWh/Year)

Peter Schwartz & Associates



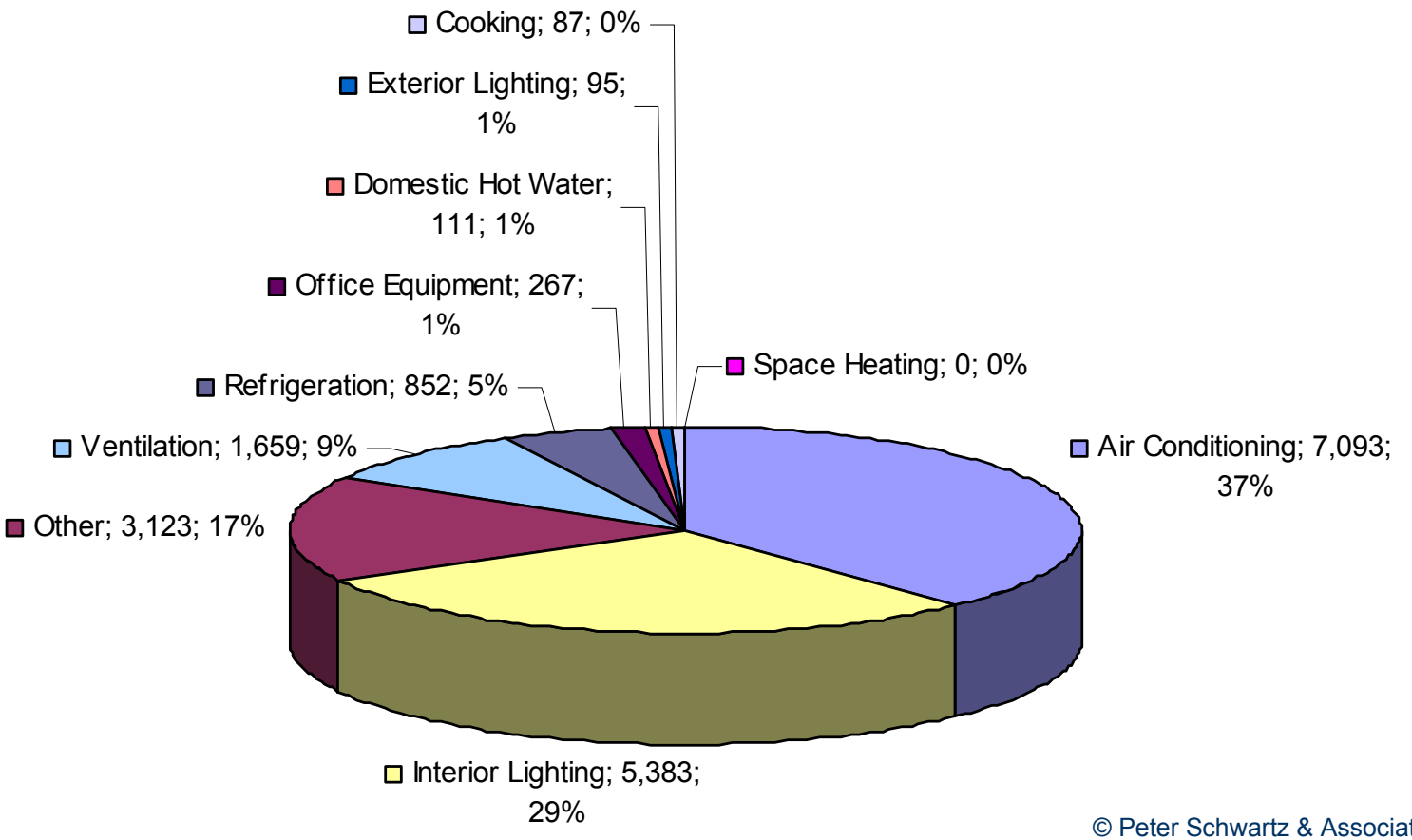
California Commercial Electricity Consumption and Peak Demand by End Use - YR 1999

Peter Schwartz & Associates

Commercial Sector End Uses	Coincident Peak Load (MW)	% of Total MW	Annual Energy (GWh)	% of Total GWh/Year
Air Conditioning	7,093	37.99%	13,794	15.41%
Interior Lighting	5,383	28.83%	30,336	33.89%
Other	3,123	16.73%	19,914	22.25%
Ventilation	1,659	8.89%	9,067	10.13%
Refrigeration	852	4.56%	6,530	7.30%
Office Equipment	267	1.43%	1,628	1.82%
Domestic Hot Water	111	0.59%	512	0.57%
Exterior Lighting	95	0.51%	5,018	5.61%
Cooking	87	0.47%	586	0.65%
Space Heating	0	0.00%	2,127	2.38%
Total - Commercial	**18,670**	**100.00%**	**89,512**	**100.00%**

