Smart Metering: IT and Power Sector Distribution – A Techno-economic Analysis

October 5, 2004

Dr. Rahul Tongia

Systems Scientist

School of Computer Science (ISRI) / Engineering & Public Policy

Carnegie Mellon University

Pittsburgh, Pennsylvania

tongia@cmu.edu

With support from PESD, Stanford University

Talk Outline

- Metering and Control – Technologies and capabilities
- Other countries (Italy)
- India – Leapfrogging opportunity?
  - Techno-economic analysis
- Issues and Challenges

US Industry Evolution

	Phase I Options Define Service 1800s to Early 1900s	*Phase II* Option Consolidation 1920s to 1960s	*Phase III* Separate Options 1970s to 2000	*Phase IV* Integrated Options After 2000
Pricing	End-Use Rates	Usage Based Rates	TOU Rates	Real Time Pricing
Metering	None	Total kWh Usage	Time Period Loads	Hourly Loads
Load Shape Objectives	Load Growth	Load Growth, Valley Filling	Peak Shaving, Shifting, Conservation	Preserve Electric Reliability, Customer Cost Management
Customer Involvement	Active, Fuel Switching	Passive, few options	Utility Command and Control	Interactive Particiaption
Demand Response	Contracts for Service	Water Heater Time Clocks	Curtailable, Interruptible, Direct Control	Demand Bidding, Risk Management
	⇩	⇩	⇩	⇩
	• Increased choice • Service tailored to customer needs	• Reduced choice • Increasing value to customers • Declining cost	• Reduced choice • Increasing costs • Loss of control • Declining value to customers	• Increasing choice • Cost Volatility • Value of Information

Source: *New Principles for Demand Response Planning*. Palo Alto, EPRI: 1006015

Metering Design – Function of Capabilities

- Parameters to be measured
  - kWh, peak kW, power factor, etc.
- Frequency of measurement
  - 15 minutes, 1 hour, daily, monthly, etc.
- Frequency of "uplinking"
- Sending signals downstream
  - Pricing, connect/disconnect, emergency, other
- Other capabilities
  - Demand Response/Demand Side Management
  - Home monitoring
  - Broadband
  - etc.

Today's focus is on IT and distribution – covers metering, Demand Response (DR), and power distribution system

