Power Sector Reform India – The Long Road Ahead

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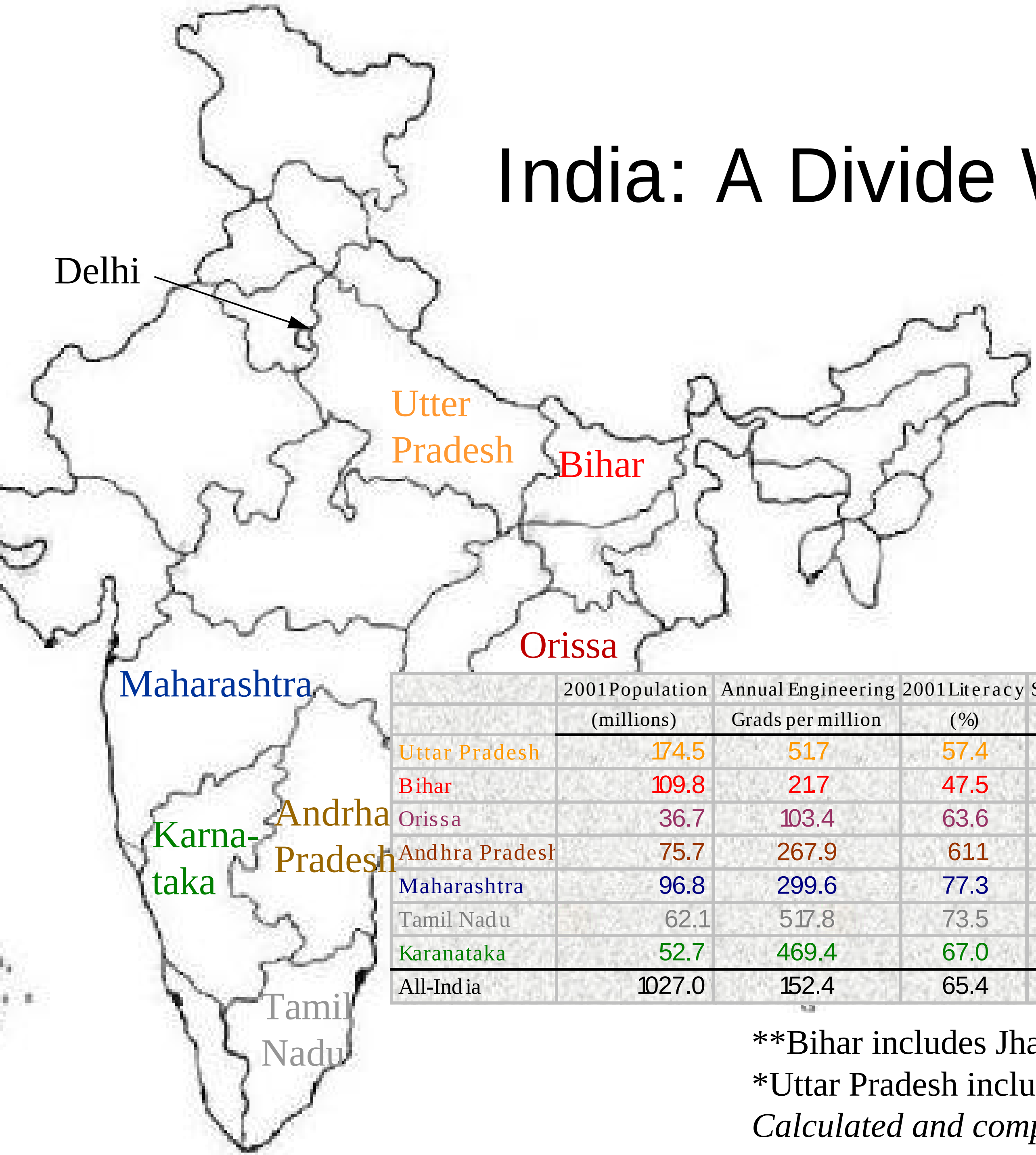
Outline

- Overview of the Indian power sector
  - Structure
  - Performance
    - Drivers for reform
- Reform steps
  - Mechanisms and modes
- Analysis
- Conclusions

India: A Divide Within



	2001 Population (millions)	Annual Engineering Grads per million	2001 Literacy (%)	State NDP/capita (in 1998-99 Rs.)	Elect. Cons./capita kWh/annum (2001)	Teledensity (2000) (per 100 popn.)
Uttar Pradesh	174.5	51.7	57.4	9,765	195.6	1.3
Bihar	109.8	21.7	47.5	6,328	152.3	0.6
Orissa	36.7	103.4	63.6	9,162	312.5	1.2
Andhra Pradesh	75.7	267.9	61.1	14,715	375.3	3.1
Maharashtra	96.8	299.6	77.3	23,398	593.8	5.4
Tamil Nadu	62.1	517.8	73.5	19,141	497.6	4.7
Karanataka	52.7	469.4	67.0	16,343	349.2	3.8
All-India	1027.0	152.4	65.4	15,735	359.6	2.9