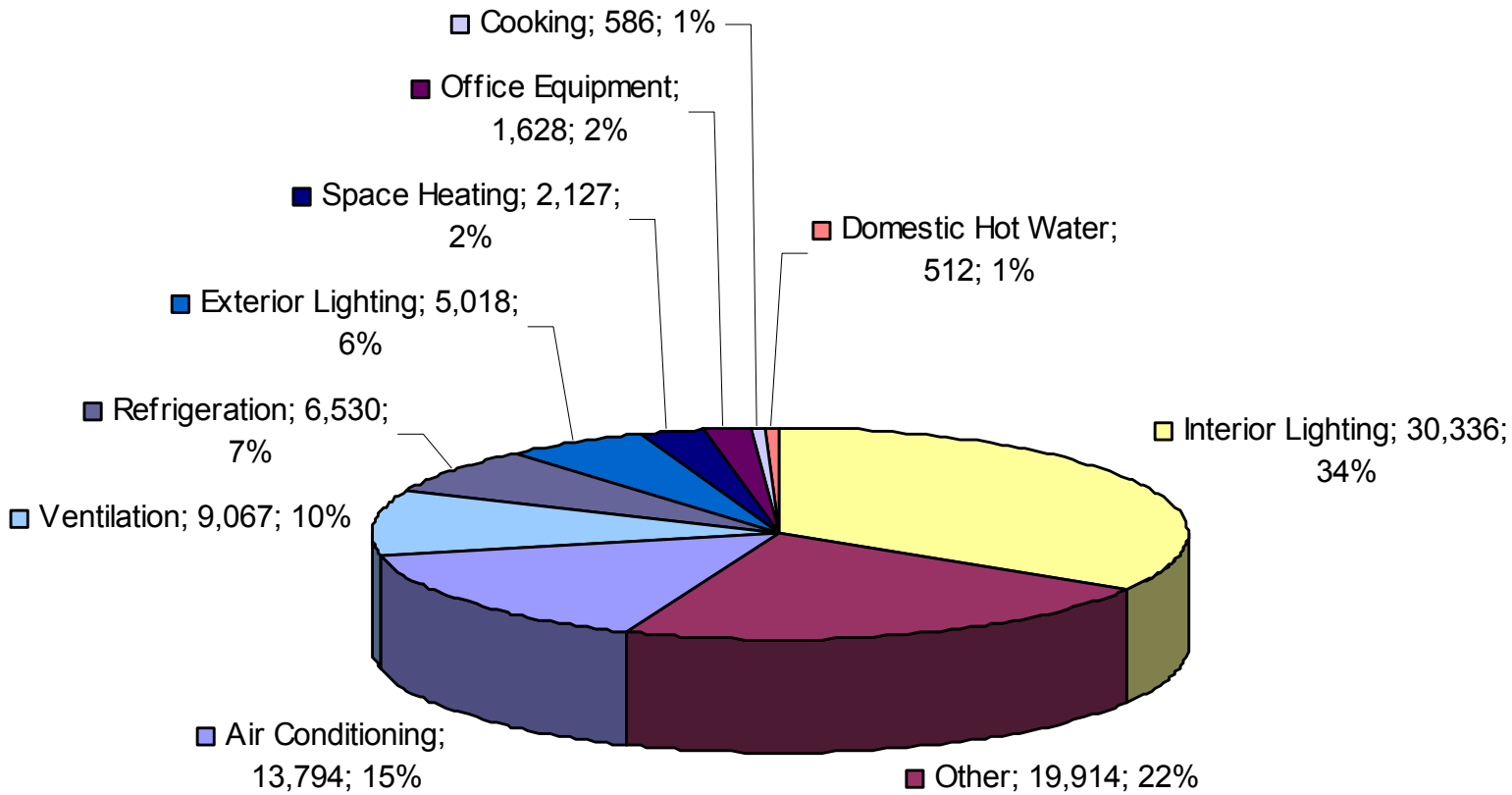
Commercial Coincident Peak Load by End Use - YR 1999 (MW)

Peter Schwartz & Associates



California Commercial Electricity Consumption by End Use – YR 1999 (GWh/Year)

Peter Schwartz & Associates



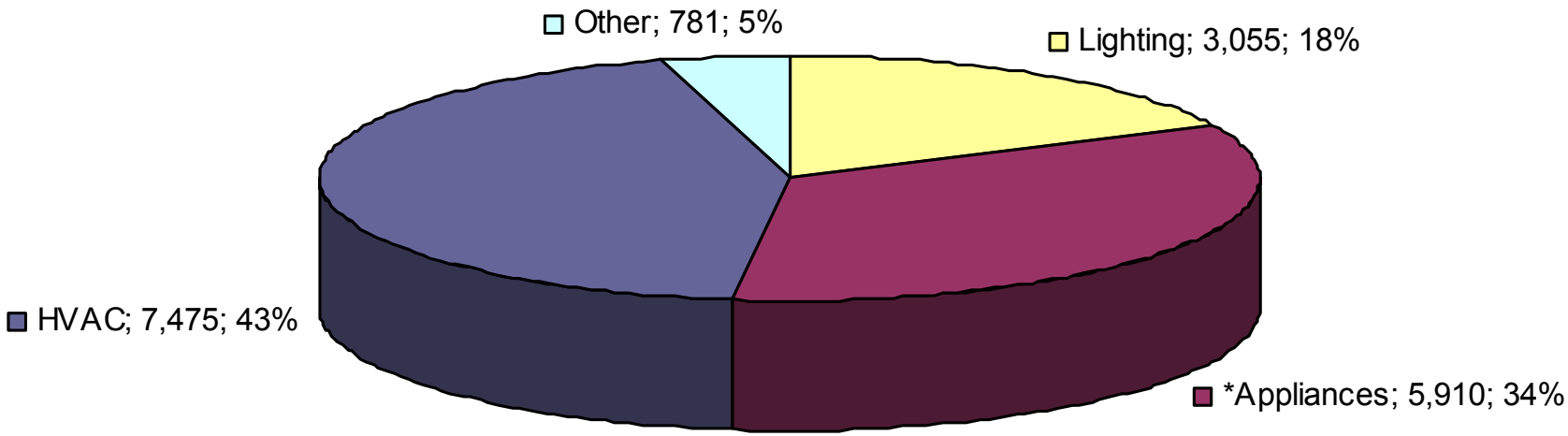
California Residential Electricity Consumption and Peak Demand by End Use - YR 1999

Peter Schwartz & Associates

Residential Sector End Uses	Coincident Peak Load (MW)	% of Total MW	Annual Energy (GWh/Yr)	% of Total GWh/Yr
Air Conditioning	7,475	43.41%	4,790	6.35%
Lighting & Miscellaneous	3,055	17.74%	24,623	32.65%
Refrigerator*	1,833	10.64%	13,668	18.12%
Cooking*	1,221	7.09%	3,569	4.73%
Dryer*	925	5.37%	5,715	7.58%
Pools & Spas (Other)	781	4.54%	4,126	5.47%
Domestic Hot Water*	555	3.22%	4,191	5.56%
Television*	465	2.70%	3,404	4.51%
Freezer*	339	1.97%	2,473	3.28%
Dishwasher*	323	1.88%	1,994	2.64%
Waterbed Heater*	138	0.80%	2,116	2.81%
Washer*	111	0.64%	731	0.97%
Space Heating	0	0.00%	4,011	5.32%
Total - Residential	**17,221**	**100.00%**	**75,411**	**100.00%**

