SMART GRID ADOPTION IN A REGULATED INDUSTRY: COMPARATIVE CASE STUDIES OF ELECTRIC UTILITIES

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Electricity: Shocking news!

"Superstorm Sandy: More than 7 million without power"

"Russian hackers infiltrated US energy infrastructure"

"India must spend $250B by 2019 to meet its power needs"

"Brazil needs 50 GW power grid expansion by 2024"

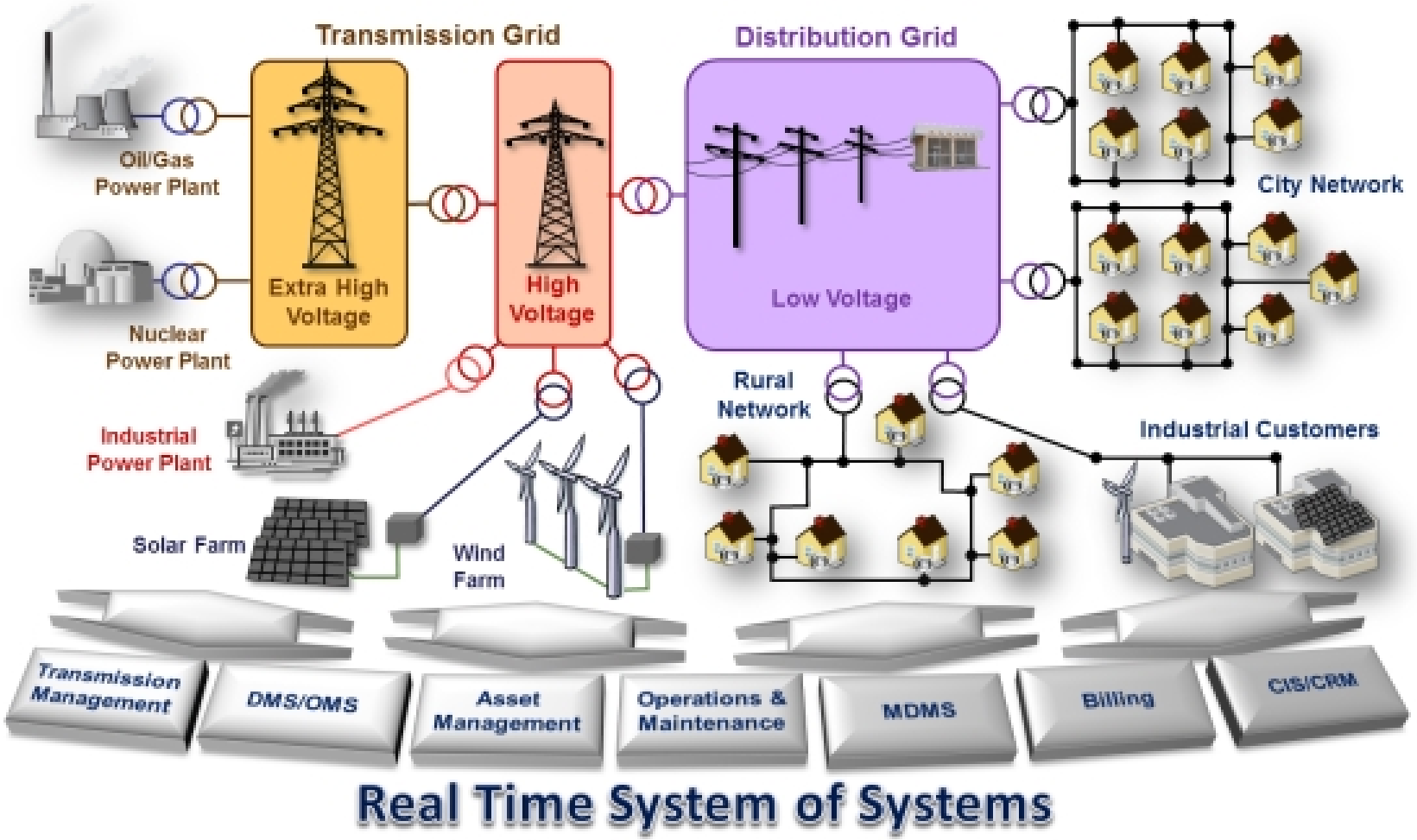
"New York's new Energy Vision to reimagine the grid"

Challenges to U.S. utilities

- Grid reliability falling.
- Vulnerable to natural and human threats.
- Need to integrate renewables, distributed sources, EVs.
- Demand reaching capacity in some places
- Electricity accounts for 25% of US carbon emissions.