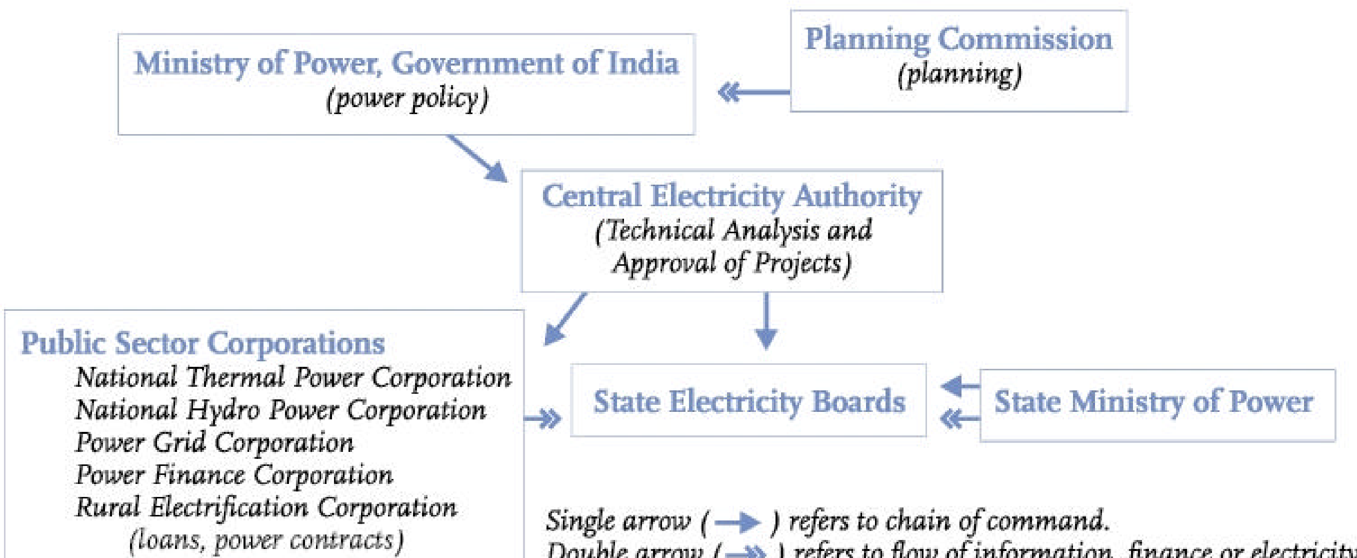
**Bihar includes Jharkhand for some data

*Uttar Pradesh includes Uttaranchal for some data

Calculated and compiled from various official sources

Pre-Reform (1991) Structure

- SEBs (State Electricity Boards) were responsible for power supply
  - Govt. Departments
  - Vertically integrated monopolies
    - Most of the Distribution
    - Much of the Transmission
    - Significant fraction of the Generation
  - Supposed to earn 3% RoR on Asset Base



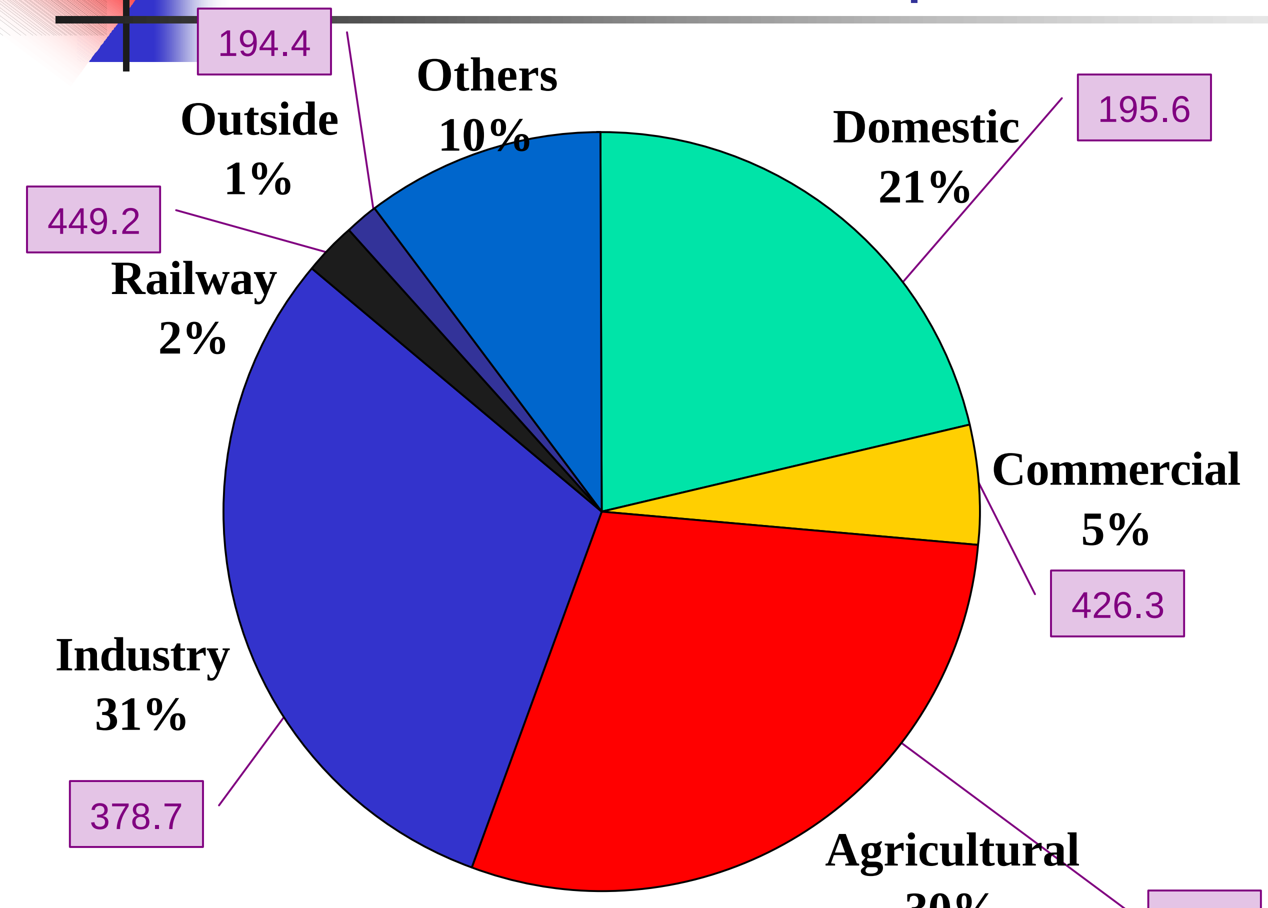
Source: Dubash (2002)

Indian Power Scenario - Overview

- Installed Capacity ≈ 105,000 MW
  - 1,500 MW in 1950
  - 4th largest in the world (estimate – varies because of captive power)
  - Coal is the predominant fuel
  - Gross generation of 515 billion kWh in 2001-02
- Per capita consumption ≈ 360 kWh
  - World Average ≈ 2,200 kWh
- 90% villages electrified