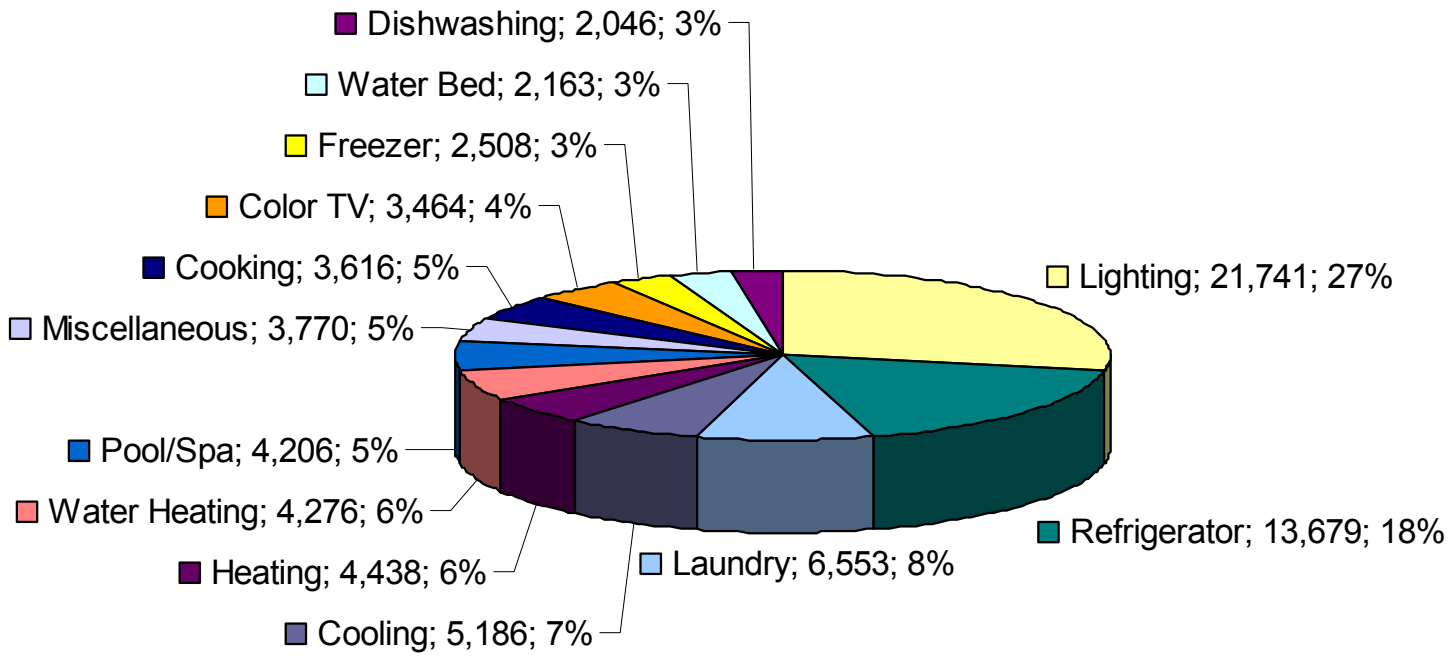
Residential Electric Peak Demand by End Use - YR 1999 (MW)

Peter Schwartz & Associates



Total Annual Residential Electricity Consumption by End Use - YR2000 (GWh/Year)

Peter Schwartz & Associates



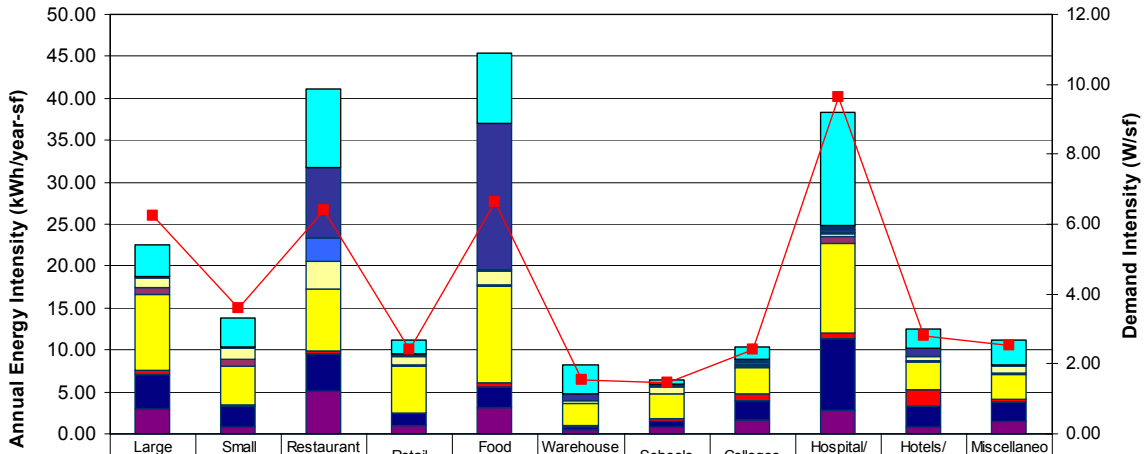
Energy Infrastructure
Strategic Planning ◆ Project Development

Where is the Cost-Effective Gold ?

Peter Schwartz & Associates

Commercial Market Sector Electricity (kWh/sf-yr) & Demand (W/sf) Intensity by End Use

