DG Transmission Impact Analysis for Rate Determination GTMax Software Demonstration

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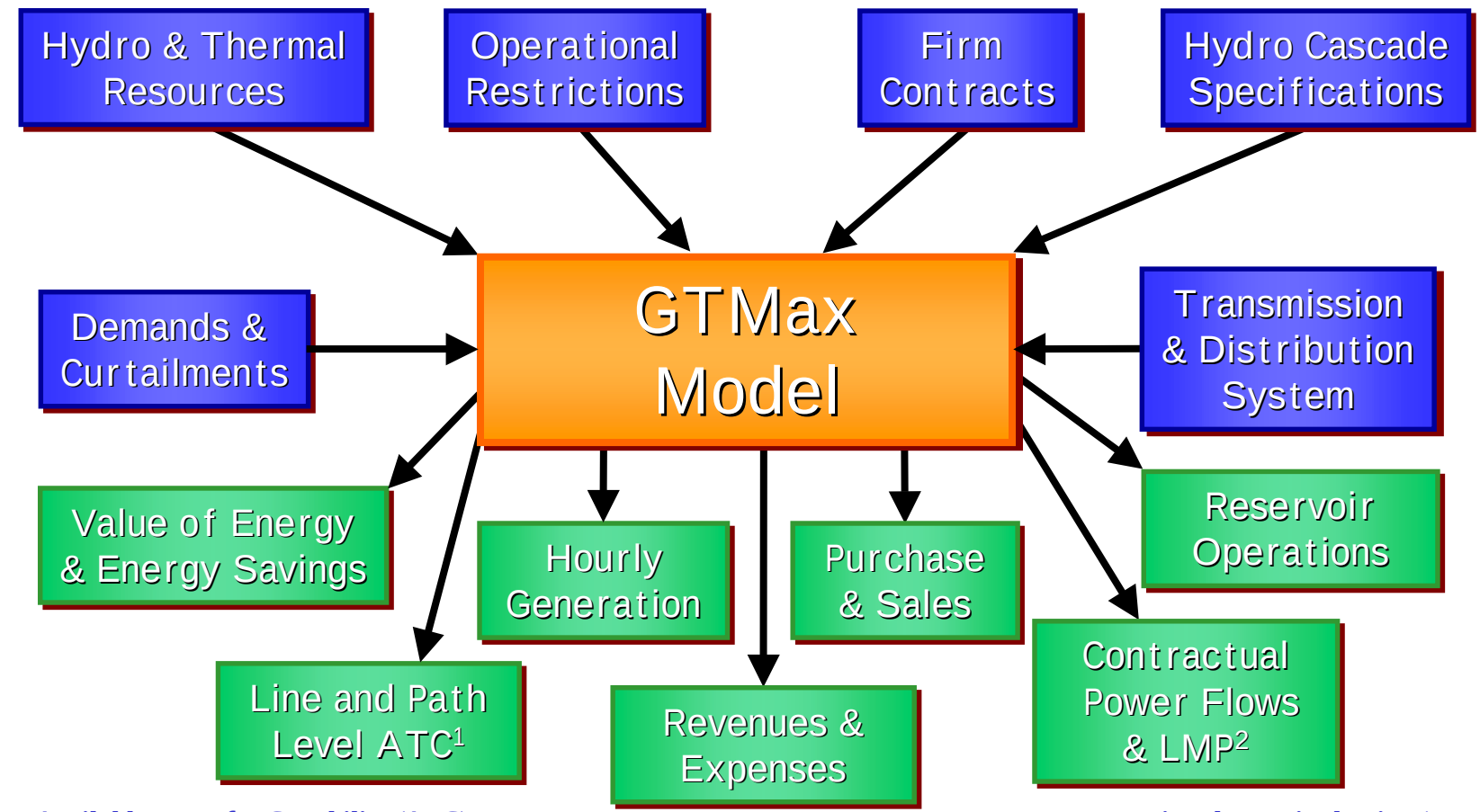
The Generation and Transmission Maximization (GTMax) Model Optimizes Power System Operations

- **Estimates the value ($) of power system components**
  - Combined heat and power (CHP) plants
  - Hydro and thermal power plants
  - Firm purchase and sales contracts
  - Spot or pool market activities
  - Power exchanges and interchange
  - Transmission systems
- **Physical and institutional constraints**
  - Generating capability
  - Technical operating minimum
  - Ramping restrictions (change in operations over time)
  - Fuel and reservoir storage limits
- **Simulations**
  - One hour time-step
  - Each run solves for a single week

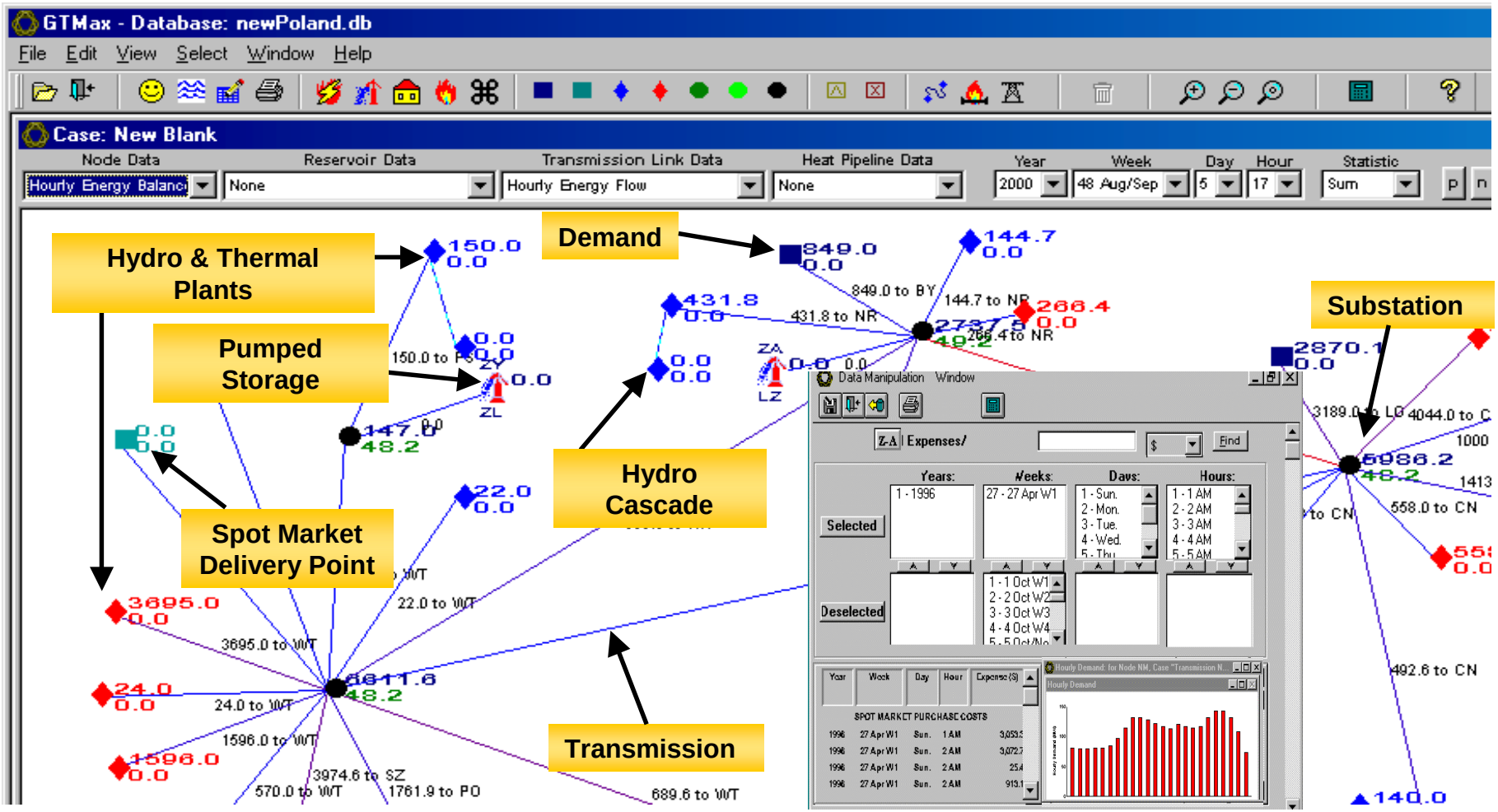
GTMax Simulates Power System Operations and Energy Transactions



1. Available Transfer Capability (ATC)

2. Locational Marginal Price (LMP)

GTMax Uses a Network Representation of the Power System



GTMax Power Networks Contain Five Types of Electricity Demands

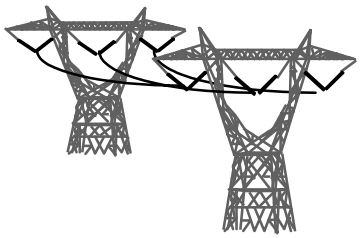
- **Service territory loads -- Demand Node**
- **Bilateral contract loads (if any) -- Firm Sales Node**
- **Hourly market sales (if economical) -- Spot Market Node**
- **Pumping loads for pumped hydro -- Pumping Node**
- **Interchanges and exchanges out of the system -- Interchange Node and Exchange Out Node**

