

Engineering Energy Systems of the Future

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Talk outline

- **Complexity** of the evolving industry architectures (basic reasons)
- Needs for novel engineering, regulatory and financial solutions for providing energy service according to **multiple tradeoffs** (instead of single criterion subject to constraints)
- An example illustrating the effects of today's regulatory and financial solutions on:
 - Short-term performance
 - Long-term energy system evolution
- **The key role of liquid transparent information exchange for arriving at desired solutions (Dynamic Energy Control Protocols –DECPs-)**
- Examples of the existing and evolving industry architectures as particular cases of DECPs-managed physical system
- Open R&D questions

Complexity of the Evolving Industry Architectures

- The industry challenge is much more complex than ever before as a result of variety of reasons:
 - the needs for more energy are growing, but it is no longer possible to build according to the existing planning and operating criteria (there is simply not enough resources to provide the same energy density per capita as at present; right of ways hard to obtain; greenhouse effects major concern);
 - it has become inevitable that we must make the “most” out of what is available (even at the expense of violating once sacred principles of unconditional service provision to the customers);
 - the “most” not a single criterion subject to constraints (instead, the notion of the “most” has become multi-dimensional and must be viewed as a result of reconciling major tradeoffs)

Single optimization subject to constraints vs. Reconciling multi-dimensional tradeoffs

Single optimization subject to constraints	Reconciling tradeoffs
Schedule supply to meet given demand	Schedule supply to meet demand (both supply and demand have costs assigned)
Provide electricity at a predefined tariff	Provide electricity at QoS determined by the customers willingness to pay
Produce energy subject to a predefined CO ₂ constraint	Produce amount of energy determined by the willingness to pay for CO ₂ effects
Schedule supply and demand subject to transmission congestion	Schedule supply, demand and transmission capacity (supply, demand and transmission costs assigned)
Build storage to balance supply and demand	Build storage according to customers willingness to pay for being connected to a stable grid
Build specific type of primary energy source to meet long-term customer needs	Build specific type of energy source for well-defined long-term customer needs, including their willingness to pay for long-term service, and its attributes
Build new transmission lines for forecast demand	Build new transmission lines to serve customers according to their ex ante (longer-term) contracts for service

Need for novel engineering, regulatory and financial solutions

- Today's engineering solutions optimize total supply cost for the forecast demand, treating everything else as a constraint.
- Current (State) regulatory solutions do not require information from the customers concerning their choices (willingness to pay for short-term QoS, long-term guaranteed supply, reduced greenhouse effects); instead, obligation to serve by a State (utility) is assumed at the pre-agreed on tariffs. By and large, price of service is seen as a constraint by both providers of service and the customers.
- Current financial arrangements are grossly distorted with regard to the (monetary) risks associated with uncertainties (demand, fuel, equipment status).
- Current (Federal) regulatory experiments are superposed on the State regulatory solutions whose emphasis is on individual utilities (States) while the interactions with neighboring States (utilities) are uncertain constraints. The FERC restructuring attempts to eliminate the constraints across States and to induce "open access".
- **None of current engineering/regulatory/financial solutions in place enable genuine reconciliation of multiple tradeoffs at value. Therefore, need for novel solutions.**

An example of effects of engineering/regulatory and financial constraints

- **Initial Architecture 0** (Utility 1 in State 1 has excess inexpensive capacity; Utilities 2 and 3 have just about enough to supply their own customers; utility 4 in State 4 has high demand, and expensive energy.)
- **Possible future architectures (at a regional 4-utility level):**