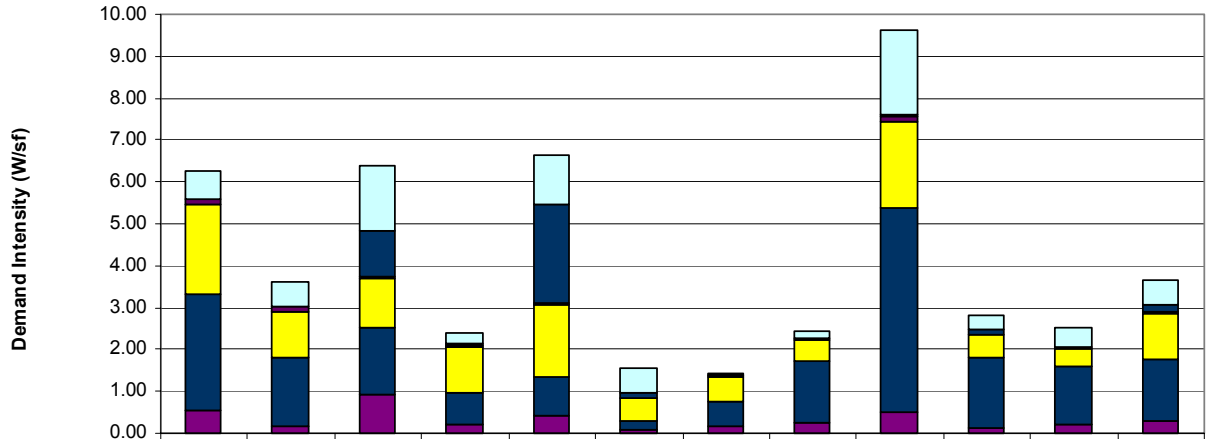
Peter Schwartz & Associates



	Large Offices	Small Offices	Restaurants	Retail	Food Stores	Warehouses	Schools	Colleges	Hospital/ Healthcare	Hotels/ Motels	Miscellaneous
Miscellaneous (kWh/sf-yr)	3.86	3.38	9.28	1.60	8.34	3.36	0.47	1.47	13.65	2.35	3.07
Water Heating (kWh/sf-yr)	0.07	0.05	0.10	0.03	0.09	0.01	0.17	0.32	0.38	0.10	0.08
Refrigeration (kWh/sf-yr)	0.02	0.04	8.28	0.19	17.46	0.84	0.12	0.31	0.33	0.89	0.10
Cooking (kWh/sf-yr)	0.02	0.01	2.90	0.02	0.11	0.00	0.06	0.07	0.12	0.10	0.01
Outdoor Lighting (kWh/sf-yr)	1.16	1.35	3.25	1.04	1.67	0.29	0.81	0.21	0.36	0.50	0.78
Office Equipment (kWh/sf-yr)	0.77	0.79	0.03	0.09	0.08	0.04	0.07	0.18	0.80	0.02	0.17
Indoor Lighting (kWh/sf-yr)	9.08	4.63	7.27	5.59	11.67	2.67	2.95	3.09	10.71	3.41	2.92
Heating (kWh/sf-yr)	0.45	0.17	0.45	0.10	0.33	0.13	0.24	0.79	0.73	1.97	0.31
Cooling (kWh/sf-yr)	4.17	2.52	4.42	1.40	2.54	0.35	0.74	2.35	8.53	2.35	2.37
Ventilation (kWh/sf-yr)	2.98	0.79	5.08	1.04	3.14	0.48	0.76	1.60	2.80	0.90	1.44
Demand Intensity (W/sf)	6.25	3.59	6.40	2.40	6.64	1.53	1.45	2.42	9.64	2.80	2.52

Commercial Market Sector Electric Demand Intensity by End Use (W/SF)

Peter Schwartz & Associates



	Large Offices	Small Offices	Restaurants	Retail	Food Stores	Warehouses	Schools	Colleges	Hospital/ Healthcare	Hotels/ Motels	Miscellaneous	Total
Miscellaneous (W/sf)	0.65	0.57	1.55	0.27	1.17	0.57	0.07	0.14	2.04	0.34	0.45	0.56
Water Heating (W/sf)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration (W/sf)	0.00	0.01	1.13	0.03	2.39	0.12	0.02	0.04	0.04	0.11	0.01	0.16
Cooking (W/sf)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Outdoor Lighting (W/sf)	0.01	0.01	0.04	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Office Equipment (W/sf)	0.13	0.10	0.01	0.02	0.01	0.01	0.01	0.02	0.12	0.00	0.02	0.05
Indoor Lighting (W/sf)	2.14	1.09	1.17	1.12	1.70	0.56	0.57	0.48	2.05	0.56	0.44	1.08
Heating (W/sf)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling (W/sf)	2.75	1.66	1.59	0.74	0.95	0.18	0.61	1.47	4.86	1.66	1.36	1.49
Ventilation (W/sf)	0.56	0.15	0.92	0.22	0.40	0.10	0.17	0.27	0.52	0.12	0.23	0.30

Commercial Market Sector Floor Area (Millions SF)

Peter Schwartz & Associates

Commercial Occupancies	Floor Area (Millions SF)
Office	1,385.31
Large Offices	1,024.28
Small Offices	361.03
Restaurants	145.17
Retail	882.35
Food Stores	230.52
Warehouses	787.43
Schools	457.47
Colleges	270.13
Hospital/ Healthcare	278.57
Hotels/ Motels	270.87
Miscellaneous	992.52
Total	**5,700.34**

- Mapping the demand intensity onto the total floor area:
  - "Bounds" the total **target** market by occupancy
  - Determines potential DR market impacts

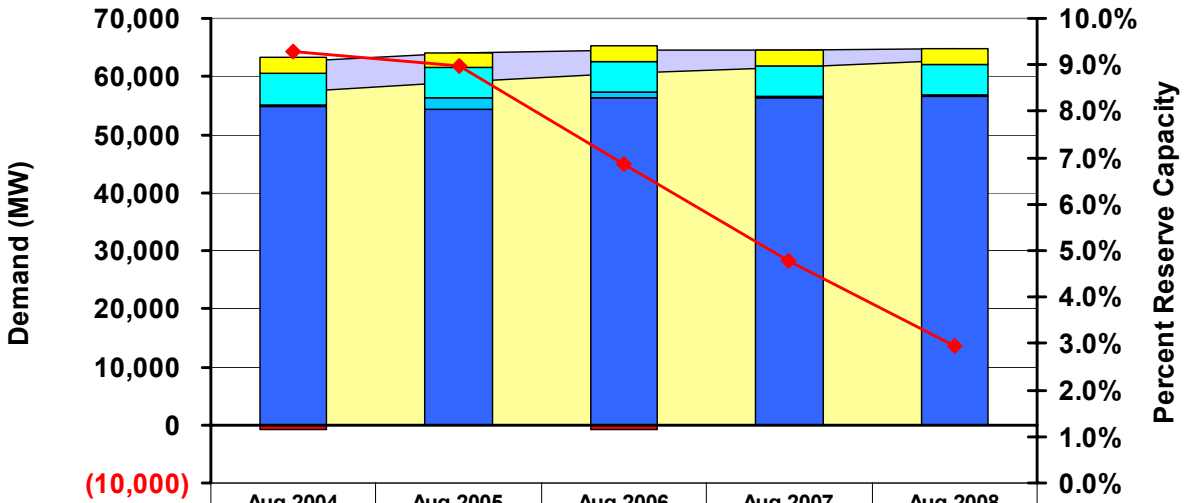
Energy Infrastructure
Strategic Planning ◆ Project Development

What is the Gold's Value ?

Peter Schwartz & Associates

2004-2008 Statewide Supply/Demand Balance (Planning Reserve)

