GridSpice - A Virtual Test Bed for Smart Grid

Amit Narayan,
Director of Research in Simulation & Modeling,
Electrical Engineering Department,
Stanford University
anara@stanford.edu

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The Modern Grid: Innovation & Complexity

New Technologies

Renewable Energy
- o Solar
- o Wind
- o Hydro
- o Fuel-Cells

Energy Efficiency
- o Demand Response
- o Smart Meters
- o Smart Appliances

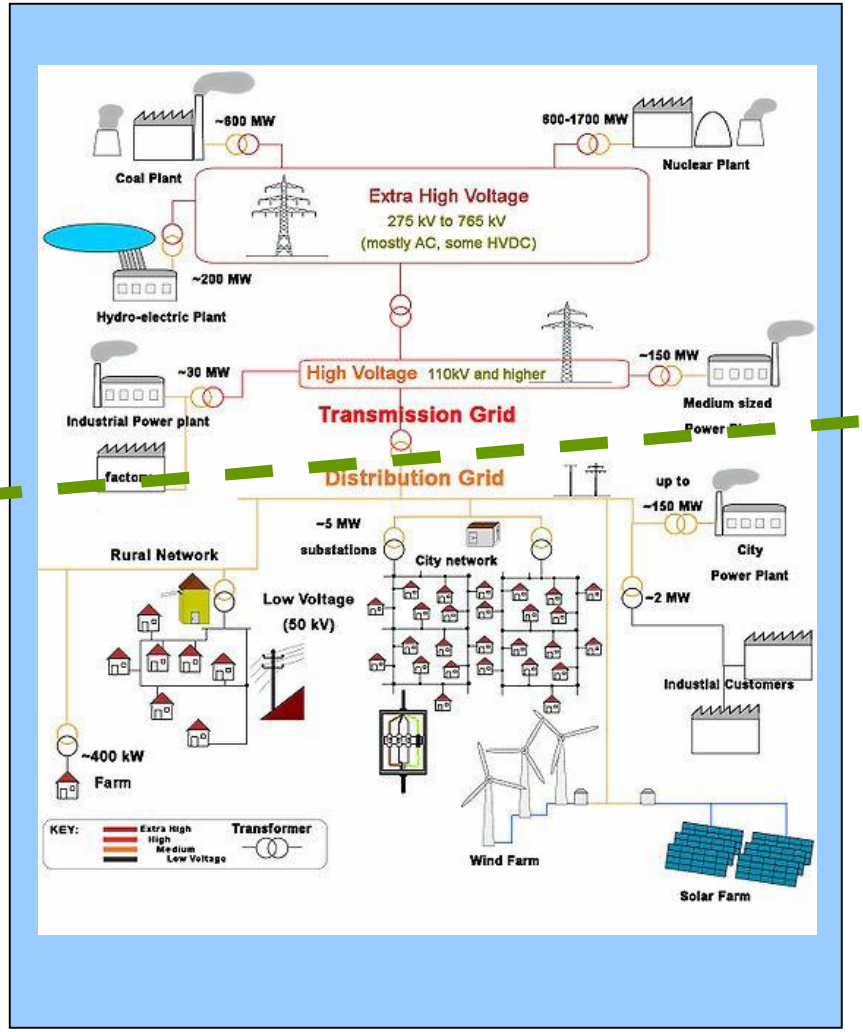
Storage
- o Utility Scale Storage
- oDistributed Storage
- oEnd-user level storage (e.g. PHEV)