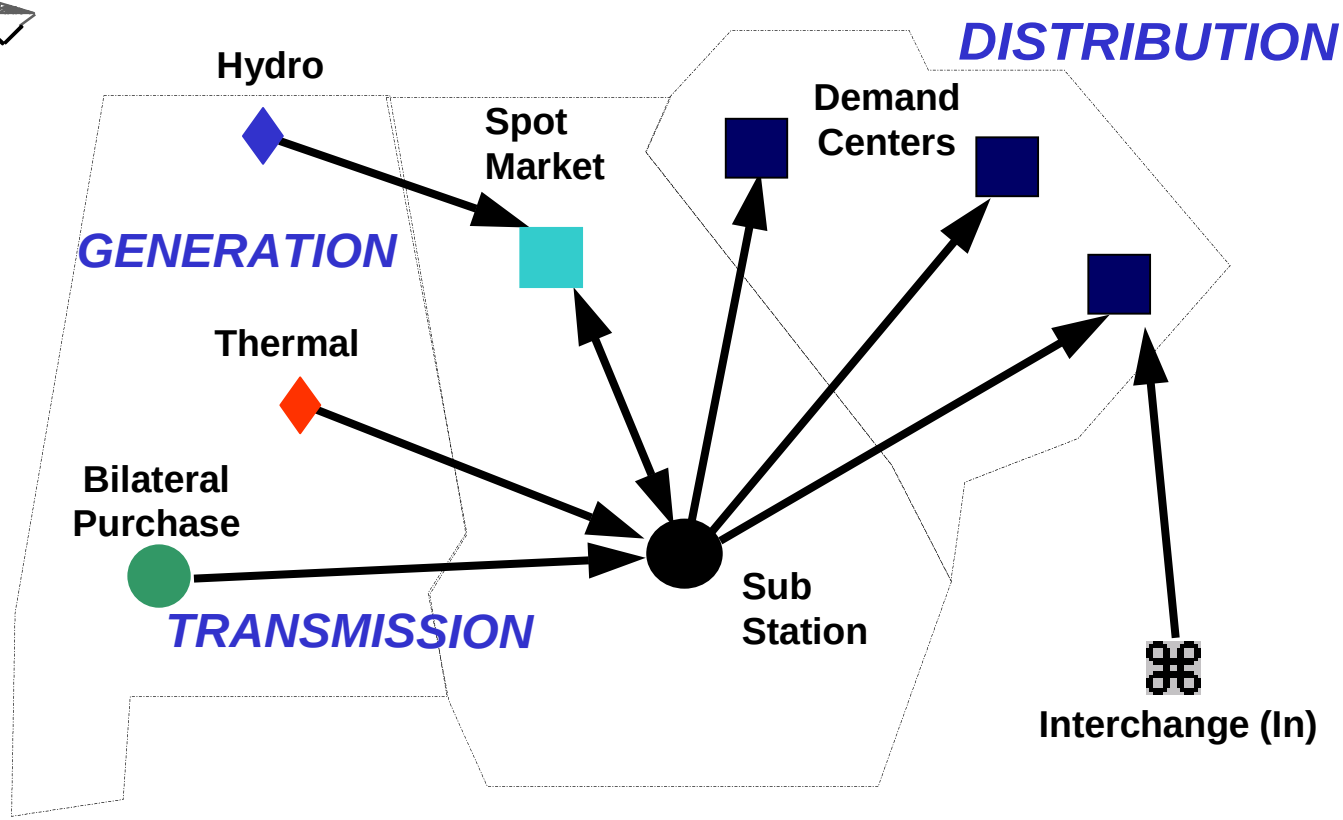
* Additional electricity must be produced because of T&D losses

GTMax Contains Six Types of Power Supply Resources

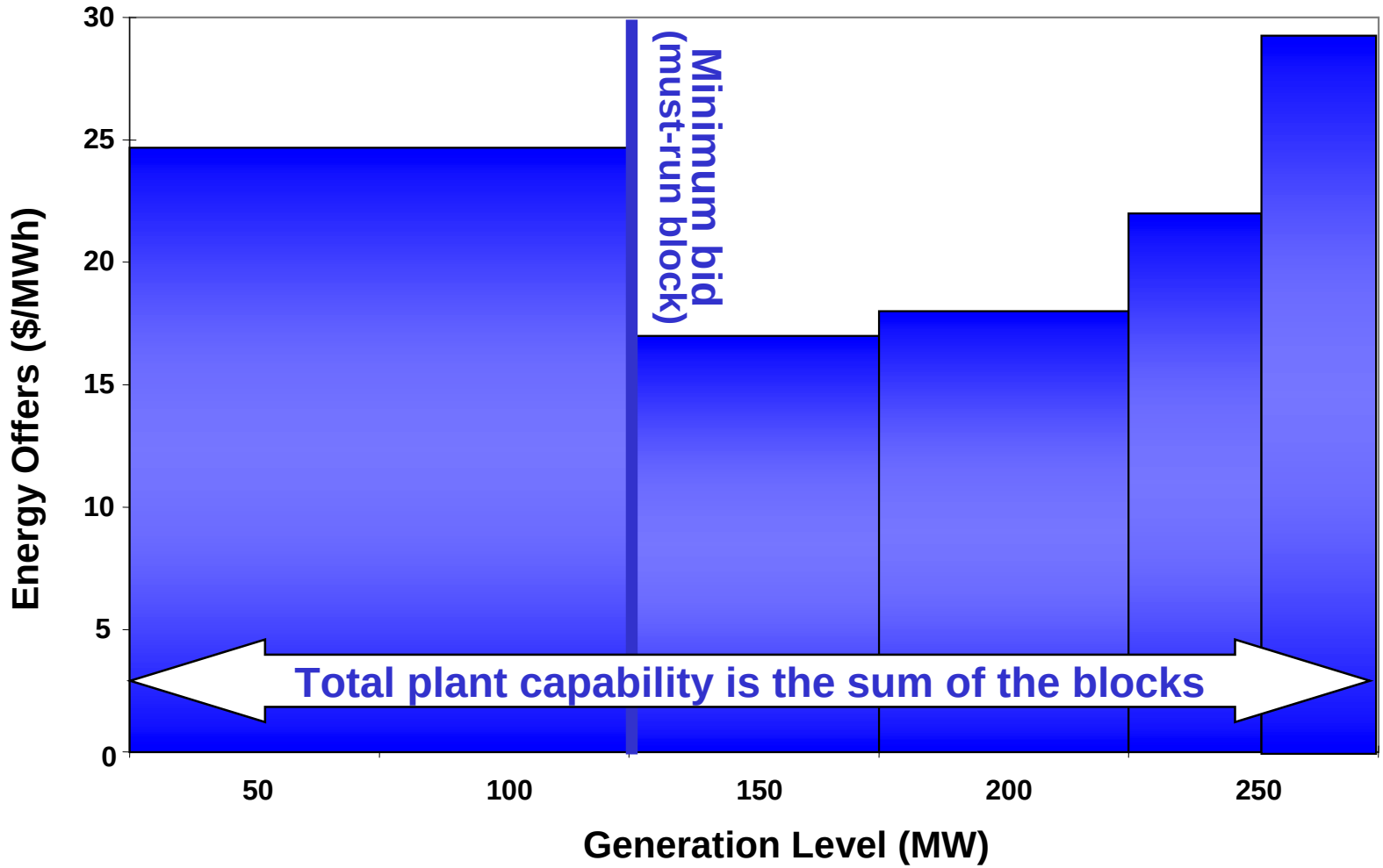
- **Thermal units -- Thermal Node**
  - Baseload
  - Peakers
- **Hydro power plants -- Hydro Node**
  - Run-of-river
  - Storage
  - Pumped storage
- **Combined Heat and Power (CHP) plants -- CHP Node**
- **Bilateral purchase contracts -- Firm Purchase Node**
- **Hourly market purchases -- Spot Market Node**
- **Interchanges and exchanges out of the system -- Interchange Node and Exchange In Node**