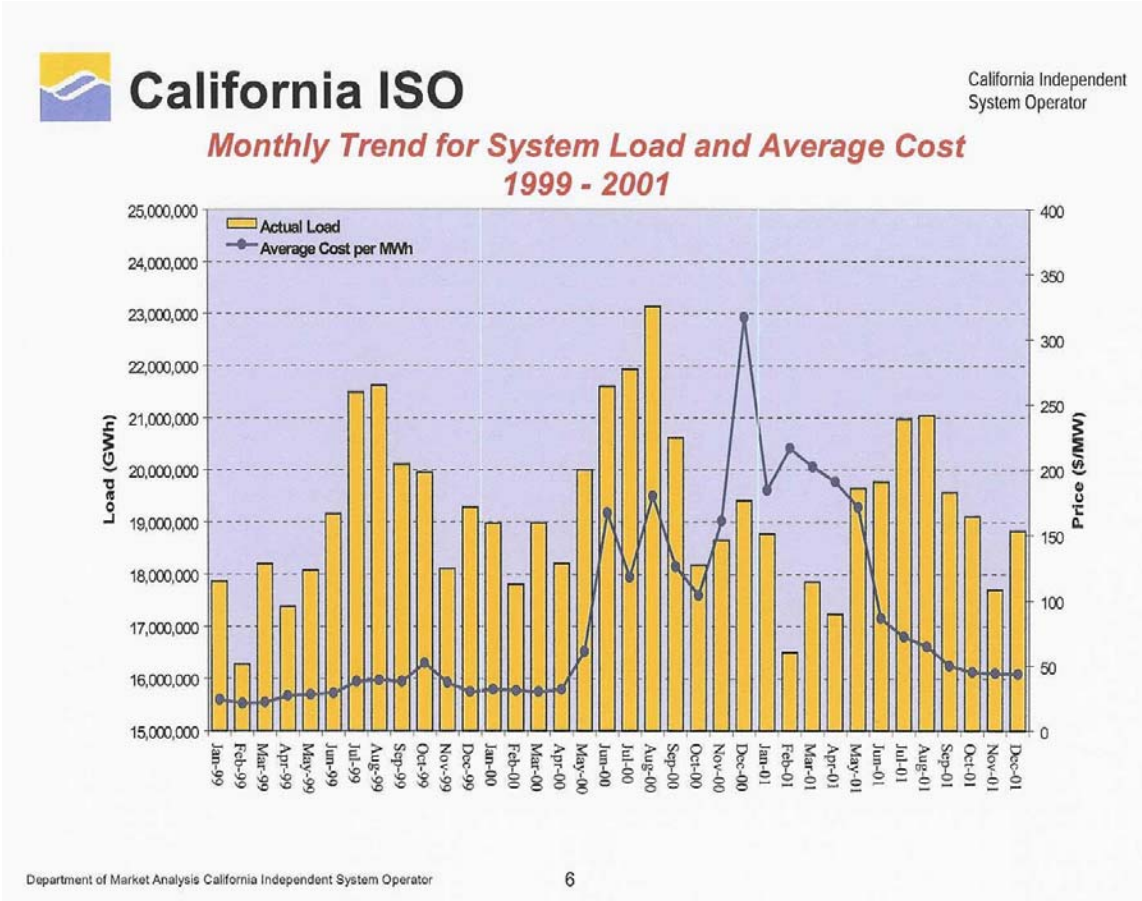
Peter Schwartz & Associates



	Aug 2004	Aug 2005	Aug 2006	Aug 2007	Aug 2008
Total Supply (MW)	62,461	64,148	64,422	64,440	64,669
1-in-10 Summer Temperature (Hot) Demand (MW)	57,416	59,137	60,502	61,654	62,914
Existing Generation	54,749	54,416	56,250	56,424	56,642
Retirements	(708)	0	(916)	0	0
High Probability CA Additions	375	1,834	1,090	218	229
Net Firm Imports	5,345	5,198	5,298	5,098	5,098
Spot Market Imports	2,700	2,700	2,700	2,700	2,700
Planning Reserve Margin (1-in-10)	9.3%	9.0%	6.9%	4.8%	3.0%

Electricity Price Volatility

Peter Schwartz & Associates



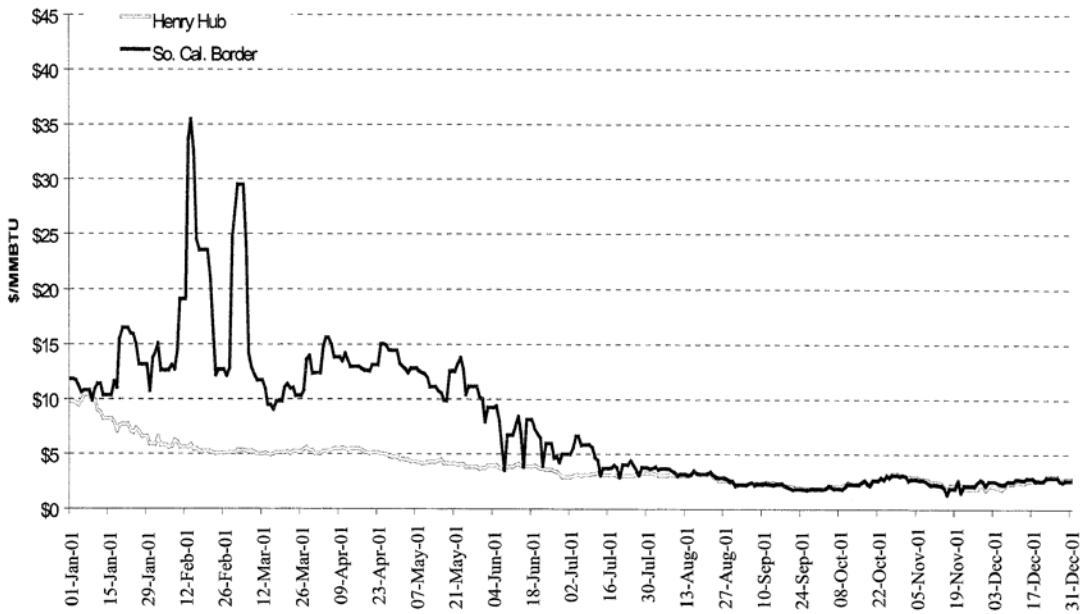
Natural Gas Price Volatility

Peter Schwartz & Associates

California ISO

California Independent System Operator

Natural Gas Spot Prices for Jan 2001 Through Present
So. Cal. Border and Henry Hub (No Transportation Costs)



Energy Infrastructure
Strategic Planning ◆ Project Development

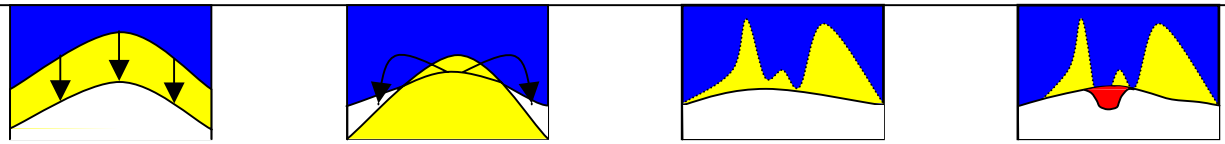
Mining the Gold

Peter Schwartz & Associates

Four Major Technology Categories:

