The Discipline of Grid Architecture for Utilities, Public Policy Makers, and Stakeholders

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How Do We Understand Issues Like These?

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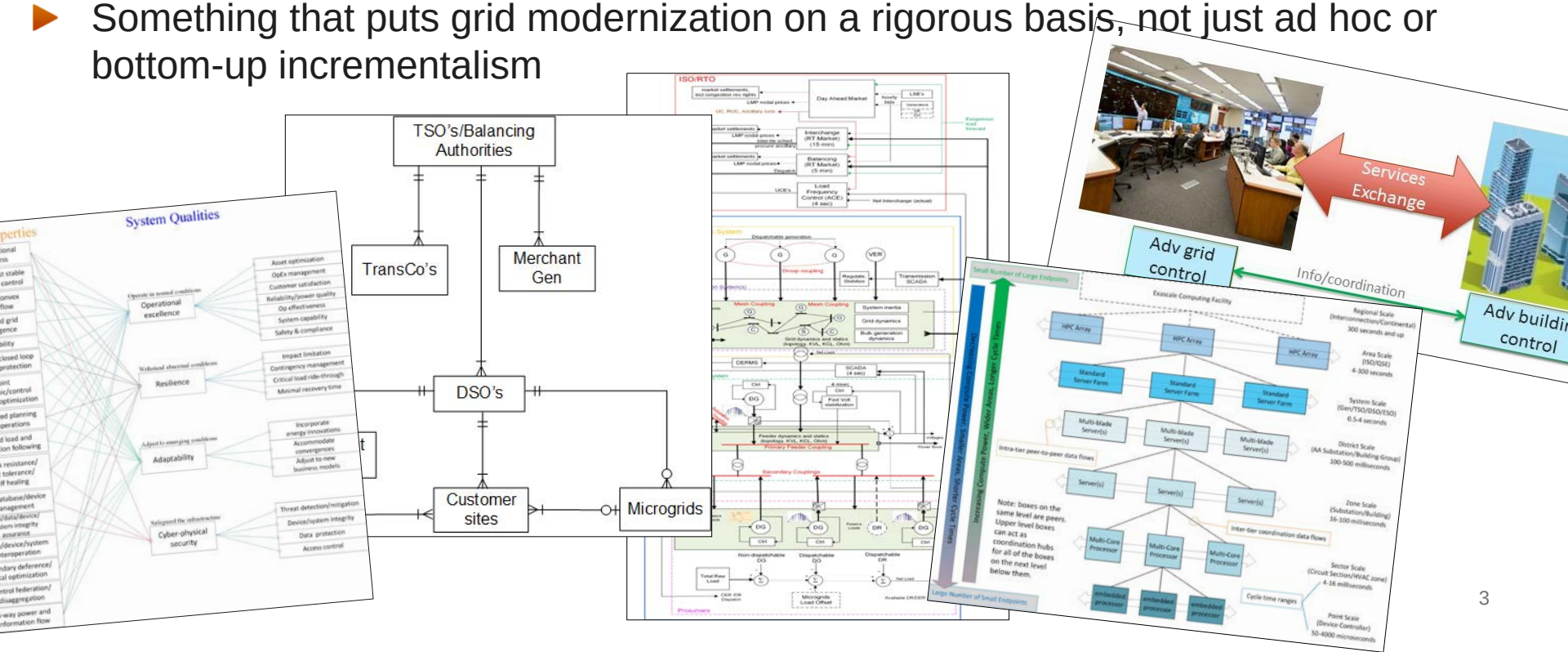
- What does the control structure for the whole grid look like? How does the grid behave as a *whole system*?
- What limits the ability of commercial buildings to supply energy or other services to electric grids?
- How do grid controls and wholesale markets interact?
- How does DER impact regulation/oversight?
- How do DER's interact with ISO/RTO functions?
- Are electric and gas networks converging or is generation just a downstream use of gas?
- Should distribution company roles and responsibilities be changed, and if so, how does this impact grid control, markets, and oversight?