The Transmission System Links Activities



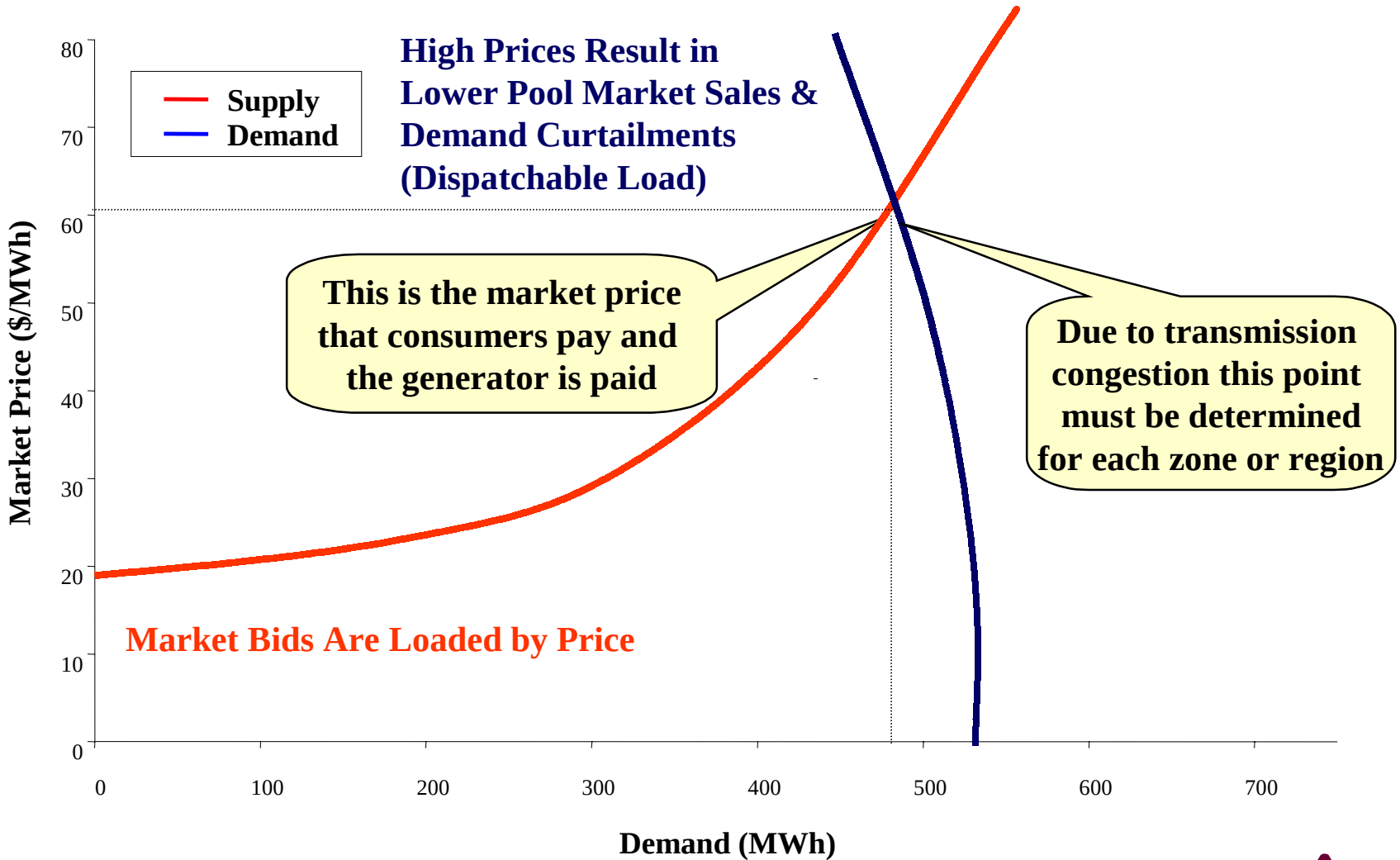


In GTMax, Hourly Electricity Bid Prices Are Specified for Each Supply Resource as a Series of Blocks

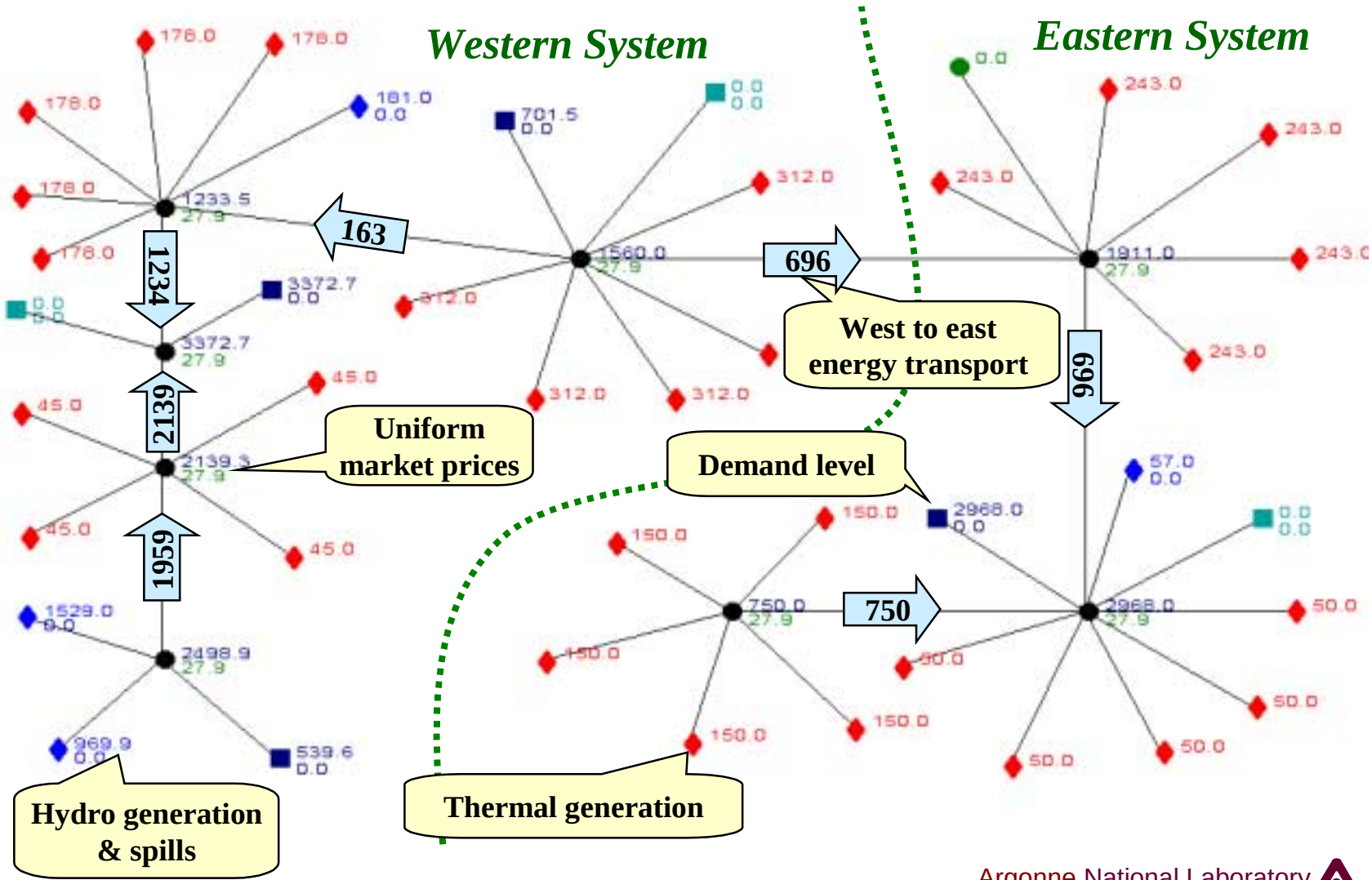


GTMax Balances Supply & Demand Bids from All Market Participants to Determine Market Clearing Prices

(Simplified Example)

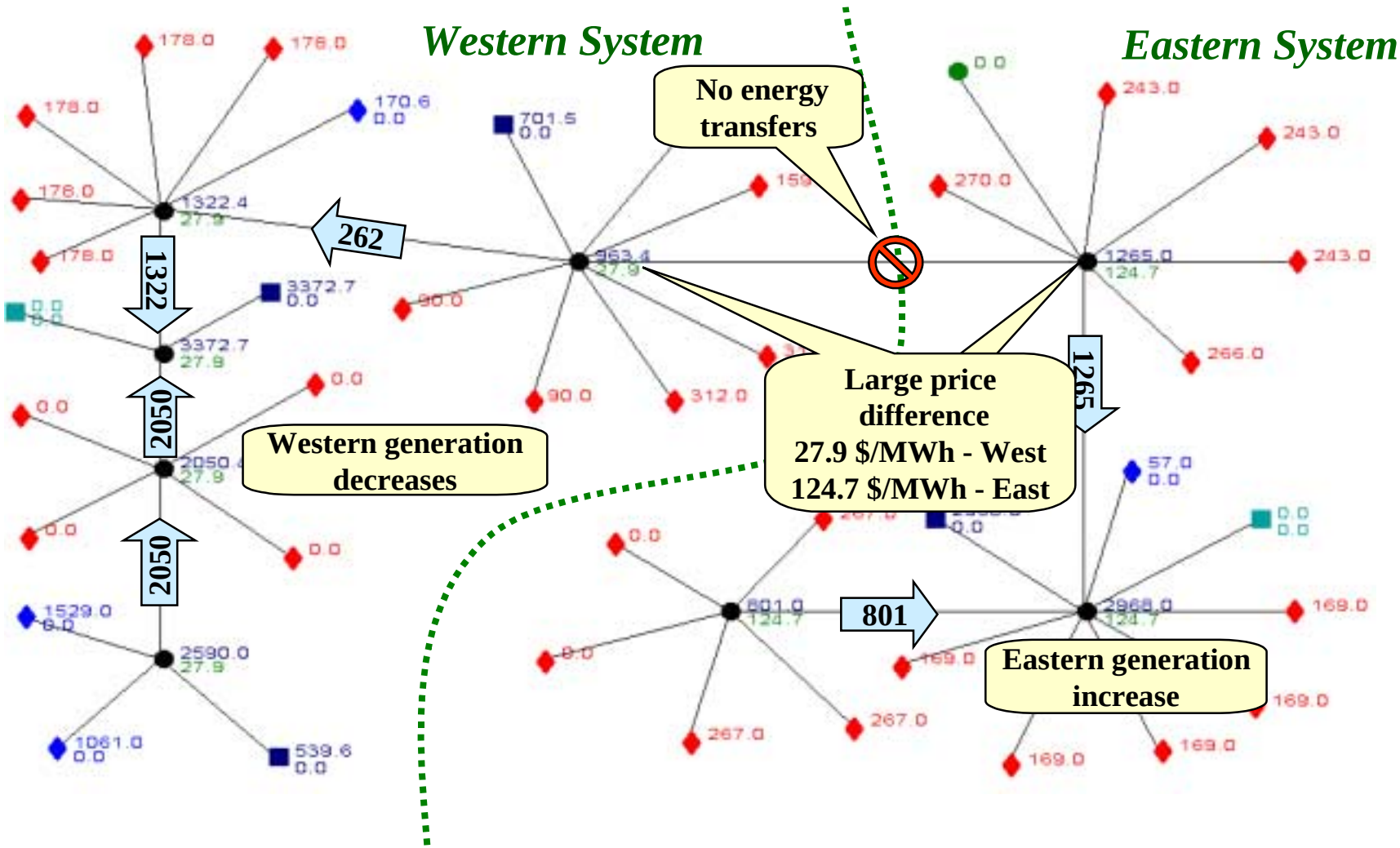


Without Transmission Congestion, Market Prices Are Nearly Identical at All Locations