  BUT, < 40% of rural houses connected
- 10,000 - 15,000 MW annual growth needed

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%) *US losses are 8-9% only*
      - Technical – 12-15% (?)
      - "Commercial" =Theft – 15-18%
- Utilities are bleeding money
  - Returns calculated as –30 to –40%
  - Losses (excluding $1.5 B subsidy) are approximately $4 billion

Utilities Pay for Politics of Agricultural Tariff

- Agriculture: 30% consumption; < 5% revenues
  - Industry bears the brunt – cross subsidy
    - They move to captive power, hurting the current system more
- Subsidies are growing
  - Not completely covered by tariff increases, government subsidy & cross subsidy
- Irrigation pumps not metered
  - Wasteful consumption
  - Inefficient pumps
  - Illegal connections
- Intermittent & poor quality supply : 6 – 9* hours/day
  - Farmers may be willing to pay for regular & good quality power

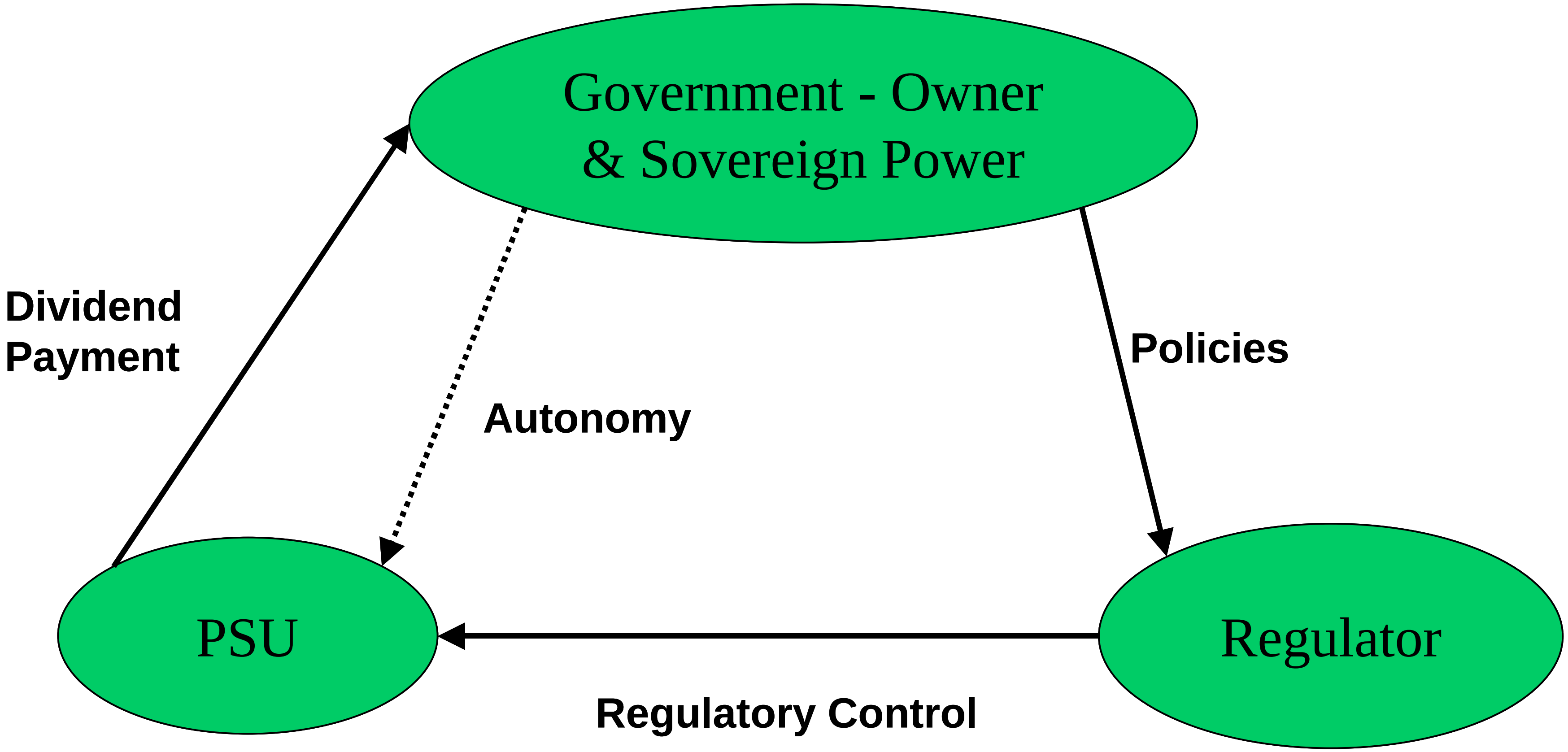
The Reforms

- Opening up Generation (1991)
  - Paralleled overall reforms and liberalization in the economy
    - Triggered by a Balance of Payment Crisis
    - Change of Central Government
  - Generation was opened to private participation
    - 8 “Fast Track Projects” were chosen, including Enron’s Dabhol
    - IPPs encouraged through attractive norms
    - PPA-based tariffs (often, no bidding)
    - Main regulation was through CEA (techno-economic clearance)
  - Why the focus on generation?
    - Easy to implement (states already had “outside” suppliers)
    - Worldwide trend
      - Players and structure (rise of IPPs)
      - Rise of natural gas combined cycle power plants
  - Limited capacity added
    - Private power was much more expensive than SEBs own power

The Reforms (cont.)

- Structural Changes (mid 1990s)
  - Establishment of independent Electricity Regulatory Commissions
  - Came, like most changes, under legislative cover
  - Intent to unbundle the SEBs
  - Some states began in the mid nineties; Center reformed in 1998
    - Began even before realization of shortcomings of generation reforms
    - Significant push from Multi-Lateral Agencies
- Distribution Reforms (APDRP) (2001) *Current Thrust*
  - Consensus realization that without fixing distribution, all other reforms will "throw good money after bad"
  - Significant funding available
    - About $1.5 Billions dollars per year - Mix of grant and loan, and some domestic development body funding
  - Combination of carrots and sticks (from Center to States)

PSUs, Government, and ERCs



Source: CERC

Electricity Regulatory Commissions (ERCs)

- Are key to the reforms
  - Set tariffs (bulk supply as well as retail)
    - Separates price-setting from operations
    - Any tariff-driven shortfall must be met through explicit government payments
- Central and State ERCs
  - States' purview is for all purely in-state transactions
  - Diminishing the role of the CEA to technical approvals
- ERCs are reasonably independent
  - Minimum 55 years age requirement – Commission members often have a govt. background
    - (?) a negative as it perpetuates business-as-usual mentalities

ERCs (cont.)

