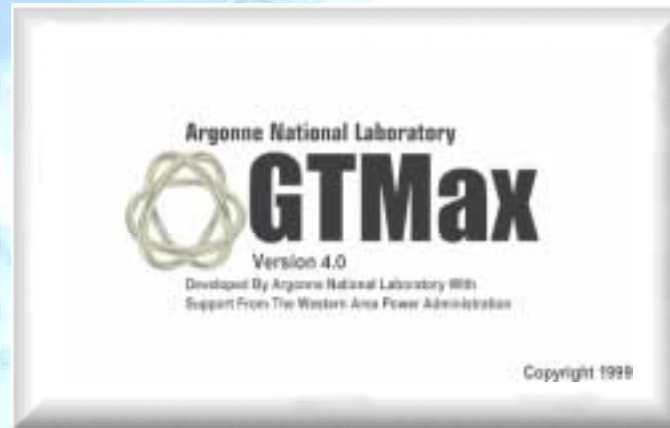


Overview of the Generation-Transmission Maximization (GTMax) Model



**The Premier Analysis Tool
for Deregulated
Electricity Markets**



*Argonne National Laboratory
Center for Energy, Environmental, and
Economic Systems Analysis*



Around the World, Deregulation is Fundamentally Changing the Way Electricity Markets Function

Past

Natural Monopoly

Vertically Integrated



Present



Transition Phase

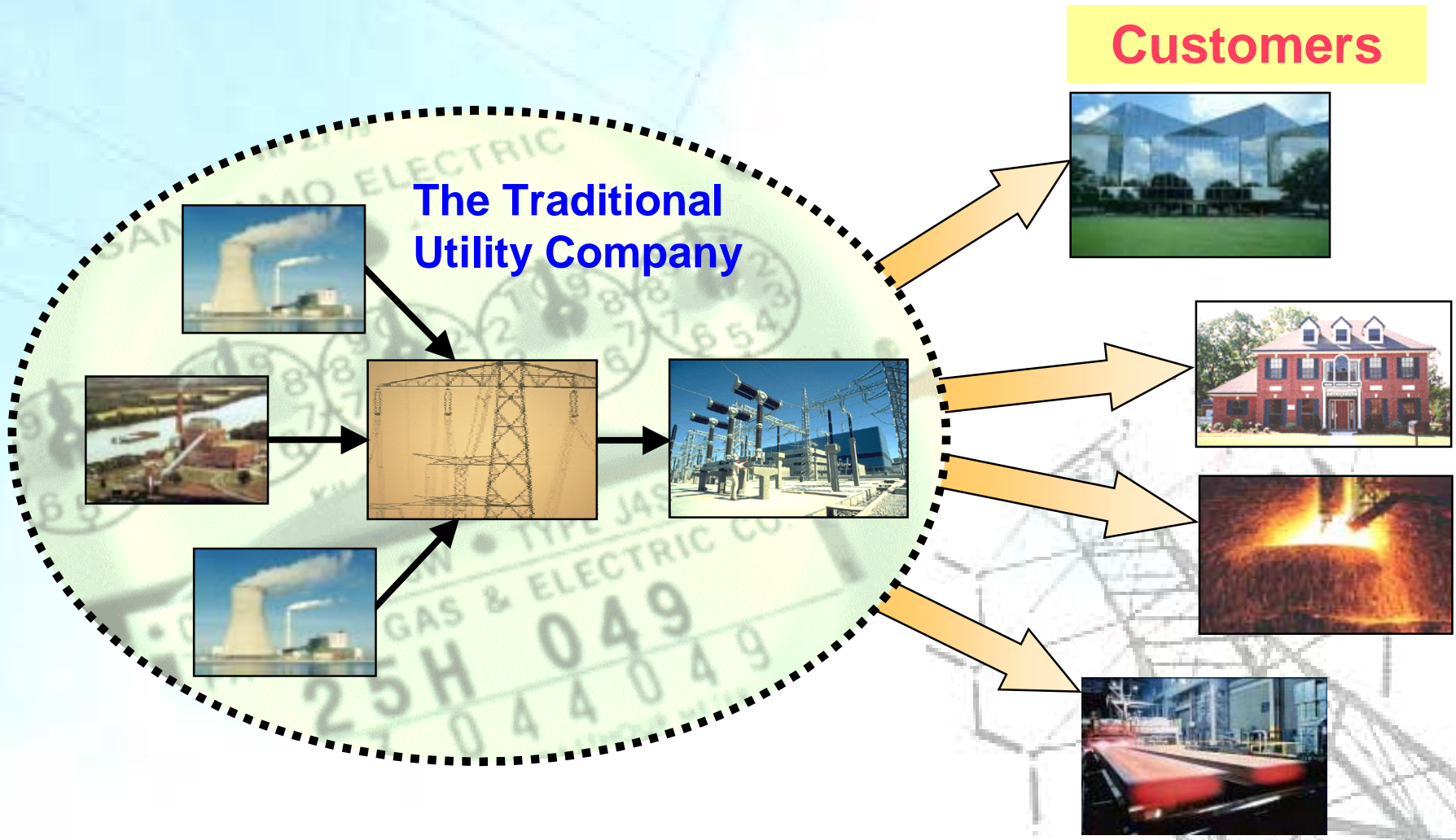
Future

Open Market

Unbundled



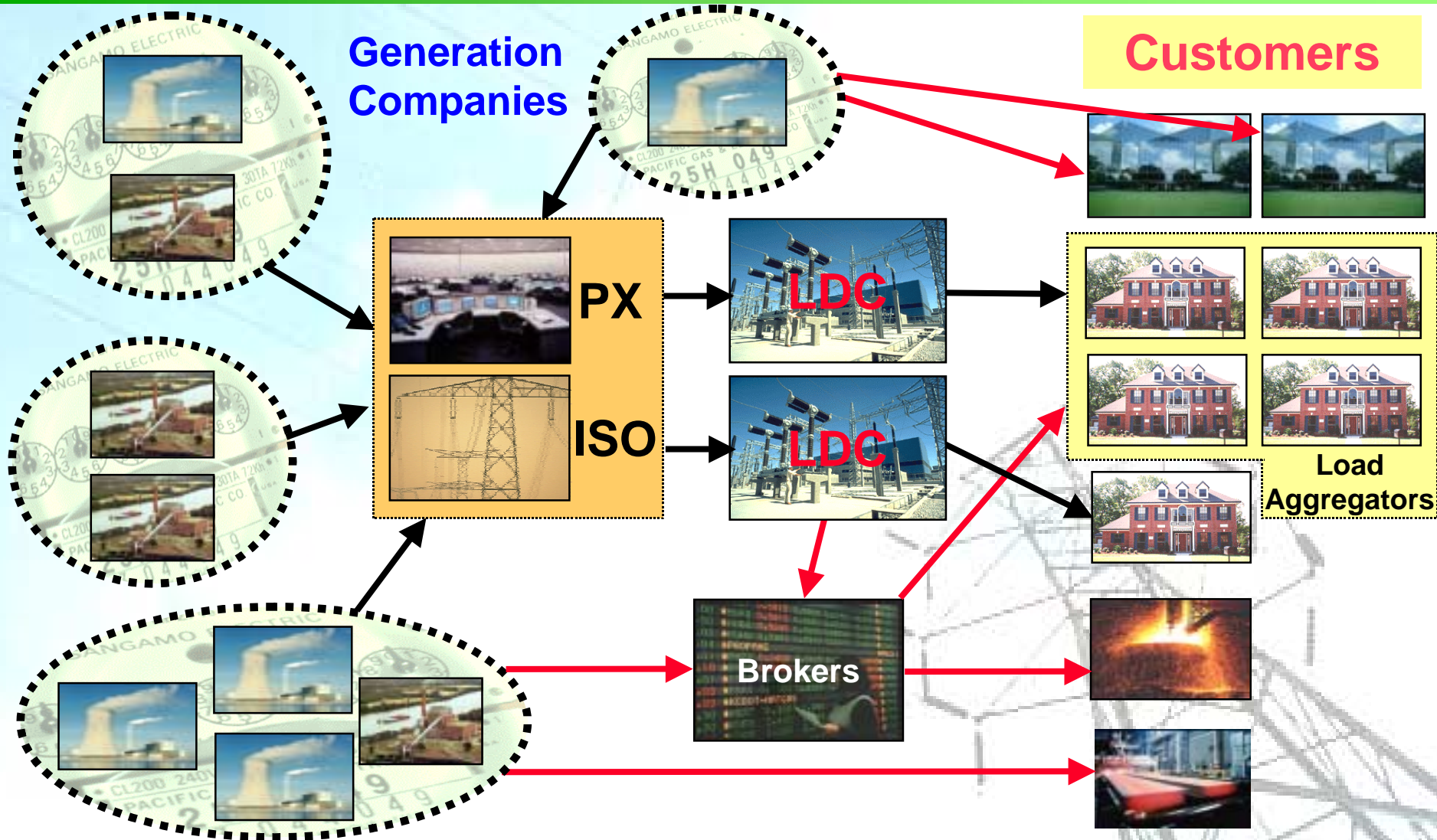
The Traditional Markets Are Dominated by Single, Vertically-Integrated Energy Companies



Customers



The New Deregulated Energy Marketplace Is Far More Complex and Has Many More Players



Argonne Developed GTMax to Study the Complex Marketing and Operational Issues in Today's Deregulated Power Markets

GTMax Can be Used by Different Market Agents in Support of their Analytical Needs

- Generation Companies, Independent Power Producers, and Power Merchants
- Transmission Companies, Independent System Operators, and Power Exchanges
- Government, Regulatory, and Oversight Bodies



Generation Companies, Independent Power Producers, and Power Merchants

- Use GTMax to estimate how much power each unit will generate and how much power they can sell in each hour at what price
- Use GTMax to estimate purchases and sales from long-term firm contracts and IPP agreements
- Use GTMax to study if their investment in power or transmission assets will yield an attractive return
- Use GTMax to develop a sound market strategy - when should they buy and/or sell power in the spot market



Transmission Companies, Independent System Operators, and Power Exchanges

- Use GTMax to estimate the locational hourly market clearing price for energy at different points in the network
- Use GTMax to estimate the projected available transmission capability on individual links or user-specified paths each hour in the region for posting on OASIS systems
- Use GTMax to determine the optimal path of contractual power flows
- Use GTMax to identify operational and network bottlenecks and the marginal value of relieving system obligations and constraints
- Use GTMax to conduct screening and siting analyses for new transmission lines



Government Agencies and Regulatory or Oversight Bodies

- Use GTMax to analyze different bidding behaviors or strategies and game playing and the impacts on the markets (market power)
- Use GTMax to study open market policies
- Use GTMax to simulate the effects of environmental and institutional limits on power plant operations and compute compliance costs
- Use GTMax to analyze the value of demand-side management and distributed generation resources



