

Multi-Agent System Capabilities of the AMES Wholesale Power Market Test Bed

MAS WG Panel Session
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Presentation Outline

□ Integrated **R**etail & **W**holesale (**IRW**) Power System Test Bed

= AMES Test Bed (Wholesale) + Distribution Feeders (Retail)

□ Ongoing studies:

(1) **Stochastic Security-Constrained Unit Commitment (SCUC)**

(2) Price-responsive demand

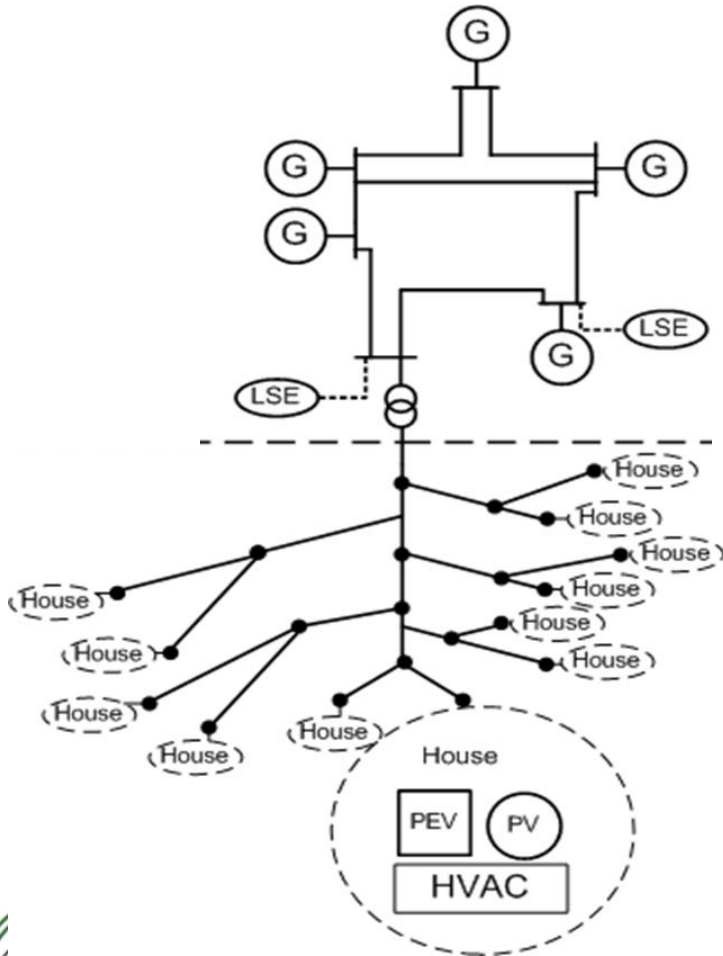
(3) Variable generation (wind, solar) and PEV

□ AMES Test Bed capabilities for topic (1)