Smart grid: “Electricity with a brain”

- Smart grid applies digital technologies to make the grid more reliable, secure, sustainable and efficient.
- DOE smart grid stimulus grants of $4 billion from 2009-2012.
- Still, adoption is slow and uneven across U.S. utilities.



Real Time System of Systems

Research questions

- What factors determine the motivation and ability of U.S. utilities to adopt smart grid innovations?
- How does the highly regulated nature of the electric utility industry affect adoption?
- What organizational challenges does the smart grid present for utilities, and how are they responding?

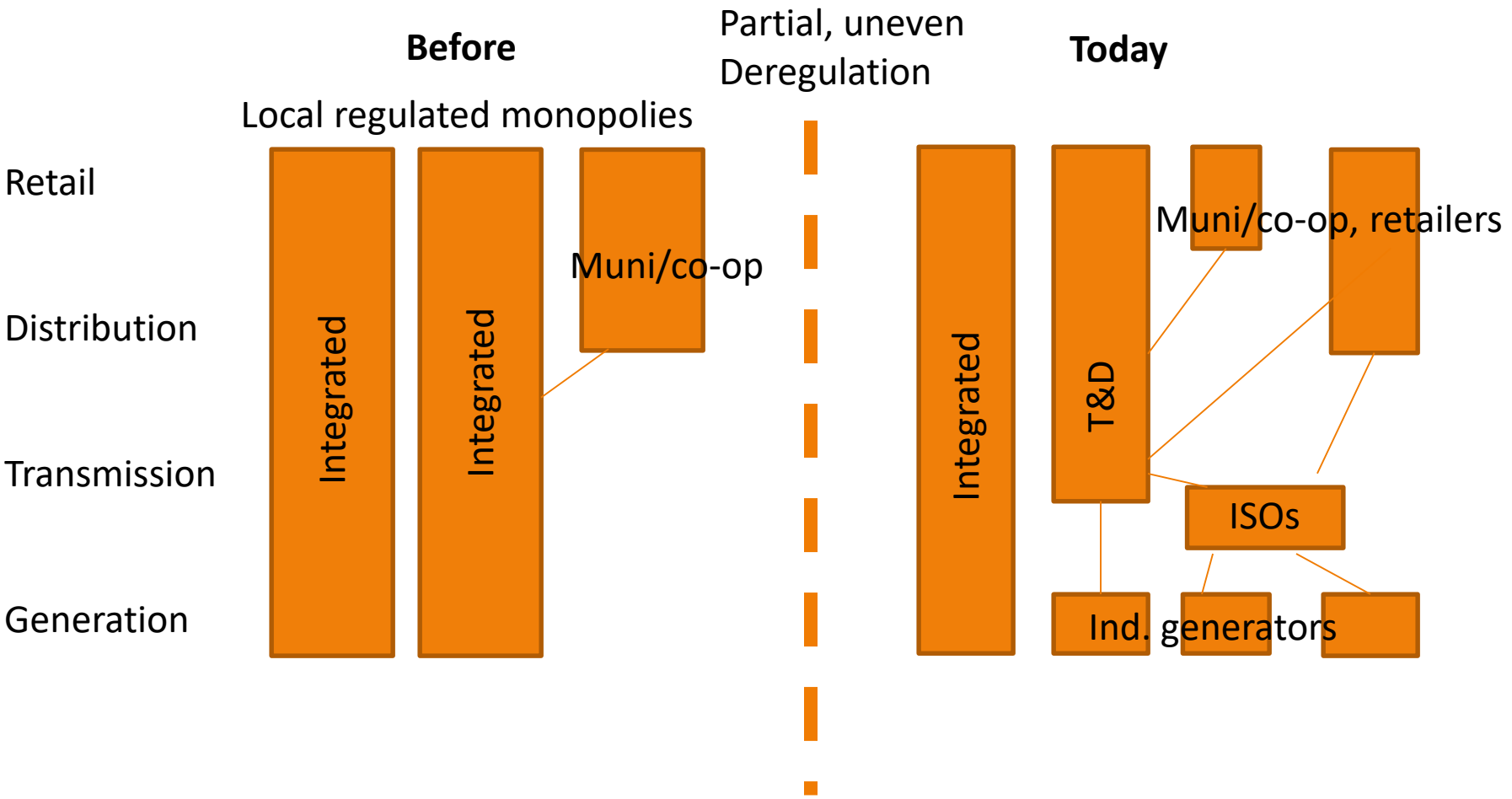
U.S. Utility Industry

- Over 3000 electric utilities
  - Includes investor-owned (IOU), municipal, cooperative, and retail power marketers.
- Less than 200 regulated IOUs serve about 68% of customers.

Deregulation of electric utilities

- Industry dominated by regulated monopolies since the 1930s.
- Deregulation started in the 1970s.
  - Public Utilities Regulatory Policies Act 1978
  - Energy Policy Act of 1992 and FERC 888, 889
  - Creation of Independent System Operators to manage wholesale markets