GTMax Objective

- Maximize the economic or financial value of an electric utility system within physical and institutional operating constraints
- Electric utility system
 - Hydro and thermal power plants
 - Firm purchase and sales contracts
 - Spot market interconnections
 - Customers (electricity demand)
 - Transmission and distribution systems
- Physical and institutional constraints
 - Capacity
 - Technical minimum
 - Ramping limits (change in operations over time)
 - Reservoir limits

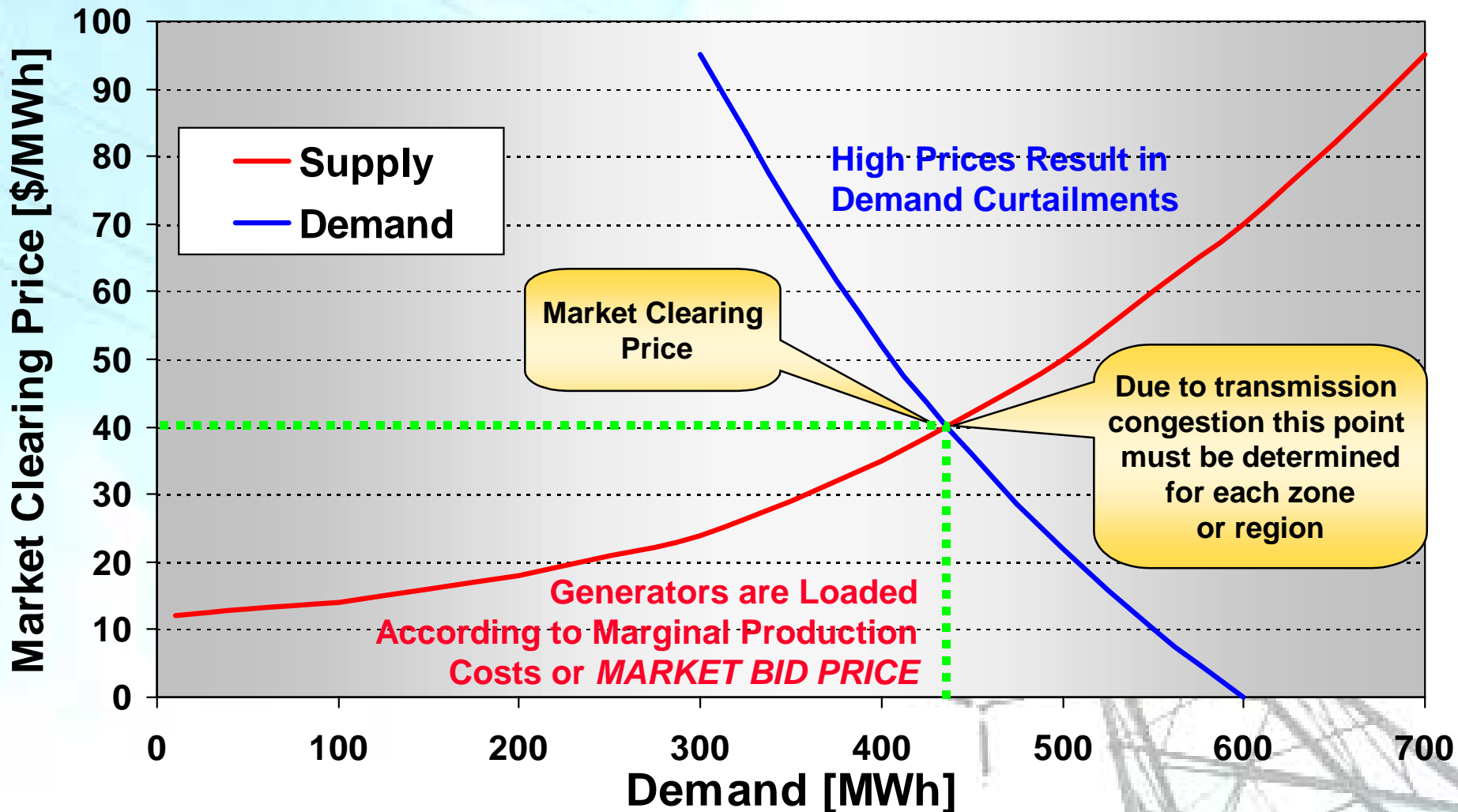
Spot Markets & Firm Contracts Are Driving the System



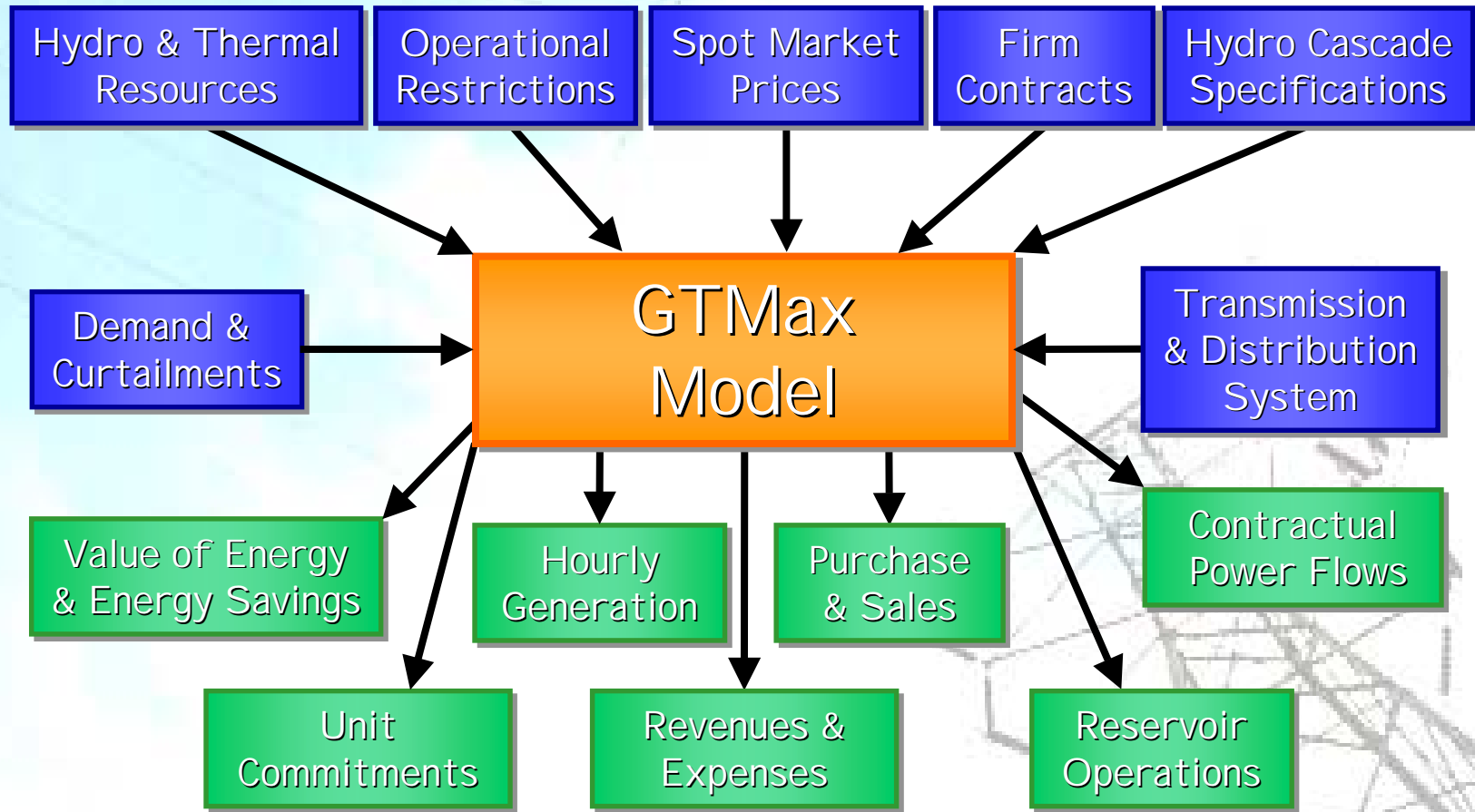
System Dispatch & Plant Operations Must Respond to the Market



GTMax Balances Supply & Demand (Simplified Example)



GTMax Operates at a One Hour Time-Step and Takes into Account Many Input Variables



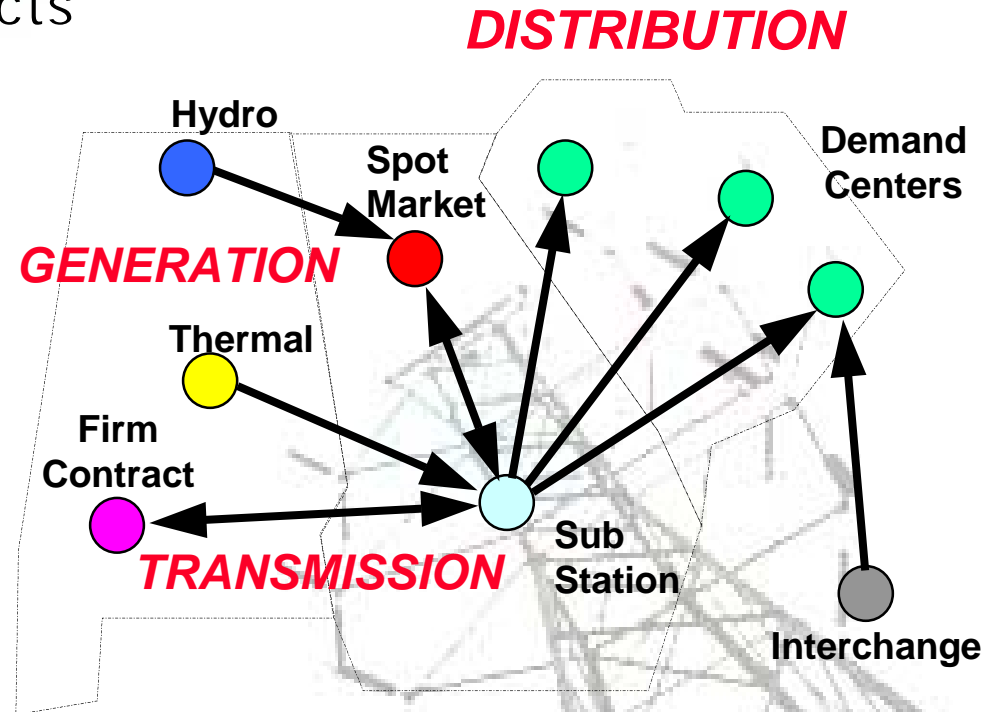
GTMax Uses a Network of Nodes & Links to Represent a Power System