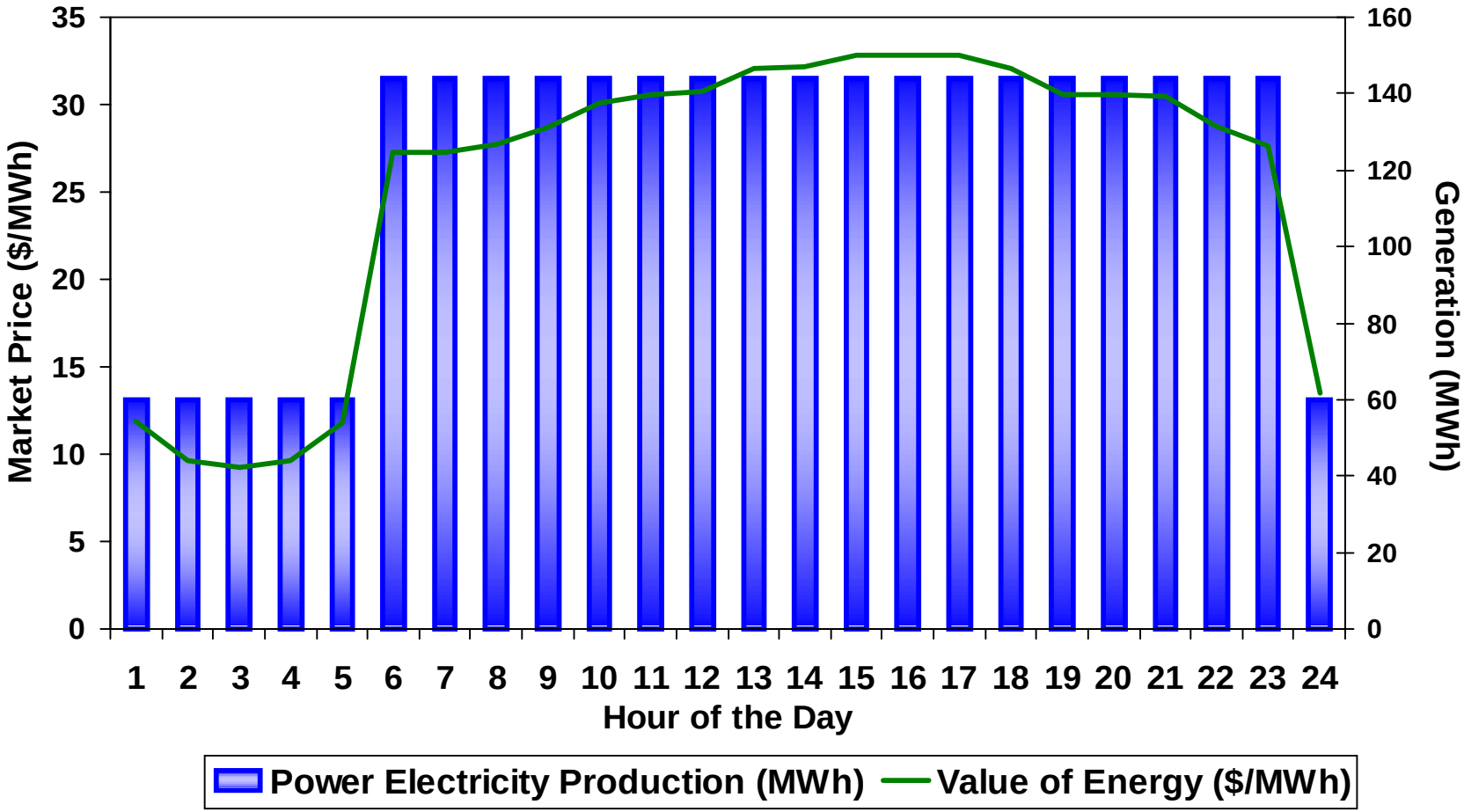


Transmission Bottlenecks Result in Different Regional Prices

Signals where to Build Power Plants or Transmission Lines



Power Operations in GTMax Respond to Market Forces Through Locational Price Signals



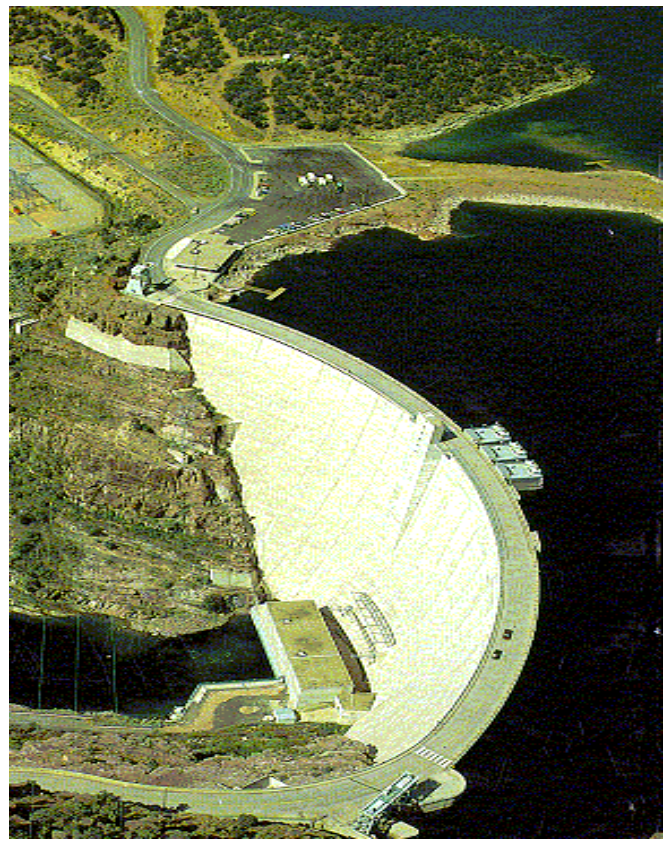
GTMax Power Plant Operations Are Constrained by Technical Limitations

- **Power plant (hydro) or unit (thermal) capability**
- **Technical minimum production levels**
- **Maximum hourly output**
- **Fuel stocks and supply limits**
- **Daily minimum & maximum energy**
- **Change in daily energy production**
- **Hourly up & down ramp rate restrictions**
  - Change in generation from one hour to the next
- **Daily up & down ramp rate restrictions**
  - Change in generation over a 24 hour period

Operational Limitations Influence the Economic and Financial Value of a Power Supply Resource

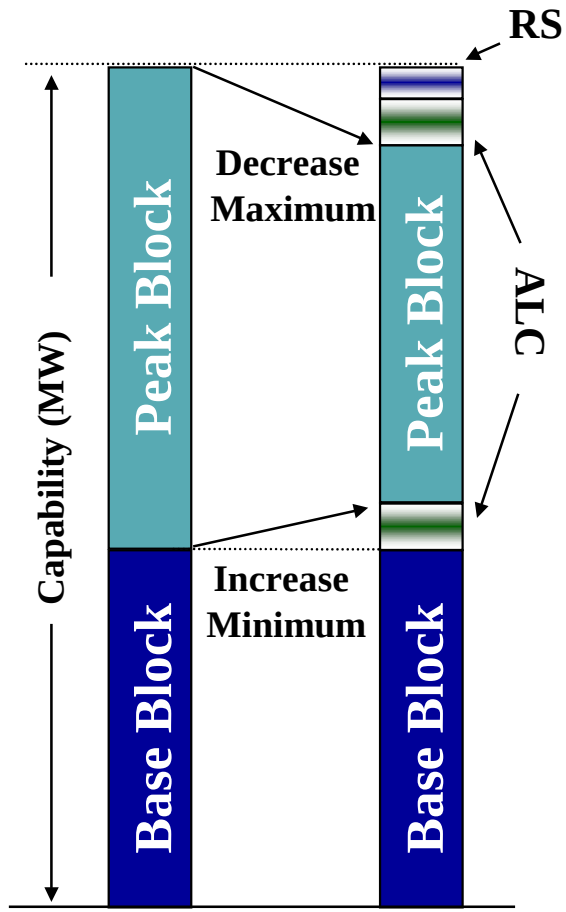
The GTMax Hydropower Dispatch Is Constrained by Reservoir Limitations