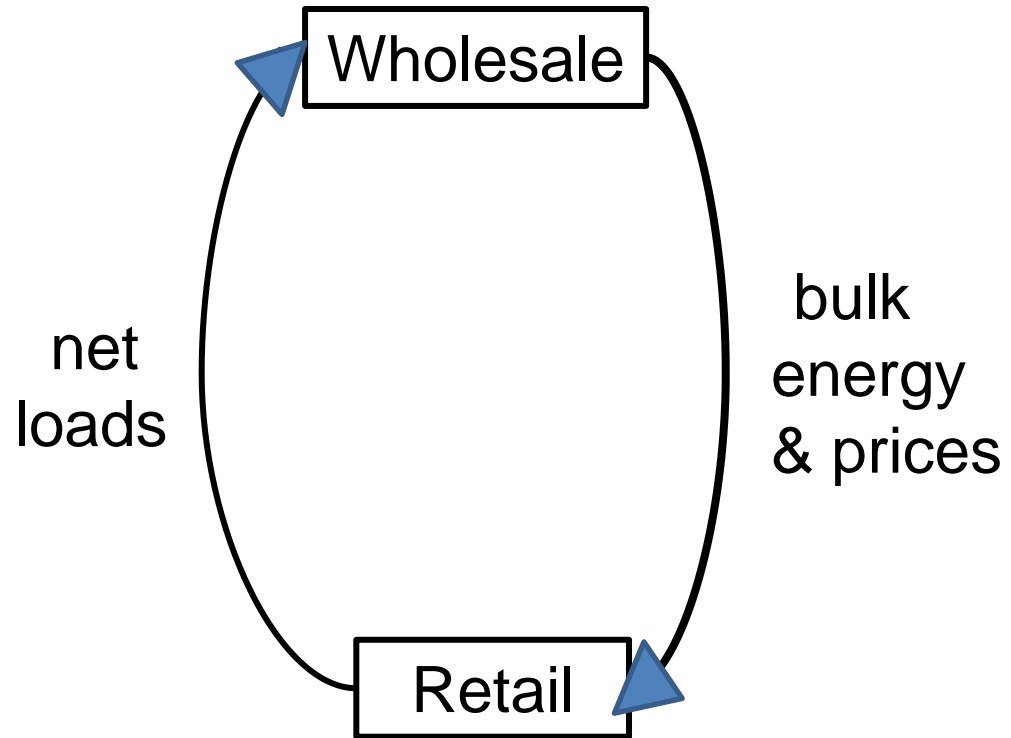
AMES = **A**gent-based **M**odeling of **E**lectricity **S**ystems

IRW Test Bed

5-Bus 1-Feeder Example:



AMES Test Bed



Distribution Test Feeders

Stochastic SCUC for Improved Power Operations

ARPAe/DOE project: Iowa State University, UC Davis, Sandia National Labs, Alstom, and ISO New England

Goal: New stochastic *Security Constrained Unit Commitment (SCUC)* method for improved handling of uncertainties

Approach (Phase 1):

- Uncertainty from variable loads & wind generation
- Use AMES for initial small-scale SCUC testing
- Use Alstom platform for larger-scale SCUC testing

AMES Wholesale Power Market Test Bed

- AMES(V2.06) released as open-source software under GPL
www.econ.iastate.edu/tesfatsi/AMESMarketHome.htm
- Agent-based platform (Java/Python/Pyomo)
- Simulates ISO-managed wholesale power market over AC grid
- Agents include
 - **Decision-making entities** (ISO, traders, ...)
 - **Institutions** (day-ahead market, regulatory framework, ...)
 - **Physical structures** (AC transmission grid, loads, ...)
- Events driven by agent interactions, starting from initial conditions

AMES-TS (V3.0): New Features in Red

➤ Traders

- GenCos (sellers)
- LSEs (buyers)
- Learning capabilities

➤ Independent System Operator (ISO)

- System reliability requirements
- Day-ahead market SCUC
- Day-ahead market SCED
- Real-time market SCUC/SCED