- Utilities attempt to ignore their orders
  - Often are challenged in court
    - Especially by govt. bodies or SEBs
    - Have won virtually all their cases
- Their *Tariff Philosophy* remains important
  - Have disallowed large hikes for some classes of consumers
  - Make (sometimes untenable) assumptions
    - E.g. on simultaneity of loads
- Aggressively pushing for loss reduction

Modes of Structural Reform

- Most restructuring is through unbundling and corporatization of the SEBs
    - GenCo
    - TransCo
        - Single Buyer
    - DistCos
        - Based on geography
  - End-game is privatization (sequential reform is perhaps politically easier)
- Many models of reform available
  - Reforms do not necessarily mean markets
  - Where would *competition* come in?
    - Generation (wholesale competition) – limited success
    - No retail competition
    - Auctions for privatizing distribution companies (or other assets)

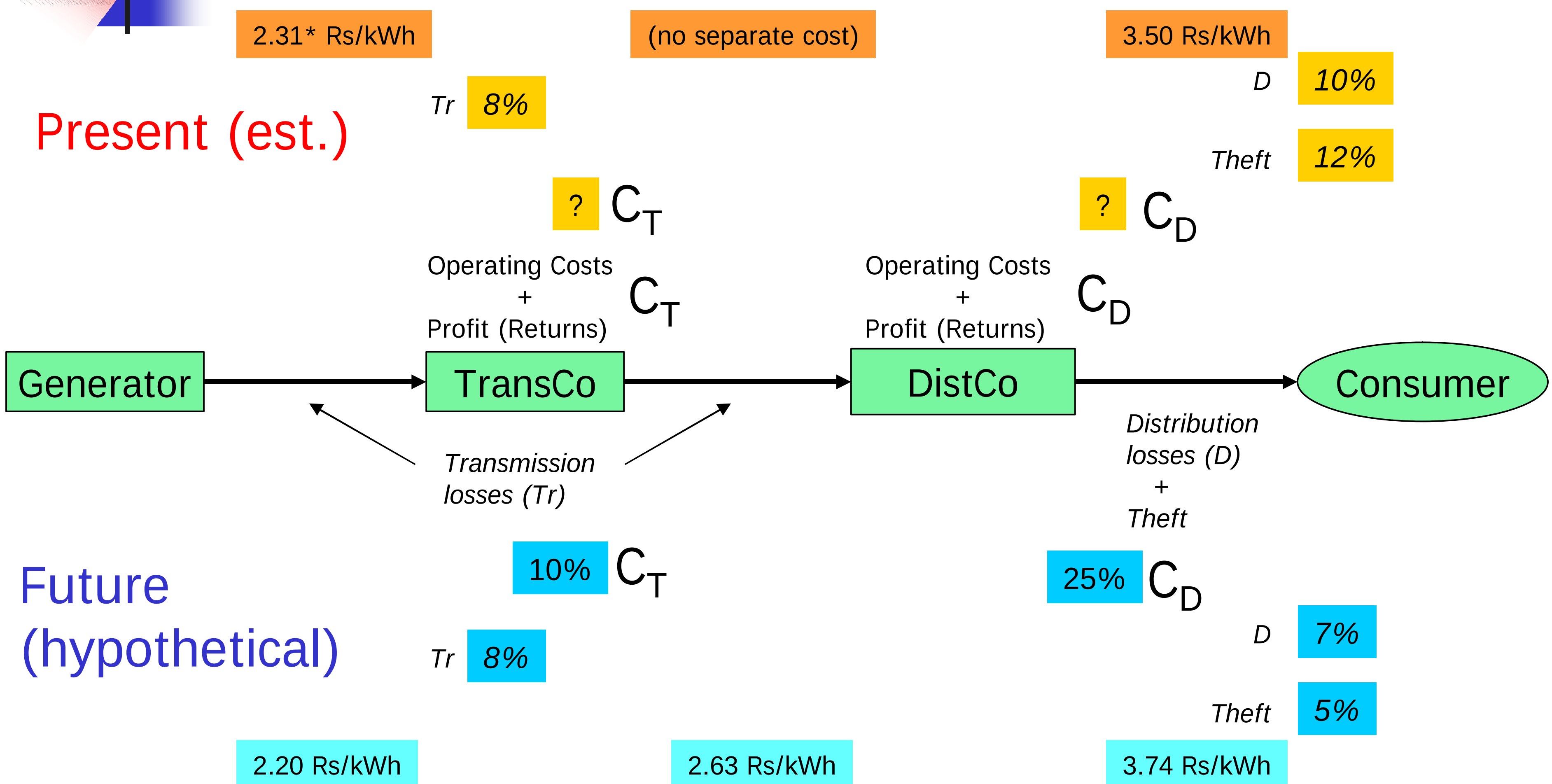
State Reforms – Three Examples

- Orissa – The Front Runner (1996 Reform Act)
  - Unbundled and then privatized distribution
    - Strong World Bank influence (design and finance)
  - Considered a failure - Consumers and utilities have both suffered
    - Losses (kWh and economic) both increased
  - Many causes of failure
    - Unrealistic assumptions and goals
      - Losses
      - Paying Customers
    - Lack of government support
  - Dampened enthusiasm for reforms, especially privatization

State Reforms (cont.)