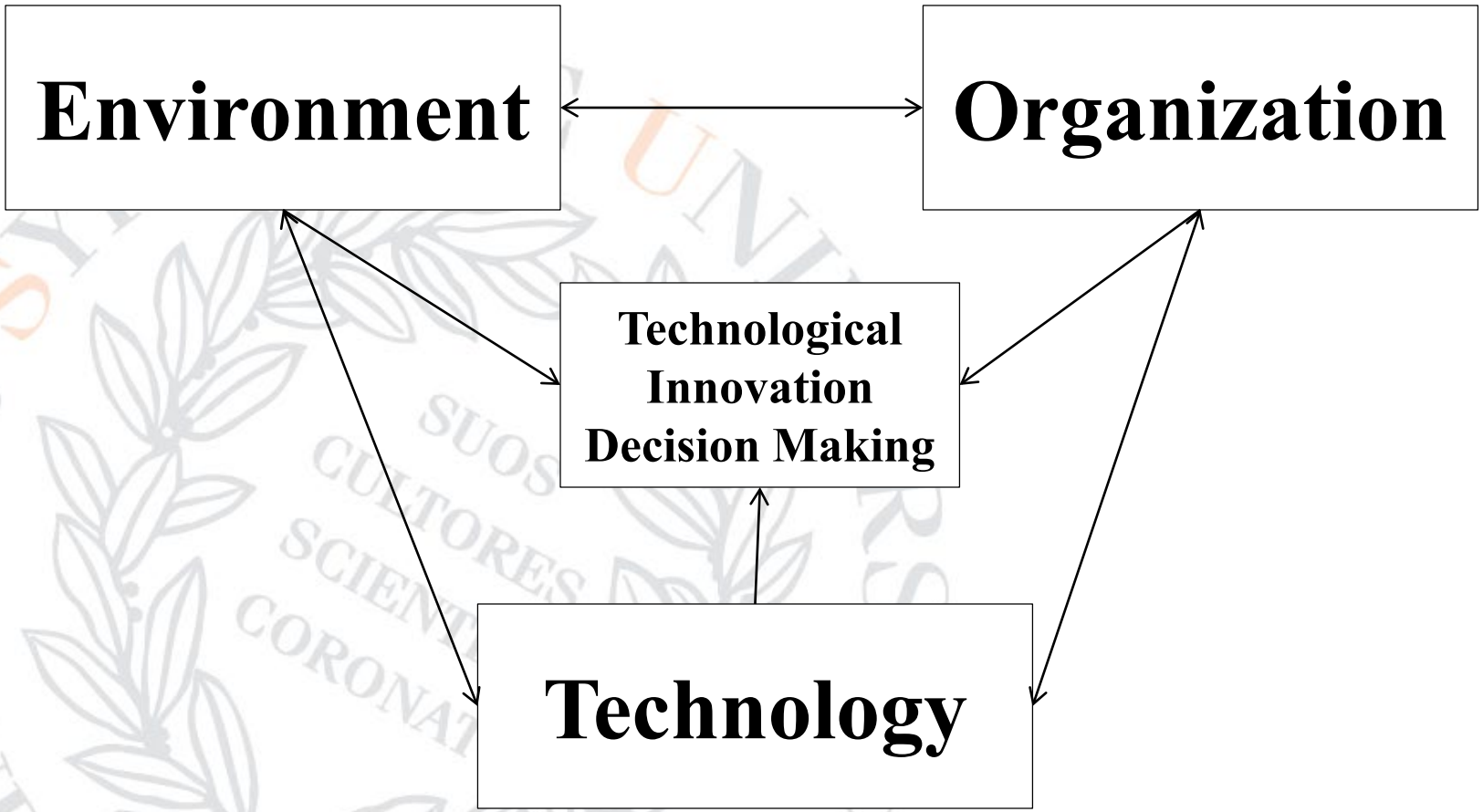
Setting: an industry in transition



Conceptual framework

- Organizational adoption of innovation
  - Technology Organization Environment framework (Tornatzky and Fleischer, 1990)
- Public policy/regulation
- Organizational learning

TOE framework



Data collection and analysis

- 45+ interviews with 25 utility companies
  - Across different ownership forms, state regulatory environments, and market structures
- Interviews with regulators, suppliers, consultants
- Extensive secondary data collection
- Ongoing survey of U.S. utilities

Adoption: Technology factors

- Perceived benefits
  - Integrate distributed generation and new uses