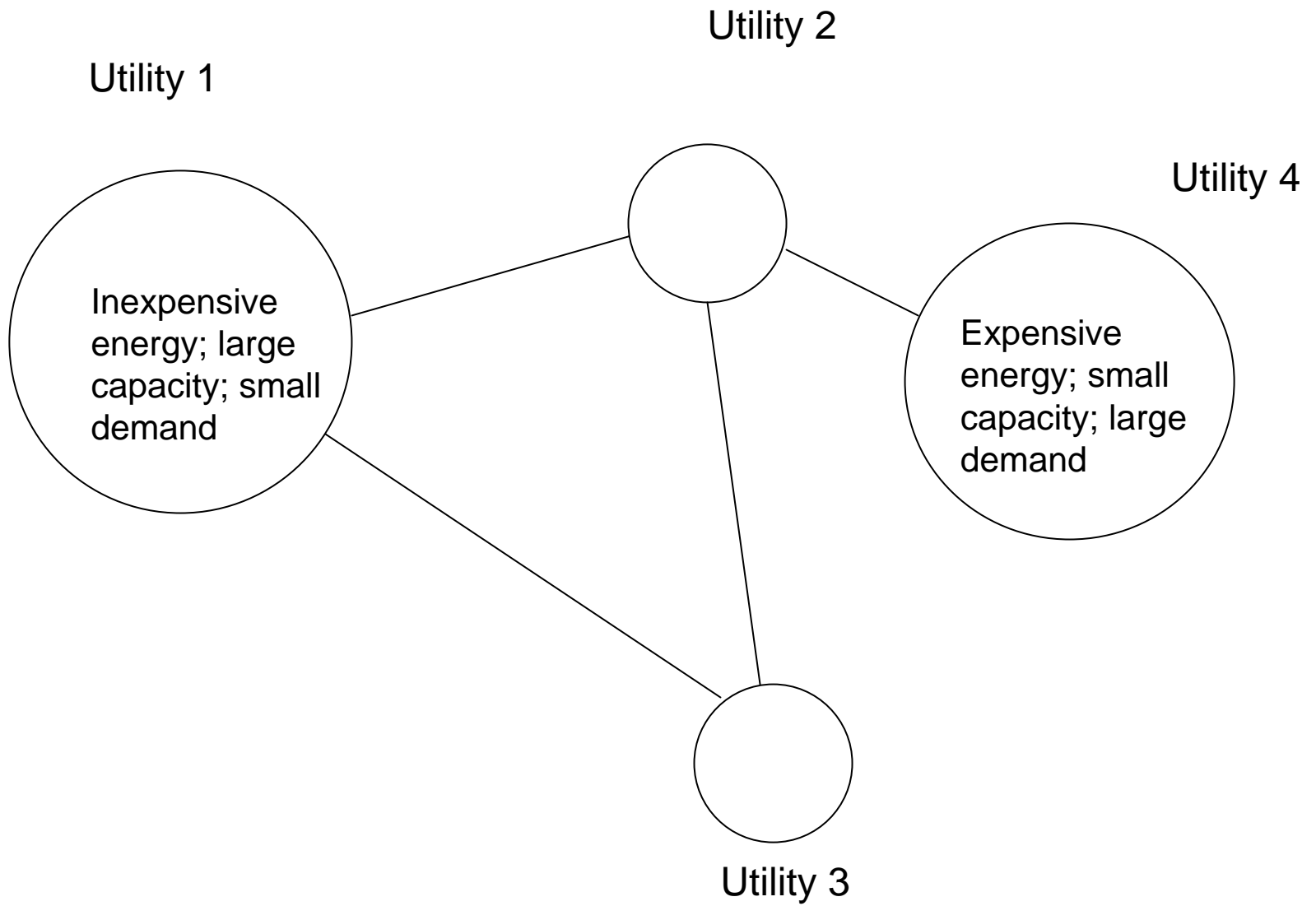
Architecture 1 – Generation divests and Utility 4 loses its large nuclear energy source to its new owners in State 1 (regulatory change only, no new physical investments). No spot markets in individual States (utilities)

Architecture 2– The same as Architecture 1, except State (utility) 4 establishes spot market and FERC demands open access competition across all four States (no new physical investments).