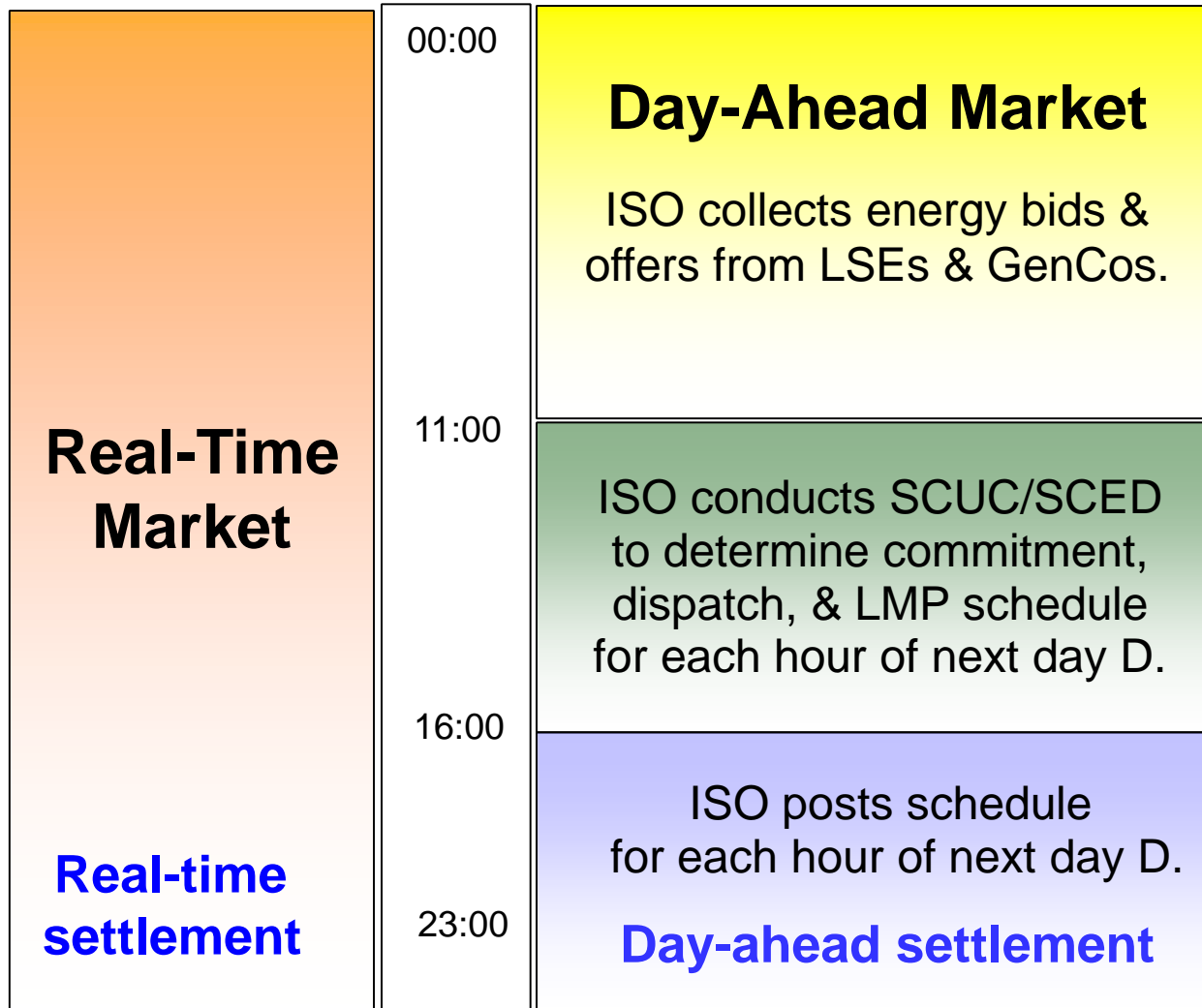
➤ Two-settlement system

- Day-Ahead Market (DAM) for day-ahead scheduling
- Real-Time Market (RTM) for real-time adjustments of DAM schedule