  - Operational benefits
  - Cost reduction
- Perceived risks
  - Loss of revenue if less energy is consumed
  - Risk of investment loss

Organizational factors

- Size: smaller firms are more agile
- Top management leadership support
- Experience with precursor technologies
- Technical expertise, especially in ICTs
- Technology champions: often one person
- Culture of innovation: regulated monopoly
- Ownership: IOU vs municipal and co-op

Environmental factors

- Competition

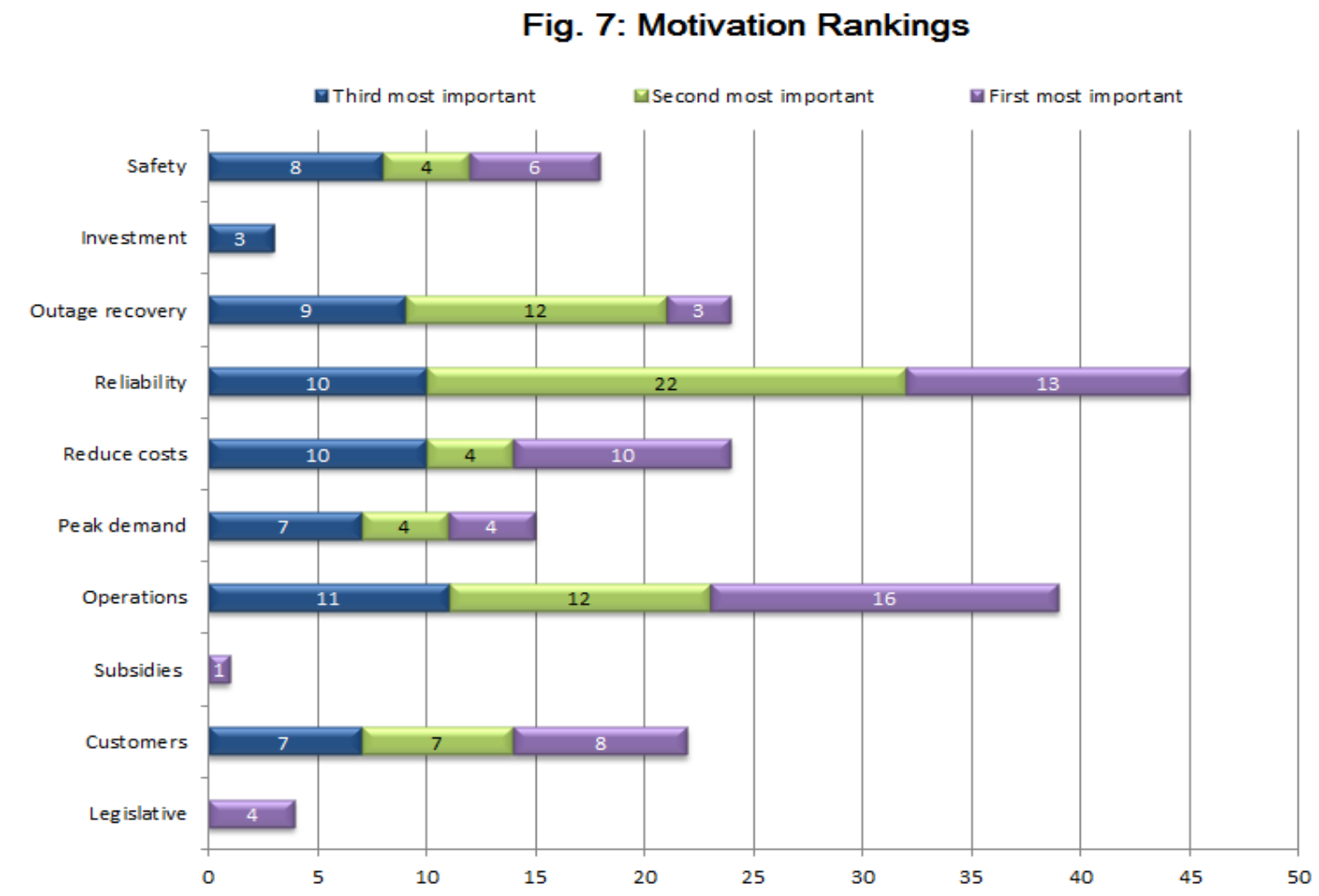
"In Texas, we compete with 40 companies every day. We are very innovative and have rolled out things like pricing plans as well as technologies and services".