- Andhra Pradesh – Seen as one of the most successful reformers (1999 Reform Act)
  - Corporatization only (privatization is some time away)
  - Strong Govt. support
    - Shortfalls are paid by AP Govt. (budget) – paid out to DistCos
  - Some issues with the process
    - ERC allows Transco to charge varying Bulk Supply Tariffs t the 4 DistCos, based on their economic situation
      - Not grounded in economic efficiency
      - Burdens privatization efforts
- Delhi – Innovative - Learning from past mistakes (2000 Act)
  - Distribution was privatized (in 2002) based on *loss reduction bids*
    - Improvements above targets split between pvt. companies and consumers
    - Indicates importance of **benchmarking** for privatization
  - Transco will receive the subsidy to cover difference

Unbundling – Increases Accounting Transparency



Unbundling "forces" profitability – raising costs

What Reforms Don't Address Directly

An institutional framework for economic success, *regardless of ownership/mode*, must send correct price signals

- Virtually no time-of-day prices today (generator or consumer)
  - Without a load duration curve, all generators want to operate as much as they can
    - Plant load factor is a dangerous measure of performance
- In-state (SEB) plant is today priced differently
  - Internally see marginal costs vs. Average costs from outside
  - Different regulations (center vs. State ERCs)
- RLDCs vs. Transco – how should dispatch be handled?
  - PPAs as currently being undertaken reduce economic efficiency
    - Long life
    - High offtake requirements
    - No accounting for variable costs

What Reforms Don't Address Directly/Completely (cont.)

- Use of average numbers masks information about marginal costs – *important for efficiency*
- Access – not just a supply issue but demand (affordability)
- Agriculture – how can the prices be rationalized?

Issues for Reforms

- Utilities still don’t function like business entities
  - SEBs used for political patronage, social engineering
  - Part of the privatization process included “deals with the devil” over labor security
    - High employee costs, perhaps greater institutional cost
    - Andhra Pradesh has over 65,000 employees for about 6,200 MW
      - Connecticut has just a several thousand employees for similar capacity!
- In a loss-making system, who has first rights to cash flow?
  - Earlier policies favored generators over other segments
  - What of cherry picking for privatization (viable, urban areas)?
- Are there enough players, and does size matter?

Future Reforms

- A Big Bang Approach?
  - Pending Electricity Bill 2001 might alter things drastically
    - Open access philosophy
    - Helps private players and some consumers, might hurt the SEBs/current utilities
- Successful reforms will depend on political will to tackle the hard issues facing the sector

Points for Discussion and Research

- Grid design
  - Signals, stakeholders, and policy
  - ABT – Availability Based Tariff
- IT and innovation

Conventional Wisdom

- One can not do real-time power flow management (transactions and billing) for transmission level flows
  - Today, pools often operate based on historical or aggregated information
- One can not measure demand (usage) from all consumers in real-time with high granularity

What has changed to make these outdated – the growth of IT technology

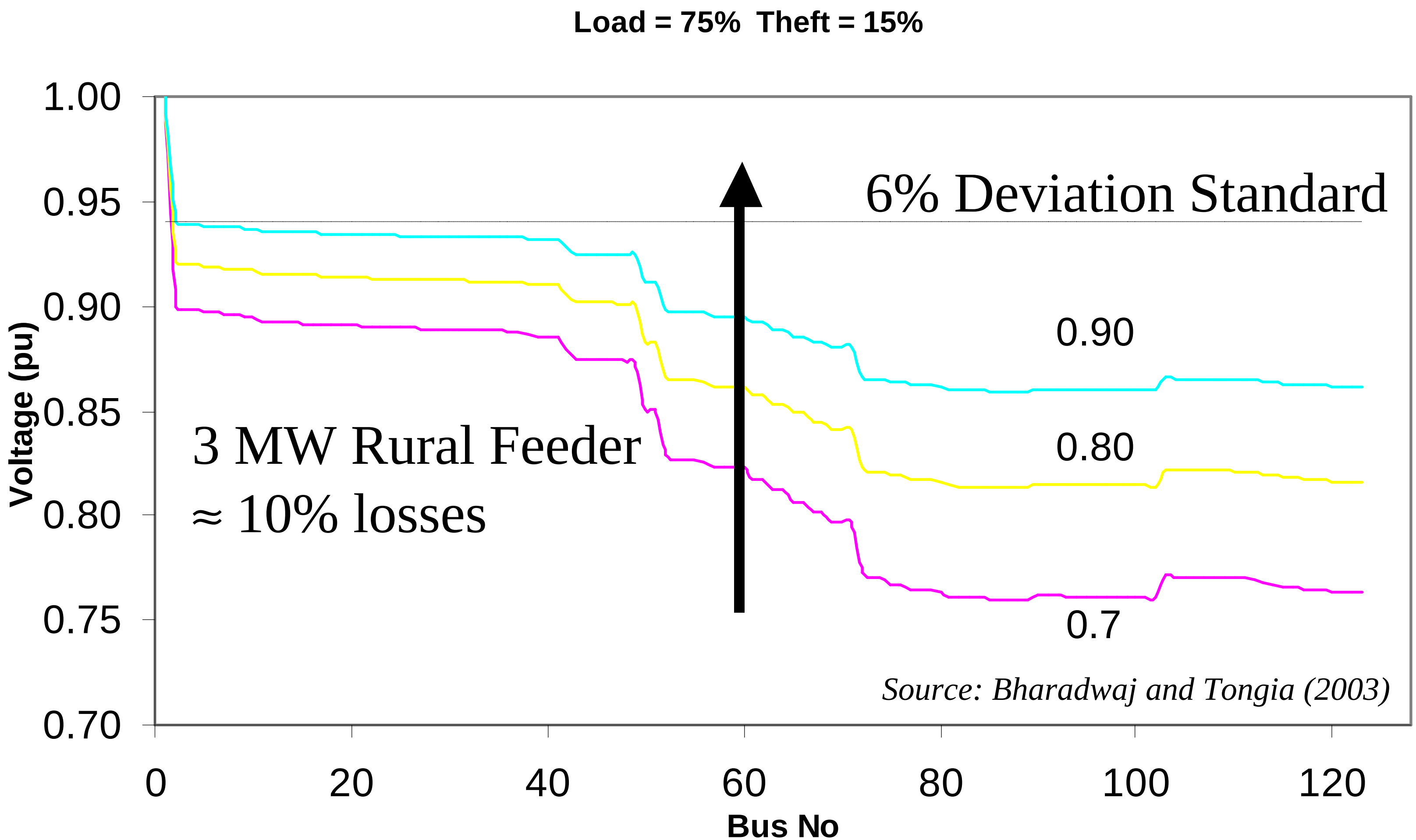
Idea – use IT for power sector management

