Economic Models & Simulation for GridWise™ — 101

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Context of Clear Risks and Impelling Benefits

If we don't act, we risk…

- Higher costs from power disruptions, blackouts, and poor power quality
- Increasing national vulnerability to threats
- A drag on U.S. global economic competitiveness
- Higher cost of electricity
- Limits on regional economic development
- Lost opportunities for business growth and job creation
- Export of high-technology industries and jobs

If we do act, we gain…

- More secure, reliable, higher quality power delivery
- Tens of billions of dollars in annual cost savings
- U.S. business and job growth
- Attraction of high-technology industries and jobs
- Reduced vulnerability to accidents and attacks
- U.S. leadership in an emerging global market for "smart" grid technologies

Source: GridWise Alliance Brochure, March 2005

GridWise Transformation Implies…

- Increase in number of market actors
- Better informed market participants
- Demand response over more market spaces
- More revealing of values across full chain
- Increased linkages between physical operations and energy markets

…For Electric Power Transactions

Economic analyses contribute

- Observation of data patterns
- Constructed explanations→ theories → tools
- Evaluations of plausibility, generality, predictive outcomes

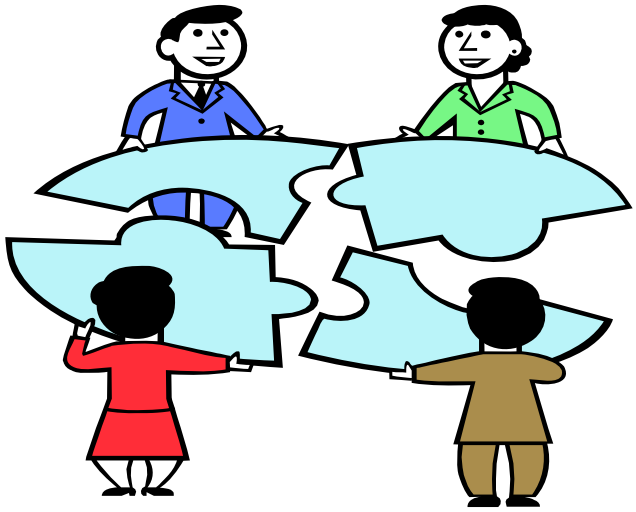
Increased Knowledge ? Increased Confusion

Characterizing features of tools

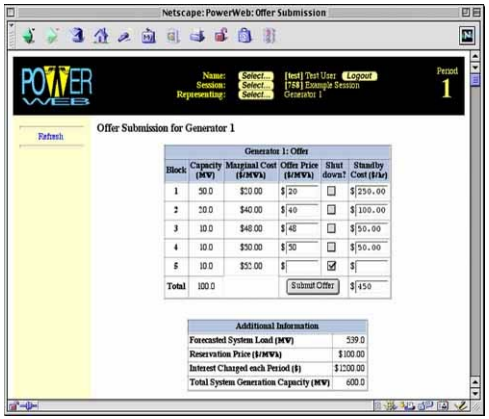
- Objectives motivating design…
  - Modeling system behavior
  - Investigating economic optimums
  - Studying effects of new technologies
- Design Scope…
  - Spatial
  - Temporal
  - Level of detail/generalization
- Assumptions…
  - Input data
  - Abstractions
  - Dynamic Interactions
  - Behavior

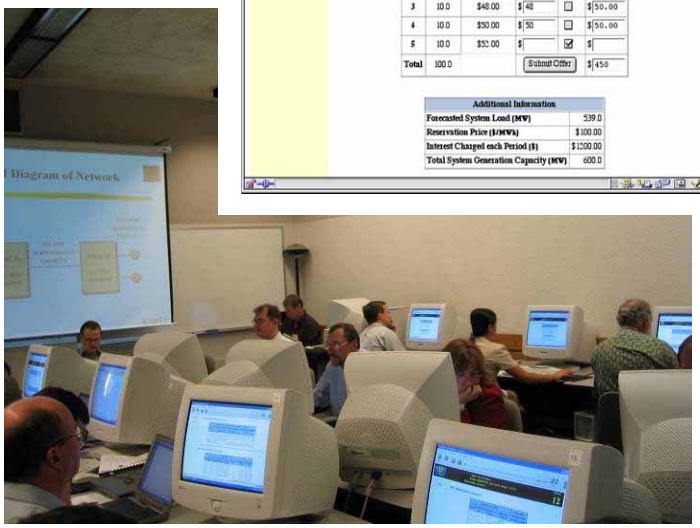
Puzzling together the complex picture

- Experimental Economics
- Traditional Input/Output Models
- Systems Dynamics
- Agent-Based Systems