- Consumer attitudes

"The whole industry is struggling with communicating new technologies with customers…So there is kind of a knowledge or understanding gap in my perspective on both sides".

- External information sources
  - Consultants, vendors, academics, associations, EPRI

Motivations for adoption: co-ops



PUC regulatory process

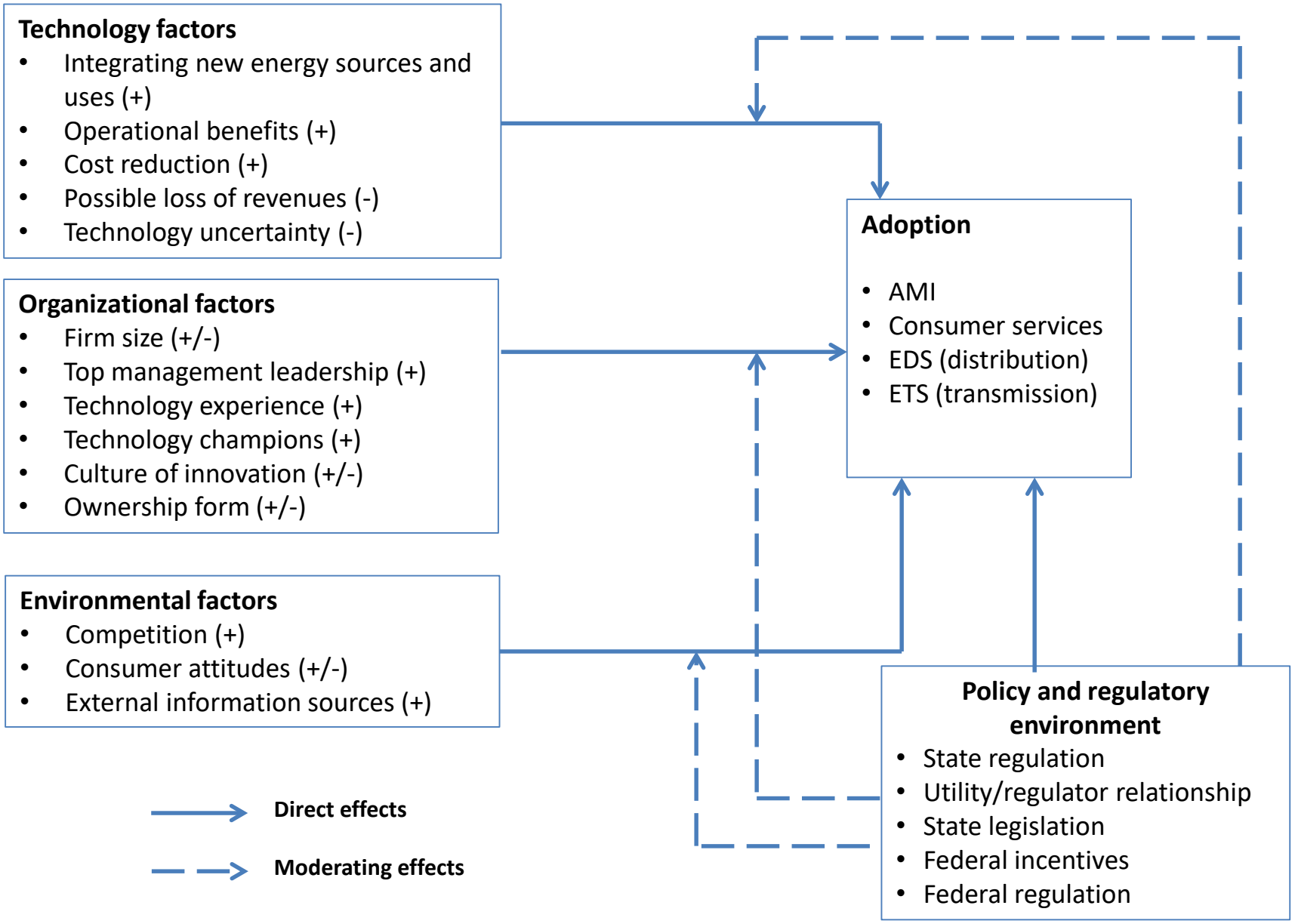
- Mainly relevant to investor-owned utilities
- Created in a time of steady growth, long-term investments, slow innovation.
- Formal rate case process can last years
  - Determine rates utilities can charge
  - Determine whether investments can be added to the rate base and cost recovered from consumers