● Nodes

- Thermal & hydro power plant
- Firm purchases & sales contracts
- Spot market interconnections
- Power interchange points
- Heat production
- Electricity & heat demand

● Links

- Transmission lines
- River systems
- Heat flows



There are Several Types of Supply Resources in the Model

- Thermal units
- Hydro power plants (limited energy)
 - Run-of-river
 - Storage
 - Pumped storage
 - Hydro plants can be specified in a cascade
 - Water is spilled (non-power release) under some conditions
- Long-term firm purchase contracts & Independent Power Producer (IPP) contracts
- Spot market purchases
- Combined Heat & Power Plants



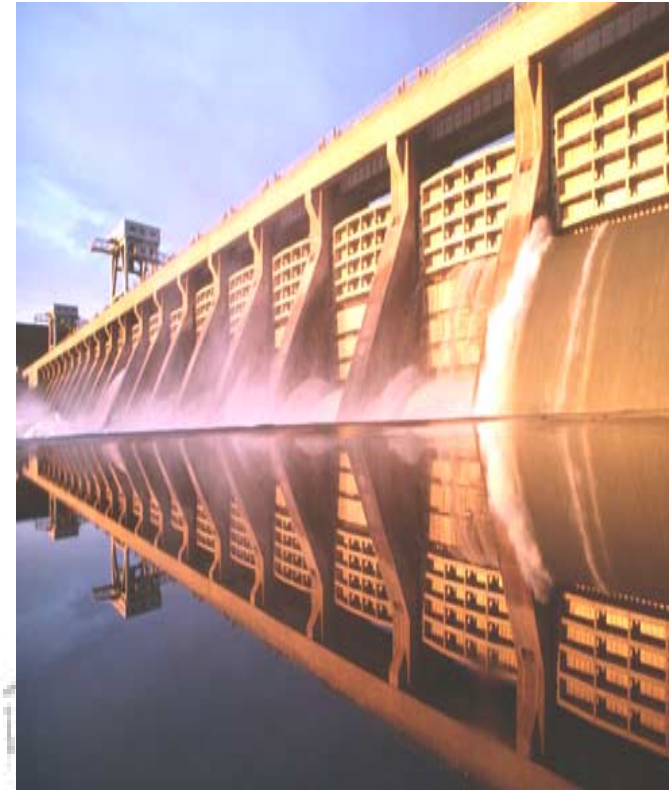
GTMax Has Detailed Thermal & Hydro System Representations

- Power plant or unit capacity
- Marginal production cost or bid price by block
- Total energy release in a week period
- Daily minimum & maximum energy
- Change in daily energy production
- Minimum hourly output
- Maximum hourly output
- 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



The GTMax Hydropower Dispatch is also Constrained by Reservoir Limitations

- Maximum reservoir elevation level
- Minimum reservoir elevation level
- Daily reservoir elevation change
- Change over a 2-day & 3-day period
- 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 of other uses
 - Elevation change per volume of water released

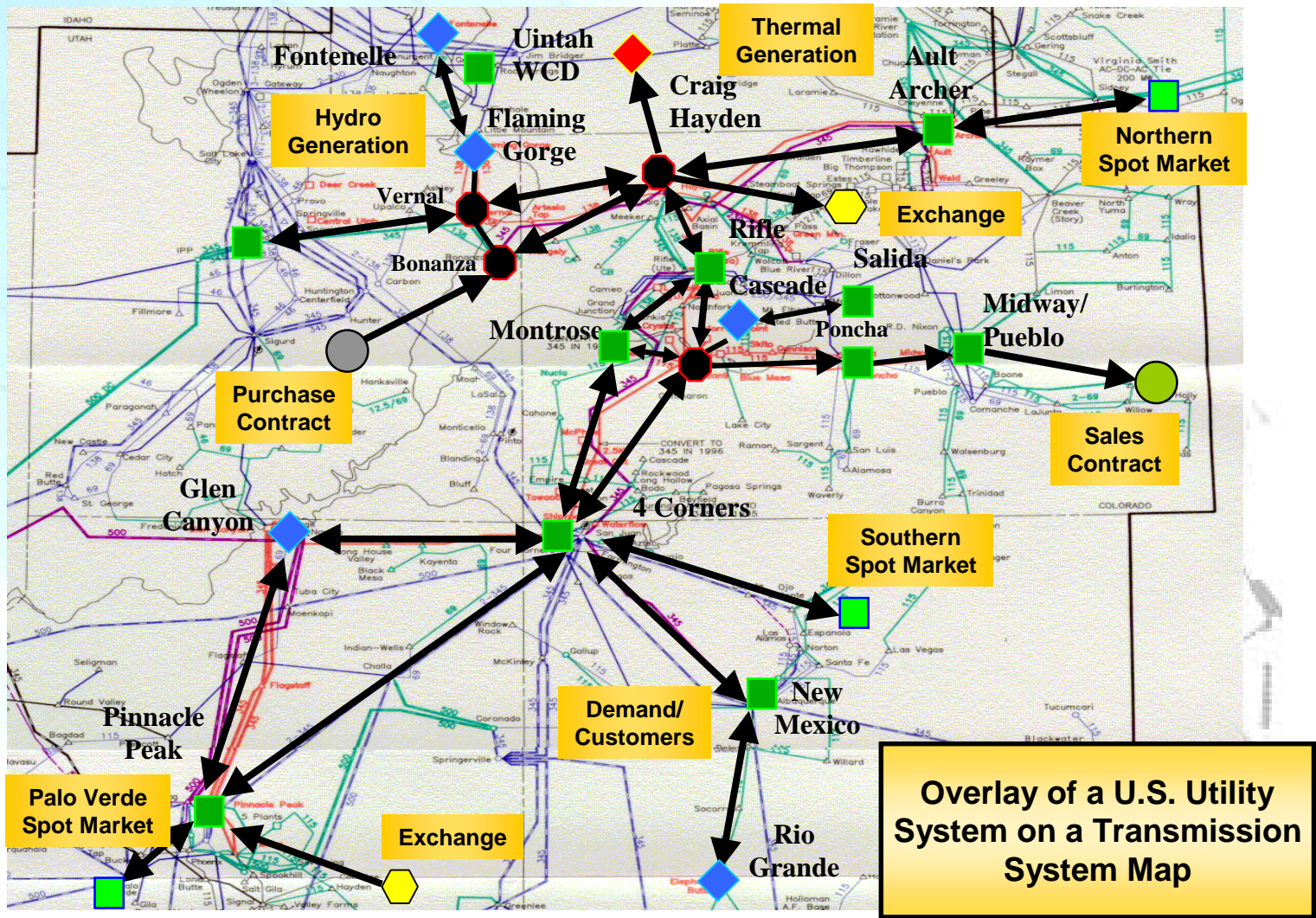


Supply Resources Satisfy Different Types of Demands

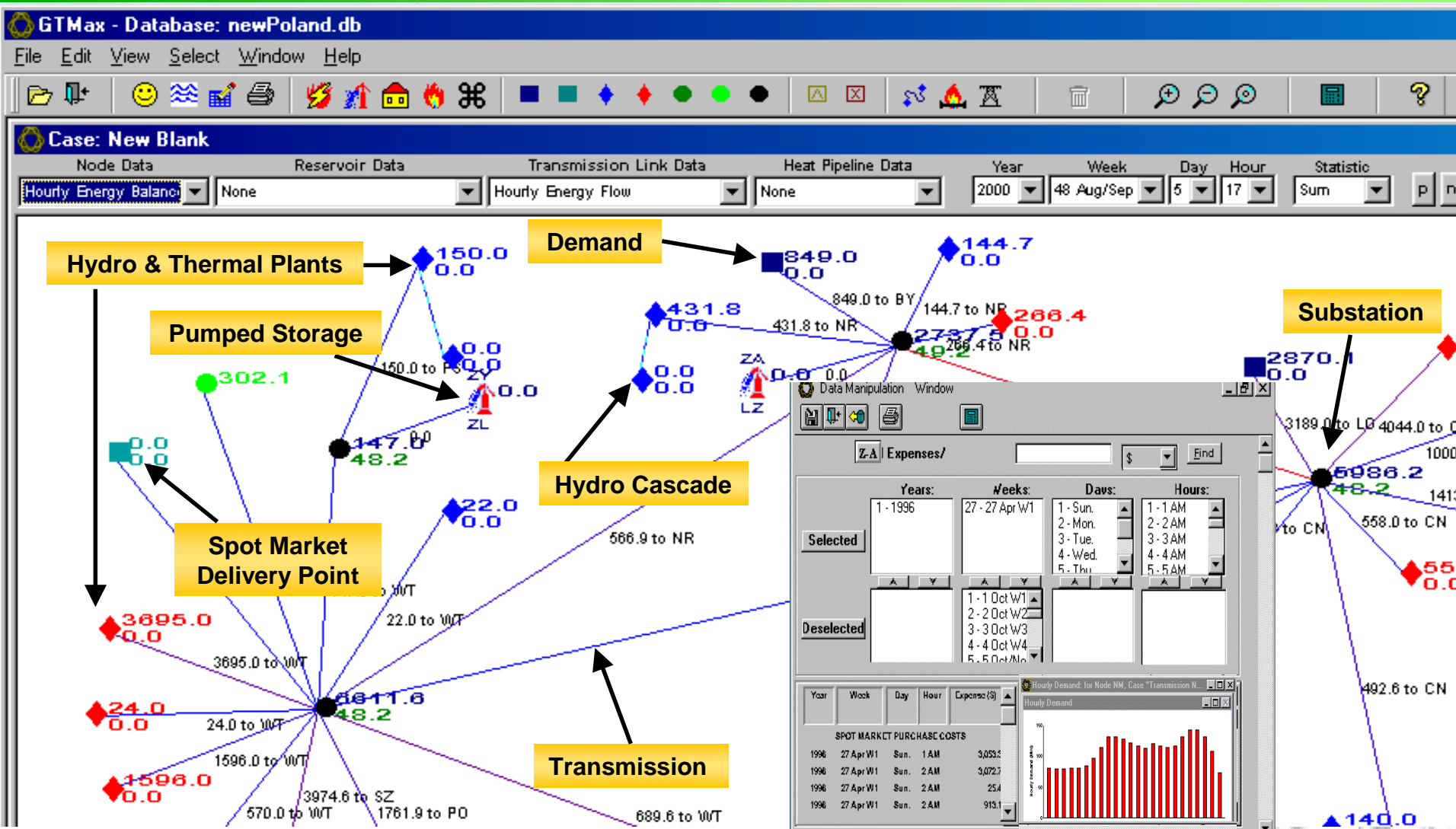
- Service territory load centers
- Firm contract loads (if any)
- Spot market demands (if economical)
- Heat demands
- Note: Additional electricity must be produced because of T&D losses