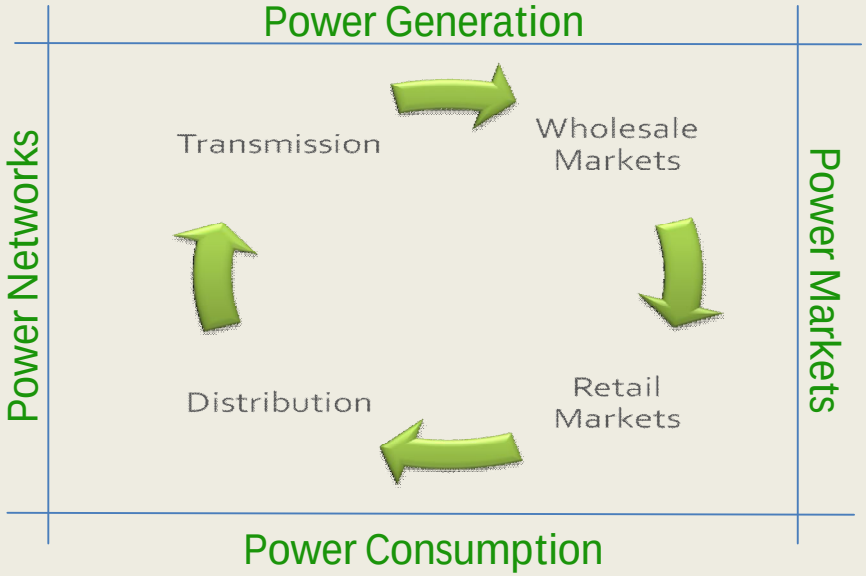
Market Dynamics

Wholesale Market Deregulation
- o Day-ahead and hour-ahead markets
- o IPPs and LSEs

Retail Market Deregulation
- o Dynamic Pricing
  - o Block Pricing
  - o Time-Of-Use
  - o CPP, CPR
  - o Real-Time Pricing

The Modern Grid: Innovation & Complexity





Complex interactions of power flows, data flows and markets

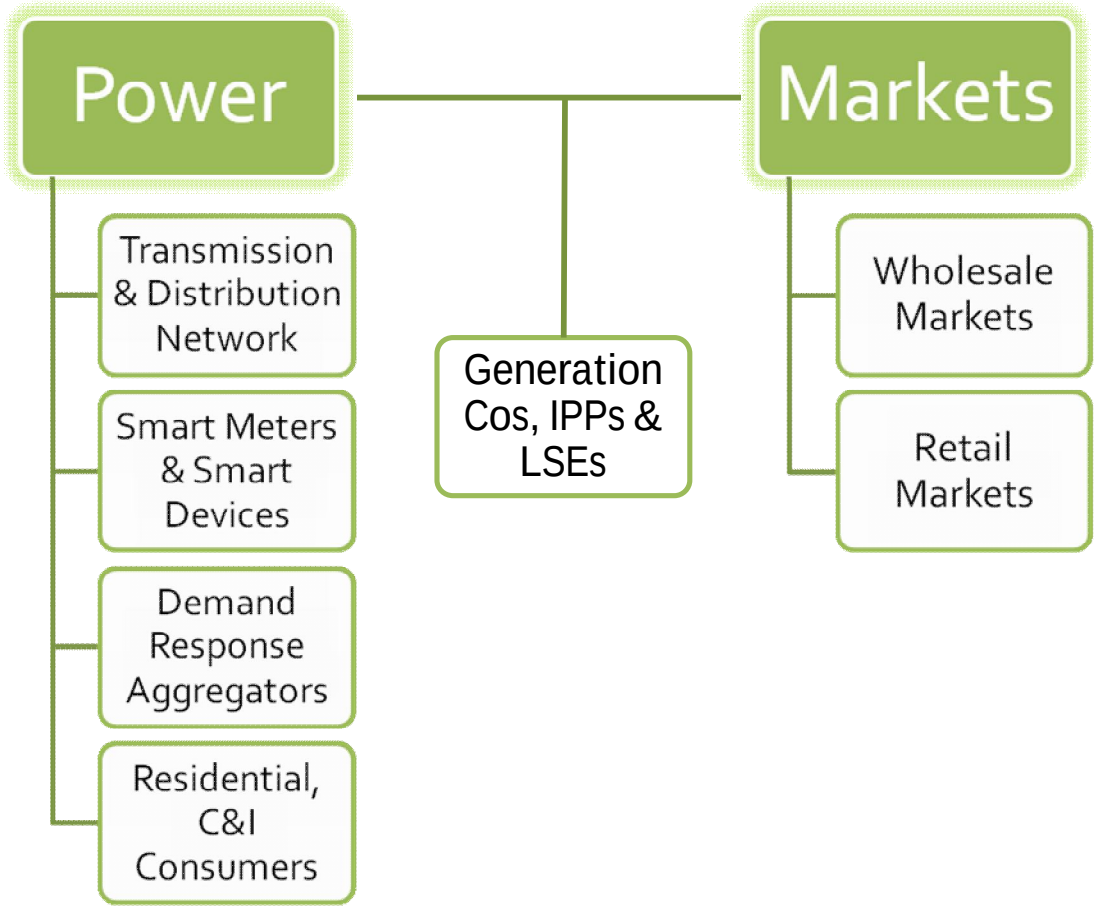
Requires new tools to model & optimize the system