Peter Schwartz & Associates

Static Load Technologies ⇒ Dynamic Load Technologies



1.0 Load Reduction /Fuel Switching	2.0 Load Shifting	3.0 Enabling Demand Response	4.0 Dynamic Demand Response

Energy Infrastructure
Strategic Planning ◆ Project Development

Key Elements to Success-
Demand Response Enabling Technologies

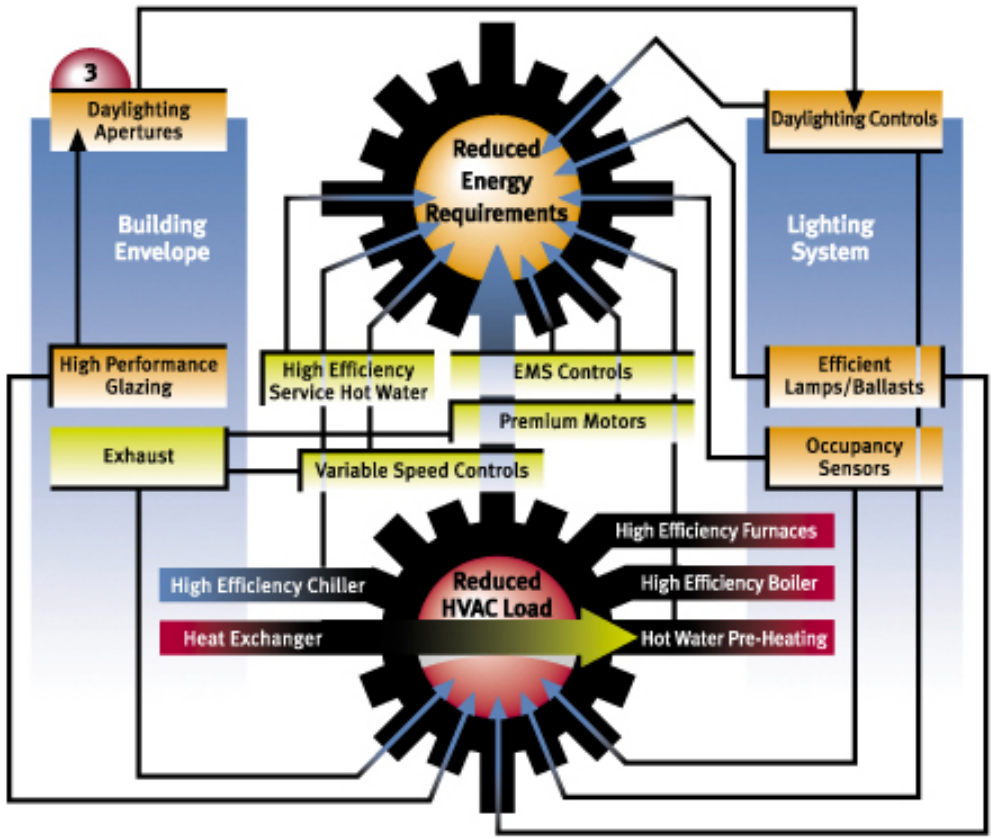
Peter Schwartz & Associates

- Installing energy-efficiency measures for permanent load reduction
- Optimize building operation—commissioning
- Installing an enhanced EMS and energy information system (EIS) system including sensors, BCS & advanced interval metering that:
  1. Reacts automatically to peaking demand conditions or external signals to reduce load;
  2. Provides the gateway for two-way communication between the EIS & EMS;
  3. Includes enhanced programming and existing system integration; and
  4. Increases the existing system's number of monitoring and control points.
- Changes in organizational policy
- Wide focus vs. compartmentalized view

Energy-Efficiency Strategies

Peter Schwartz & Associates

- Need for WHOLE building integrated approach.
- PG&E's *Savings By Design* is an excellent example.
- Need to take technology further.



Demand Response Enabling Technologies

Peter Schwartz & Associates

- **Building Envelope Control Technologies:**
  - **Daylight harvesting strategies**
  - **Dynamic fenestration shading controls**
  - **Natural ventilation & night flushing**

Demand Response Enabling Technologies

- **Centralized Lighting Control Technologies:**
  - Lighting sweep strategies
  - Override strategies
  - Demand limiting strategies
  - Occupancy sensors
  - Dimming capabilities throughout building

Demand Response Enabling Technologies

Peter Schwartz & Associates

- **HVAC Control Technologies and Strategies:**
  - **Time & temperature control –** On/off control; Space temperature control; Combined time and temperature control; Other operating temperature and time control
  - **Advanced time & temperature control –** Shut-off with high limit: Night ventilation; Optimal start
  - **Variable capacity control –** Variable-air-volume (VAV) designs; Variable-speed exhaust systems; Variable-speed cooling tower controls; Variable-speed drives for centrifugal chillers; Variable-speed pumps for condenser water or chilled and hot water pumps
  - **Demand-response ventilation –** Carbon dioxide sensing systems; Occupancy sensing systems; Carbon monoxide sensing systems for garages
  - **Peak load shifting strategy –** Thermal energy storage
  - **Chilled-water system control –** Chilled-water temperature control; Condensing temperature control; Cooling tower/evaporative condenser fan control

End Goal- Convert buildings into Negawatt power plants

Peter Schwartz & Associates

- Create dynamic, demand-responsive buildings that in turn,
- Enable a flexible, demand-responsive electric market

Energy Infrastructure
Strategic Planning ◆ Project Development

Barriers to Mining the Gold

Peter Schwartz & Associates

Demand Response Market Issues

- Systems integration
- Legacy systems
- Capital for infrastructure investments
- Technology gaps
- Transitory market structure
- Regulatory barriers
- Clear market signals:
  - Price increases
  - Capacity constraints
  - Electricity shortages

Energy Infrastructure
Strategic Planning ◆ Project Development

Customer Challenges to Participating in Demand Response Programs

Peter Schwartz & Associates

- Framework for analysis
  - Load response programs
  - Price response programs
- Overcoming technical challenges

  Generic issues:
  - Baseline estimation
  - Operating equipment
  - Interconnection requirements
  - Metering and verification (including net metering)
  - Communication
  - Load profiling
  - Environmental
- Mass Market Issues -- Special circumstances
- Unique Loads and Large Customer Issues

Customer Challenges to Participating in Demand Response Programs (cont.)

- Overcoming economic challenges

  General

  - Valuing reliability
  - Commodity pricing and price volatility (including price caps)
  - Revenue loss
  - Settlements
  - Non-economic gaming
  - Social values and costs
- Mass market issues
- Unique loads and large customers

Customer Challenges to Participating in Demand Response Programs (cont.)