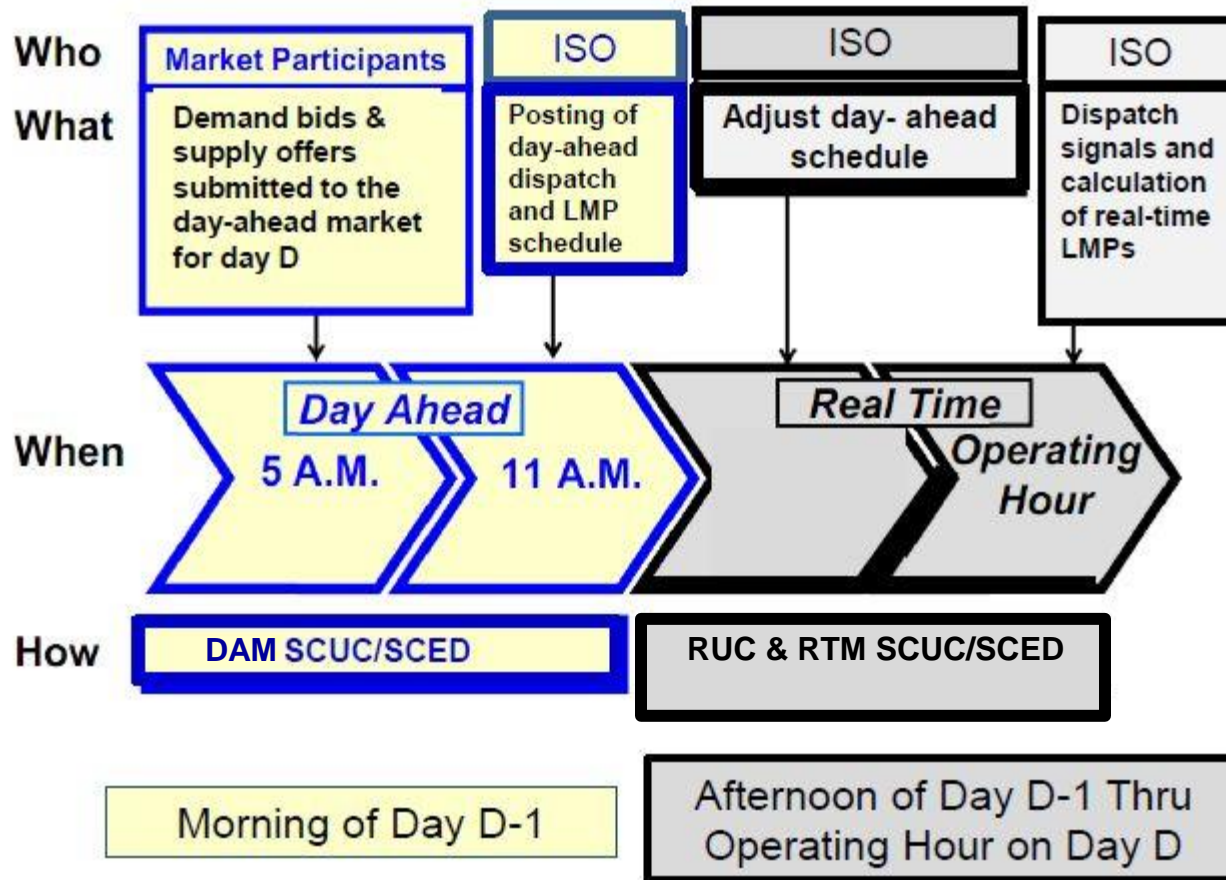
➤ AC transmission grid

- Generation Companies (GenCos) & Load-Serving Entities (LSEs) located at user-specified transmission buses
- Grid congestion managed via Locational Marginal Prices (LMPs)