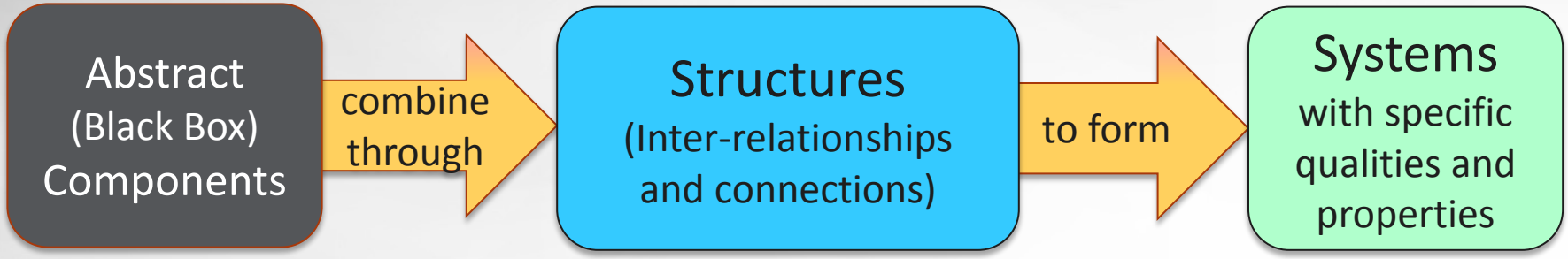
Grid Architecture is a Practical Tool

- What we need is something that shows holistic depictions of the extended grid at a systemic level, with multiple views into the various structures
- Something that enables an understandable vision of how to change and evolve a highly complex system…and how to identify/design platforms, trace value streams, etc.
- Something that puts grid modernization on a rigorous basis, not just ad hoc or bottom-up incrementalism



System Architecture Definition/Purpose

- A *system architecture* is a set of views of a (complex) system whose purpose is to help think about the overall shape of the system, its attributes, and how the parts interact.



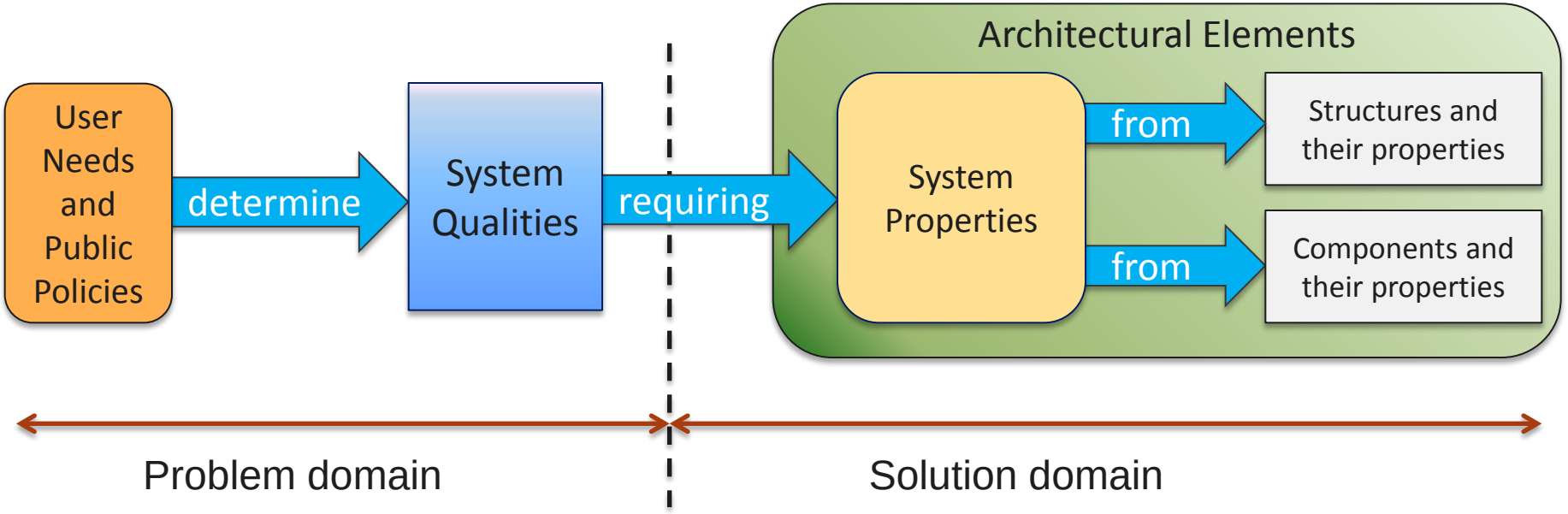
- Some Purposes of System Architecture
  - Help manage complexity (and therefore risk)
  - Assist communication among stakeholders
  - Remove barriers and define essential limits
  - Identify gaps in theory, technology, organization, regulation…
  - Identify/define interfaces and platforms
  - Enable prediction of system qualities

How Do Stakeholders Benefit?