Technologies vs. Capabilities

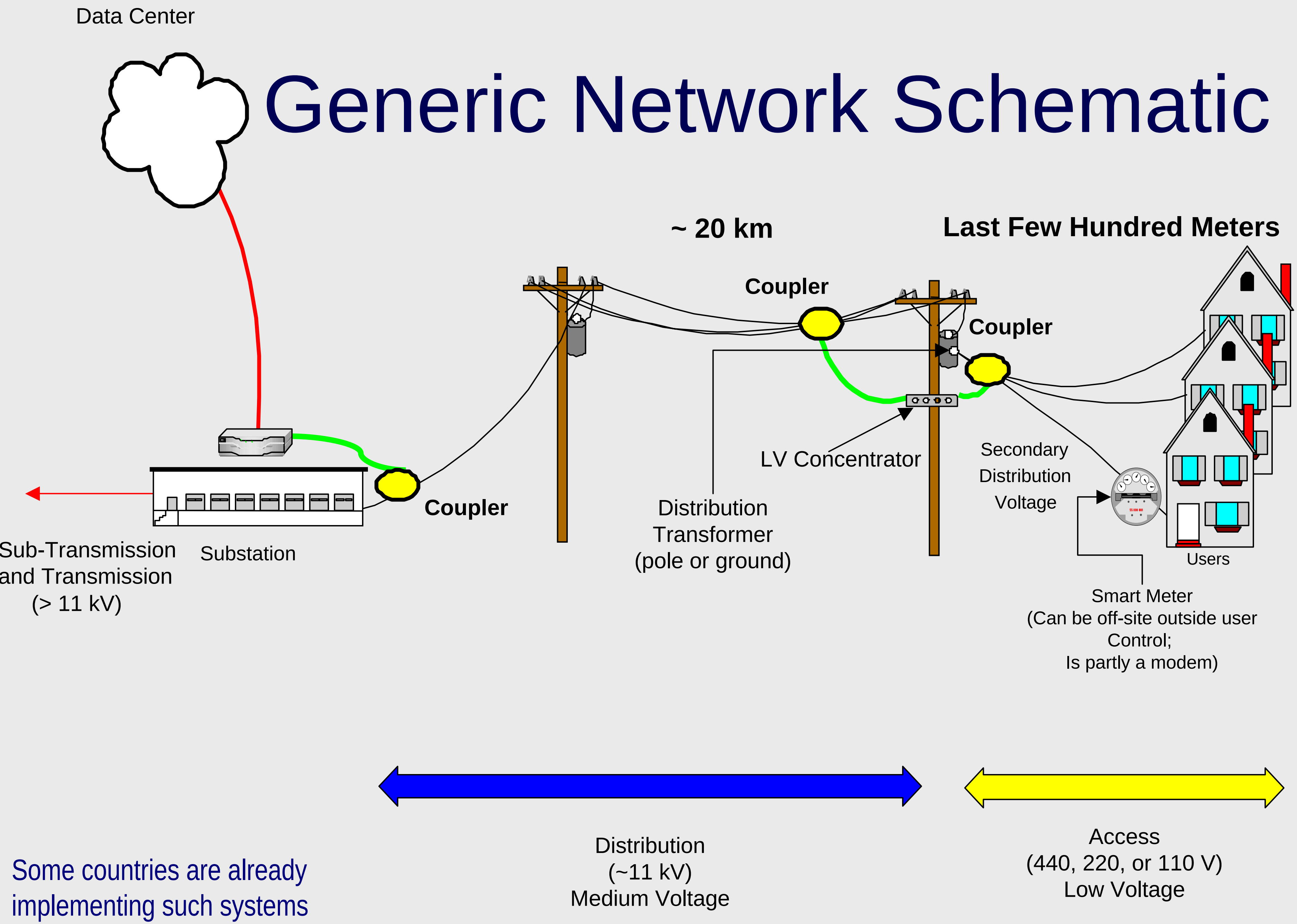
		Accuracy	Theft Detection	Communications	Control	Capabilities
Past	Electro-mechanical Meter	low (has threshold issues for low usage)	poor	expensive add-on	nil	
Current Efforts	Digital (solid state)	high	Node only	External; AMR potential	Limited	*Historical* usage reads only
Possible Future	Next Gen. Meter and integrated IT system (proposed)	Arbitrarily high	High (network level)	Built-in (on-chip)* *Can do much more than Automated Meter Reading (AMR)	Full (connect / disconnect); Extending signaling to appliances	Real-Time control; DSM

Source: Tongia (2003)

US AMR/Smart Metering

- Automated Meter Reading (AMR) penetration by 2002 (all capabilities/technologies):
  - 16.9% penetration by meter (Scott Report)
  - ~1/3 of utilities have some level of AMR in place
    - Public Utilities are the real laggards
  - More use of wireless than other countries
- Many Smart IT pilots/deployments in the US focused on Real Time Pricing or Demand Response
  - California
    - E.g., RTEM: 25,000 advanced meters installed – 9/01-6/02 - SCE
      - TOU pricing (with web access)
      - Consumers typically
        - Reduced peak loads
        - Reduced overall loads
        - Reduced Costs