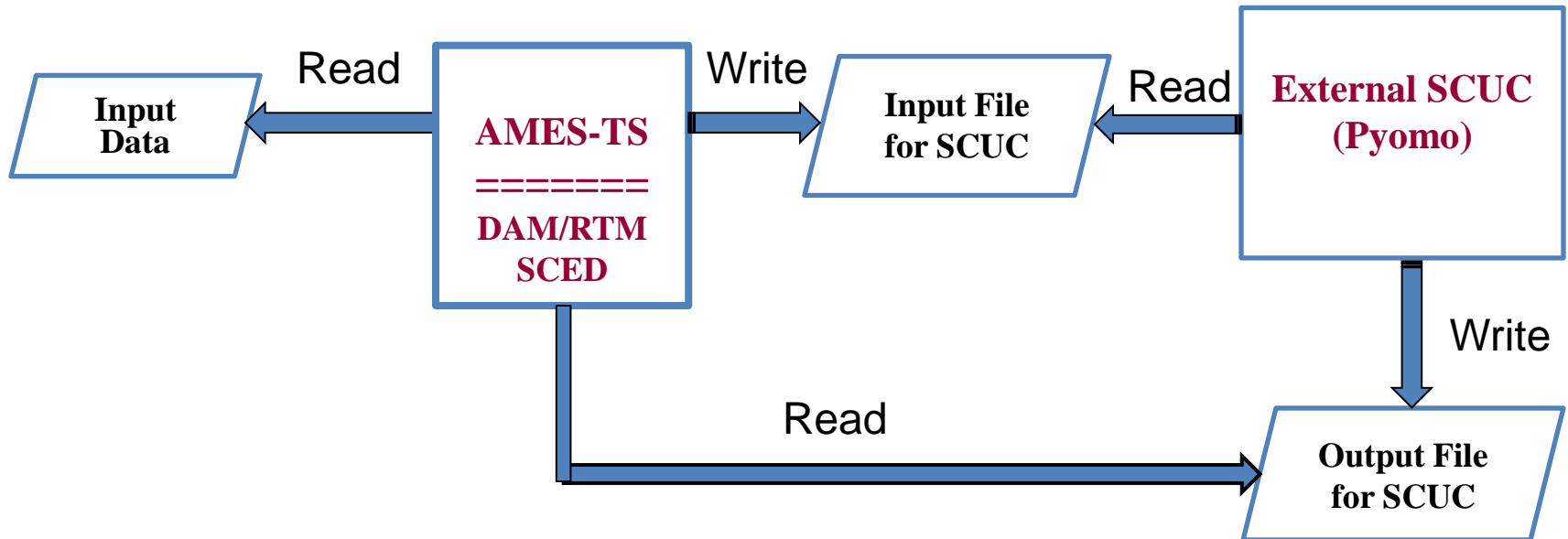
Two-settlement system activities during a typical day D-1



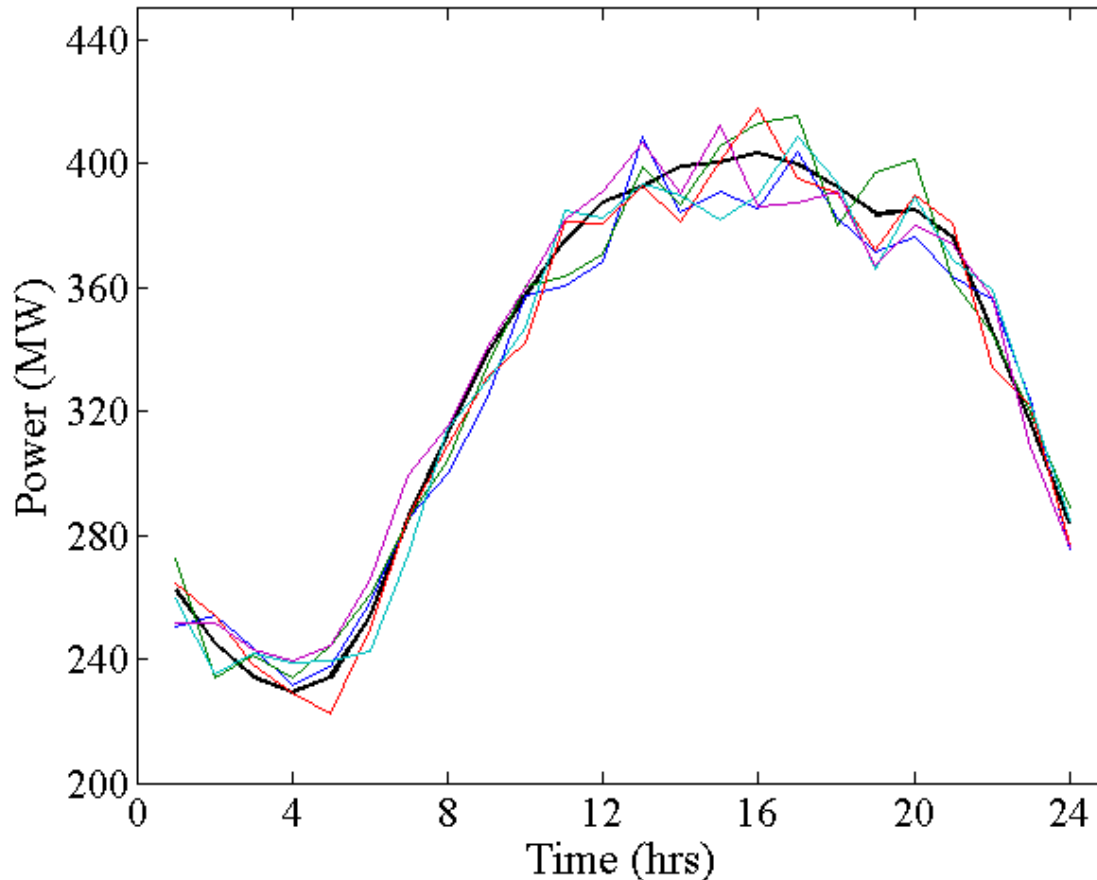
Two-settlement system activities during successive days D-1 and D