- Posit – If new meters are to be installed, why not "smart" digital meters, which are also controllable, and communications-enabled?
  - *Incremental* costs would be low
- Instead of just quantity of power, can also improve *quality* of power
- Analysis presented is based on collaborative work with a major utility in India (*name withheld for confidentiality reasons*)

Quality of Power

- India is focusing on quantity of power only
  - Current "shortfall" numbers are contrived
    - Based only on loadshedding with minor correction for frequency
    - Do no factor in peak clipping fully
    - Do not account for lack of access (e.g., over 60% of rural homes lack connections)
- Quality norms are often missed
  - Voltage – often deviates by 25+%
  - Frequency – often deviates by 5% (!)
- Even farmers pay a lot for their bad quality power (around 50 p/kWh implicit, even higher in some regions)
- Use of voltage stabilizing equipment
  - Additional capital costs (in the multiple percent range)
  - Efficiency losses (2-30% lost!)

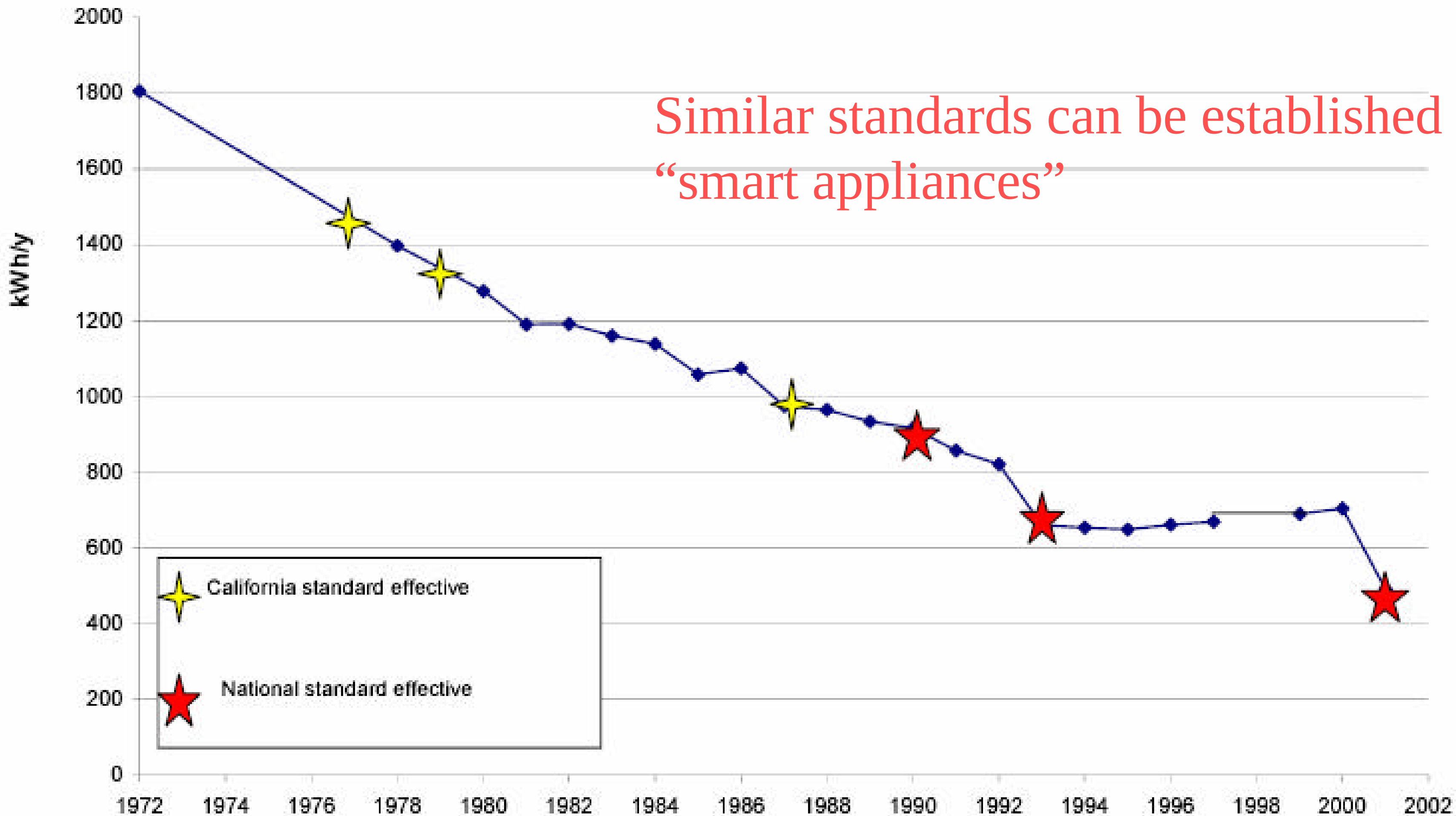
Actual power quality (voltage profile) for rural feeder in India



Why a Focus on Distribution?

- It’s where the consumer (and hence, revenue) is
- High losses today
  - Technical losses, 10+ % in rural areas
  - DSM and efficiency measures possible
  - Use of standards required
    - Use a combination of technology, industrial partnership, and regulations
    - Learn from experiences elsewhere
    - Bulk of India's consumption is for just several classes of devices
      - Pumpsets
      - Refrigerators
      - Synchronous motors

US Refrigerator Efficiency Standards



Similar standards can be established for "smart appliances"

Future of Appliances and Home Energy Automation Networks

- Incremental cost of putting networking and processors into appliances approaching a few dollars
  - India has IT strengths and can develop innovations for this sector
  - Could allow time of use and full control (utility benefit/public good/user convenience)
  - Link to a smart distribution system
    - Micro-monitor and Micro-manage every kWh over the network
      - E.g., refrigerators – don't operate or defrost during peaks (5% of Indian electricity usage)
    - 5% peak management could lead to a 20% cost reduction
    - Italy is already implementing such a system (ENEL)