Generic Network Schematic



Some countries are already implementing such systems

Real Prospects for Smart IT System

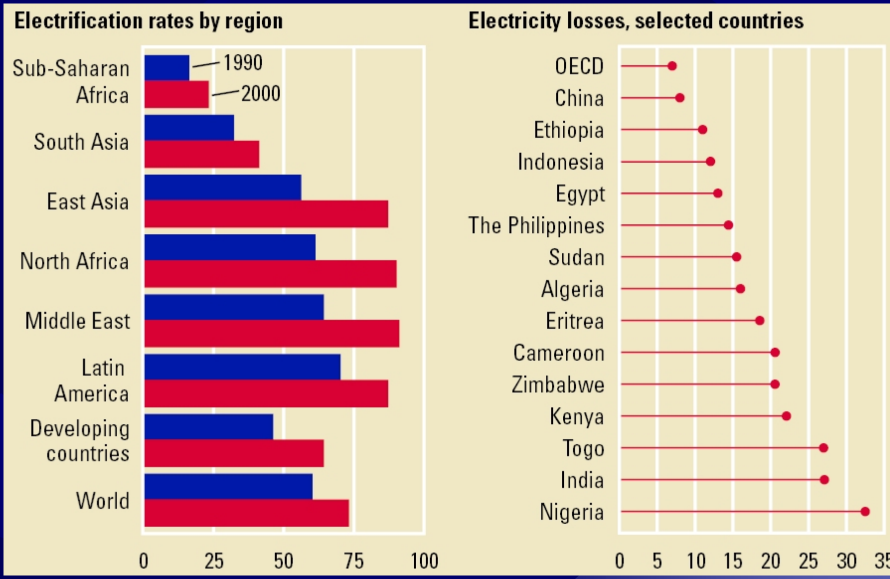
- ENEL (Italy) offers glimpse of possibilities
  - All users (~30 million) to be converted by 2005-06
    - ~20 million converted today; 700,000+/month
  - ~80-100$ total (avg.) cost per node, installed
    - Includes back-end
    - Total 2.4 billion Euros
  - ~4 Year payback *just from operational savings*
  - 2-way communications and control capabilities
- Developing Countries: hard to make apples to apples comparison
  - Utilities lack "standard" equipment required in conjunction with IT solutions
    - ARCs, Variable Transformers, etc.

Enel System

- Technology
  - Hybrid wireless (GSM) and PowerLine Carrier (PLC)
  - Store and Forward architecture (not fully real time)
    - Function of when the technology decisions were made?
- Blanket deployment – lowers costs
  - Assumed existing meters were a sunk cost
- Other driver(s) than typical CBA
  - Changing load ratings (3.3 kW, 6 kW, or 9 kW) for consumers previously required truck roll
  - Deregulation by 2007
  - ~3% bad collection
- Partnering with IBM for modifications and reselling worldwide