- All stakeholders, especially users/customers/prosumers:
  - Share common vision of the future grid
  - Enable stakeholder communication
- Regulators and Legislators
  - Appreciate interactions and consequences of potential changes
- Solution architects and system designers
  - Understand subsystems in whole grid context
- Utility executives
  - Relate proposed changes to overall utility strategy, goals and constraints
- Suppliers/product vendors/researchers
  - Benefit from reduced barriers and better grid access
  - Identify technical gaps to be filled

High Level View of the Process

- System Qualities come from the *consumer* viewpoint
- System Properties come from the *provider* viewpoint
- Structures and Components make up the architecture



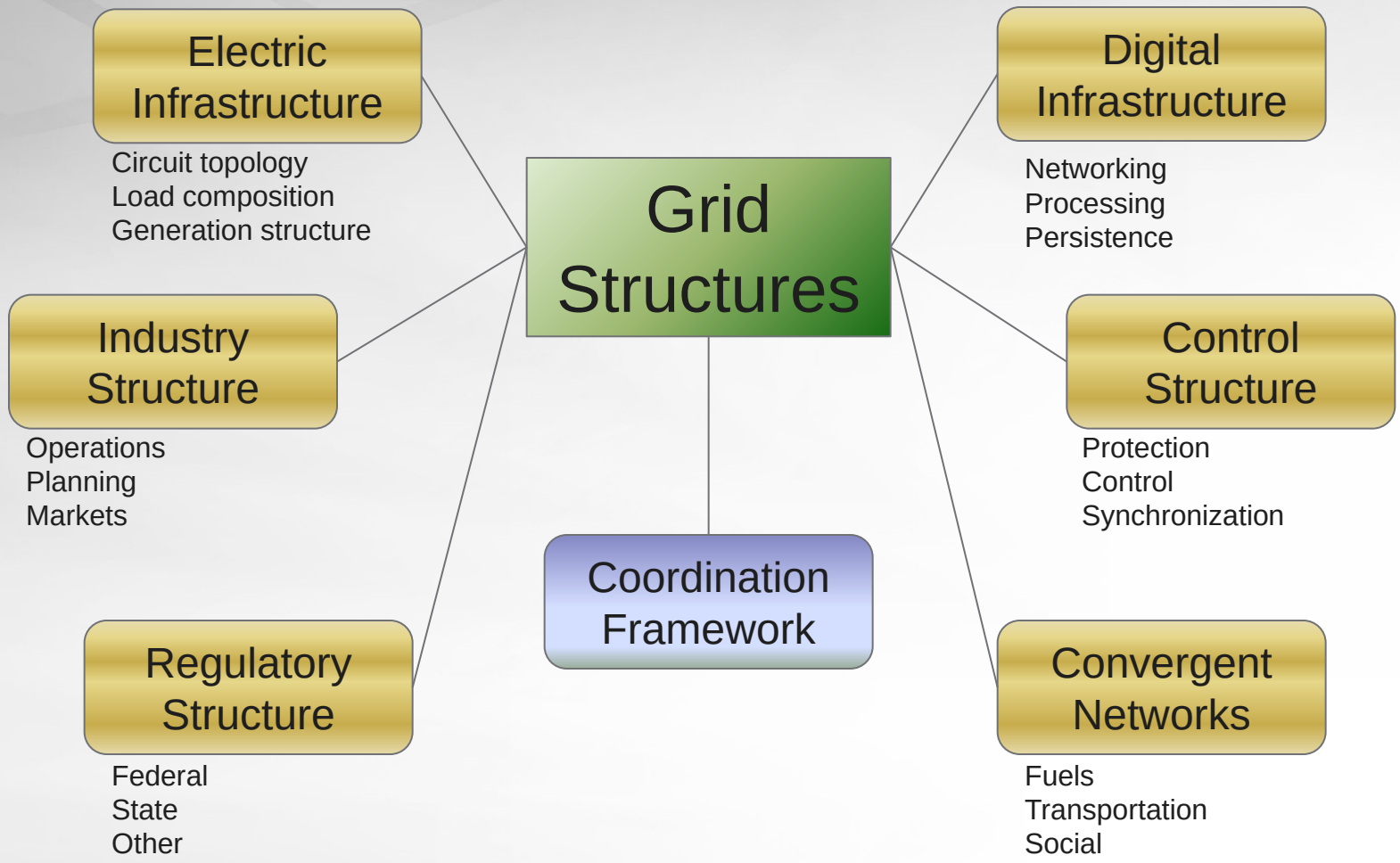
Old and Worn

- Grids are big circuits; control is just an app
- Data tsunami
- Systems of systems
- Cylinders of excellence (i.e. siloes)
- Architectural “elegance”
- System integration

New and Way Cool

- Grid/market/control interaction
- Value Stream Analysis
- Network of Structures
- Convergence and platforms
- Architecture quantification
- Structural de-constraint

The Grid is a Complex Network of Structures



Some System Architecture Principles

- A good architecture is one that meets the needs of the stakeholders (especially the users).
- Essential functionality drives complexity, not architectural “elegance.”
- The architect must be cognizant of the global system when optimizing subsystems.
- Stakeholders should be involved in the process as much as possible, giving frequent and honest feedback on all aspects of the system architecture.
- Architecture must be consumable (i.e. understandable) by the stakeholders.