Our Research Objectives

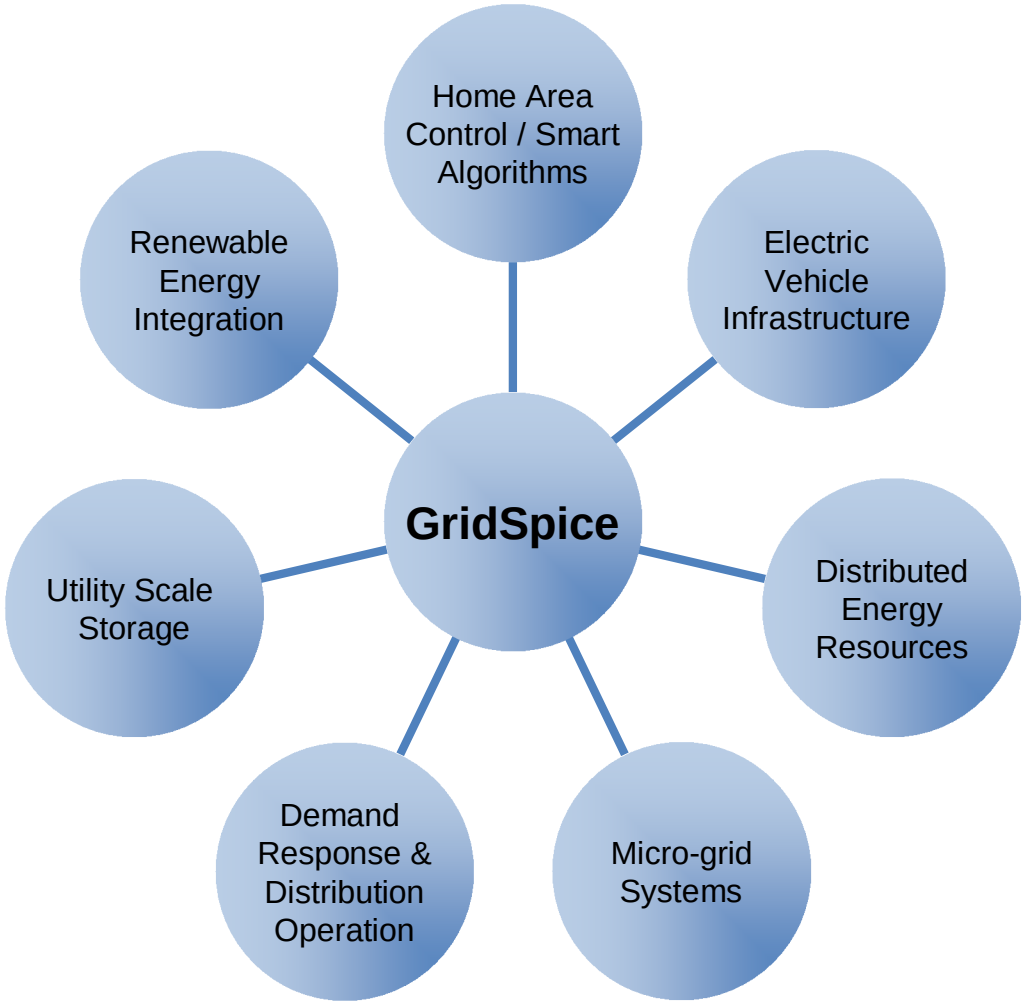
- Create a framework to model all interactions of a smart-grid
  - Power Flows, Communication and Market Operations
    - Distribution and Transmission Operations
    - Wholesale and Retail Operation
  - Provide all operating and business metrics of interest
- Allow researchers, system operators and planners to work together
  - Provide easy-to-use, cost-effective, and realistic models of the system
  - Serve as a catalyst for a faster adoption of innovative ideas in the Smart Grid Space
- Maximize ROI, reliability and system efficiency, reduce costs and risk for all constituents
- One-hundredth the cost of expensive “pilot city” projects and more comprehensive