Regulatory obstacles

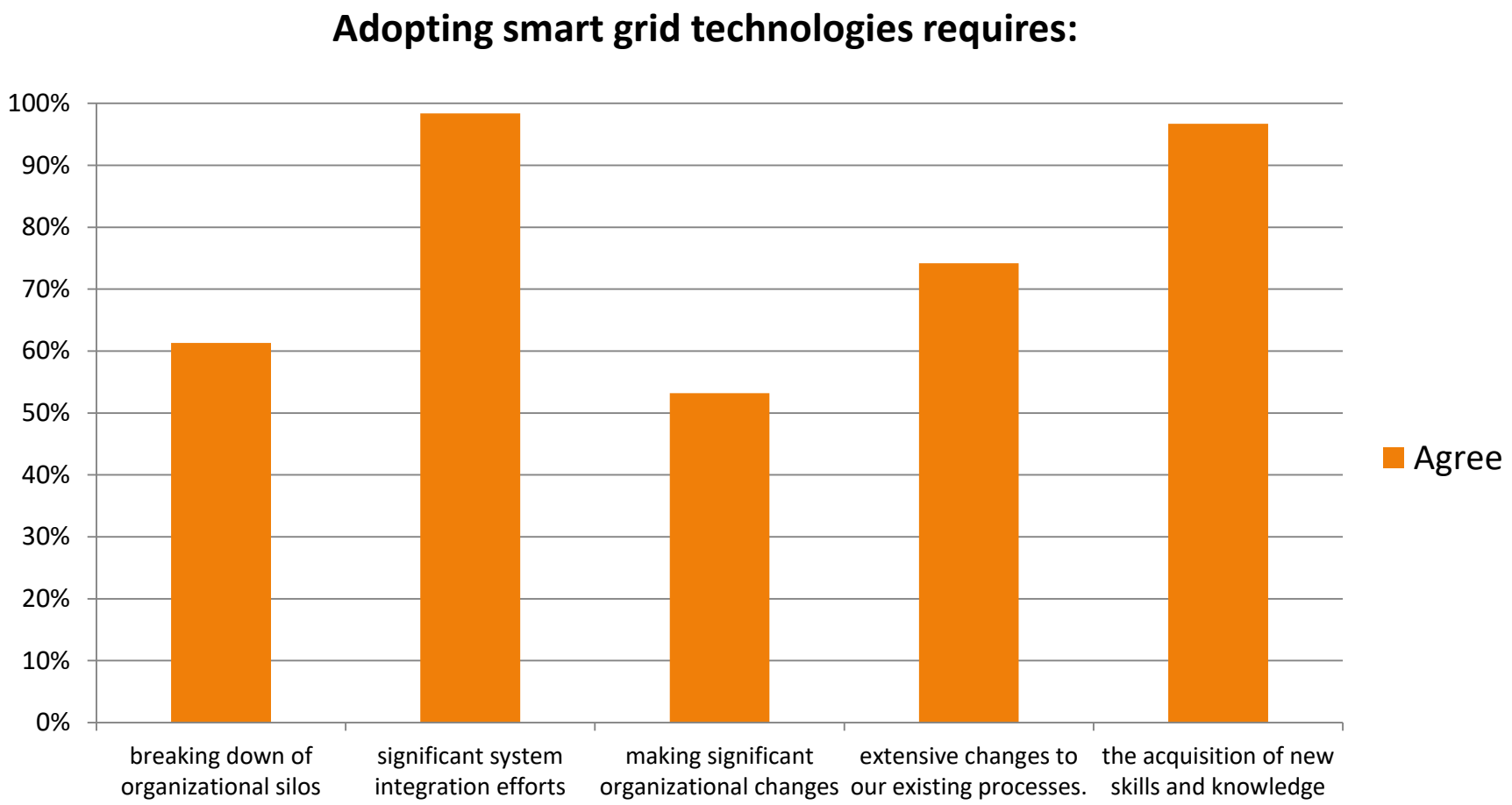
- Revenue models: “cost plus” model based on kwh delivered discourages efficiency
- Pricing: flat retail rate reduces incentives for consumers to conserve or shift usage
- Evaluation process and criteria discourage risky investments