Dep't of Energy Grid Architecture Work

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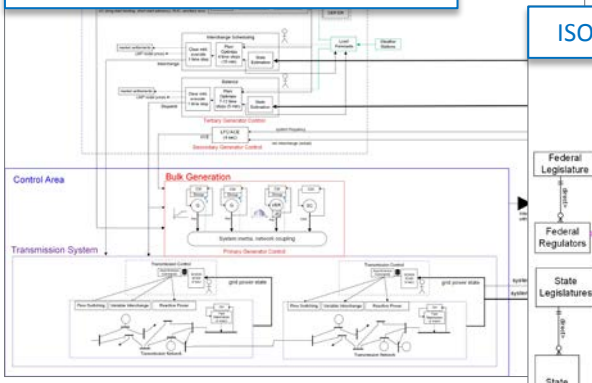
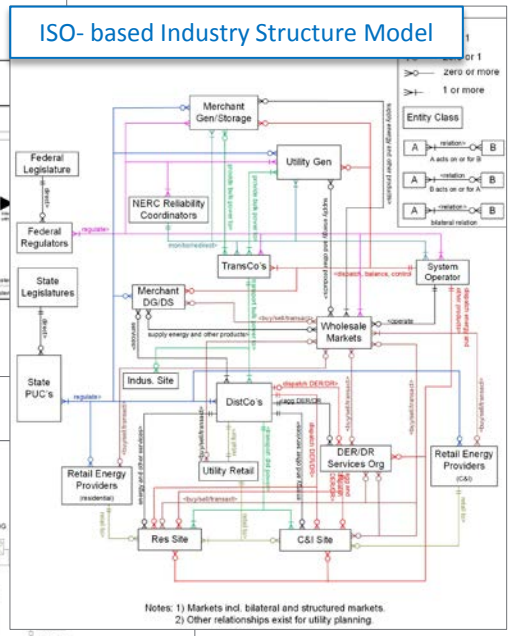
- Done to support analysis at DOE
- Viewed as a means to understand change in the grid
- Work has started to go viral – has been referenced in conferences by industry people and
- Even being used in an energy law class at GWU
- Presented to NY REV working group, resulting in engagement with NY REV on architecture
- New request to engage with a coalition of utilities working on a project with architectural implications
- On-going architecture work via Office of Electricity