The GridSpice Solution

Modeling the interactions between all agents of the smart grid

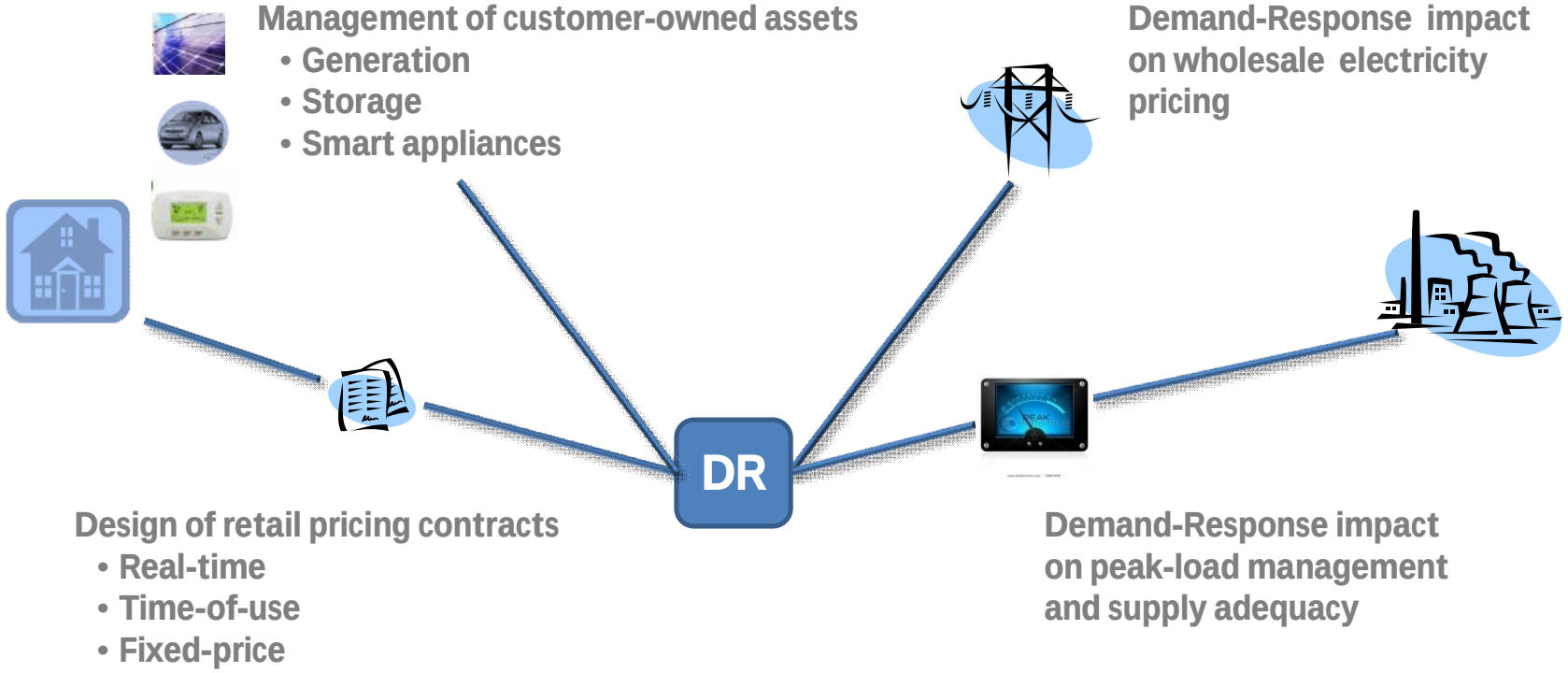


GridSpice - Initial Applications

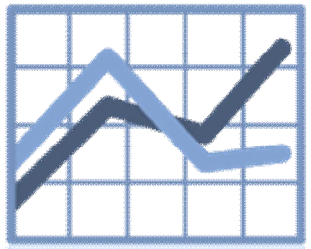


Application: Modeling Demand Response

Price Sensitivity and Load Management



Application: Electric Vehicle Adoption



Wholesale Markets

Impact on
Wholesale Prices

EV Pace of Adoption
Charging / Discharging Locations
Load Mobility
Impact on Peak Demand
Dynamic Pricing Models
Role of Aggregator