ISO in AMES-TS obtains SCUC solutions via calls to **Pyomo** = *Python Optimization Modeling Objects*



AMES-TS accepts net load data inputs



Net Load

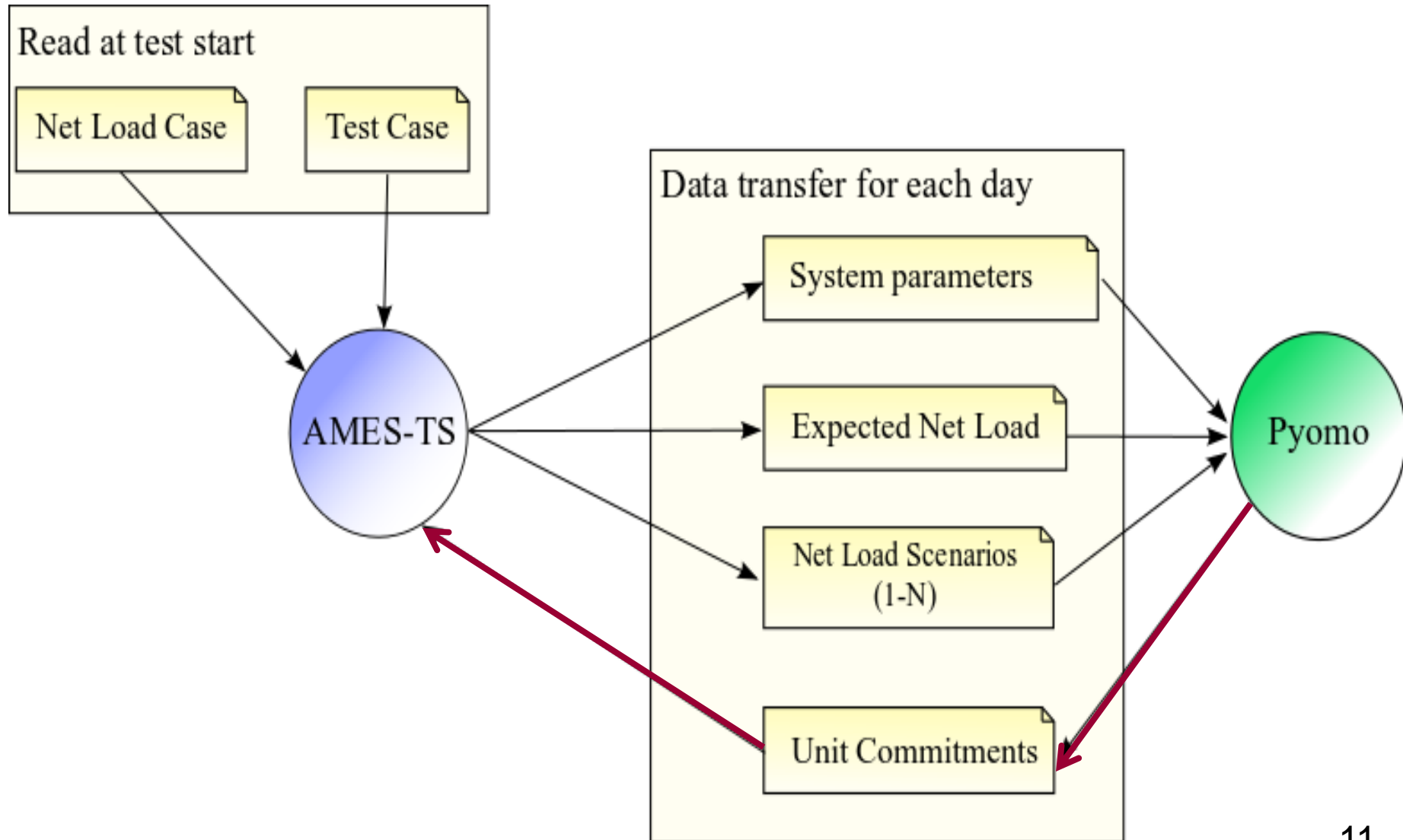
= Conventional load minus
non-dispatchable wind