Experimental Economics

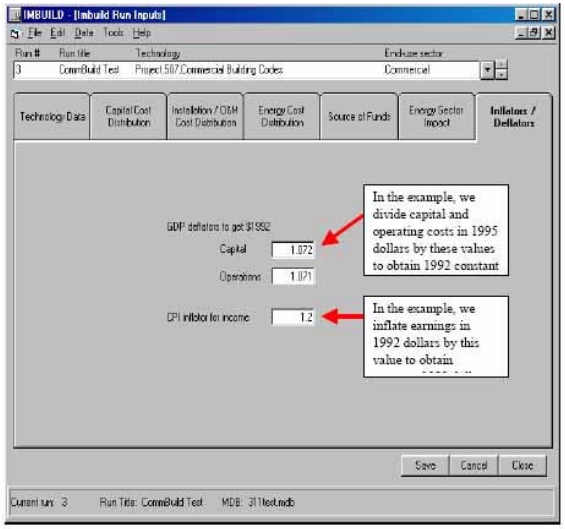




- Analyzing economic behavior in a controlled, laboratory setting
- Human subjects key
- Examples for GridWise
  - Auction Mechanisms/Gaming
  - Market power and Demand Response (Rassenti, Smith, Wilson)
  - PowerWeb—learning, transparency, risk/loss aversion… (Cornell/PSERC)

Source: Timothy Mount, and Ray Zimmerman. “Introduction to PowerWeb: How Electric Networks and Repeated Auctions Work.” Cornell University. Presented at the Power Market Summer Study Session, Portland OR. August 2004.

Traditional Economic Input/Output Modeling

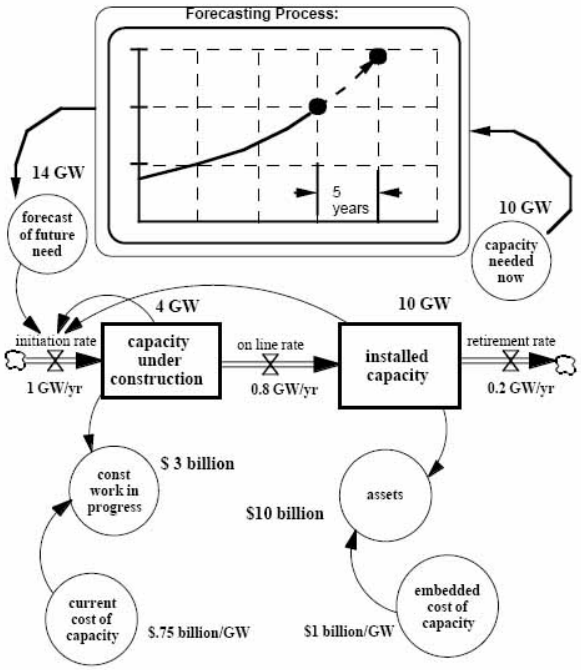


- Computational matrices
- Input and output flows responding to demands
- Examples of multi-sector energy analyses
  - General Equilibrium models (Edmonds, *et al.*)
  - Static technology penetration (Scott, *et al.*, Laitner)
  - Alternative energy policy (Roop, *et al.*)

Source: M.J. Scott, J.M. Roop, R.W. Schultz. "ImBuild II: Impact of Technologies on Energy Efficiency Programs." Pacific Northwest National Laboratory, June 2002.