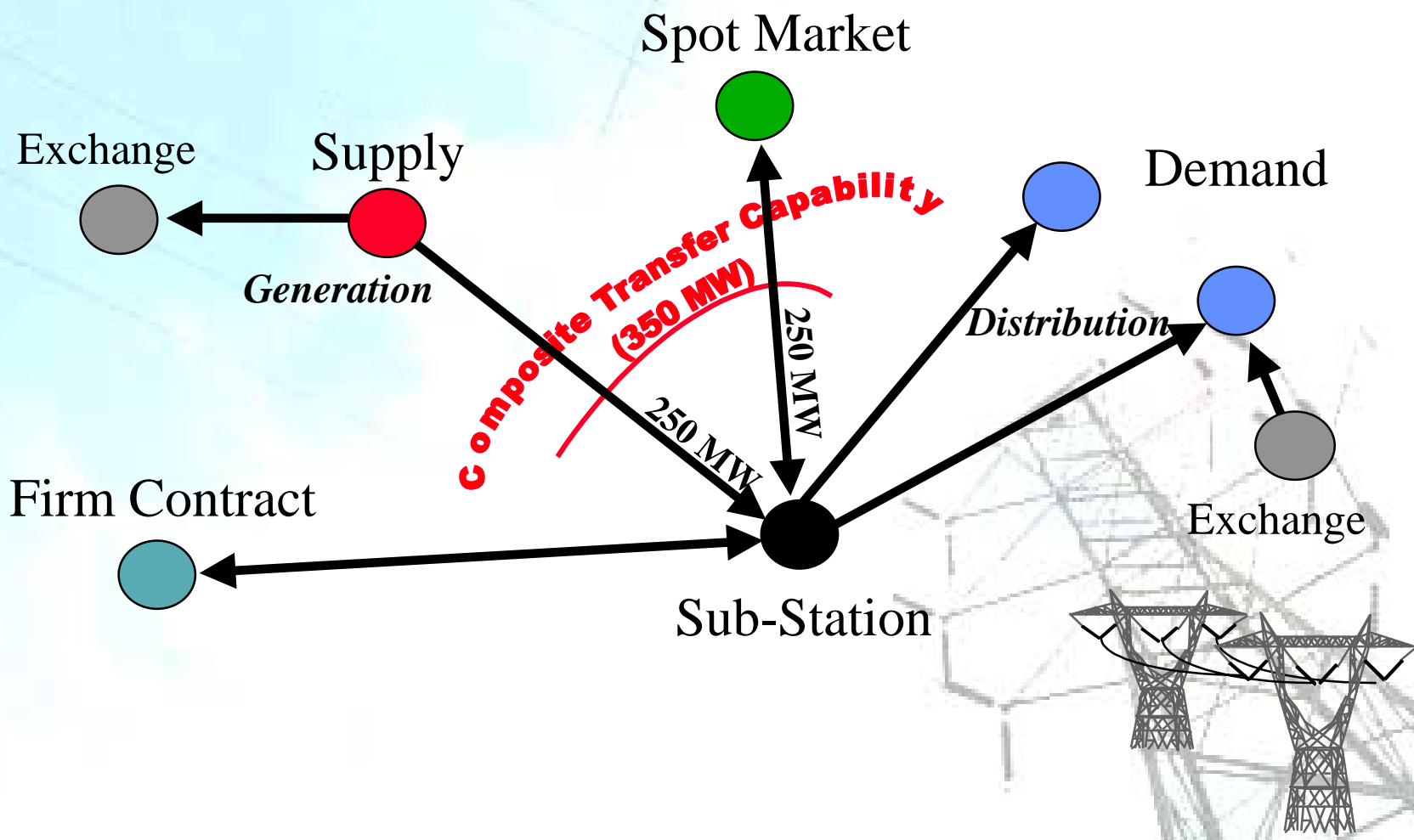
The Transmission System Links Different Types of Activities



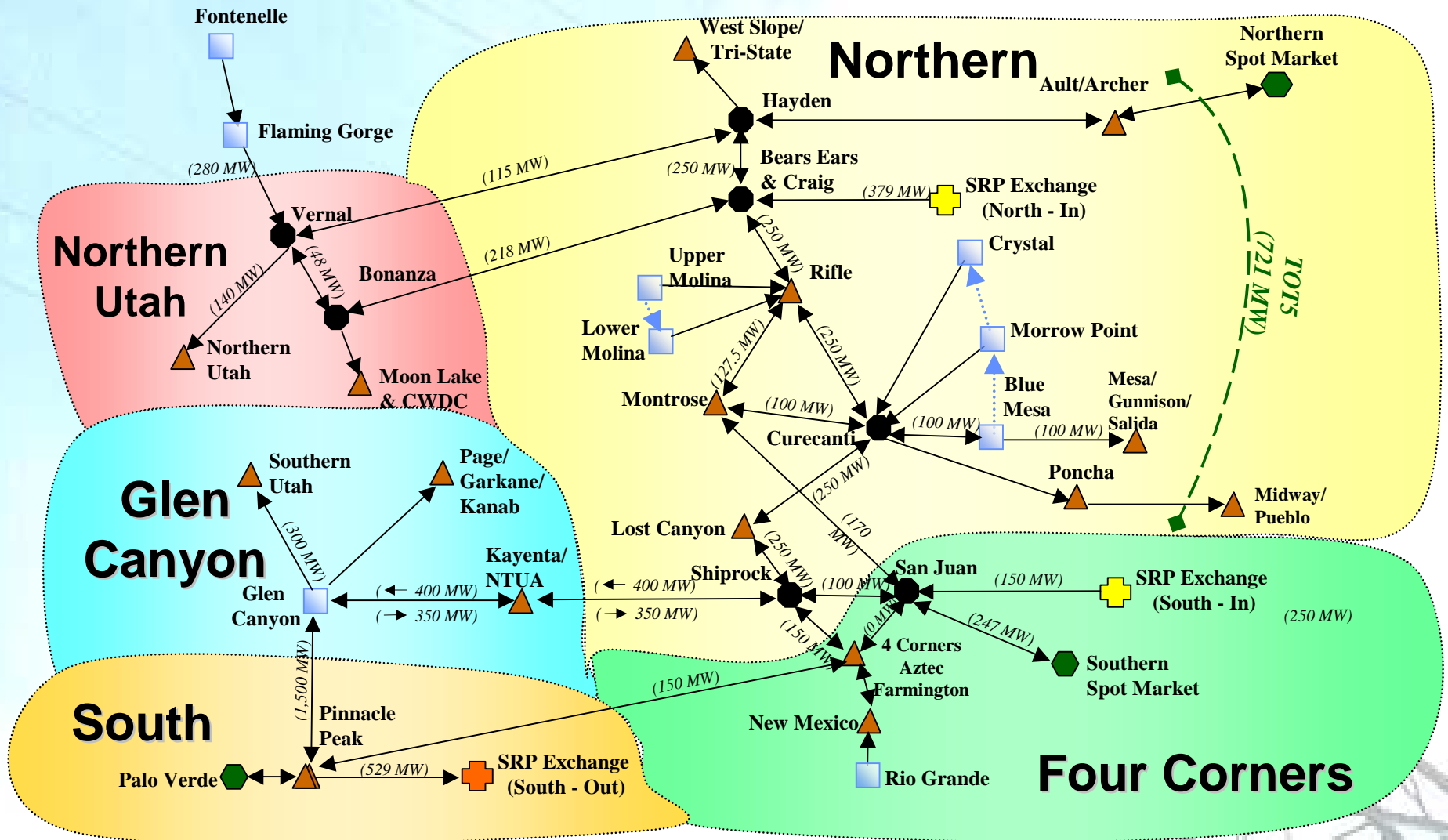
GTMax Employs a User-Friendly Geographical Information System (GIS) Interface



GTMax Accounts for Composite Transfer Capability (The Total Is Less Than The Sum of The Parts)