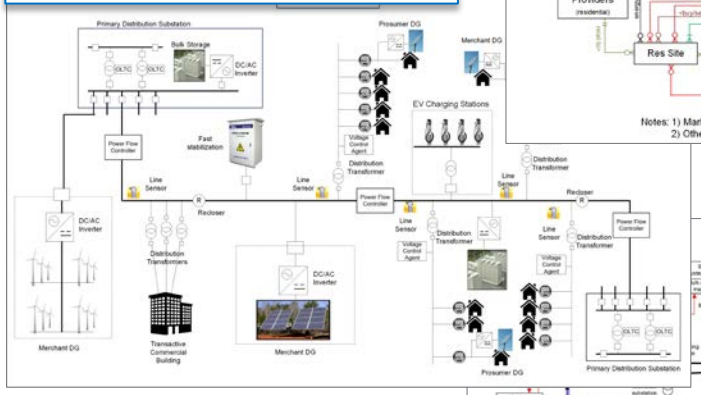
Integrated Market/Control Model

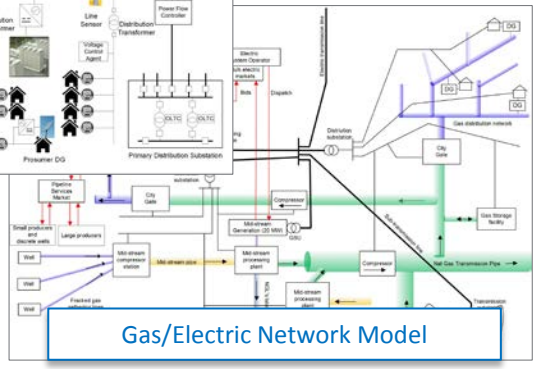


ISO- based Industry Structure Model



Flexible Distribution Circuit Model

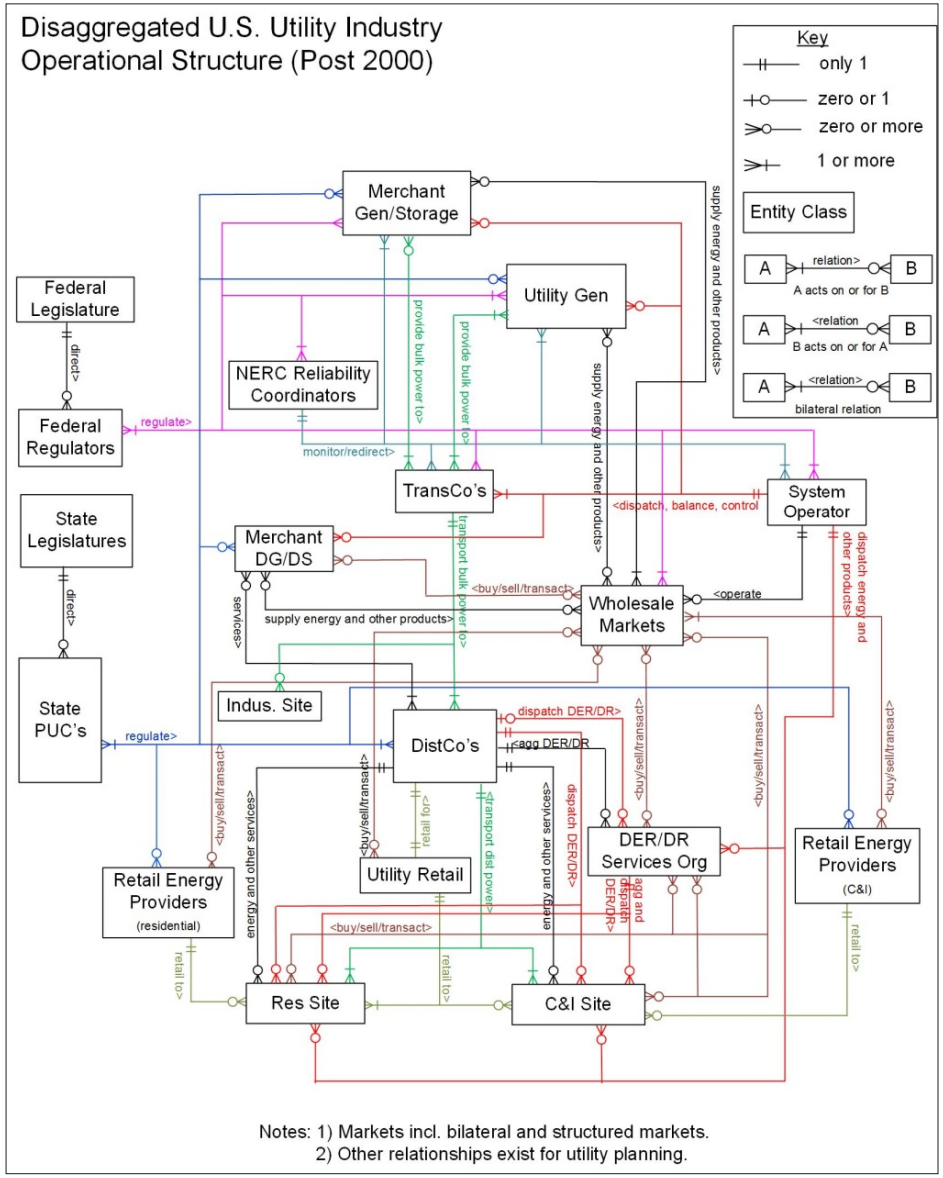




Gas/Electric Network Model

Example: Industry Structure

- One way to represent is via Entity-Relationship Diagram
- Each box is a *class* of entities
- Lines represent relationships
- We break it down in layers for each type of relationship (regulatory, market, etc.)
- Diagram requires detail for drilldown to explain each relationship