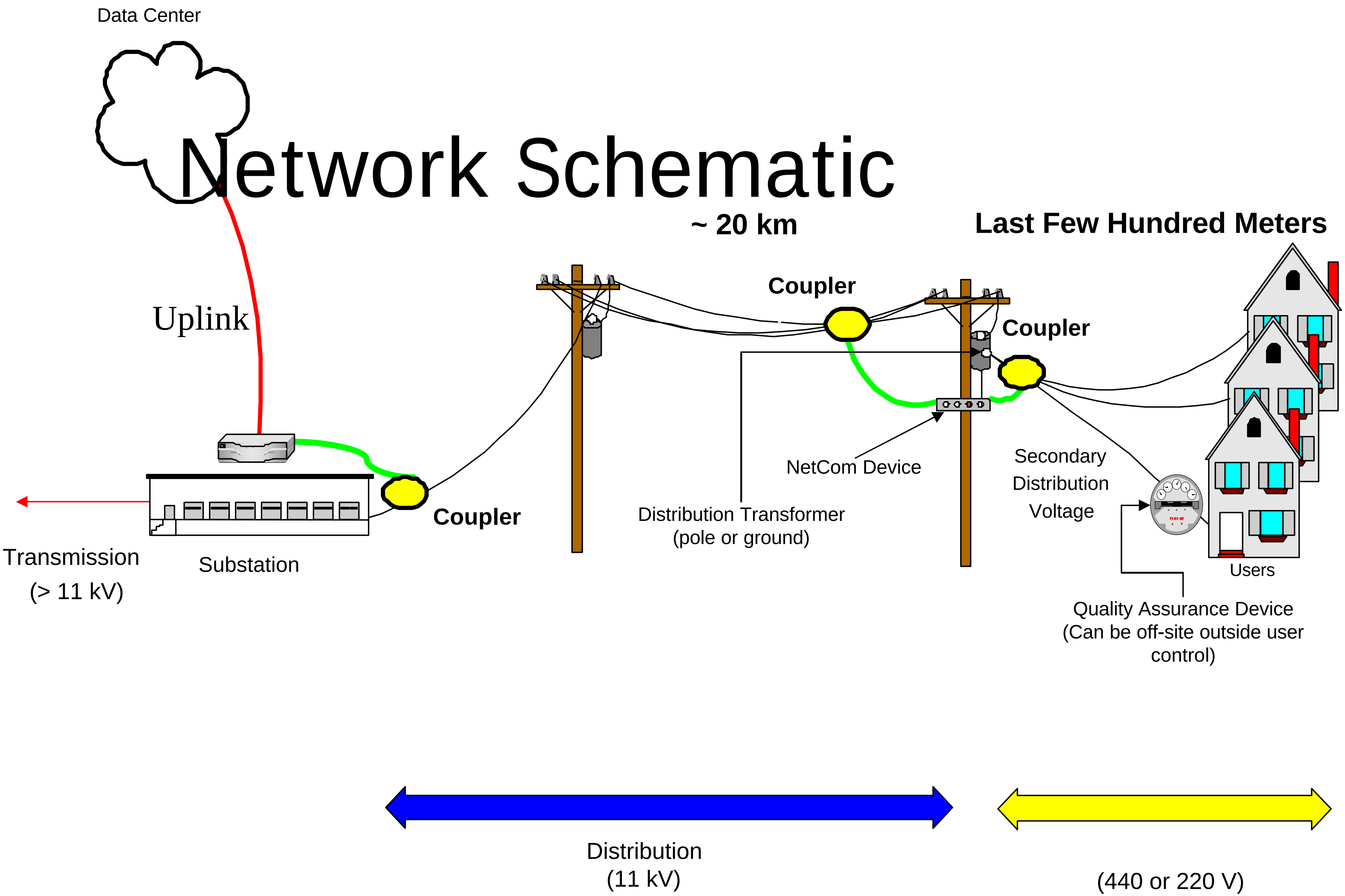
Objectives and design goals for a new IT-enabled

- Implement a basic infrastructure to…
  - Micro-measure every unit of power across the network
  - Allow real-time information and operating control
  - Devise mechanisms to control the misuse and theft of power through soft control
- Which would…
  - Reduce losses
  - Improve power quality
  - Allow load management
  - Allow system-level optimization for reduced costs
  - Increase consumer utility, satisfaction, and willingness to pay

Additional Benefits

- A system which will offer
  - Outage detection and isolation
  - Remote customer connect & disconnect
  - Theft and tamper detection
  - Real time flows
    - To allow real time pricing
  - Suitability for prepayment schemes
    - Popular in South Africa and elsewhere, where similar problems had been faced
  - Load profiling and forecasting
  - Possible advanced communications and services
    - Information and Internet access
    - Appliance monitoring and control

Network Schematic



Components of the solution

- One segmentation – locational
  - At consumer
    - Meter/Gateway
      - Meter could be pole-side if required
    - In home network
      - Needed connect to enabled devices (appliances)
      - Eventually, homes would also have Decentralized Generation available (?fuel cells, flywheel storage, etc.)
  - Access (low voltage distribution)
    - From gateway to a *concentrator*, on user side of distribution transformers – Using PowerLine Carrier (PLC)

Solution Components (Cont.)

- Concentrator upwards
  - Concentrator – Each Distribution Transformer (aka Low Voltage Transformer) feeds on the order of 100-200 homes in India (as in Europe). In contrast, US Distribution Transformers feed 5-10 users.
  - Communications medium
    - Over Medium Voltage PLC to the Sub-station

      or
    - Wireless
- Substation upwards (uplinking)
  - Usually based on leased lines or optical fiber

Technologies for various segments

- In-Home Network
  - Appliances
    - Emerging Standards are talked about (Maytag, Samsung, GE, etc.)
    - Using Simple Control Protocol (or other appropriate “thin” protocols)
- Meters
  - Solid-State meters exist, but not yet the norm in developing countries
  - Most have communications capabilities for external ports
  - Lowest cost solution (if feasible) – PLC – target 5$ incremental cost

Technologies for various segments (cont.)