Systems Dynamics

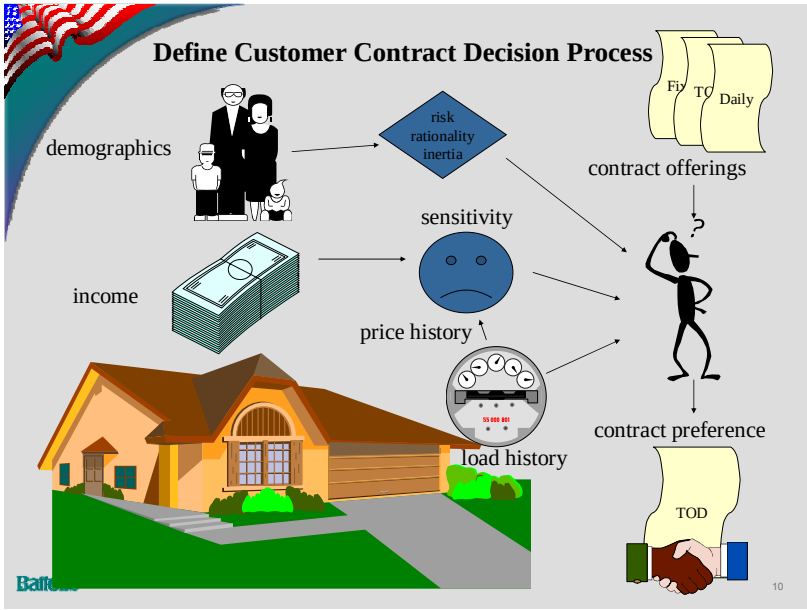
Fig. 3. The financial challenge during the "Golden Years"



- Dynamic behavior of complex systems
- Engineering control theory & mathematical nonlinear systems dynamics
- Examples for GridWise
  - Planning/ electricity sector stock and flow structure (Ford)
  - Deregulation/Restructuring
    - Competitive Industry Gaming Model (CIGMOD)
    - Energy 2020

Source: Ford, Andrew. "System Dynamics and the Electric Power Industry," Jay Wright Forrester Prize Lecture, 1996.

Agent-Based Systems



- Encapsulated data and methods representing entities in complex systems
- Computational platforms
- Examples for GridWise
  - Market platform testing (Tesafatsion, *et. al.*)
  - Testing regulatory structures (SEPIA, EMCAS)
  - Behavior (BTS & DSS)

Source: Joe Roop and Eihab Fathelrahman..".Modeling the Distribution Utility as an Agent in the Wholesale Market". Presented at the IAEE/ The United States Association for Energy Economics (USAEE) Meeting. July 2004

Different methods, different strengths

	Experimental Economics	**Input-Output Models**	**System Dynamics**	**Agent-Based Systems**	
PLUS	Behavior Validation Teaching Clarity	Mature Broad scope Policy 'Big Picture'	Interactions & flows Temporal—dynamic Mathematical Science	Interactions Decision making Flexibility	**PLUS**
MINUS -	Costly Human-Subjects Limited Scope	Static nature Depending on input data	Model dependent Computational needs Behavior/human element	Computational needs Maturing Model complexity	**MINUS -**

Filling in the missing puzzle pieces

- ↑ # Actors
- ↑ Information
- ↑ Demand response
- ↑ Values revealed
- ↑ Linkages

- Adding actors to models
- Studying effects of greater information
- Studying demand elasticity at different levels
- Studying economic impacts of newly revealed values
- Linking economics and physical systems behavior

What is the research agenda?

- Interdisciplinary programs
- Models and simulation linking economics to physical systems
- Corroboration & collaboration between methods
- “Vulgarization”

…?

Thank You

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Potential Topics

- Behavior & impacts of ‘markets’: ancillary services, reserves (various), retail, energy vs wires separation
- Behavior and impacts of services: choice in power quality, levels of price signal availability/awareness, aggregated demand response, statistical demand response
- Reliability as a product, insurance
- Investment effects of these transformations

Selected References

- GridWise Alliance Brochure, March 2005, www.gridwise.org.
- Timothy Mount, and Ray Zimmerman. “Introduction to PowerWeb: How Electric Networks and Repeated Auctions Work.” Cornell University. Presented at the Power Market Summer Study Session, Portland OR. August 2004.
- Stephen J. Rassenti, Vernon L. Smith, and Bart J. Wilson, Controlling Market Power and Price Spikes in Electricity Networks: Demand-Side Bidding. Interdisciplinary Center for Economic Science. July, 2001.
- M.J. Scott, J.M. Roop, R.W. Schultz. “ImBuild II: Impact of Technologies on Energy Efficiency Programs.” Pacific Northwest National Laboratory, June 2002.
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