An example of effects of engineering/regulatory and financial constraints (continued)

- Architecture 3** —The same as architecture 0, except many new small gas power plants added
- Architecture 4** —The same as architecture 1, except many new small gas power plants added
- Architecture 5** —The same as Architecture 0, but transmission interface constraint
- Architecture 6** -The same as Architecture 5, but new transmission added
- Architecture 7** - The same as Architecture 0, except mandatory 10% new renewable resources in all four states (including many novel technologies, such as low-cost solar, wind, etc)

REGION

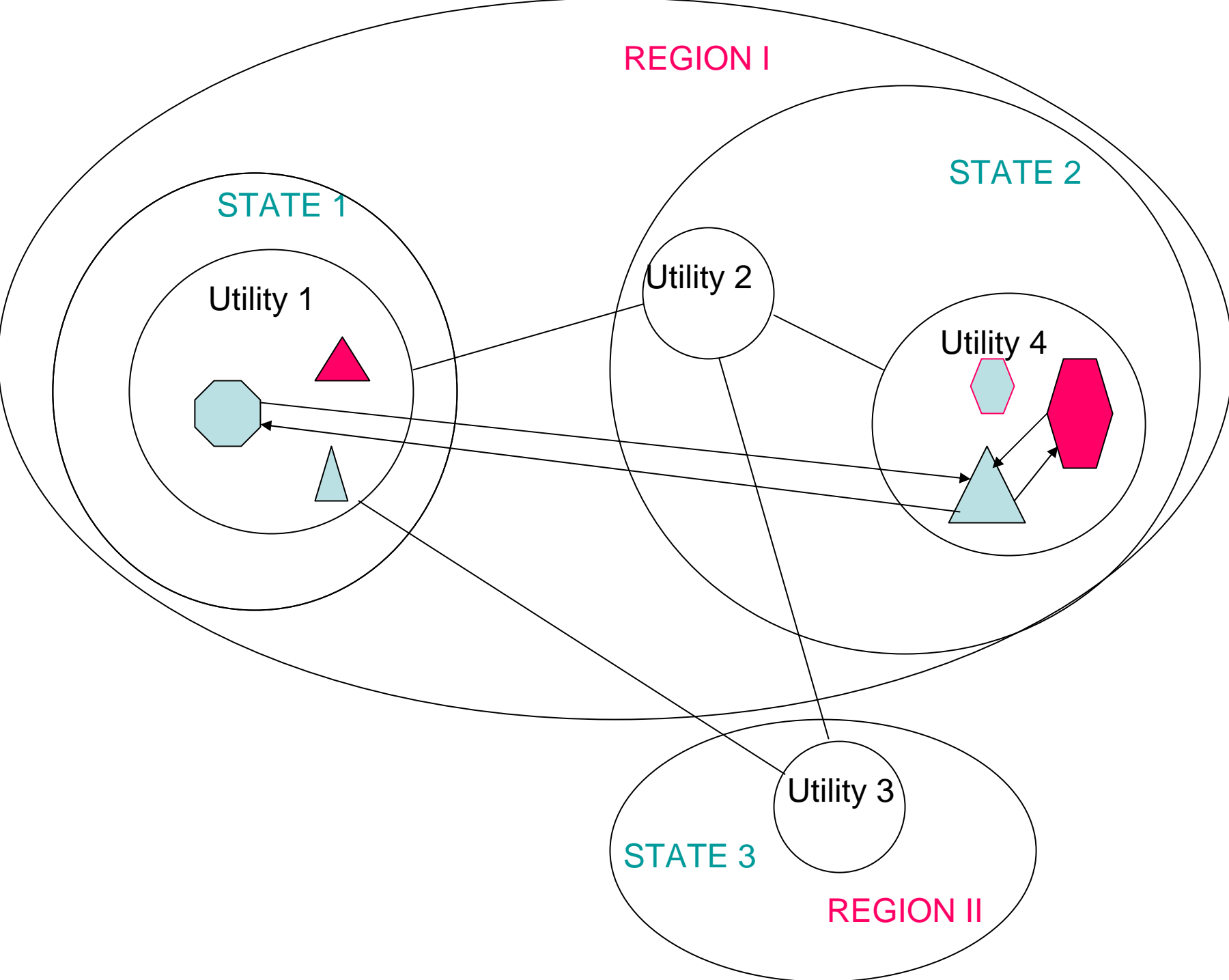


Vastly different performance of candidate architectures

- **Architecture 0** - sub-optimal utilization of regional resources.
- **Architecture 1** – suboptimal utilization of regional resources; utility (State) 1 subsidizing owners of their divested power plants;
- **Architecture 2** -- Very interesting \$\$ flow. ETC (a full paper will be posted on the conference web site with detailed analysis of outcomes); new engineering challenges.
- Only some candidate architectures become real-world solutions depending on regulatory rules/constraints. Very different performance.
- Major problems: Biased solutions, without systematic reconciliation of tradeoffs. Often one time solution w/o ability to evolve into better performance.