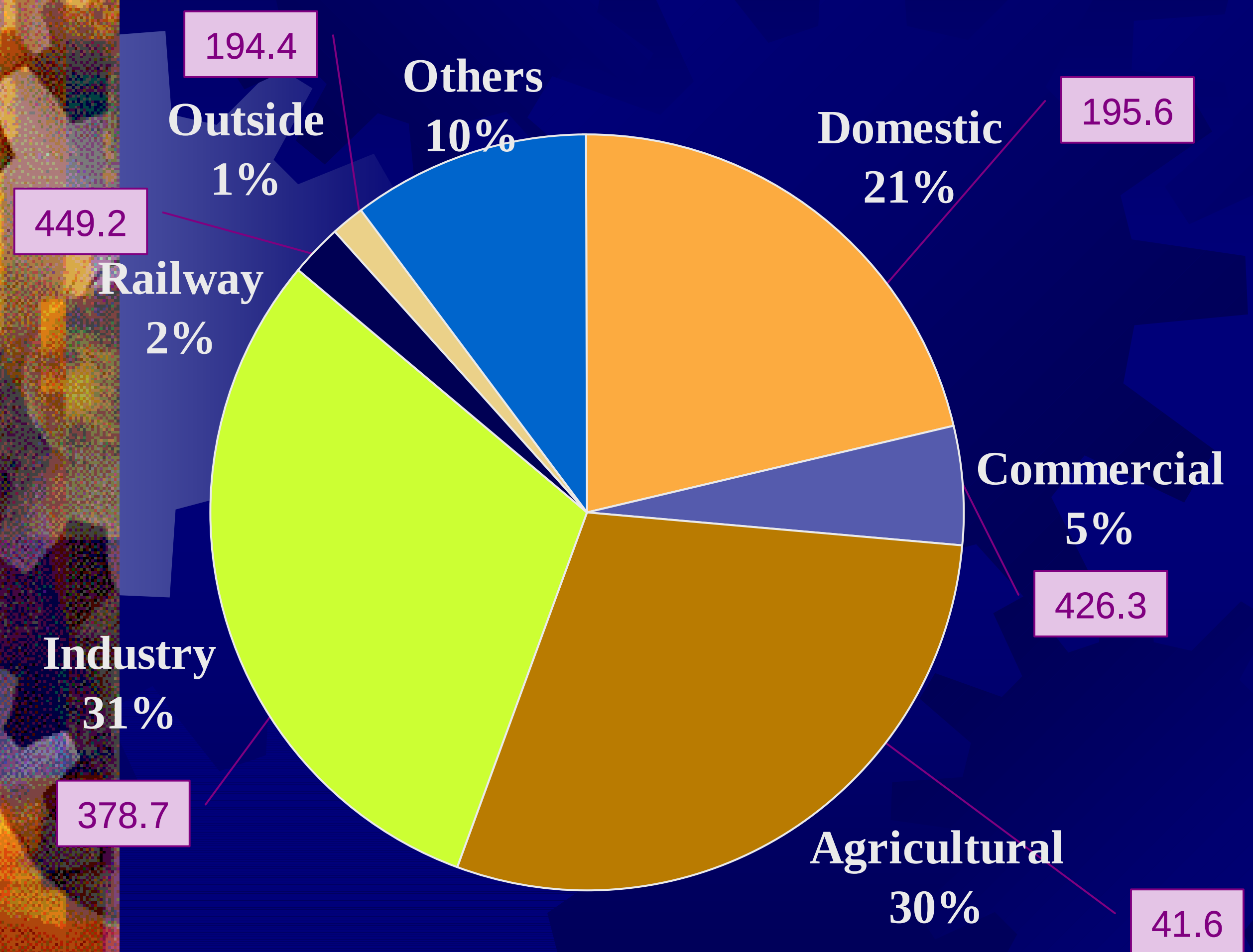
The Indian Power Sector Today – Salient Features

- 112 GW capacity –
  - Per capita consumption only ~350 kWh
- Growth of 10% annually required
  - Industrial/commercial demand
  - Over ½ of rural homes not yet electrified
- Loss-making state-owned utilities (billions of $ losses)
  - High "T&D" losses
    - Theft estimated ~10-15%
  - Undergoing reforms to improve performance
    - Newest Elec. Act 2003 might give exit strategies for captive generation



Source: World Bank (2003)

Not Enough Paying Consumers: Mismatch in Consumption & Tariffs (2001-02)



Consumption ≈ 315 Billion kWh

Prices

239.9 ps/kWh
(Average)
≈ 5.00 ¢/kWh

Source: Planning Commission

The Bottom Line

- “Cost of supply” is Rs. 3.50/kWh, realization only Rs. 2.40/kWh
  - Much of the electricity is sold below cost (and some well above cost)
  - Much of it is unaccounted for
    - High T&D losses (~30%)
      - Technical – 10-15% (?)
      - “Commercial” =Theft – 15-18%
- Utilities are bleeding money
  - Returns calculated as –30 to –40% (on Net Assets)
  - Losses (excluding $1.5 B subsidy) are approximately $4 billion

IT and Power Sector in India

- IT already used* in transmission and generation (SCADA systems)
- This presentation: Distribution sector
  - Massive reforms underway
    - Technical upgrades for a lossy system
    - Metering
    - ~4+ Billion US$ earmarked annually for this (plus non-govt. funds)

Goals and Hype for IT

- Public pronouncements: IT the "silver bullet"
  - End theft
  - Improve finances, etc.
- Reality: IT can't erase fundamentals
  - Tariff Irrationality and System Design
  - Physics of losses – quite high
    - *But*, IT can improve operations significantly
      - Variable Transformers, VAR compensators, etc.