- **Maximum reservoir elevation level**
- **Minimum reservoir elevation level**
- **Daily reservoir elevation change**
- **Change over 2-day & 3-day periods**
- **Elevation levels are functions of:**
  - Initial reservoir conditions
  - Hourly up-stream reservoir releases
  - Side flows
  - Pumped water from a lower reservoir
  - Hourly reservoir releases
  - Water extracted for irrigation or other uses
  - Elevation volume function
- **GTMax computes the marginal value of water**

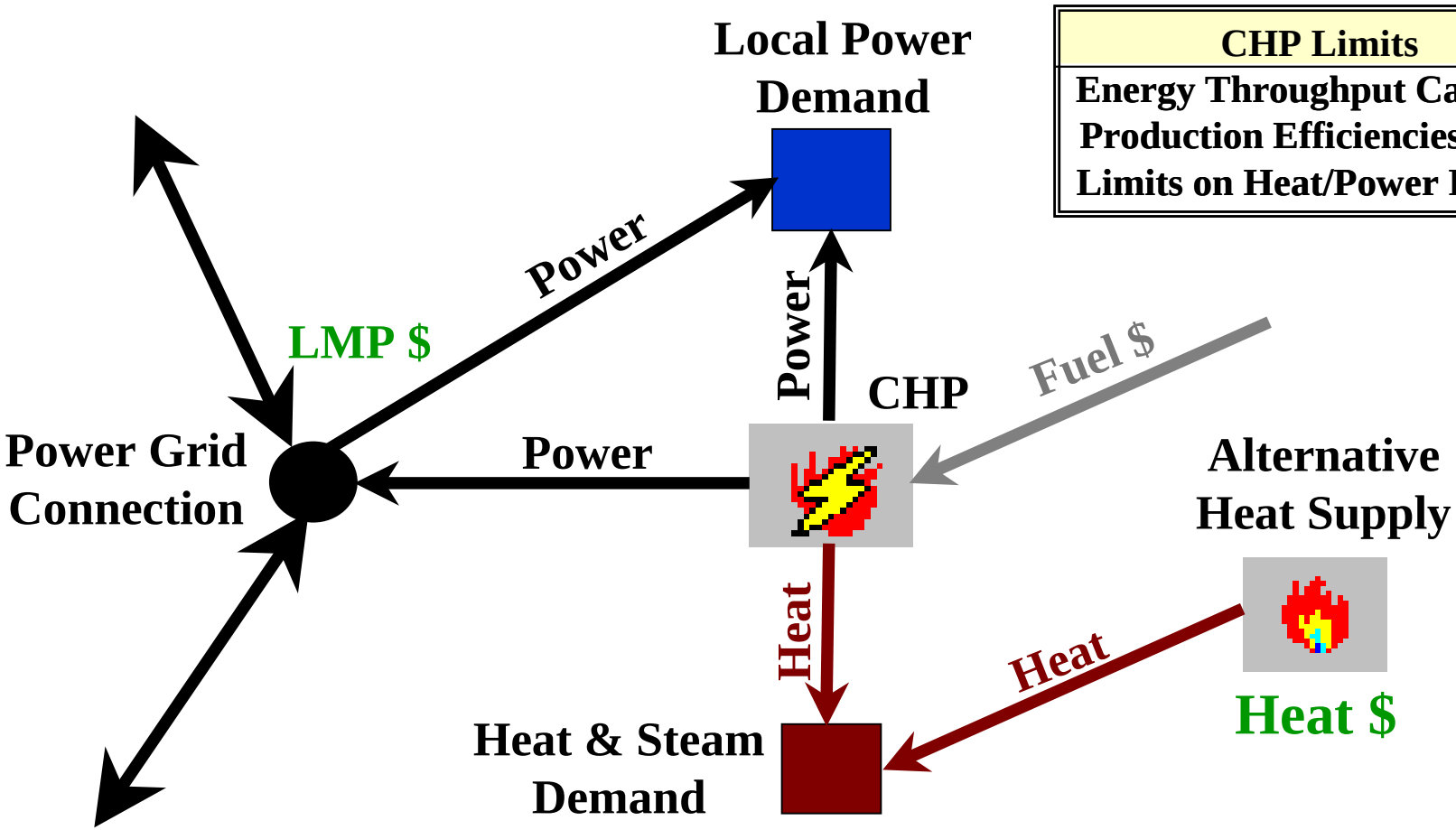


Power Operations Account for System Needs & Security/Reliability

- **Regulation services (RS)**
  - Affects minimum & maximum generation
- **Spinning reserves (SR)**
  - Affects maximum generation
- **Unit commitments**
  - Base block is expensive and its capacity is not needed by the system to meet the demand
- **RS and SR requirements are specified on a regional basis**

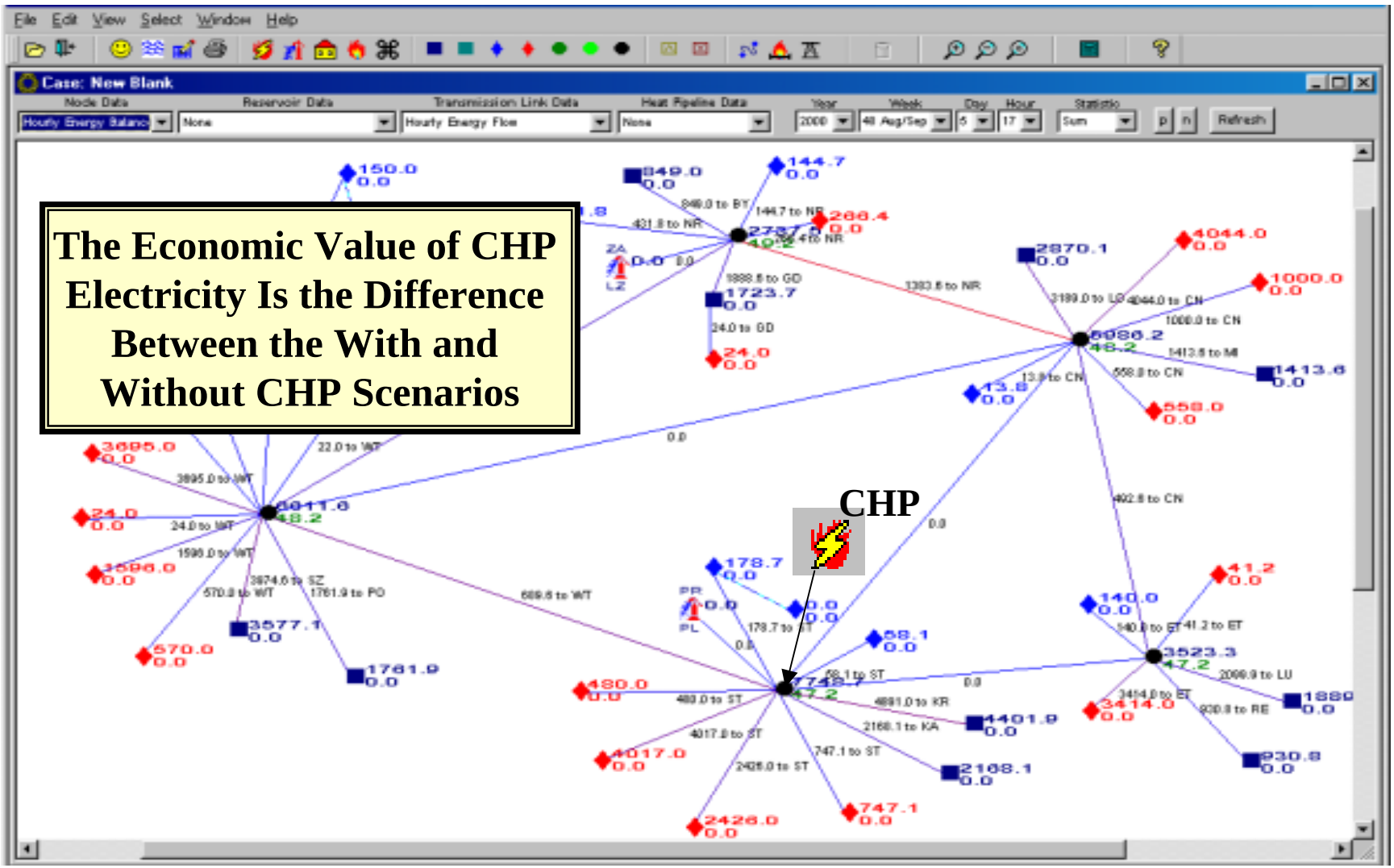


The CHP Representation in GTMax Considers Both the Electricity Market and the Demand for Heat