Energy Sourcing / Load Management

Weather

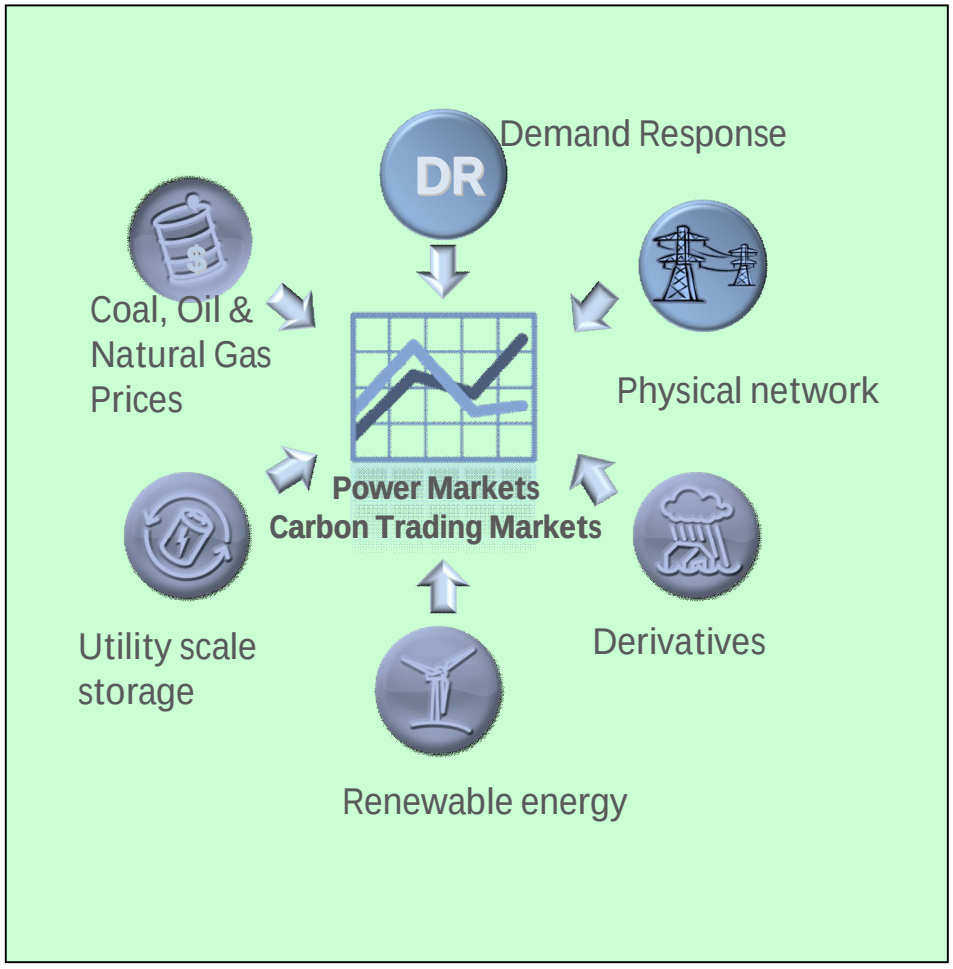
Physical
Network

Demand
Response

Renewable Energy

Oil & Natural
Gas Prices

Application: Trading, Risk Management



MISO – Apr 25, 2006, 7:55pm

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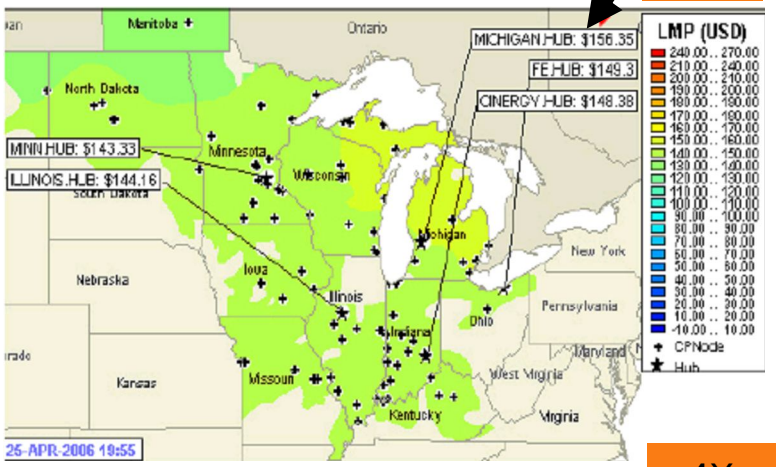

MISO – Apr 25, 2006, 8:00pm

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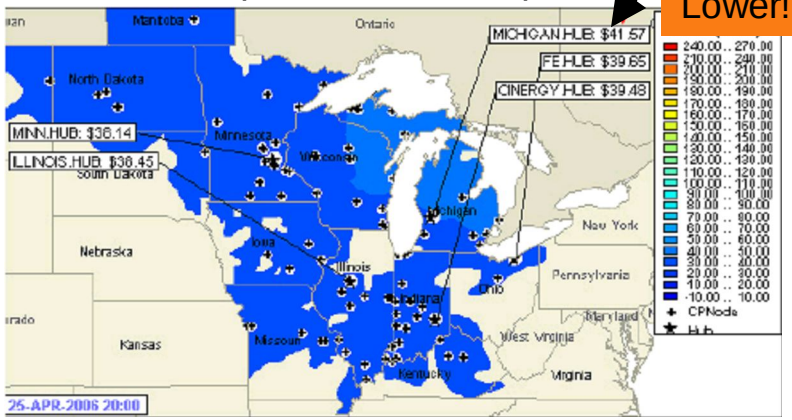