Black Curve: Expected net load
scenario for next day

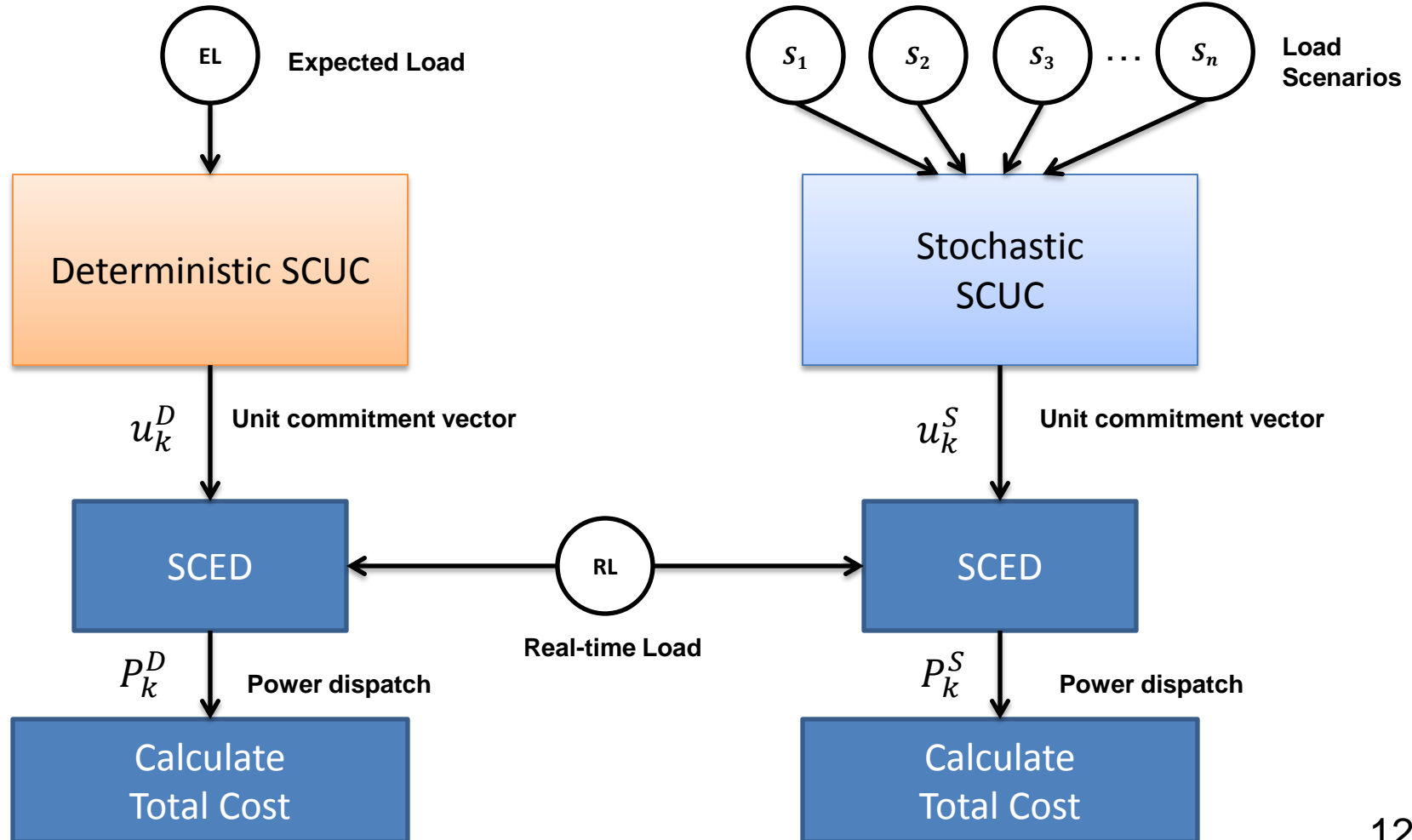
Colored Curves: Possible net
load scenarios for next day