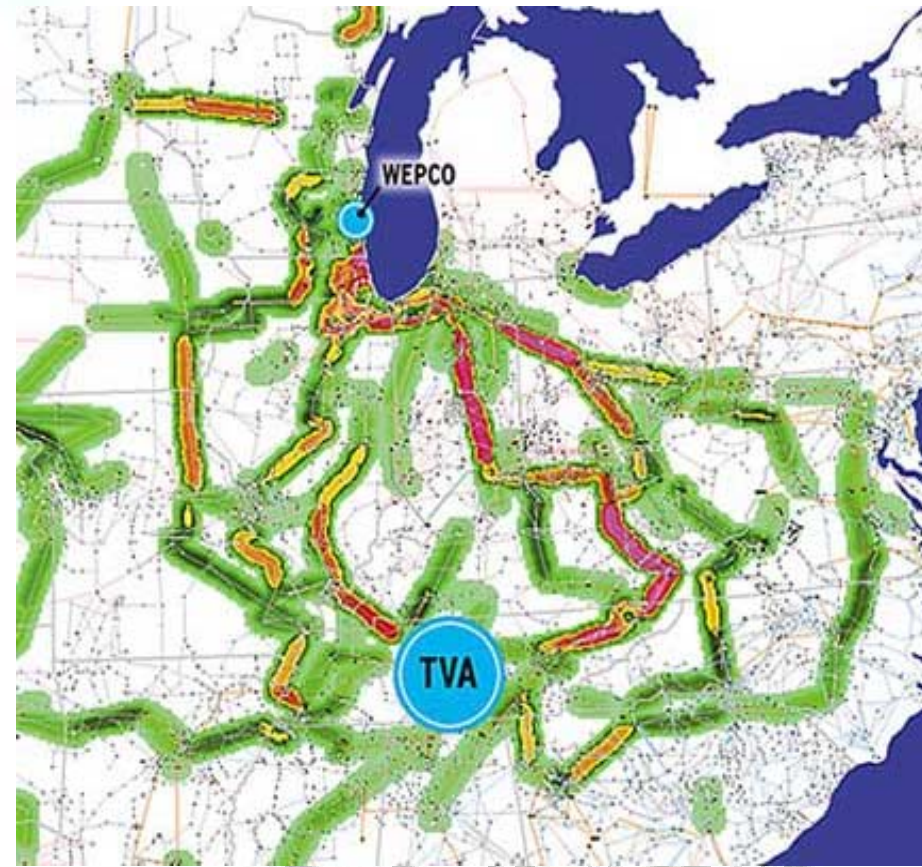


GTMax Allows the User to Define Regions



Argonne is Developing a Transmission Model for Computing PTDFs in GTMax

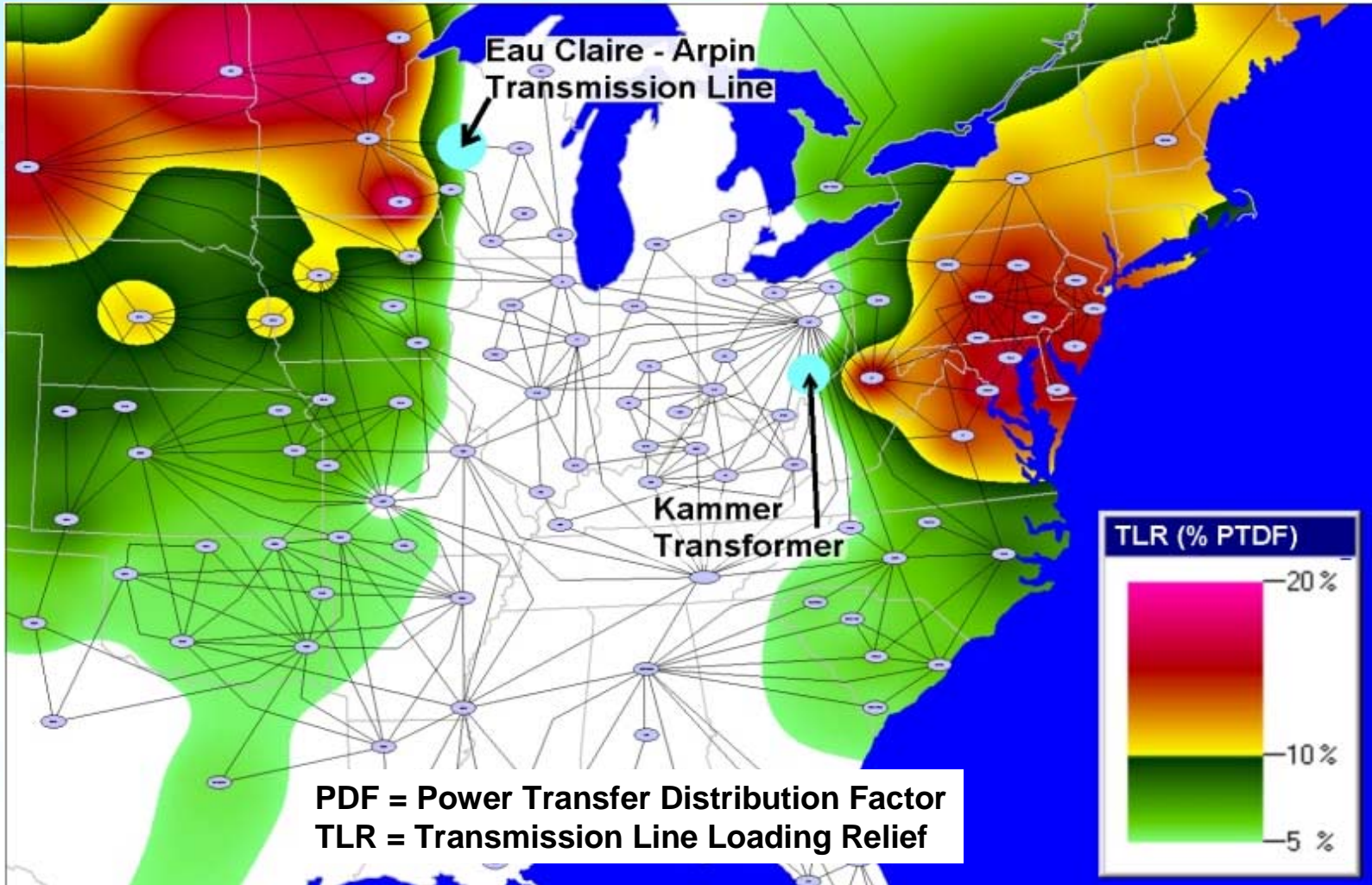
- **EXAMPLE:** Hypothetical power transfer from utility in eastern Wisconsin to TVA
- Transfer affects lines as far away as Nebraska and eastern Virginia
- Of the 45 000 lines modeled in the case, 171 had PTDFs above 5%, while for 578 the PTDFs were above 2%



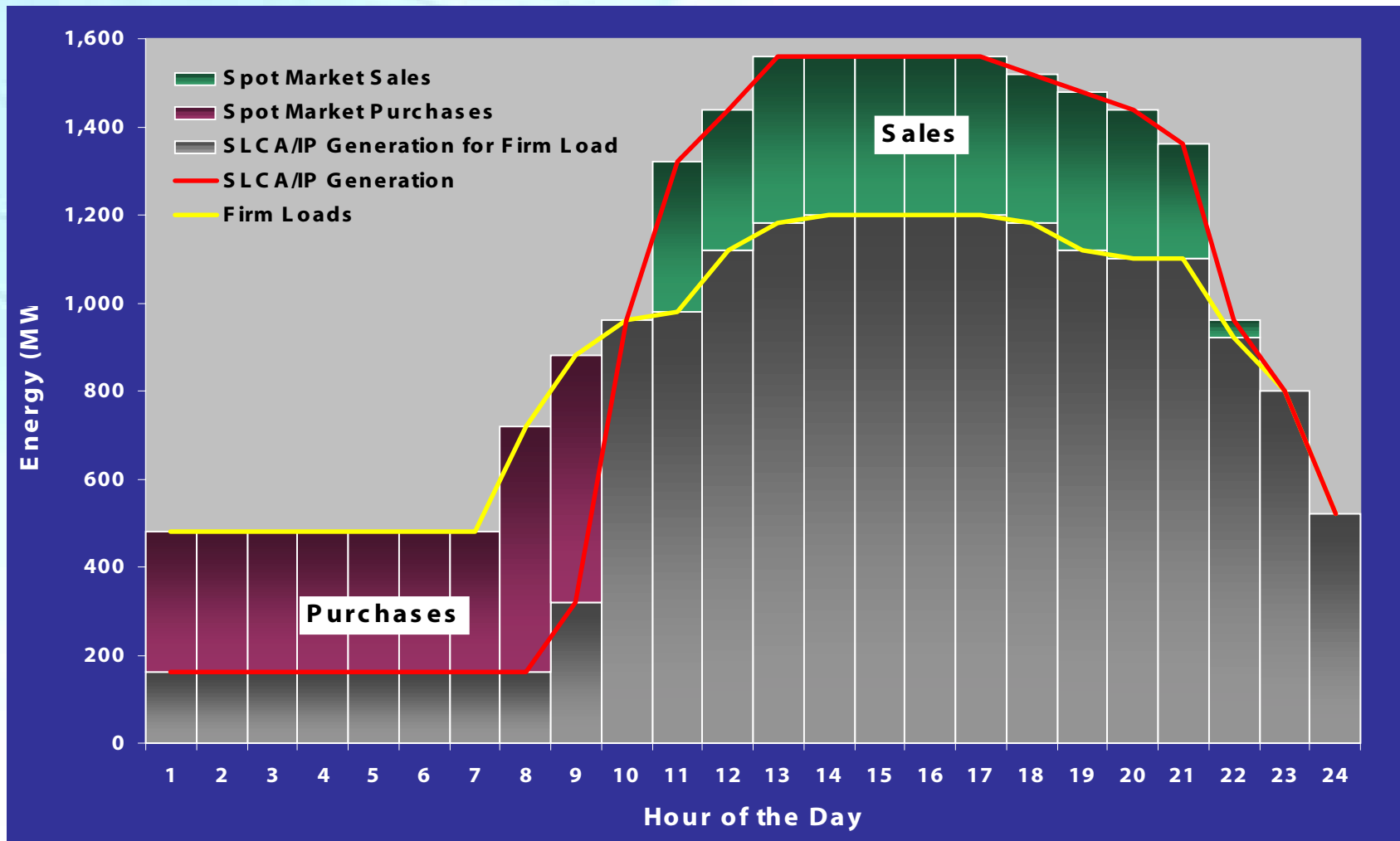
PTDF = Power Transfer Distribution Factor



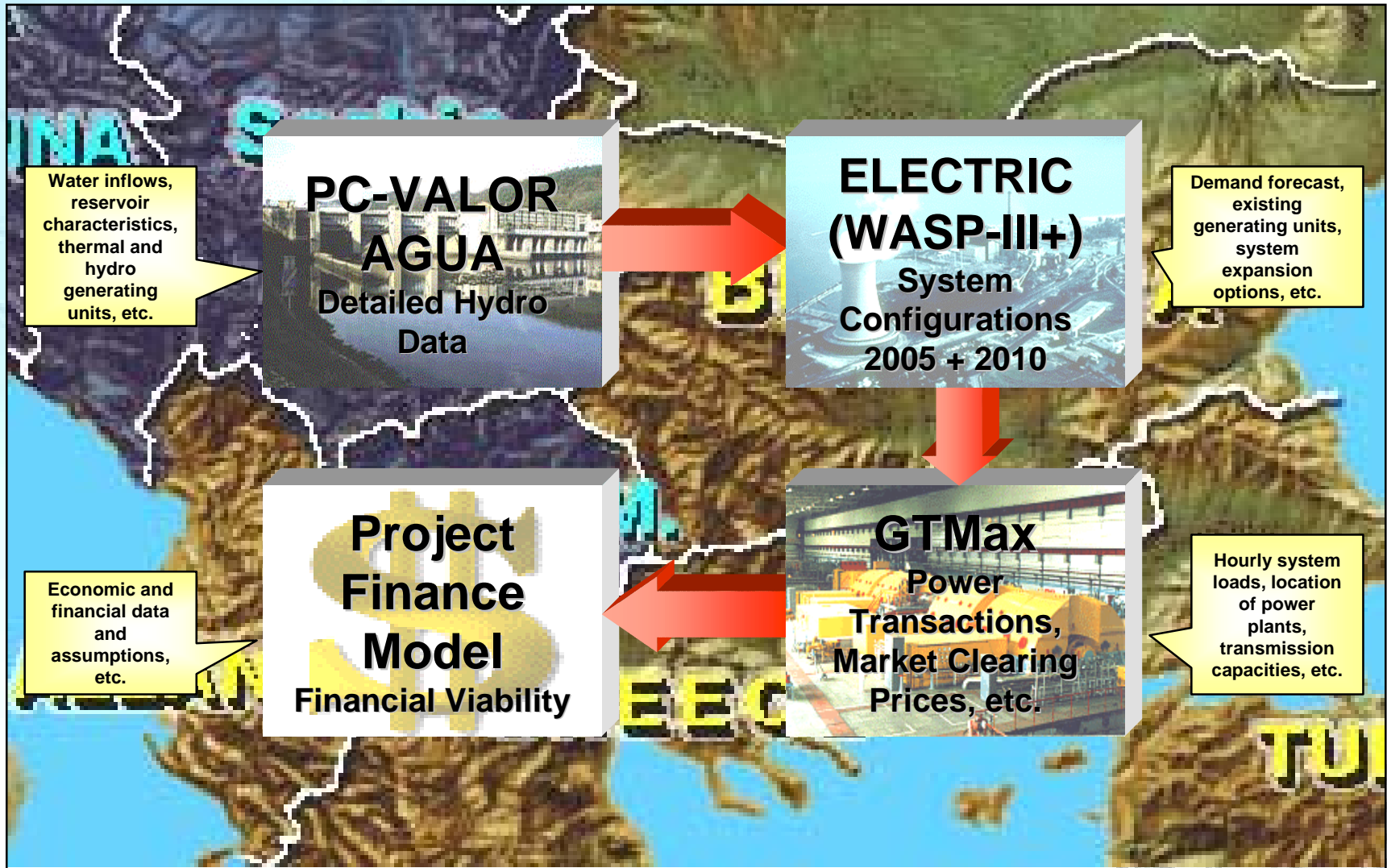
Transmission Constraints Played a Critical Role in U.S. Midwest Price Spikes of up to \$7.5/kWh in June 1998