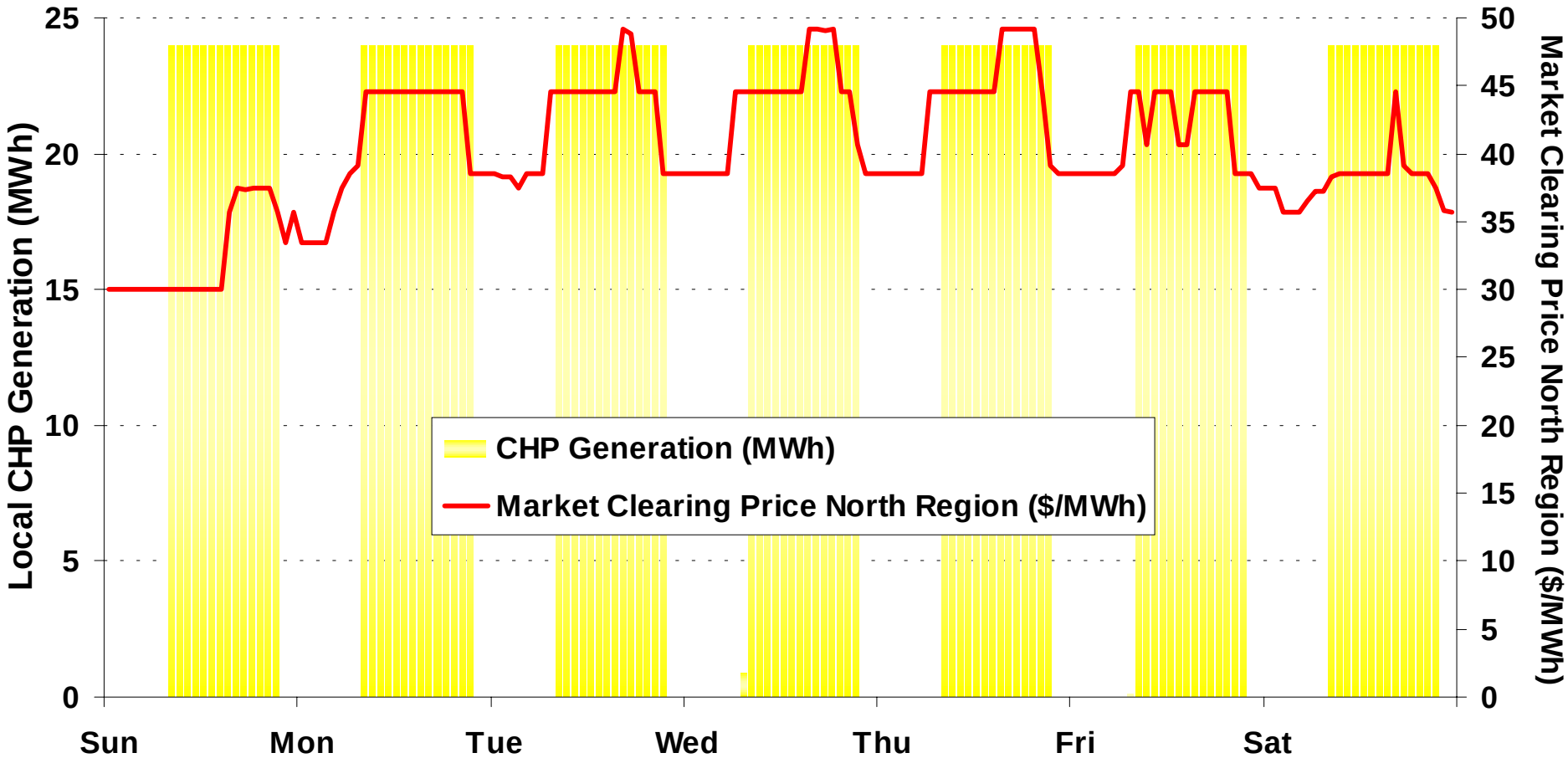


The Polish Energy Market Agency Used GTMax to Estimate the Financial Viability of Small CHPs in Poland

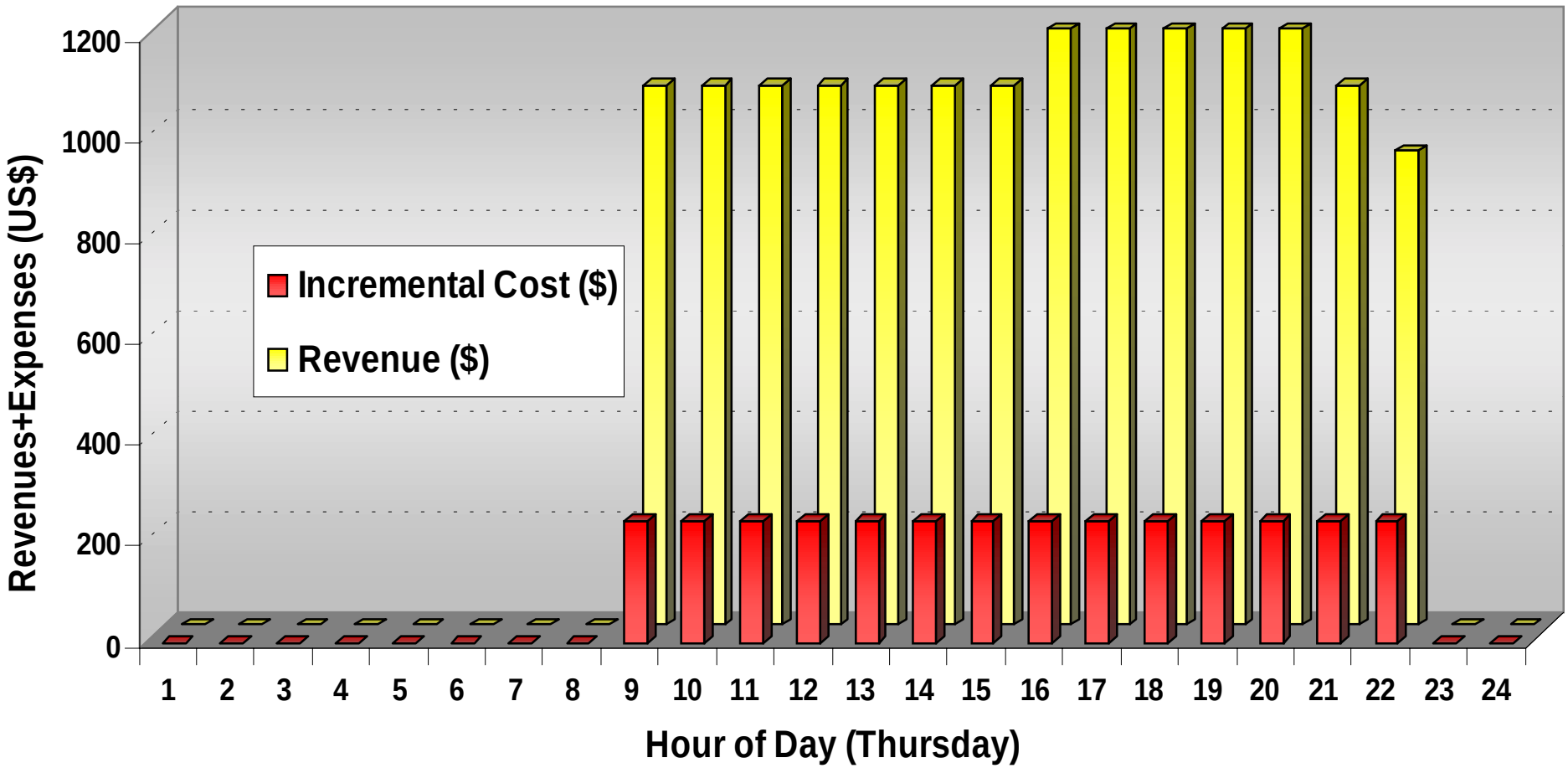
(International Atomic Energy Agency Technical Cooperation Project)



Operation of New Cogenerators in Poland Is Driven by Locational Market Prices and Technological Limitations