- Access
  - Low Voltage PLC is available today
  - Being explored for Internet access, in fact (Megabits per second)
- MV
  - Crossing through transformers remains a technical challenge
  - Going long distances an issue
- Uplinking
  - Availability of optical fiber or leased lines can be met through planning

Technologies vs. Capabilities

	Accuracy	Theft Detection	Communications	Control	Capabilities
Electro-mechanical Meter	low (has threshold issues for low usage)	poor	expensive add-on	nil	
Digital (solid state)	high	Node only	external	Limited	Historical usage reads only
Next Gen. Meter (proposed)	Arbitrarily high	High (network level)	Built-in (on-chip)	Full (connect/dis-connect); Extending signaling to appliances	Real-Time control; DSM

Design Model and Business Case

- Only 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 every network node that needs monitoring and/or control
  - Substations
  - Transformers
  - Capacitor banks
  - Relays

  etc.

Design Model and Business Case (cont.)

- Investment in long run only a few thousand rupees per targeted user (Target <75$ capex)
  - When amortized, implies requirement of improvements in system of only a few percent!
  - Savings will come from
    - Lower losses/theft
    - Increased sales possible
    - Lower operational costs
    - Load management
    - Better consumer experience (and hence, possibility for higher tariffs)
    - Future interaction with smart appliance and smart home networks

Economics of case system

- Estimated System (Rural-centric)
  - 62 Consumers (all classes) per Distr. Transformer
  - 98 Distribution Transformers per Sub-Station

	Number of Nodes	Equipment cost ($)	Cost ($)
Domestic (applicable)	200,000	75	15,000,000
Commercial	383,000	75	28,725,000
Agricultural	673,000	75	50,475,000
High-Tension			
Distribution Transformers	70,306	500	35,153,000
Substations	714	5,000	3,570,000
			132,923,000
	Other IT and infrastructure (capitalized)		10,000,000
			142,923,000
	15%	<-annualized rate incl. Amortization	
Needed Savings	$ 21,438,450	annually	
11,625,000,000	kWh sold annually		
0.06	Electricity Rate ($/kWh)		
$ 697,500,000	Annual Costs		
3.1%	<- Need improvements worth		

Economics (cont.)

- 6-7 year payback on investment (conservative) possible with just 3% improvement in system
- Savings will come from
  - Theft Reduction
  - Time-of-Day and DSM measures (peak reduction)
  - System Quality, reliability, and uptime
  - Higher Collection

Challenges

- Protocols
  - Use of thin protocols to reduce capex for embedded systems
  - Security – PLC can be a shared medium
- PLC
  - How to couple around transformers or other obstacles
  - How to go long runs with low errors (and high enough bandwidth) – Shannon's theorem provides a limit
  - Noisy line conditions in many developing countries
- Appliances
  - Need for standards to bring down costs and ensure inter-operability
- Design – Should the PLC signals pass through the meter/gateway directly to appliances?
- How active or passive should consumer behavior modification be?
- Costs *(as always)*

Development strategies

- Standards
- Pilots
- Technology Transfer
- Indigenous R&D
  - Industrial
  - National Labs
  - Academic

  Partnership between these

A New World for Power Systems

- Includes “smarts” for significant improvements in efficiency
- New services can be enabled once the appropriate infrastructure is in place
- Segmentation of development allows independent, modular innovation, e.g., home automation and appliances
- Developing countries (esp. Asia) can lead the way through leap-frogging

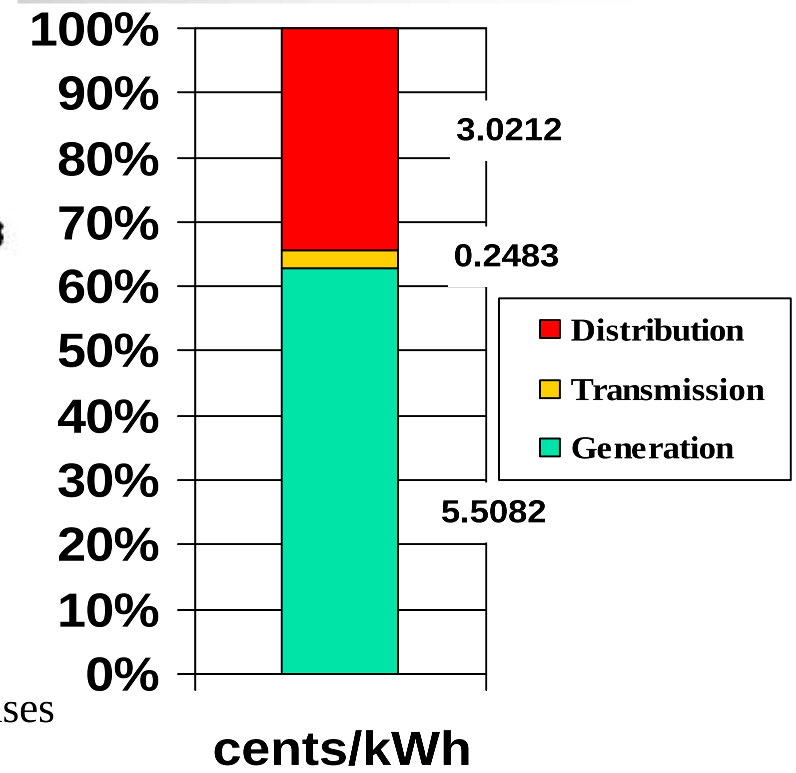
Thank You

Unbundling – Where It Can Lead to?

Current Charges

Customer Charge			6.38	
Generation	432	kWh@ 5.5082¢	23.80	
Transmission	432	kWh@ 0.2483¢	1.07	
Distribution	432	kWh@ 3.0212¢	13.05	
Transition	432	kWh@ 0.0000¢	0.00	
Pennsylvania Tax Adjustment			0.83	
Total DLC Basic Service				45.13

My Pittsburgh, Pennsylvania Bill, January 2003



$$\frac{\$45.13}{432\,kWh} = 10.45\,cents/kWh$$

But, excluding the Customer Charge, comes to 8.95 c/kWh

Adding the Customer Charge solely into Distribution increases this by almost 1.5 cents/kWh.

This is a rather high bill versus the US average: ≈ 6.7 c/kWh (1999) (excluding end-user taxes)

Regional differences – Northeast

Sectoral – Residential pays more than average