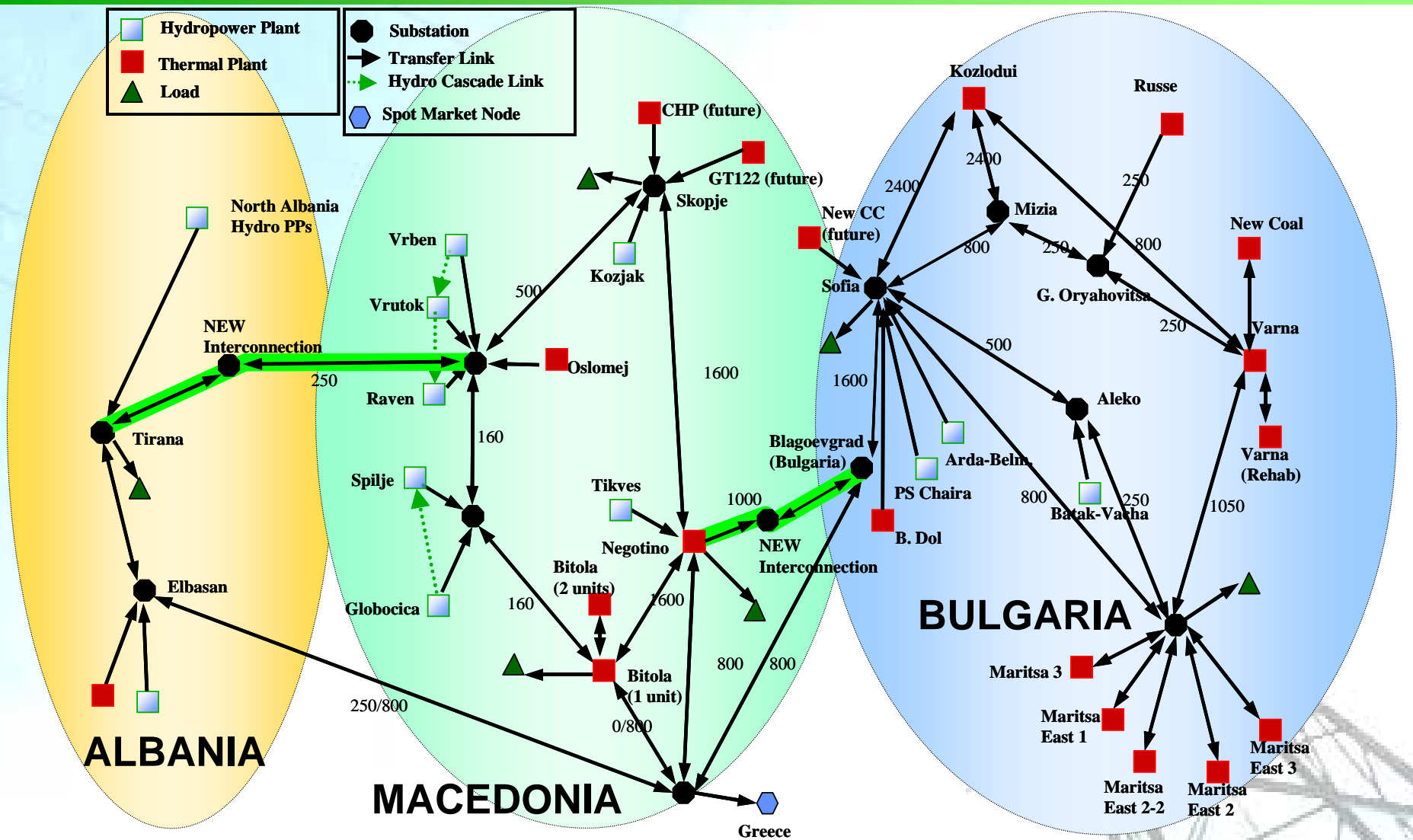
Application: Hydropower Plant Operations of a Large U.S. Utility are Usually Driven by the Market Price of Electricity



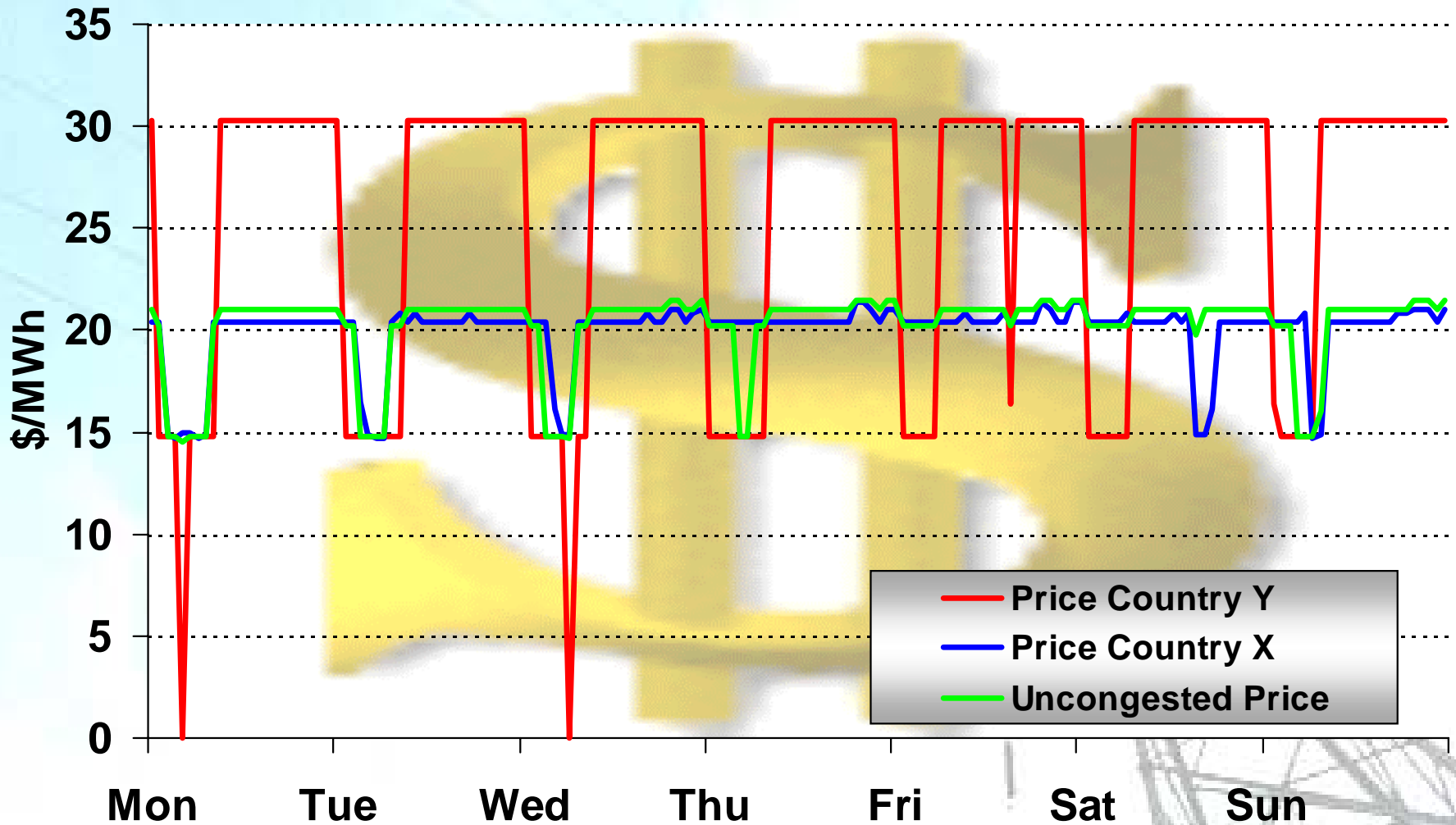
Analyzing the Economic and Financial Viability of Two Transmission Lines in the Balkans for a Large International Power Merchant