Insight Example: DSO Models

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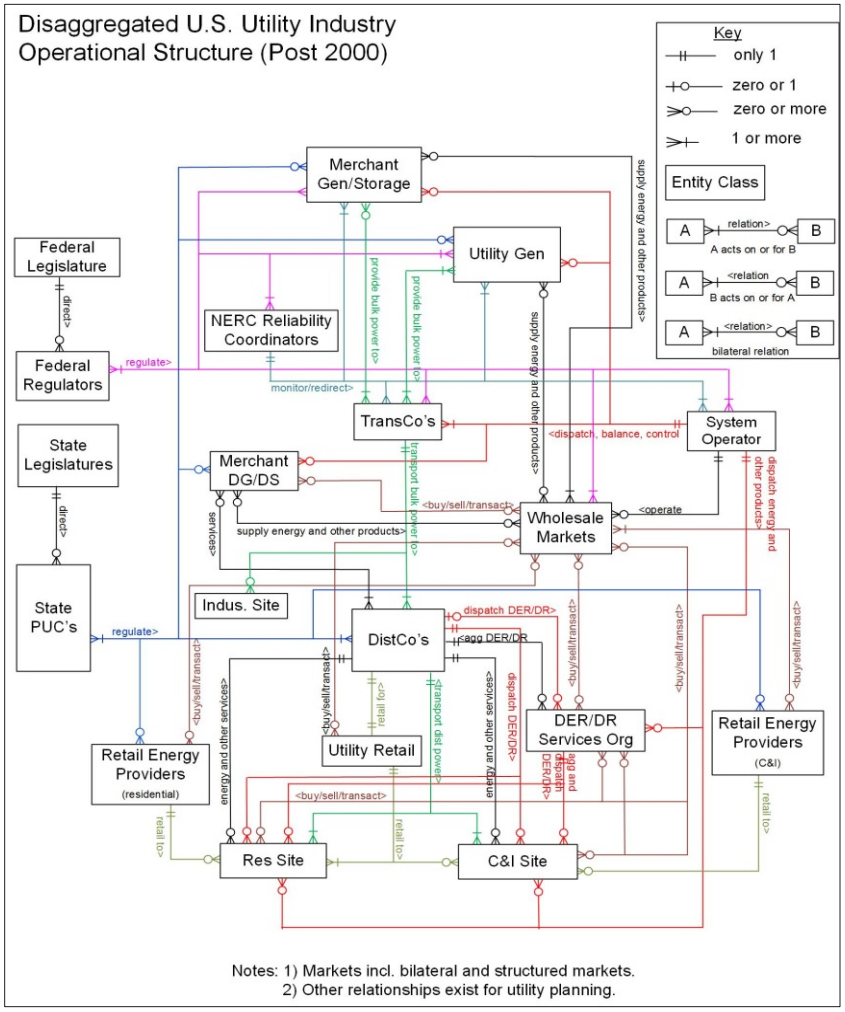
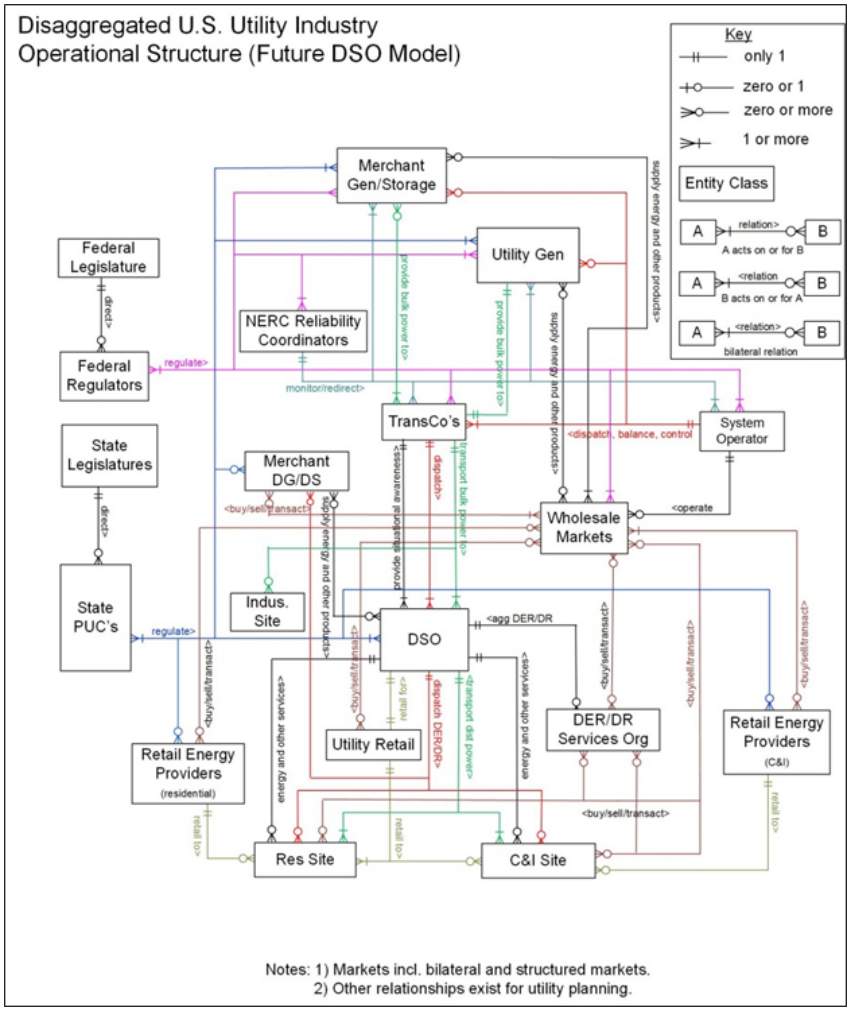


Notes: 1) Markets incl. bilateral and structured markets.
2) Other relationships exist for utility planning.