- Overcoming institutional challenges
  - Distribution organizations
  - Retail marketing organizations
  - Curtailment service providers
  - Generation organizations
  - ISO/RTO organizations
  - Equipment and services providers

Energy Infrastructure
Strategic Planning ◆ Project Development

"If you build it, deregulation will come"

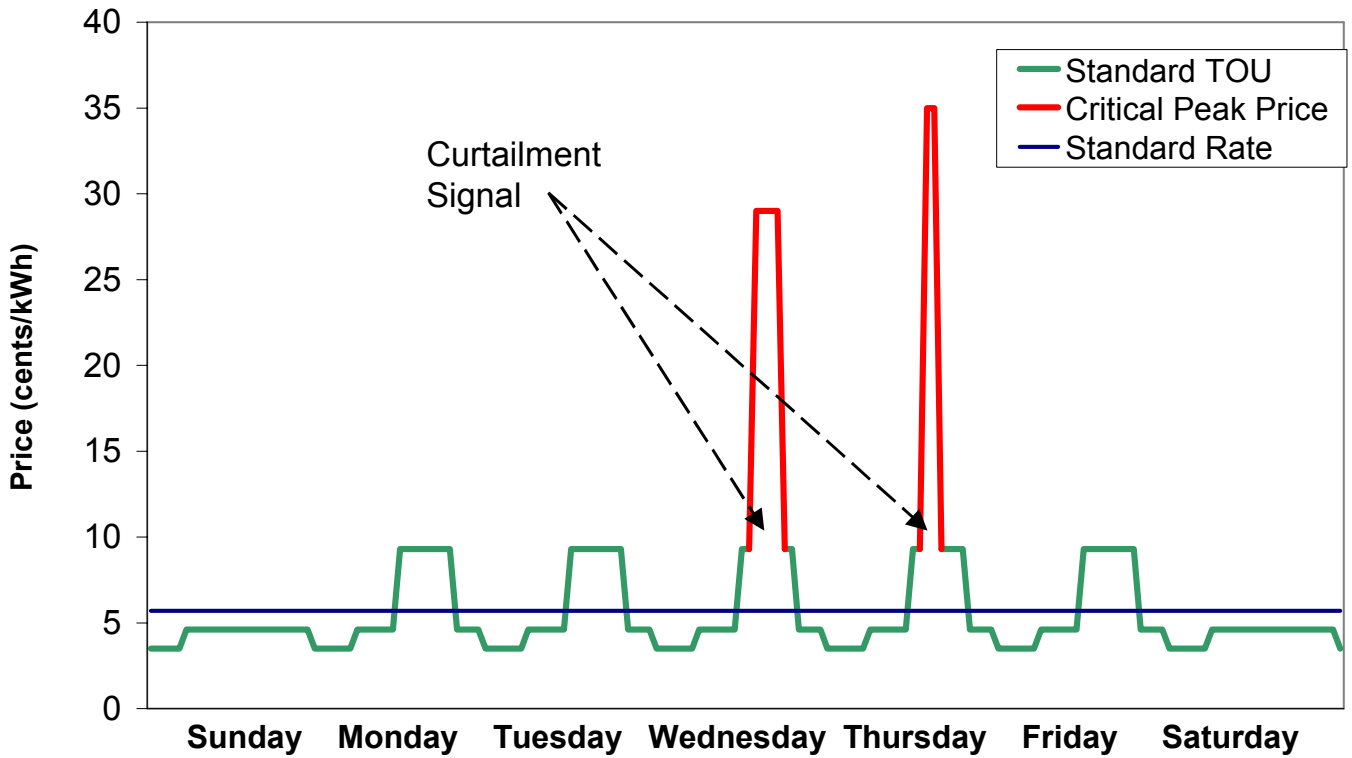
Peter Schwartz & Associates

First, what is **IT**? An electric market where:

1. Regulatory agencies establish fair & level playing field
   - Electric market with stable rates & tariffs
   - Rates & tariffs reflect actual, real-time energy costs
   - Negawatt capacity has same (or better) treatment as megawatt capacity
2. Market infrastructure provides for seamless, real-time communication of market signals to customers managing & operating buildings
3. Buildings incorporate dynamic, demand-responsive technologies

Critical Peak Pricing (CPP)—(Based on Gulf Power tariff)

Peter Schwartz & Associates



"If you build it, deregulation will come"

Peter Schwartz & Associates

HOW?

1. Establishes link between wholesale cost & retail price
2. Enables customers to respond intelligently and cost-effectively to market signals
3. Encourages investment at all levels of the marketplace:
   - New & upgraded generation
   - Enhanced T&D
   - Dynamic building technologies
   - Distributed & renewable generation
   - Negawatt capacity

Benefits of Demand Response

- Enhances market efficiency
- Cost reduction
- Enhance system reliability
- Creates opportunities for risk management
- Potential environmental improvements
- Customer service and choice
- Market power mitigation

Indirect Benefits of Nationally Deployed Dynamic Pricing Solution

Peter Schwartz & Associates

- Avoid need for ~250 "peaker" power plants
- Power infrastructure for peaks reduced by 31,000 MW, saving $16 billion in (one-time) capital costs

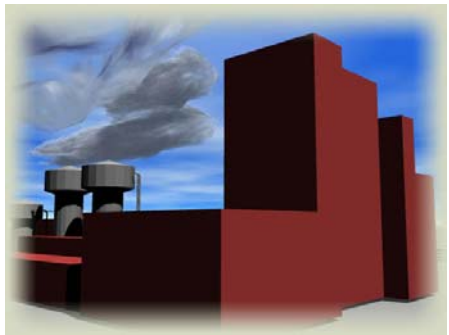
- Reduces water used for hydro-electric generation
- Gas demand reduced by 680 bcf/year
- Gas transmission reduced by 2 bcf/day
- Mitigates natural gas price volatility

Note: Assumes 125 MW peaking plant, $500/kW capital cost, 25% load factor, 10,000 heat rate, 0.9 lb NOx/MWh
Source: Department of Energy; EIA Power Annual Volume II; BAEF Report; EIA RECS 1997; McKinsey analysis

Indirect Benefits of Nationally Deployed Dynamic Pricing Solution

Peter Schwartz & Associates

- Enough saved electricity to supply 7 million new homes annually
- Blackouts & resulting lost productivity avoided



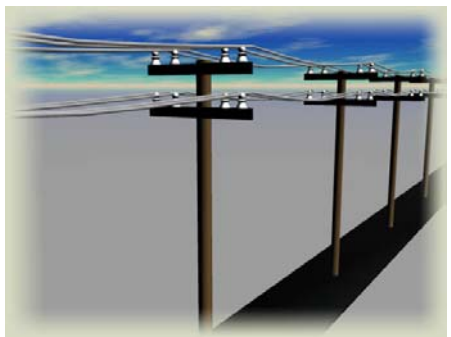
- Eliminate 31,000 tons of NO_X emissions annually