GridSpice - Modeling Approach

- *Complex adaptive system (non-linear)* to model interactions of power systems, wholesale and retail markets and consumer behavior
- *Agent based simulation* to model complex adaptive systems
  - Modeler constructs a virtual world populated by various agents (social, economic, structural, biological etc), the rules of interaction and initial conditions
  - Modeler steps back and observes how this world evolves without any further intervention
  - Stochastic, dynamic open-ended game between participants

GridSpice - Agent Based Modeling

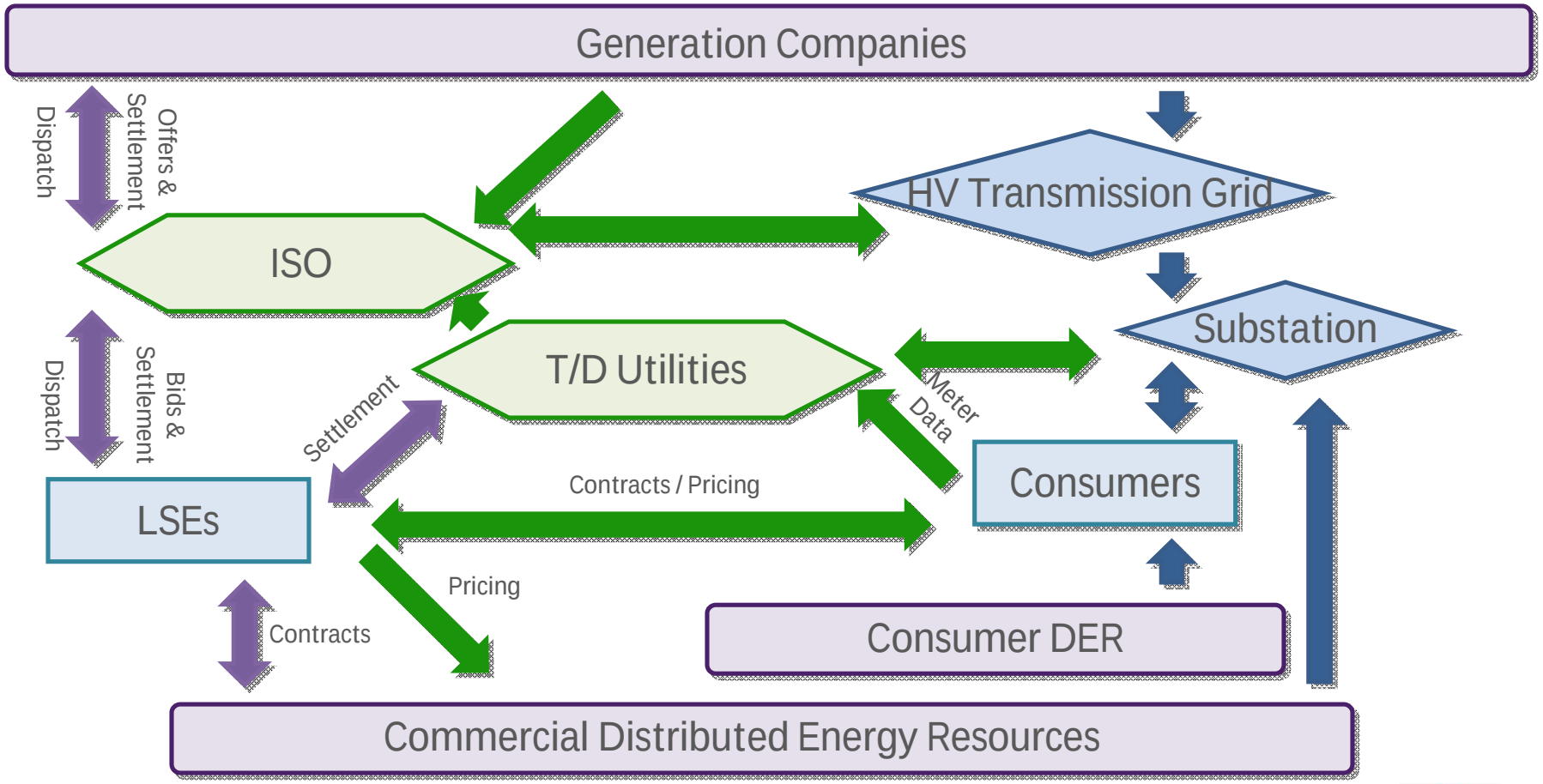
- *Agents* are encapsulated software entities capable of
  - *Adaptation* to their environment
  - *Communication* with other agents
  - *Goal directed learning*
  - *Autonomy* – self activation and self-determinism based on internal private processes
- System shows *Emergent Behavior* that is difficult to predict *apriori* based on closed form solutions