IT and India’s Power Sector

- IT Task Force Report for Power Sector (2002)
  - Good introduction but incomplete vision
  - Recommendations
    - 2 “quick win” pilot projects
      - Integrated billing system for Commercial & Industrial consumers
      - Energy accounting system – mainly for MV distribution
    - “Advanced technologies” mainly looked at tamper-proof Automated Meter Reading (AMR)
      - Solutions seem expensive, and limited in potential
- *Can we consider a new paradigm?*
  - Don’t simply extrapolate
  - <u>Leapfrogging Opportunity</u>

Grand Vision for IT
(Way beyond AMR)

- Be able to…
  - Micromonitor and control every kWh
  - Provide improved power quality
  - Remote connect/disconnect
  - Manage loads and offer new services
  - And, of course, reduce theft
- While allowing…
  - Improved utility operations
  - Next Generation DSM

Smart IT: Techno-Economic Model

- Target specific users
  - All agricultural (almost one-third of the load)
  - All Industrial and larger commercial users
  - Only the larger-size domestic users
    - Estimated 2/3 of homes only use <50 kWh per month
- Include network nodes that need monitoring and/or control
  - Substations
  - Transformers
  - Capacitor banks (as applicable)
  - Relays (as applicable)

    etc.
  - *Excludes capital for utility equipment like transformers*
- New system designs and services are not factored in
  - Pre-paid metering
  - Future interaction with smart appliances, smart home networks, etc.
  - Distributed generation

Economics of Smart IT System – (Utility Name Withheld)

- Estimated System
  - 96 Consumers (all classes) per Distr. Transformer
  - 163 Distribution Transformers per Sub-Station

  (Averages only)
- ***~5% of India in population;~ 6% in power consumption (2001 estimates)***

	Number	Equipment cost ($)	
LT - Dom. (Applicable 20%)	1,654,000	70	115,780,000
LT - Comm.	988,000	70	69,160,000
LT - Agri	1,396,000	80	111,680,000
Industry - LT	231,000	80	18,480,000
HT (all)	5,089	100	508,900
Other (utility nodes)	100,000	200	20,000,000
DTRs	130,000	600	78,000,000
Substations	800	7,000	5,600,000
			419,208,900
		Other IT and infrastructure (capitalized)	20,000,000
			439,208,900
Needed Savings		14.9%	<-annualized rate
65,388,885	US$ to justify the investment		
22,625,000,000	kWh sold annually		
0.08	Avg. cost/kWh	3.60	
1,810,000,000	gross costs (not revenue as collection/tariffs are low)		
13.01	Paise/kWh GROSS cost of system		
3.61%	need improvements worth		

System-wide implications – Smart IT

13.0	paise/kWh GROSS cost		
Savings	*Ultimate Potential*	*Plausible*	*Notes*
Theft Reduction	35	8.8	1/3 of thieving load on system
Freeing up capacity	18.1	9.1	Limited Peak shifting (short term) -- 3%
Avoiding shortfalls			
Reduction of catastrophic failures	0.4	0.4	1 major failure in 15 years avoided
Improved GDP impact	3.3	1.4	conservative est. pro-rata
Operational Improvements			
CRM benefits	0	0	Assume really cheap labor in India
Load Planning	6.3	3.1	Better supply portfolio (existing only) - excl. "peak" pricing
Technical losses and failures	0.108	0.1	3% operational potential
DTR failure reduction	1.5	0.8	~10-15% failure rate today!
Consumer benefits	1.2	0.6	Lower DTR failures and downtime, equipment
Improved power quality			
Agricultural alone	25	8.3	1/3 of potential is realized
Industrial	2.4	1.2	Based on capital stock and one-time 1% incr. equip.lifespan
TOTAL Benefits (paise/kWh)	93.3	33.7	