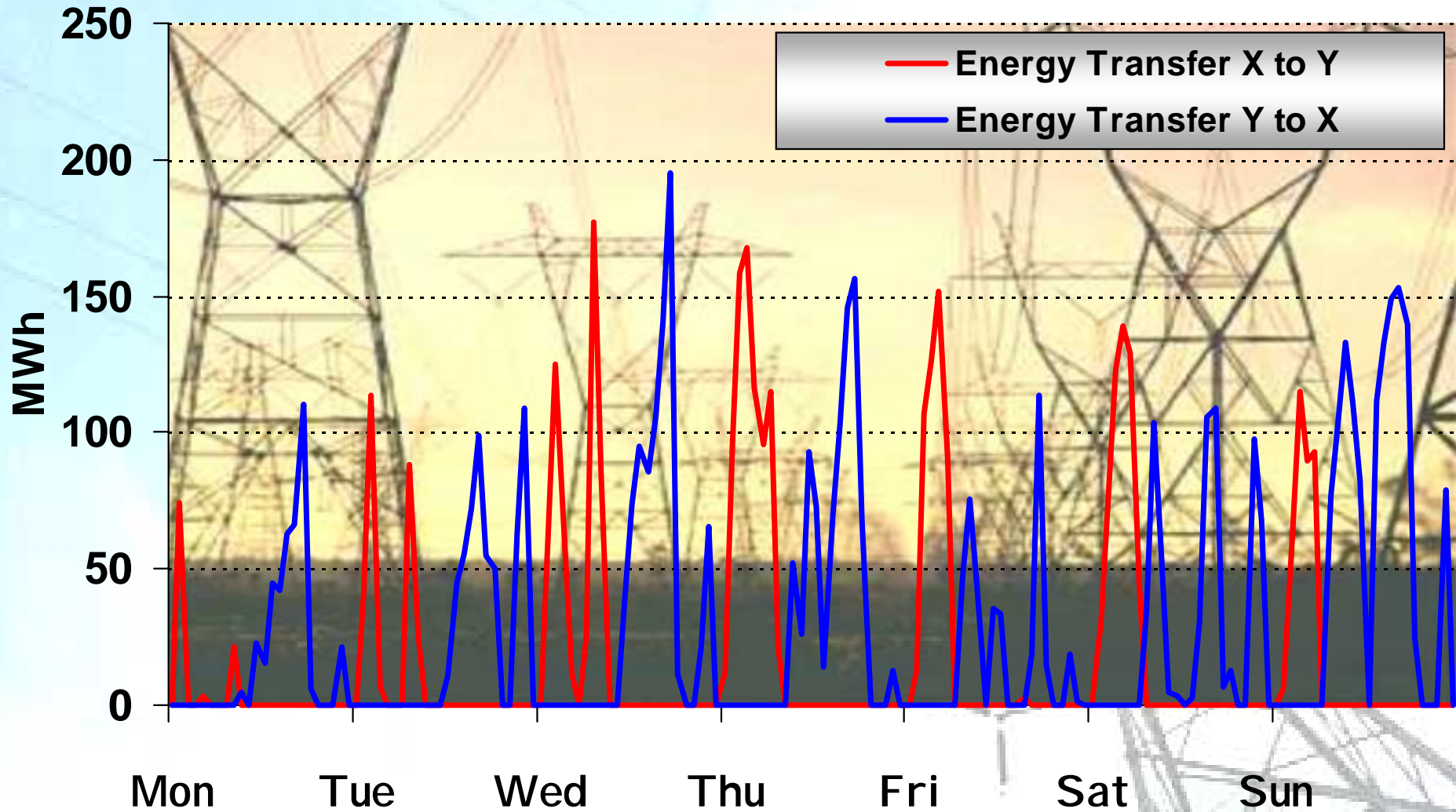
Three Distinct Regions were Modeled in the Balkan Transmission Lines Project



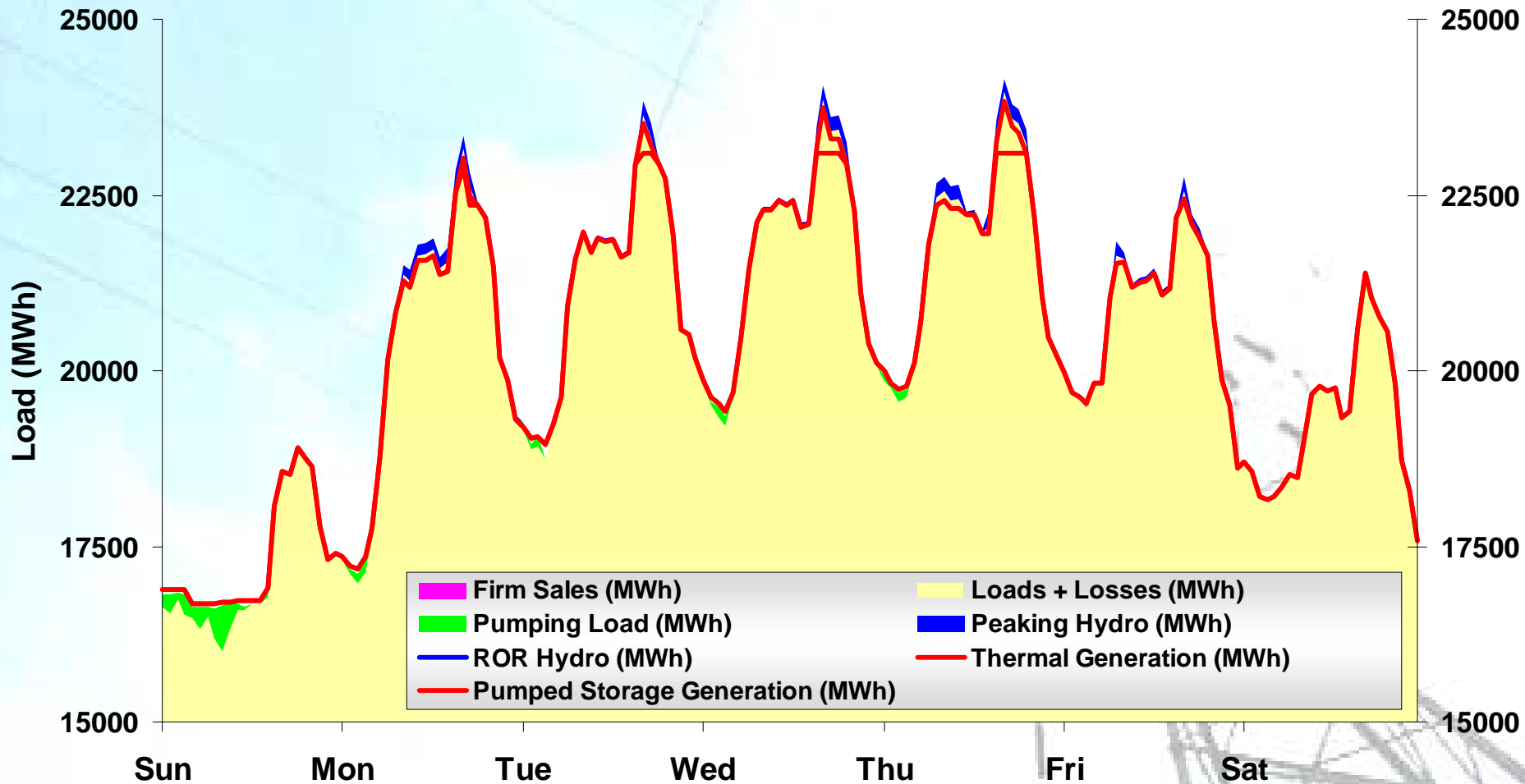
GTMax Projected Market Clearing Prices in the Balkans Based on Marginal Production Costs



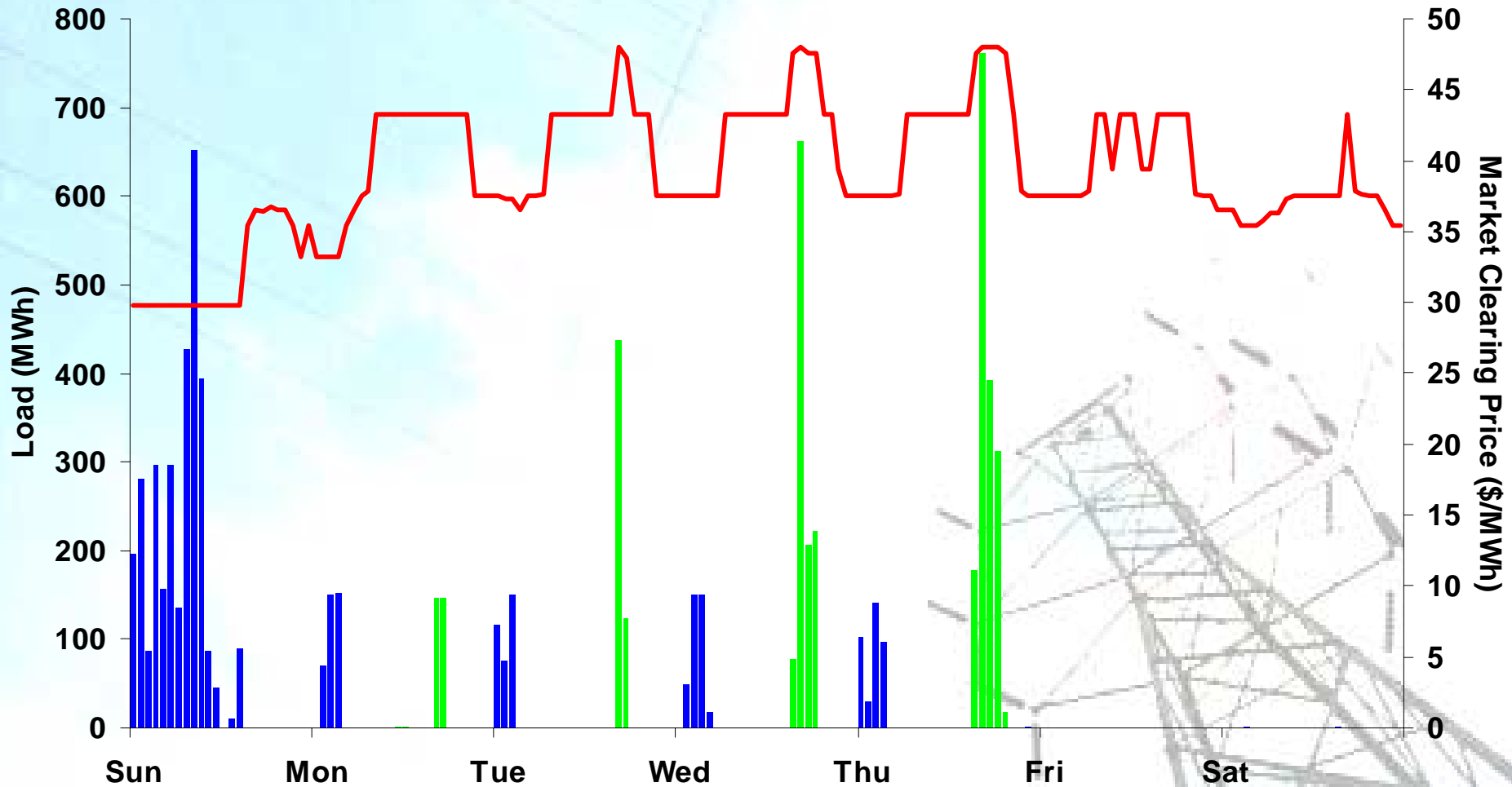
GTMax Estimated Bulk Power Transfers Between Regions