AMES inputs load & wind data as
NetLoadCase
= [LoadCase - WindCase]

AMES-TS Data Flow



AMES-TS testing of deterministic vs. stochastic SCUC



Illustrative Findings

- Total Cost = Startup + No-Load + Shutdown + Operational
- Total Cost Saving (TCS) = % Change in Total Cost
(Deterministic → Stochastic)
- Illustrative findings (to date) for an 8-Zone Test Case under a range of start-up/shut-down and no-load costs: TCS varies from 0.13% to 1.91% with a Reserve Requirement (RR) = 0 and from -0.18% to 1.91% with RR>0
- More details will be presented at the following Thursday talk:
D. Krishnamurthy, W. Li, and L. Tesfatsion, “A Small-Scale Test System for Wholesale Electric Power Market Operations Based on ISO-NE Data,” in Panel Session titled *Development of IEEE Test Systems for Economic Analysis*, Thurs., July 25, 8-10:00am, MAR - Dundarave

AMES-TS can handle additional sources of uncertainty

- LSEs can submit DAM demand bids for **price-responsive loads** as well as for conventional loads, as in actual DAMs
- GenCos & LSEs can engage in **strategic trading**, as in actual DAMs
 - Can learn how to submit offers/bids to increase profits
 - Can exploit opportunities to exercise “market power”
- ➔ AMES-TS can test for robustness against gaming of market rules

High Performance Computing Enhancements

- ❑ In current simulations the bottleneck is memory
- ❑ A High Performance Computing (HPC) cluster has recently been installed at ISU for ARPAAe project purposes
 - The cluster has 12 computing nodes with a total of 400GB RAM.
 - Each computing node has 16 cores, each running at 2.5GHz.
- ❑ Will enable systematic study of larger test cases in shorter time (e.g., more GenCos, more load scenarios, more uncertainty sources)
- ❑ Will enable SCUC to be implemented with parallel processing

Conclusion

The AMES Wholesale Power Market Test Bed:

- versatile agent-based platform for the study of ISO-managed wholesale power market operations
- being used to study new stochastic SCUC formulations
- wholesale level of an Integrated Retail & Wholesale (IRW) Test Bed being used to study retail/wholesale feedback loop

On-Line Resources

❑ IRW Project Homepage

www.econ.iastate.edu/tesfatsi/IRWProjectHome.htm

❑ AMES Test Bed Homepage (Code/Manuals/Publications)

www.econ.iastate.edu/tesfatsi/AMESMarketHome.htm

❑ Agent-Based Electricity Market Research

www.econ.iastate.edu/tesfatsi/aelect.htm

❑ Open Source Software for Electricity Market Research, Teaching, and Training

www.econ.iastate.edu/tesfatsi/electricoss.htm