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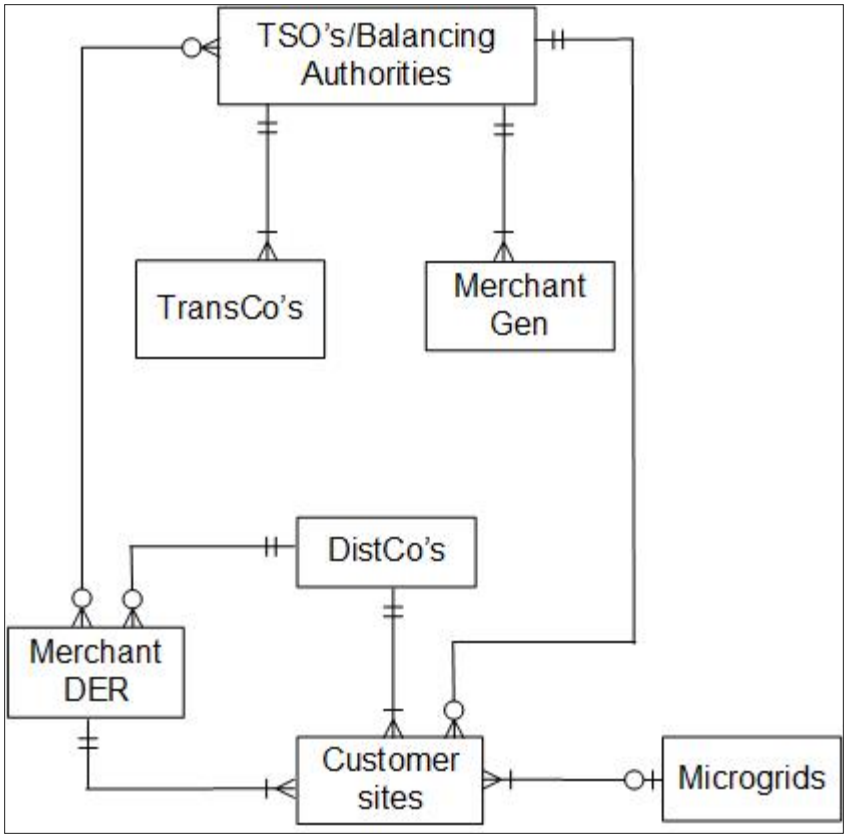
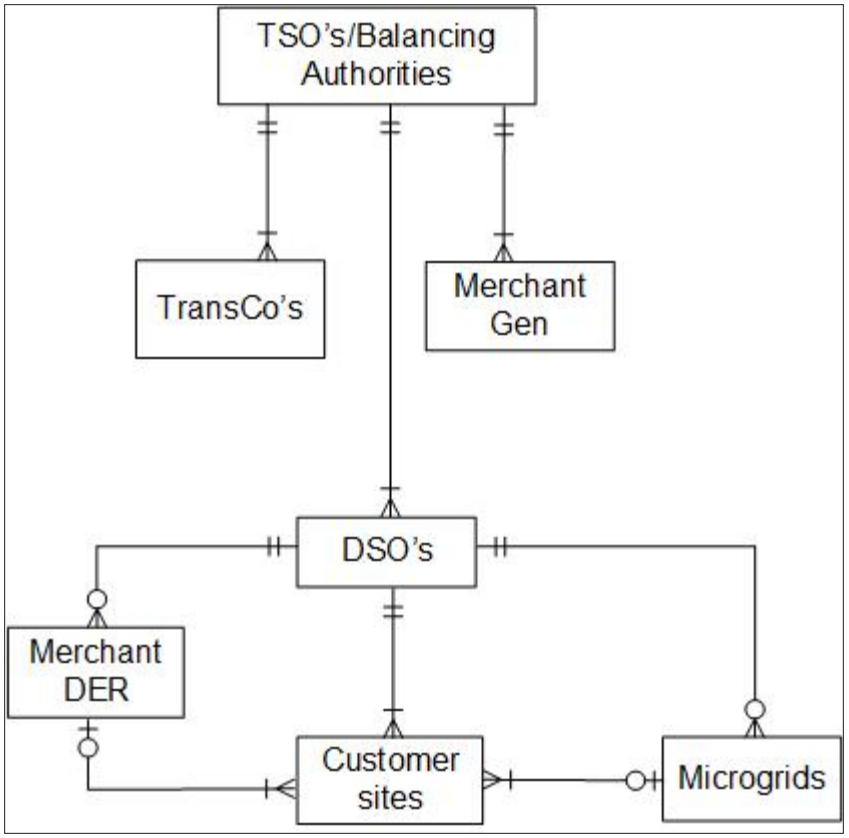
Example: Typical Coordination Framework