Possible ways forward: DECPs

- Dynamic Energy Control Protocols (DECPs) as a means of reconciling tradeoffs
- For example, in order to implement supply-demand balancing, **S and D need to iteratively communicate over time.**
- Or, to build a specific type of energy resource, **iterative sharing of future uncertainties through transparent and liquid market arrangements becomes essential (need for long-term energy/capacity forward markets).**
- Or, to build a specific transmission line, **iterative sharing of future uncertainties and associated risks is essential (need for longer-term forward transparent transmission contracts).**
- Depending on the temporal and spatial granularity of the DECPs much can be achieved in terms of **reconciling tradeoffs through choice and information exchange.**



Industry architectures as a function of DECPs in place

- **Architecture 0- Regulated industry** (communications top-down at the utility control center level; planning and operations w/o much active info exchange with the customers; communications between utility and State regulators – annual, regulation lags in response to utility performance; no information exchange between States; no choice in response to price of electricity)
- **Architecture 1** —Divested generation (new communications between power generation and utilities, purchasing on behalf of their customers ; the rest is the same by and large as in Architecture 1.
- **Architecture 2** -- Additional info exchange day ahead between the control center (spot market) and power producers selling into the spot market. Very little information exchange between some (large) customers and the spot market.

Engineering Energy Services of the Future by Careful Design of DECPs

- It can be shown that depending on the type of information exchange in place, the system performance is qualitatively different
- New regulation needed to define type of information exchange required for predictable performance (short-term, and long-term)
- For example, if power delivery is to be equally valued as generation (local exp generation equivalent to far away cheap generation plus value of transmission), one must have well-understood protocols in place for both building new transmission and providing it according to well-defined contractual arrangements (of particular importance is T-value for short-term reliable service, as well as for longer-term assurance that there will be energy in the areas where no generation is planned)
- Another example, if effects of pollution are to be paid for by those who use energy, there ought to be a protocol for customers providing their willingness to pay for cleaner energy, and the power suppliers providing offers to sell different primary energy. Clean energy should be allowed to be offered at the higher price.

Summary

- Possibly the most immediate problem is a design of new regulation of systematic information concerning (1) needs of customers to have long-term assured electricity services, as well as (2) the offers to build generation and transmission. These protocols would provide basic mechanisms for adjusting energy utilization while reconciling the key tradeoffs.
- This is essential for risk allocation associated with impossible to predict long-term future demand. Risk should be distributed over time and all industry participants. The only sustainable solution is the one which reflects the scarcity of resources and their actual costs in the future. Otherwise, false expectations concerning price of services and the effects on the environment.

Summary (2)

- The main R&D challenge is design of new regulatory policy which recognizes
 - THE NEED TO REPLACE CONSTRAINTS BY TRADEOFFS, WHOSE RECONCILIATION WOULD TAKE PLACE IN AN ITERATIVE EXCHANGE OF INFORMATION AMONG THE INDUSTRY PARTICIPANTS
 - STUDY PERFORMANCE AS A FUNCTION OF TYPE OF INFORMATION AVAILABLE
 - PROPOSE DYNAMICALLY ADJUSTABLE INFORMATION EXCHANGE PROTOCOLS FOR WELL-UNDERSTOOD INDUSTRY PERFORMANCE
 - DECIDING ON THE TYPE OF INFORMATION EXCHANGE (EX POST AND EX-ANTE) SHOULD BE A MATTER OF QUANTIFIABLE MODEL-BASED DESIGNS WHICH LINK ENGINEERING, REGULATION AND ECONOMICS
- NEED TO POSE THESE PROBLEMS IN OUR CLASSROOMS