Implications for regulators

- Delinking revenues from volume sold can change incentives, reward efficiency and other goals.
- Dynamic or time-of-use pricing is needed for successful demand response.
- Rate setting process needs to be revamped.
- Utilities need to be able to experiment with new business models and technologies. Requires regulatory flexibility
- Regulators need to close the knowledge gap to understand new technologies. Average commissioner tenure is 3.5 years, often little utility background. Mostly lawyers and ex-legislators.


Technology factors
• Integrating new energy sources and uses (+)
• Operational benefits (+)
• Cost reduction (+)
• Possible loss of revenues (-)
• Technology uncertainty (-)
Organizational factors
• Firm size (+/-)
• Top management leadership (+)
• Technology experience (+)
• Technology champions (+)
• Culture of innovation (+/-)
• Ownership form (+/-)
Environmental factors
• Competition (+)
• Consumer attitudes (+/-)
• External information sources (+)
Adoption
• AMI
• Consumer services
• EDS (distribution)
• ETS (transmission)
Policy and regulatory environment
• State regulation
• Utility/regulator relationship
• State legislation
• Federal incentives
• Federal regulation
Direct effects
Moderating effects

Organizational challenges



Organizational responses

- New governance mechanisms
  - Steering committees, cross-unit teams
  - Utility transformation programs focusing on process change, skills, internal education
- Changing organizational culture to foster collaboration and innovation
  - Scary to some employees, but many are excited

Perceived skill/knowledge levels

Source: Syracuse University survey of U.S. utility companies: Preliminary results as of 10/1/14.

Acquiring knowledge and skills

- Internal training and hiring.
  - Especially for long-term ability to maintain a system
  - "There's a huge learning curve, but now we've got people who have excellent knowledge of the system."
- External knowledge acquisition
  - For one-time jobs, such as meter installation
  - When internal workers lack specialized skills, such as data warehousing, or system deployment