GridSpice: Open-Source Model

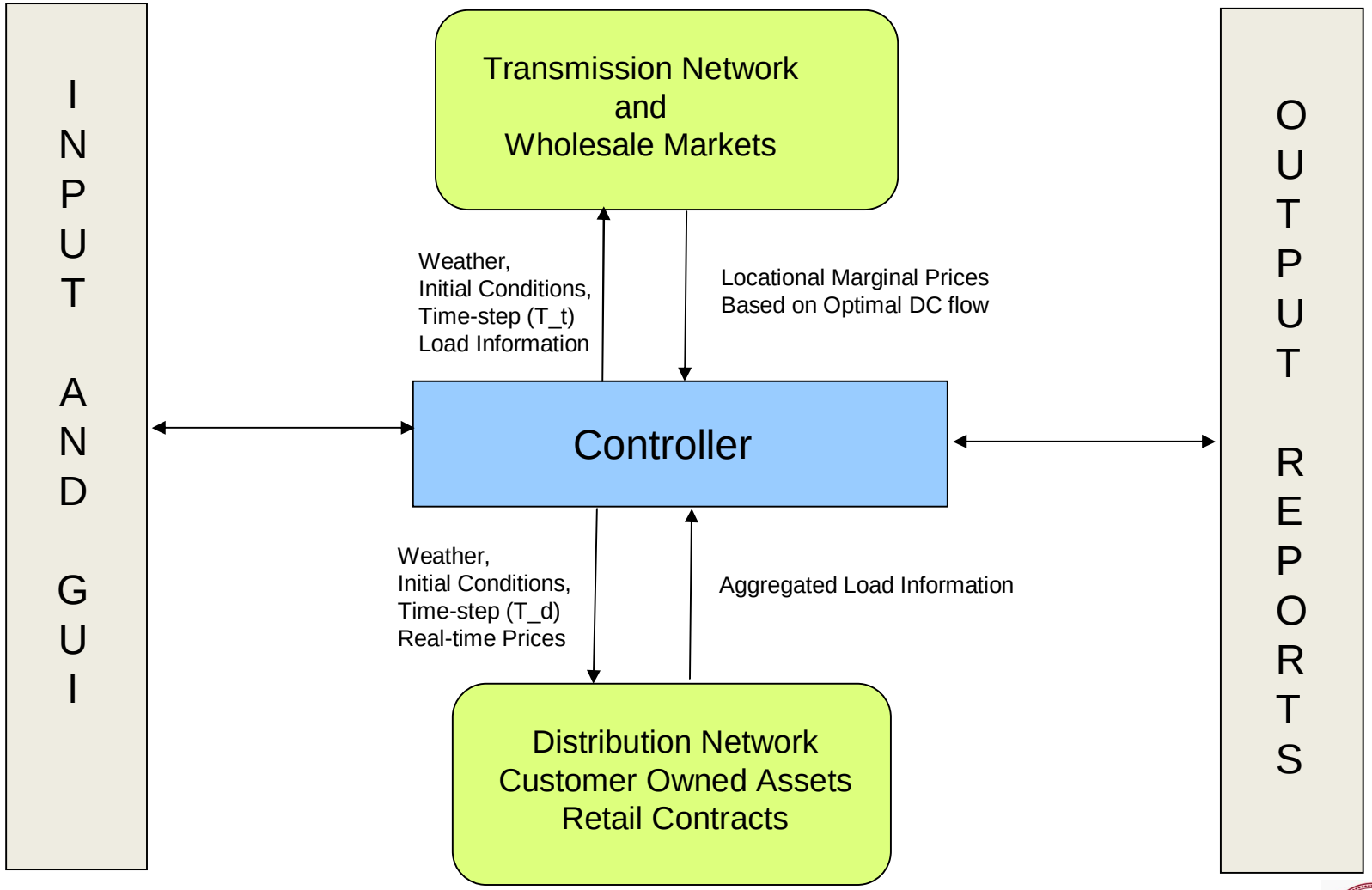
- Leveraging *other* open-source simulation modules *when possible*
  - Partner with other universities, research labs and industry
  - Reduces cost of development, lets us focus on new ideas and innovation