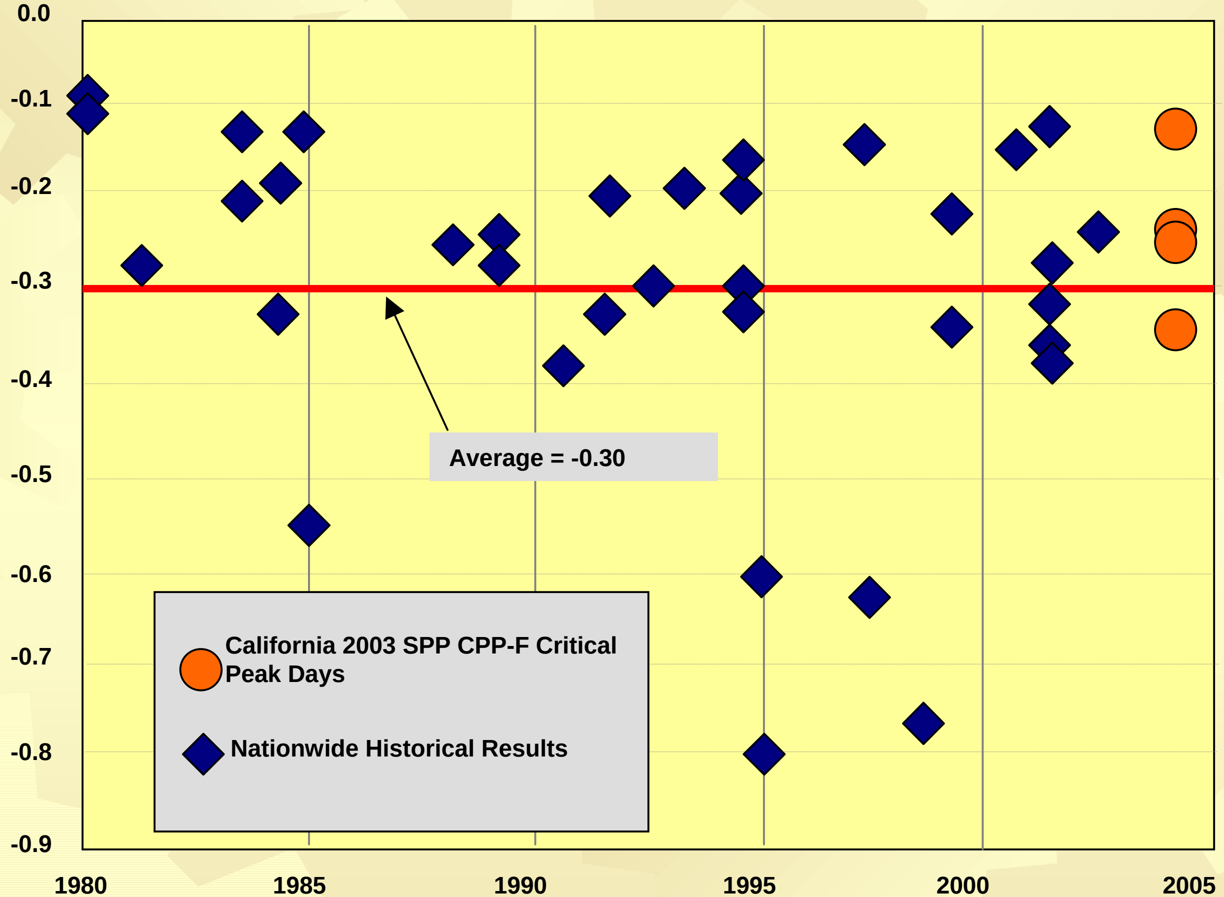
Reasonably conservative assumptions
-- Cost per node assumed several % higher than ENEL's project (which was blanket deployment)
-- Only includes benefits where IT could play a role even within "Ultimate Potential"
– Excludes trickle down/multiplier effects or +ve externalities like higher industrial growth

100 paise = 1 Rupee (Rs.)
1 US$ = ~ 45 Rs. (2004)

US Industry Experience

Own-Price Elasticities

California SPP vs. Nationwide Historical Results



Source: Predicting California Demand Response, Chris King and Sanjoy Chatterjee, Public Utilities Fortnightly, July 1, 2003.