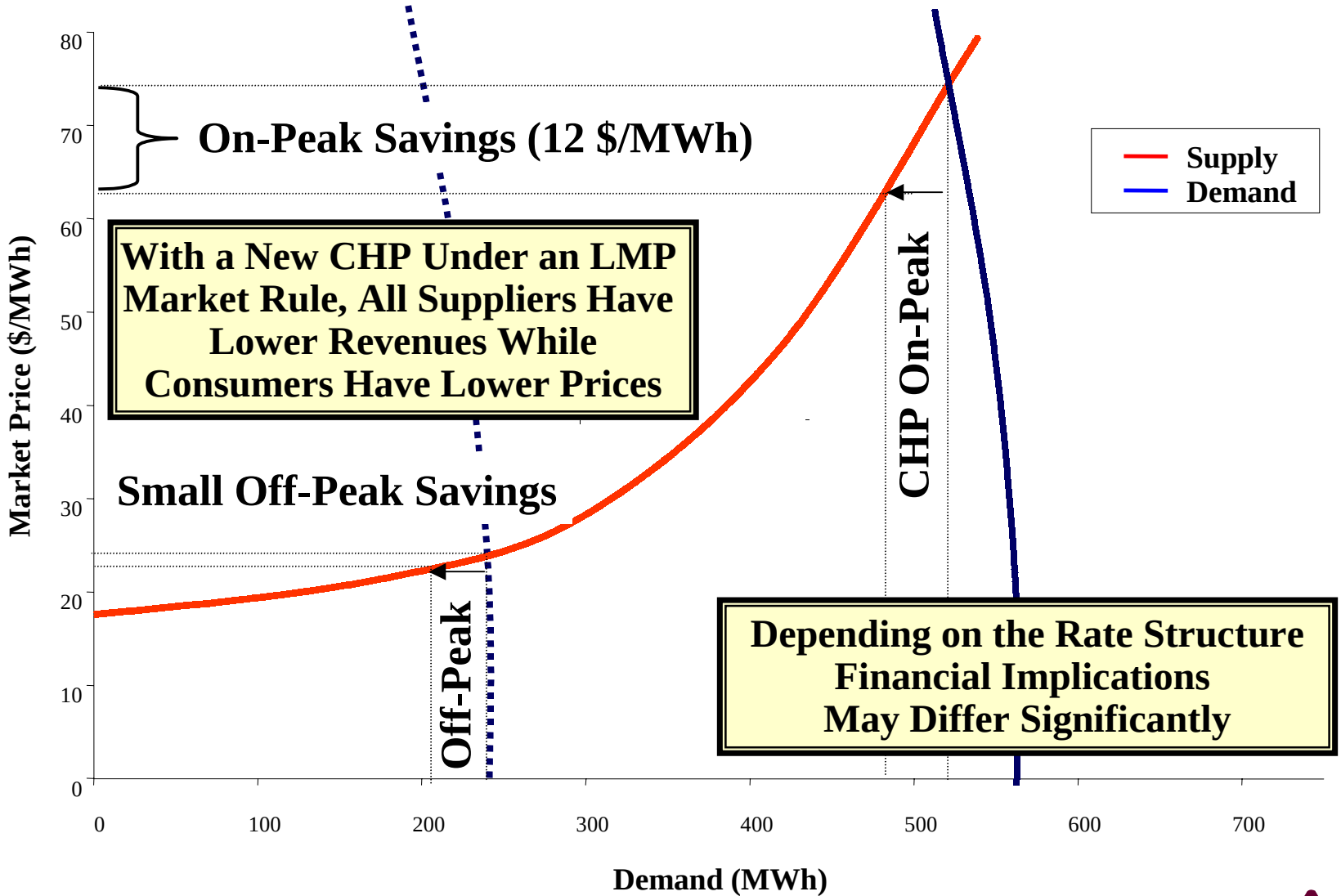


Revenues From New CHP Power Sales Are Greater Than Production Costs



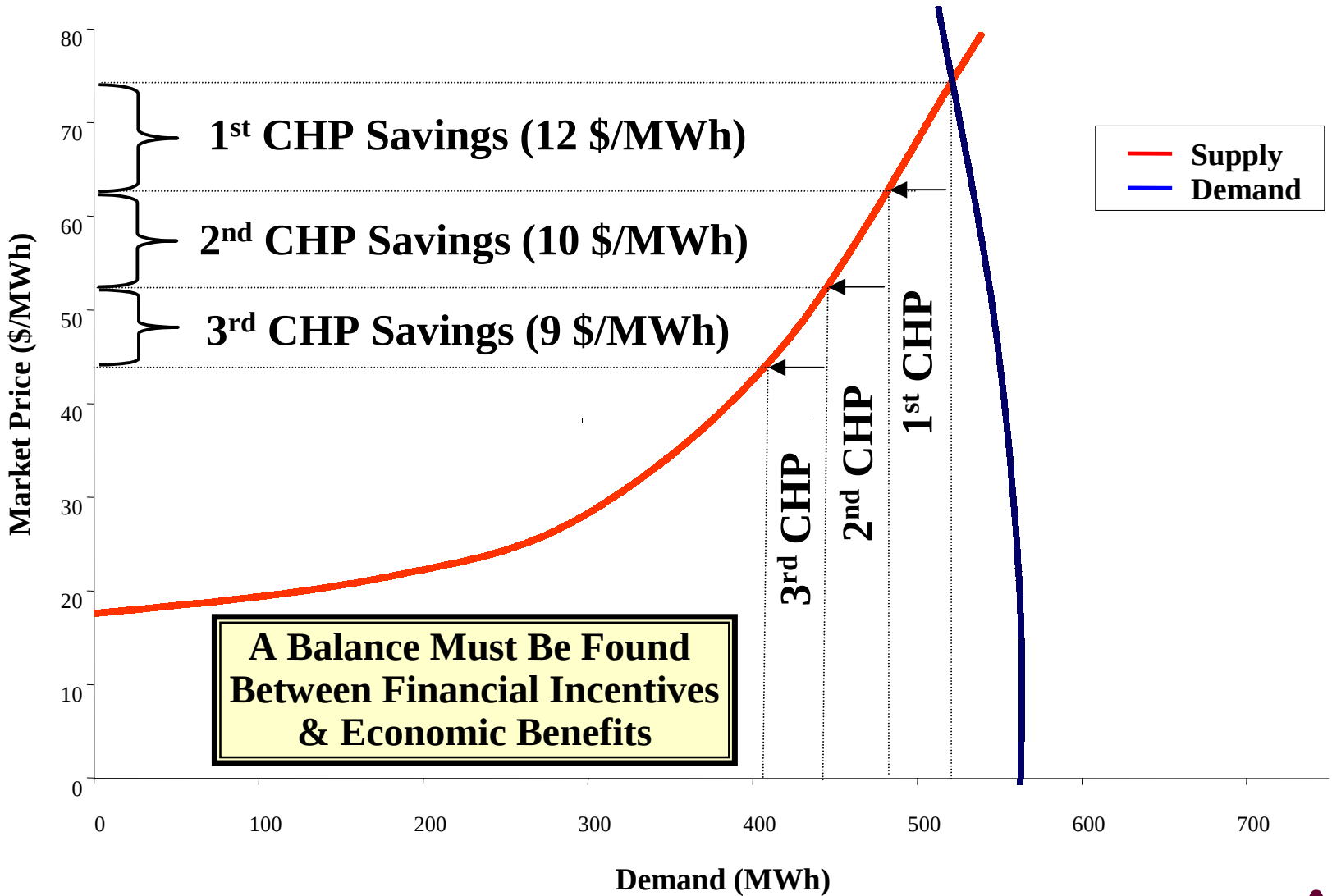
Economic and Financial Benefits of CHPs Are a Function of the Supply and Demand Balance

(Assuming the CHP Bid/Supply Cost Is Lower Than the Equilibrium Price)



Increasing CHP Generating Capability Decreases Economic and Financial Incentives

(Assuming CHP Bids/Supply Costs Are Lower Than the Equilibrium Price)



GTMax Has Been Used for Numerous Studies and Several Activities Are Currently Underway

- **Power Marketing EIS for the Western Area Power Administration**
- **Flaming Gorge Operations EIS for the Bureau of Reclamation (BOR)**
- **Role and Value of Hydropower in the Future Southeastern European Regional Electricity Market for USAID**
- **Balkan transmission line study for ENRON and USTDA**
- **GTMax training and model enhancements for Comision Nacional de Energia Atomica (CNEA), Buenos Aires, Argentina (USDOE)**
- **Polish power market study through an IAEA technical cooperation project**
- **GTMax Philippine DOE training course and power market games for USAID**
- **Hell's Canyon Project is being conducted by the BOR, U.S. Department of the Interior and U.S. Fish & Wildlife Service**
- **GTMax will be used to model Loveland Area Projects (WAPA)**
- **GTMax will be linked to the WAPA SCADA in Montrose Colorado to assist power marketers**

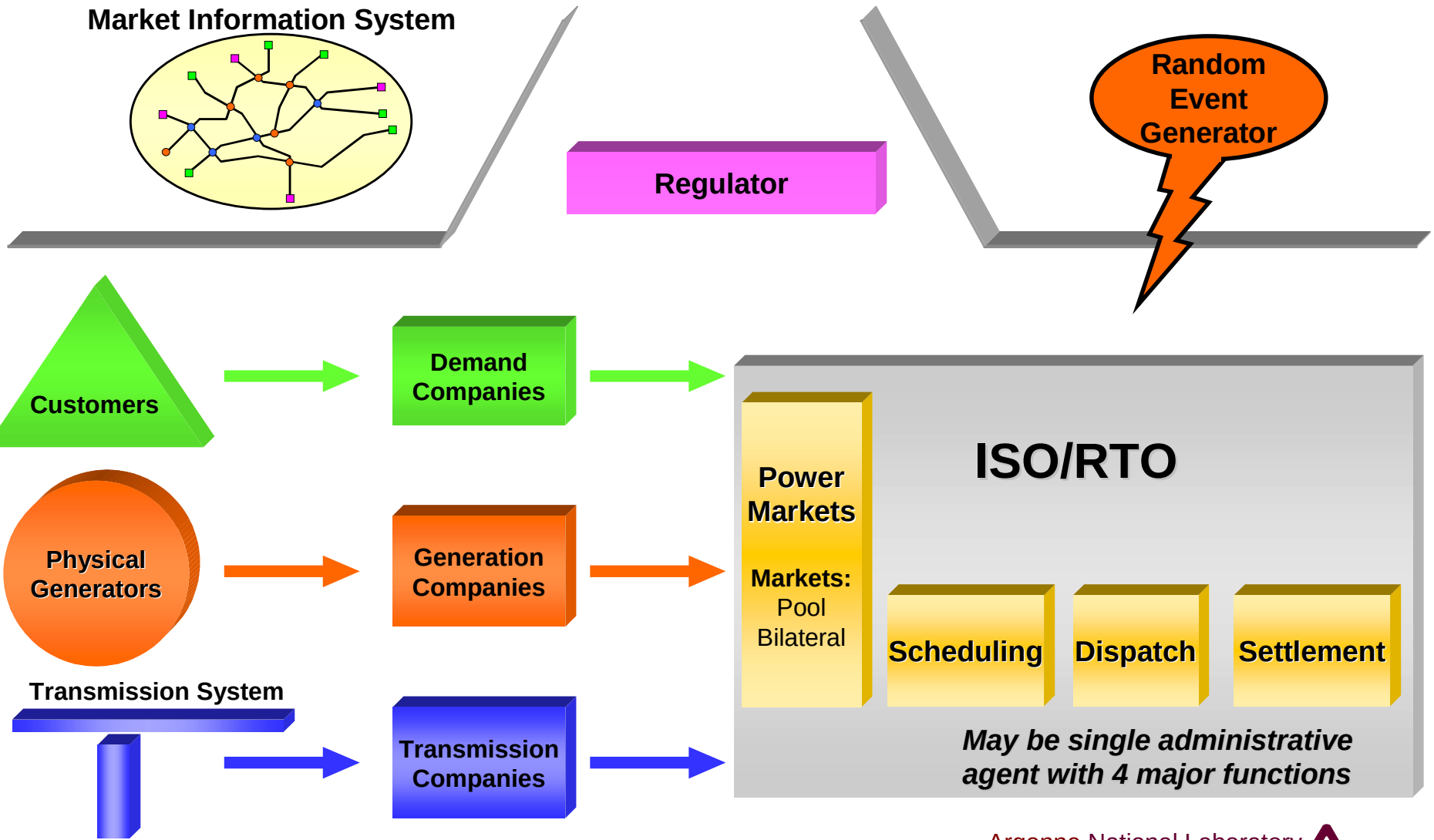
Argonne Is Developing the *Electricity Markets Complex Adaptive System* (EMCAS) Model to Simulate Market Participant Behavior