GridSpice – An Integrated View of the Smart Grid

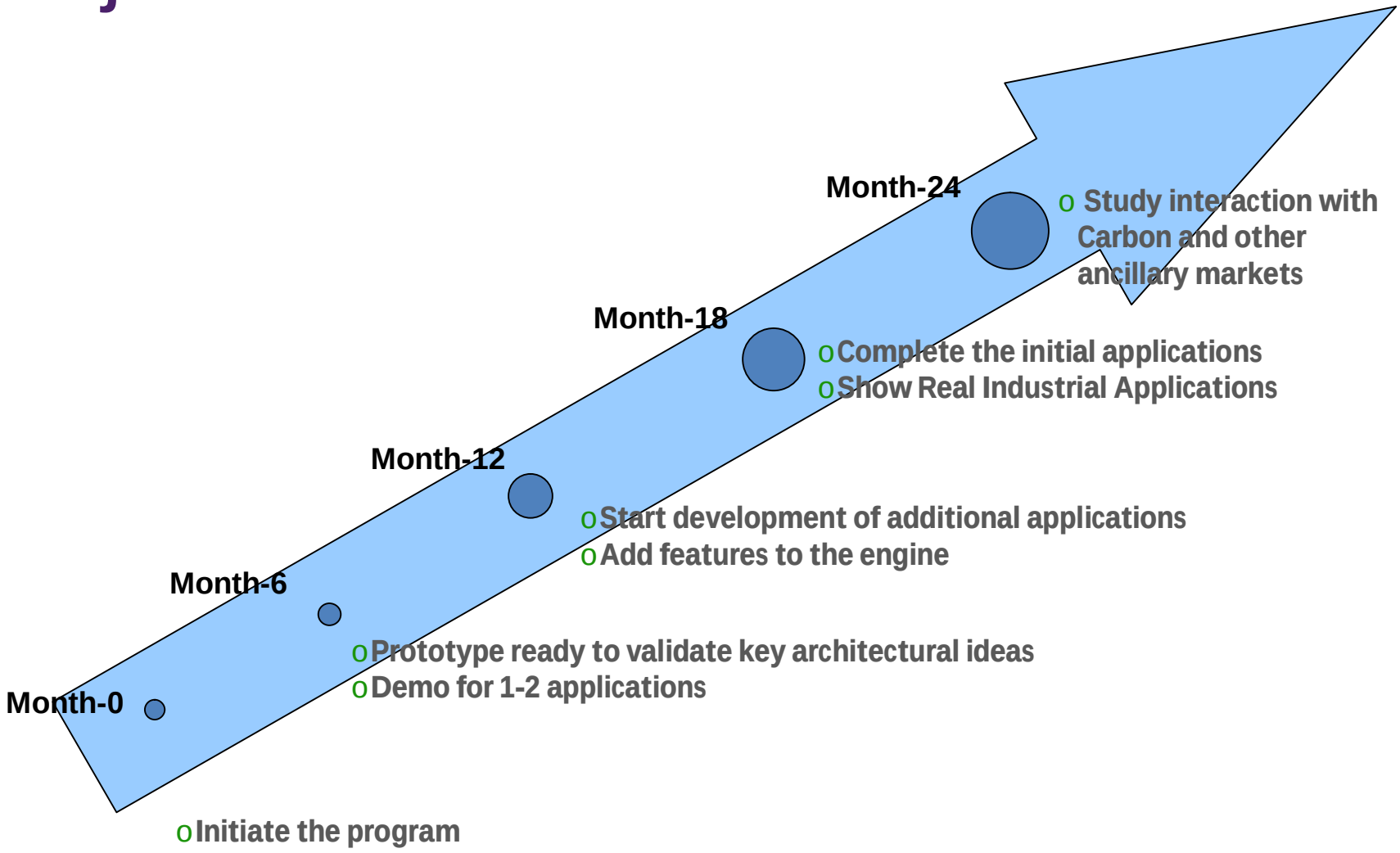
Market Processes | Data Flows | Power Flows



GridSpice Architecture



Project Milestones and Timeline



Conclusion

GridSpice –

A new software simulation & optimization platform

to enable the sustainable energy infrastructure of the future.