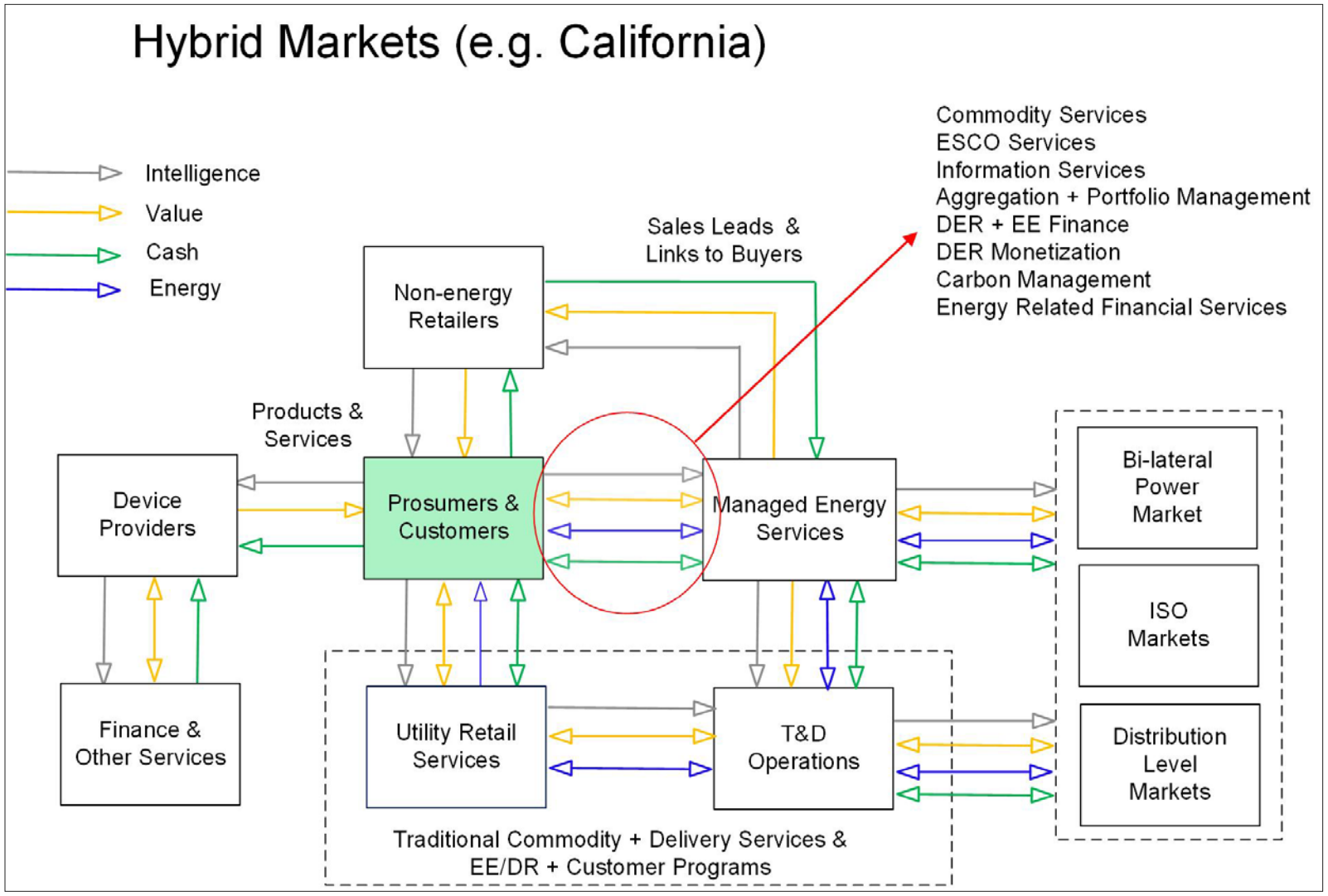
- Structurally problematic
  - Level bypassing
- Potential reliability issues
  - For high DER penetration
- Scalability problems
- Unnecessary connectivity raises extra cyber-security issues

Example: DSO Coordination Framework



- Structurally sound
  - No level bypassing
- Clear roles
  - Managing DER volatility
- Better scalability
- Connectivity and data flow patterns easier to secure

Value Stream Allocation and Analysis



Source: Paul De Martini, Newport Consulting Group

Take-Aways and Steps to Consider

- Grid architecture is a discipline that helps manage the complexity of grid transformation
- It uses abstract components, structures and properties, but focuses on structure as the key definer of capabilities
- The processes and bases are rigorous but are centered around stakeholder input
- Engaging with a good architect early on provides the most value but can be helpful almost anywhere in the process

Changing Lightbulb

- Q: How many grid architects does it take to change a light bulb?

- A: Only one, but the change has to be structural and involve the whole grid.

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thank you

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