- **Represents multiple market participants (agents) with decentralized decision-making – agent based modeling**
- **Incorporates agent learning and adaptation based on performance and changing conditions**
- **A wide range of market strategies are available to the different agents**
- **User-specified market rules affect the behavior of individual agents as well as the system**

"[Agent based simulation] has considerable similarity to the mathematical theory of games of strategy, but, unlike the generalized games solved by von Neuman or Nash, these are repeated games with non-zero sum payoffs."

A.M. Wildberger, EPRI

EMCAS Uses an Agent-Based Architecture to Represent Participants in the Electricity Marketplace



In EMCAS, Company Agents Seek to Maximize the Corporate Utility Function, Not Overall Social Utility

- **Each company agent can have a set of corporate objectives**
  - Profit
  - Market share
  - …other…

- **Multiple objectives can be combined into a utility function**

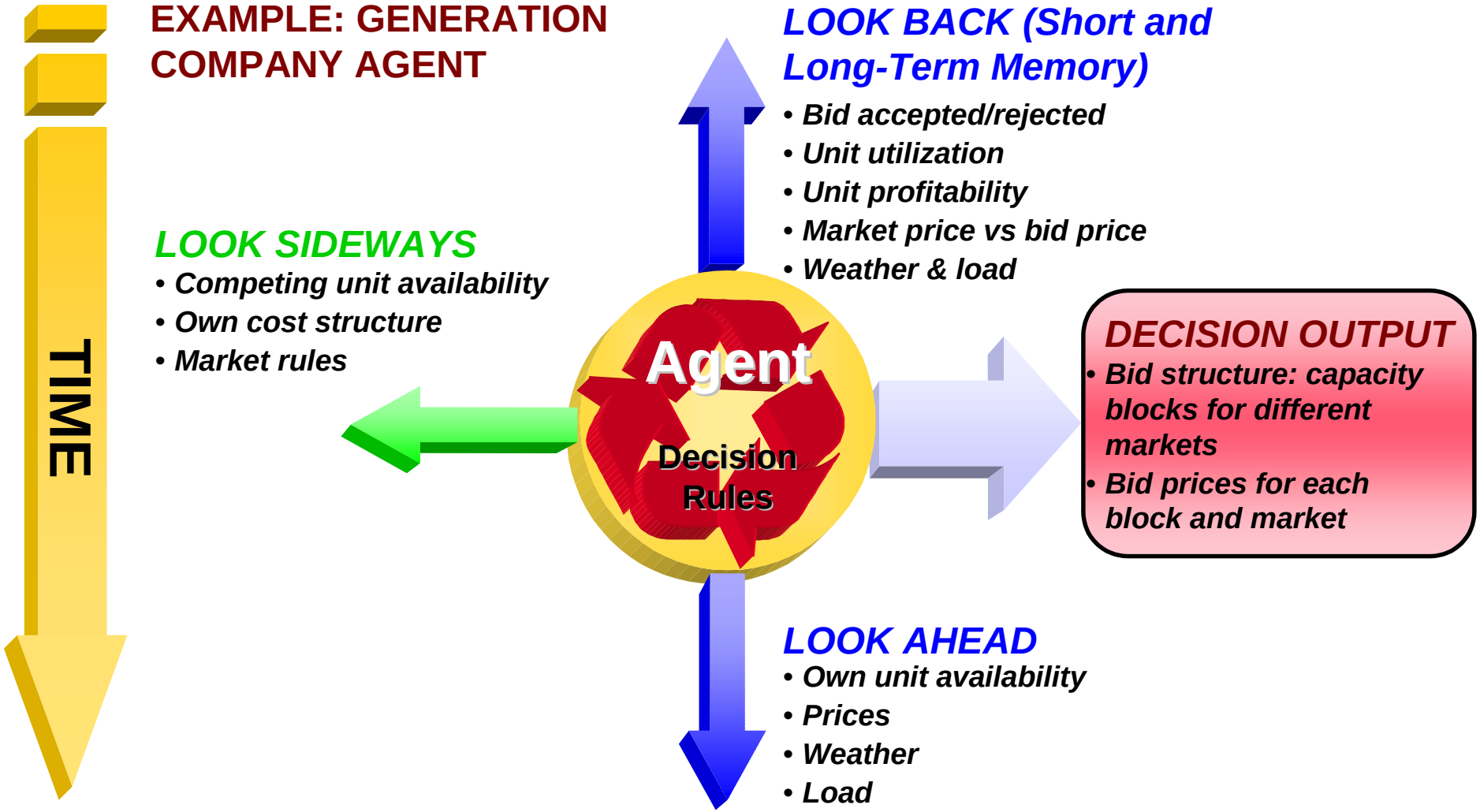
Utility Function = f (Profit, Market Share, ..other..)

Not all companies necessarily have the same objectives

Not all companies necessarily use the same utility function

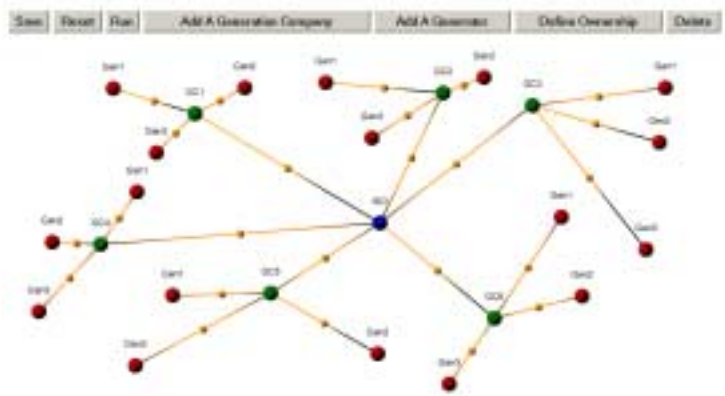
Agents Obtain Information and Decide Among Options Available to Them

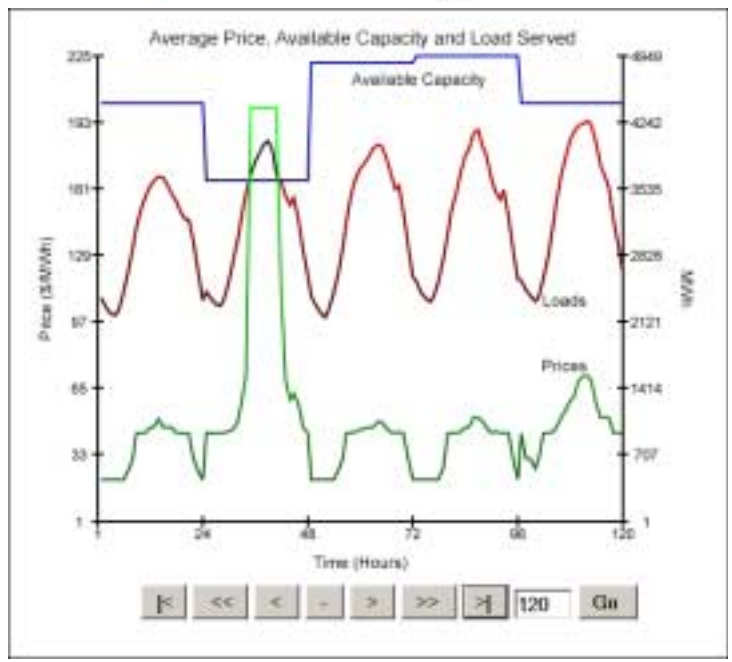
EXAMPLE: GENERATION COMPANY AGENT



There Are Multiple Advantages to the EMCAS Agent-Based Simulation

- **Decentralized decision making is represented**
- **Alternative company strategies can be simulated**
- **Adaptation occurs in the simulation**
- **Market rules can be tested**
- **Transient conditions can be studied**
- **Contributors to system problems can be identified**





Summary

- GTMax is a network model that simulates the flow of electricity, fuel, heat, power, and money among various activity nodes
- The model optimizes power system operations within physical and institutional constraints
- Locational market prices act as signals for power produces and consumers
- The EMCAS model uses agent-based modeling methods to predict market participant behavior
- GTMax has been used extensively over the past several years and can be used in support of future CHP tariff studies