Implementation of Smart IT in India: General Barriers

- Financing
  - Funding likely available (internal + external)
- Lack of technology/R&D savvy
  - Tenders for equipment lead to poor outcomes
- Real-time pricing
  - How much to propagate this through?

Implementation of Smart IT: Organizational Barriers

- "Inertia" of some utility ground-staff
  - Reduces their extra income (theft connivance) or local standing
- Bad decisions carry some *irreversibility*
  - E.g., reintroducing meters for the 12 million+ pumpsets is very hard
  - Half-way measures for Digital Metering ($100s of millions at a state level)

Today's Inertia: (Simply) Digital Metering Solutions

- Simply move to Digital Metering, down to DTR level
  - Driven by "mandate" for "universal" metering
  - Mainly for historical (accounting) purposes
    - ToD usage recorded but read infrequently
  - Using "standard communications" won't work or scale
    - Modems can not offer (near) real-time control
    - 5 min. intervals: > 100,000 reads annually
- Cost-Benefits of simply Digital Metering
  - Expensive meters yet limited capabilities
    - $20+ for low end up to ~ $200 for 3 phase at 11 kV level
  - Still costs about 1/3, and *no metering for agriculture*
  - Only benefits: some theft reduction, marginal operational improvements
  - <u>Estimated costs ≈ benefits if lucky</u>

Incremental costs for a Smart IT can be v. low (< ~$5–15/node)

Implementation of Smart IT: Agricultural Barriers

- Incorporating agricultural users
  - They (violently) resist Metering
  - Without Agriculture
    - Lose perhaps 2/3 of anti-theft benefits, much of the shiftable load
      - But residential/commercial peaks remain

- Consider: Smart System BUT Dumb Agriculture
  - Similar to Smart System but sans agriculture
  - Costs are ~ 50 – 70% of Smart IT (depending on depth into rural areas)
  - Benefits 2-3 times that of simply digital metering
    - Still covers
      - Industrial/commercial users
        - Paying 2/3+ of revenues
      - Residential+Commercial Consumers – responsible for the peak
  - Allows migration to full Smart IT solution including agriculture