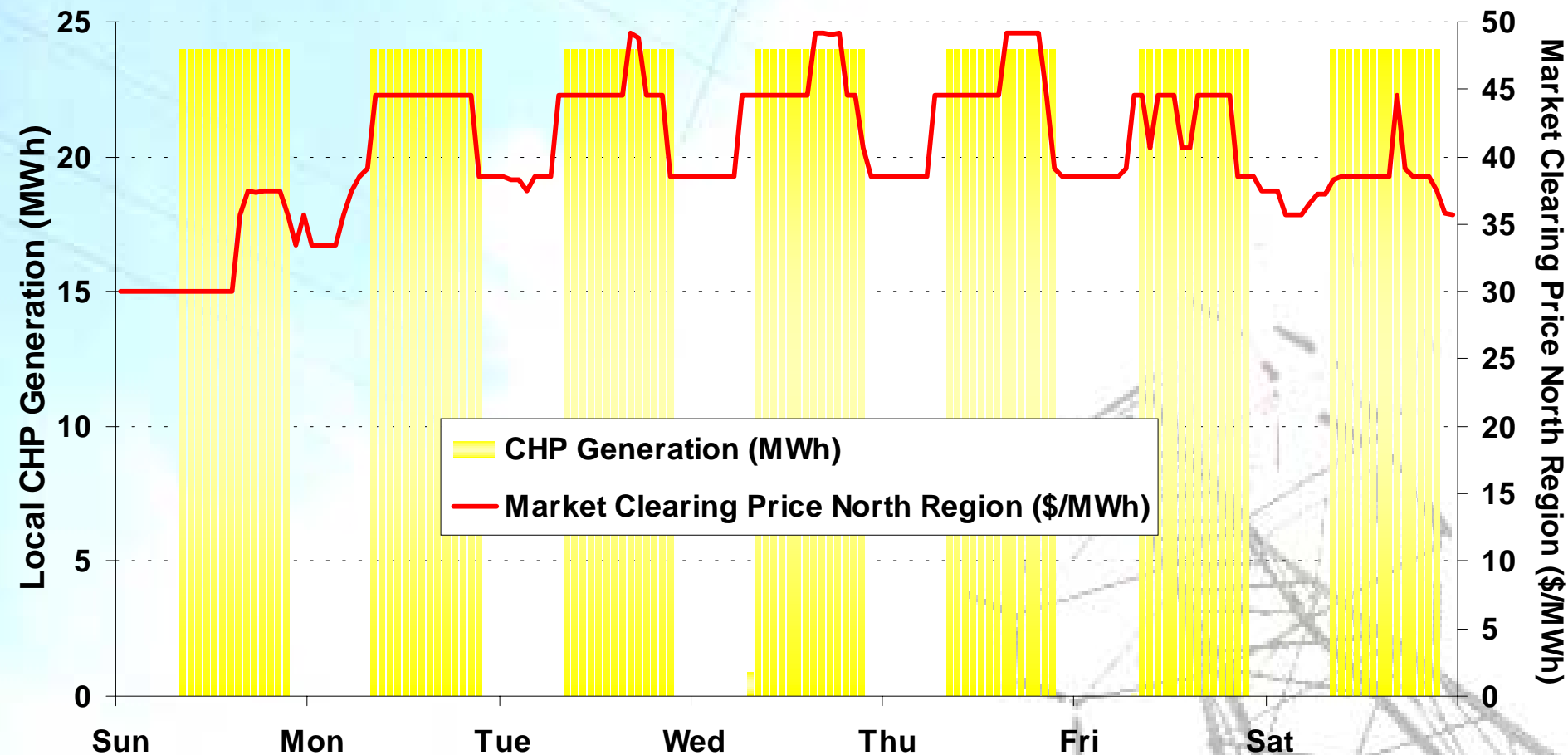
Poland's Pumped Storage Units Increased Loads Off-Peak (Pumping) to Satisfy Peak Demand (Generation)



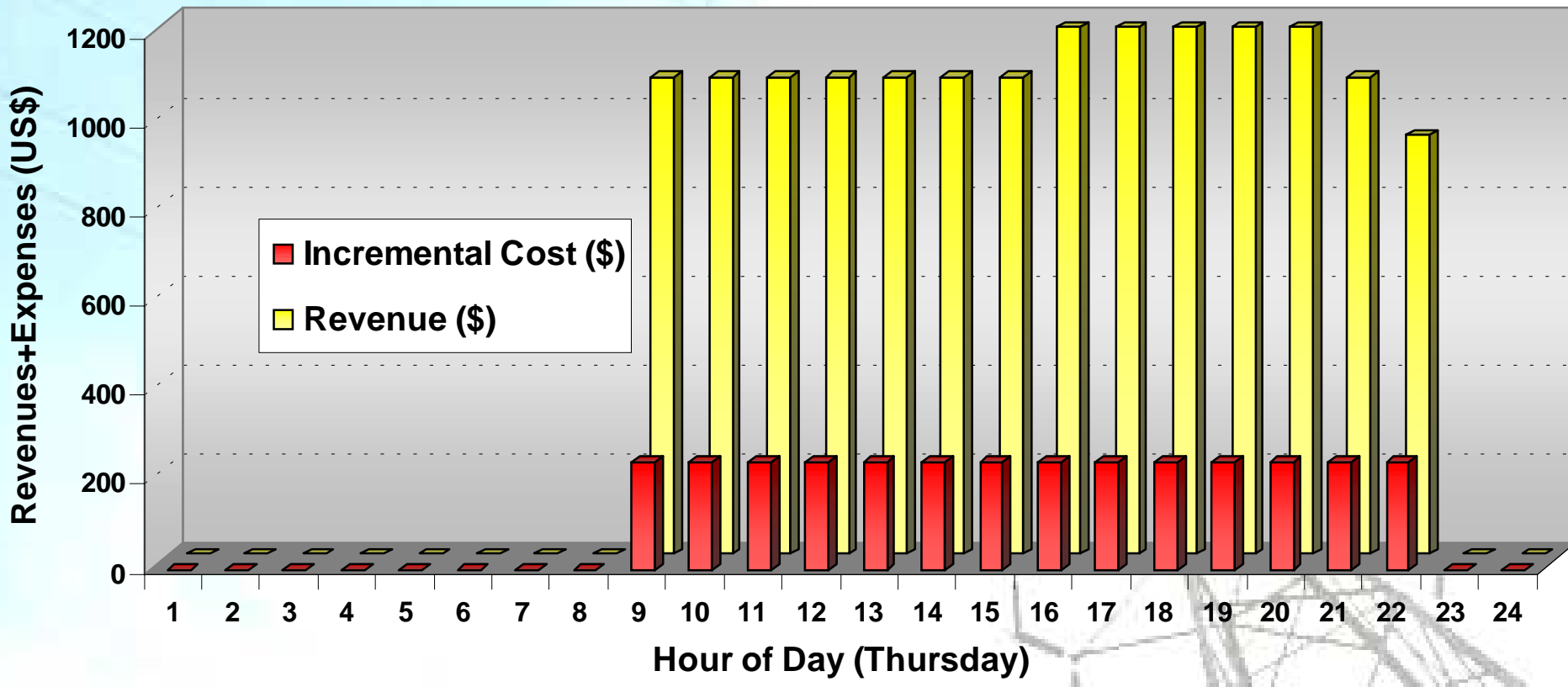
Poland's Pumped Storage Operations Respond to Market Price Signals



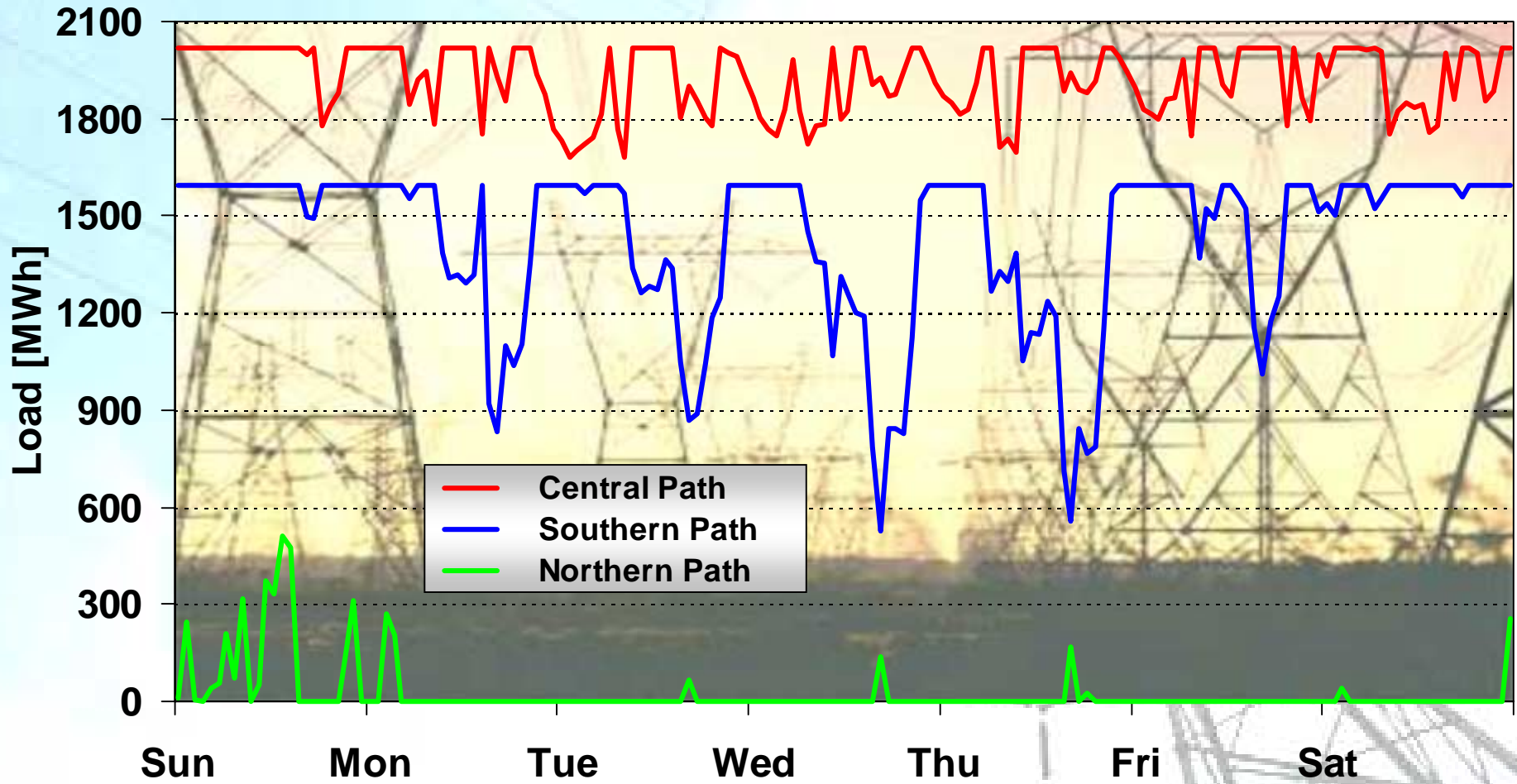
Operation of New Cogenerators in Poland is Driven by Market Prices



Revenues From the New Cogeneration Plant Are Greater Than Production Costs



GTMax Calculated Available Transfer Capabilities for Three Paths From East to West Across Poland



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