Note: Assumes 125 MW peaking plant, $500/kW capital cost, 25% load factor, 10,000 heat rate, 0.9 lb NOx/MWh
Source: Department of Energy; EIA Power Annual Volume II; BAEF Report; EIA RECS 1997; McKinsey analysis

Indirect Benefits of Nationally Deployed Dynamic Pricing Solution

Peter Schwartz & Associates

- Other environmental benefits:
  - Cleaner water
  - Reduced thermal pollution
  - Hydro power impact on ecosystems



- Other system benefits:
  - Avoided transmission & distribution investment
  - Reduced meter reading costs

Source: Department of Energy; EIA Power Annual Volume II; BAEF Report; EIA RECS 1997; McKinsey analysis

Demand Response Example 1

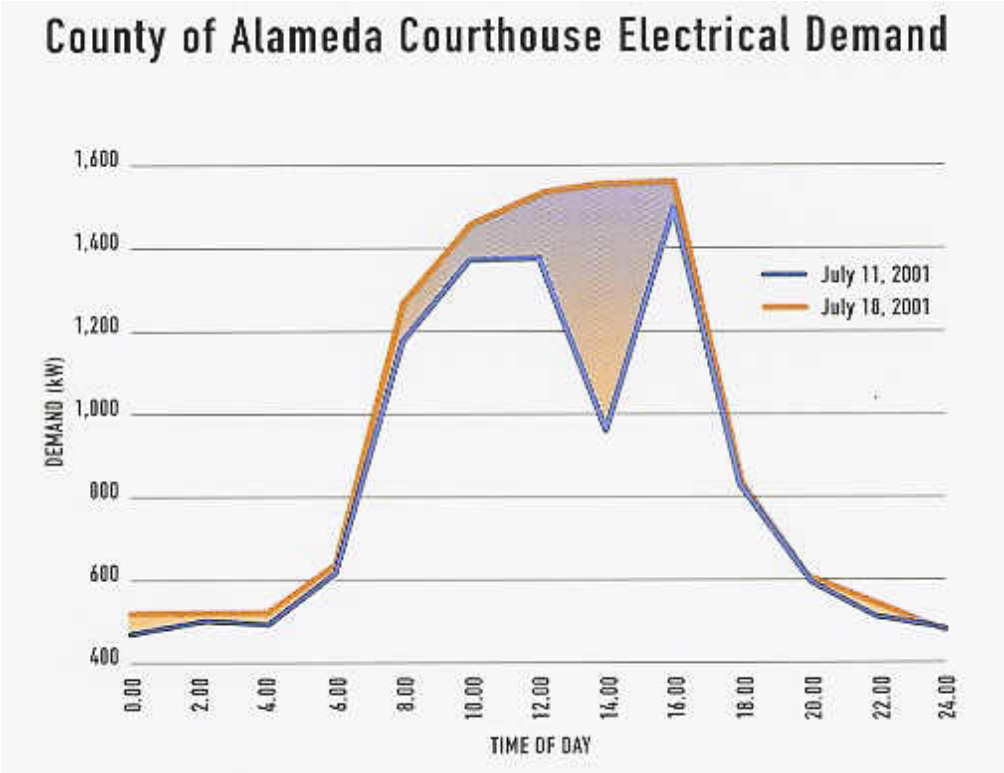
Peter Schwartz & Associates

Issues:

- Unpredictable energy supply
- Inability to curtail energy use & maintain occupant comfort
- Rising energy costs

Demand Response Example 1

Peter Schwartz & Associates



Demand Response Example 2

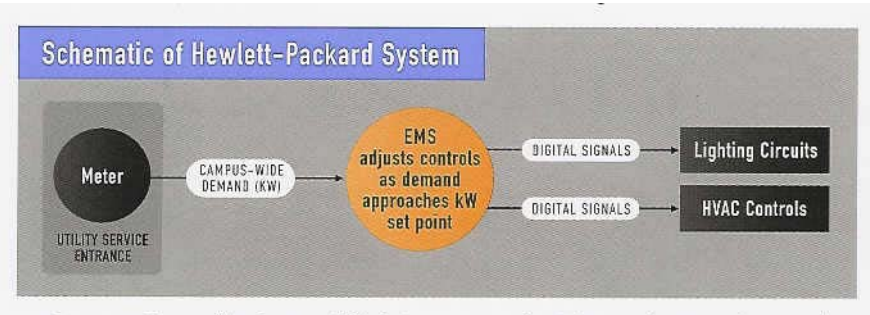
Peter Schwartz & Associates

Issues:

- Labor- and time-intensive to shed load
- Inability to curtail energy use & maintain occupant comfort
- Unpredictable energy supply

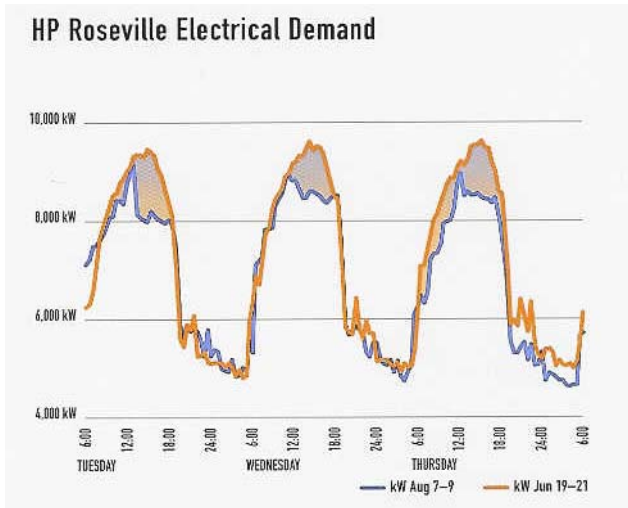
Demand Response Example 2

Peter Schwartz & Associates



- Automated demand control ventilation tied to CO_2 sensors to ensure air quality
- Automated lighting controls (multiplexers installed) to shut off pre-determined, non-essential lights
- EMS programmed to gradually close VAV boxes & control valves to reduce chilled H_2O
- VFD's on CWPs reduce circulation until chillers shut off

- Expanded EMS capabilities
- High-speed LAN
- DDC
- Power monitors linked to interval meters



Demand Response Example 2

- Results:
  - Cut peak load ~ 12%
  - Automated load shedding ~ 1.5 MW curtailable
  - Increased occupant comfort
  - Targeted HVAC control
  - Energy cost savings ~ $1.5 million annually