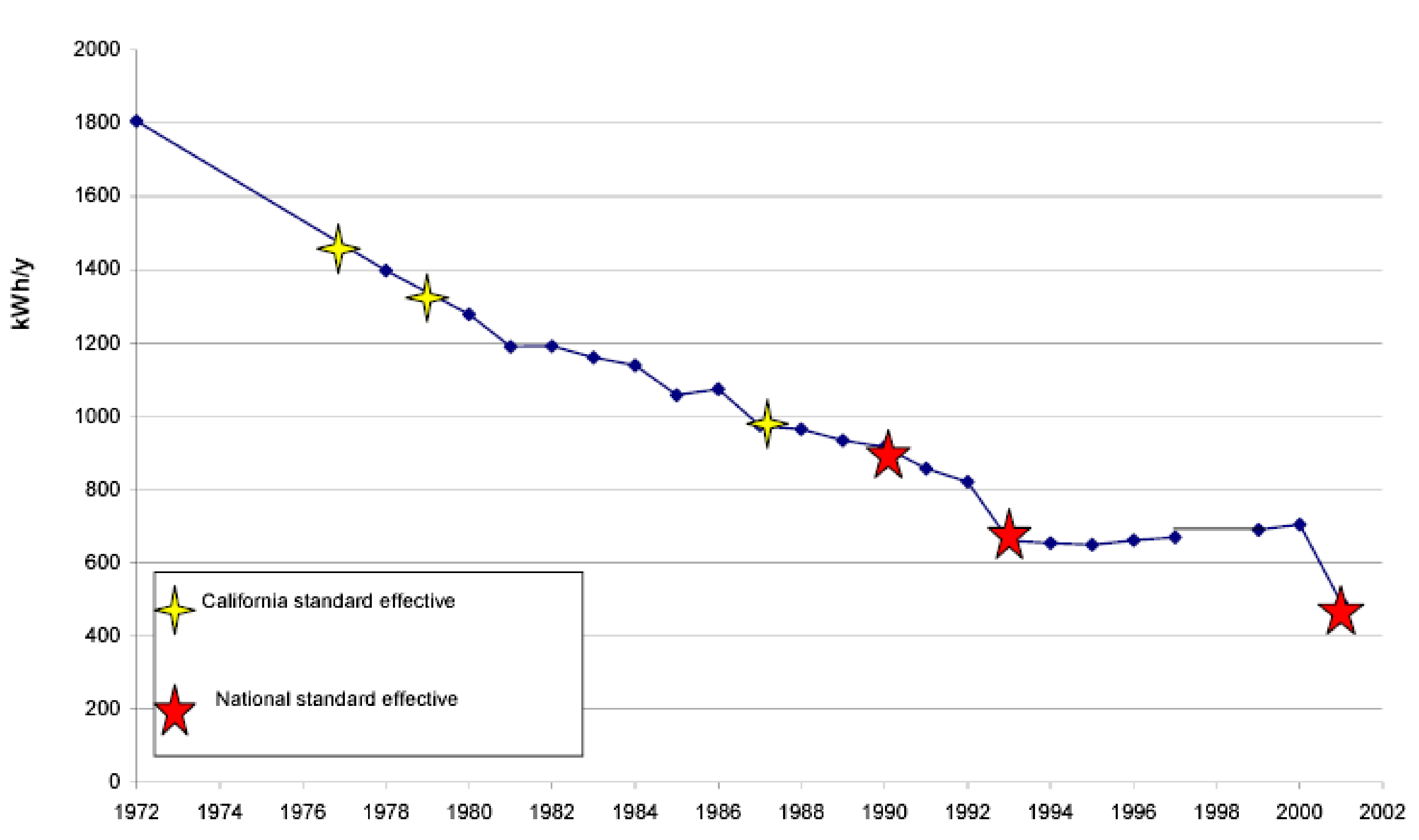
Implementation Strategies and Research

- Political Needs
  - State by State
  - National Standards
  - Interaction with Private utilities

- Technical Needs
  - Scalable, modular design
  - Open, scalable standards
    - Prevent technology/design lock-in
    - Increase competition
  - Bringing down costs
  - Demonstration

Prove system design and convince stakeholders

Role of Standards: US Refrigerator Standards



Source: www.standardsasap.org

Opportunity and Need

- Help move the Indian power sector towards *viability* and *sustainability*
  - Leapfrogging
  - Prevent lock-in/lock-out
- Spur structural and operational shifts
  - Enforce against human failings
- Indian IT capabilities available to be harnessed
  - Global opportunity potentially
- Some willing utilities
  - Testbed for new ideas
- Research on technology in the context of political economy

General Issues

- General Questions
  - Technical Viability – does it work?
    - Function of capabilities and budget
  - Financial Viability – does it save money?
    - Who gets the benefits? Externalities?
  - Political Viability – can this be implemented and integrated?
    - Regulators – what innovative/pass-through pricing will they allow?
      - Complexity (critical peak, day before, etc.)
      - Sending the right signals

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Design Issues

- Questions of Design
  - Time frames for implementing – waiting for "right" technologies
  - Directionality of information flow
    - Interim for DR: why not use digital radio for announcing "peaks"?
  - Is the WAN the bottleneck? Use of complementary infrastructure (e.g., broadband)
  - Real Time Pricing plans
  - Modularity and scalability for implementation and realizing benefits
- Demand Response and DSM
  - Short Term vs. Long Term abilities to shift loads
    - Human Intervention vs. passive
  - New technologies for the home (e.g., smart refrigerators)
  - Standardization and new standards
    - 802.15.4 ("Zigbee") – changes the consumer side?