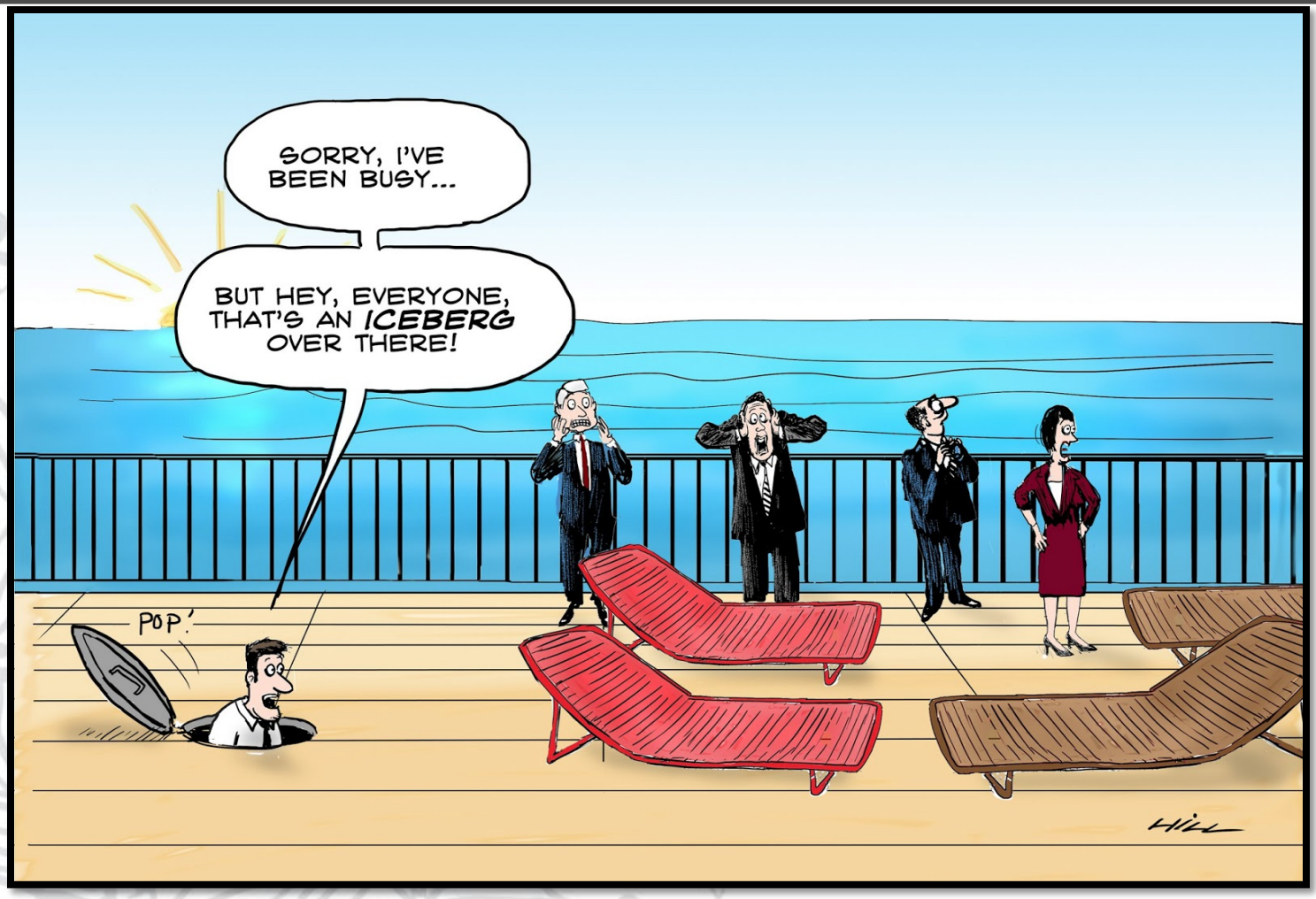
Some insights

- Industry highly fragmented and heterogeneous. No one galvanizing the market to drive adoption of innovation by utilities. No “killer app”.
- Pace of adoption varies from rapid to glacial
  - Motivations are pragmatic not transformational.
  - Few utilities see urgent need to change
- Organizational demands become more challenging over time
  - They grow as utilities move from adoption to integration
  - Going from pilot to broad deployment is a major hurdle

The times, they are a-changin'

- Changing technologies, markets
  - Solar, wind, storage, EVs, demand response strain the grid
  - Big customers becoming net producers, not contributing to upkeep of the grid
- Changing regulatory environments
  - New York State "Reforming the Energy Vision"
  - Massachusetts mandates 10-year grid modernization plans
  - California mandates for smart grid, renewables, storage
- New players in the market
  - Google, IBM, Cisco, Opower, iTron, Tesla/Solar City

Preparing for the future



Smart grid research at the iSchool

- "Adoption of Smart Grid Technologies by Electrical Utilities: Factors Influencing Organizational Innovation in a Regulated Environment." (NSF SES-1231192)
- "Data Privacy for Smart Meter Data: A Scenario-Based Study" (NSF SES-1447589)
- Research Experience for Undergraduates (NSF REU). Terrance Andersen
- Big Data: Analysis of Pecan Street data on 1000 households
- Advanced Security Models for the Internet of Things--partnership with Unisys and National Grid
- Dissertation in progress: You Zheng
- Total: 4 faculty, 4 Ph.D. students, 8 Masters' students, 2 undergrads