MANCHESTER 1824

The University of Manchester

Overview of Power Market Organization

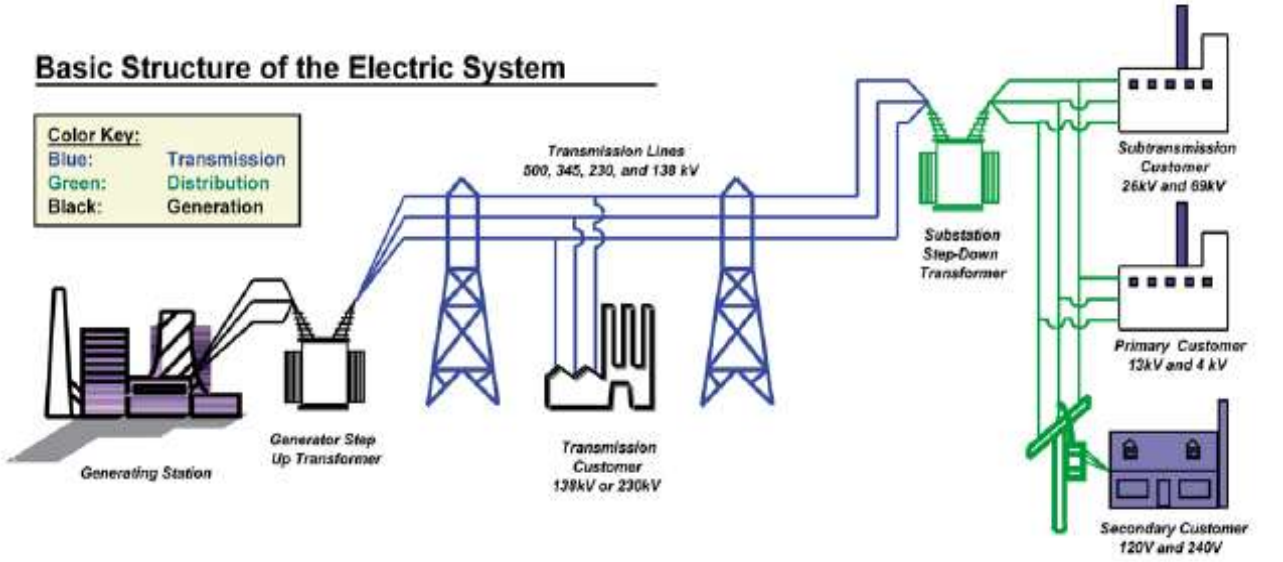
** **Important Acknowledgement**:

These notes are based on lecture slides by Daniel Kirschen for Kirschen/Strbac Chapter 1, with edits by Leigh Tesfatsion

Last Revised: 30 August 2011

Wholesale and Retail Power System Operations

Source: http://www.nerc.com/page.php?cid=1|15

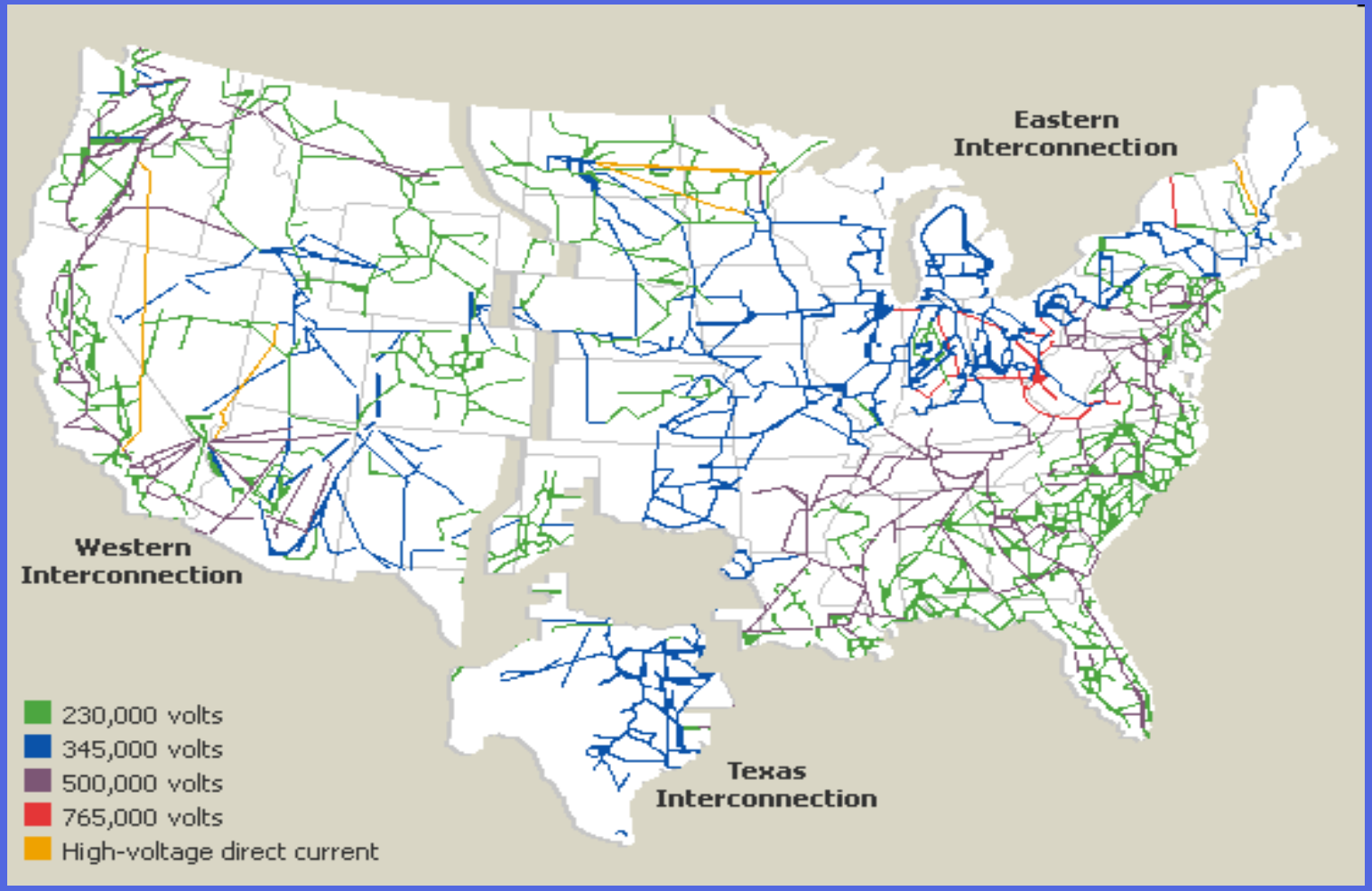


Generation **Transmission** **Distribution**

Wholesale

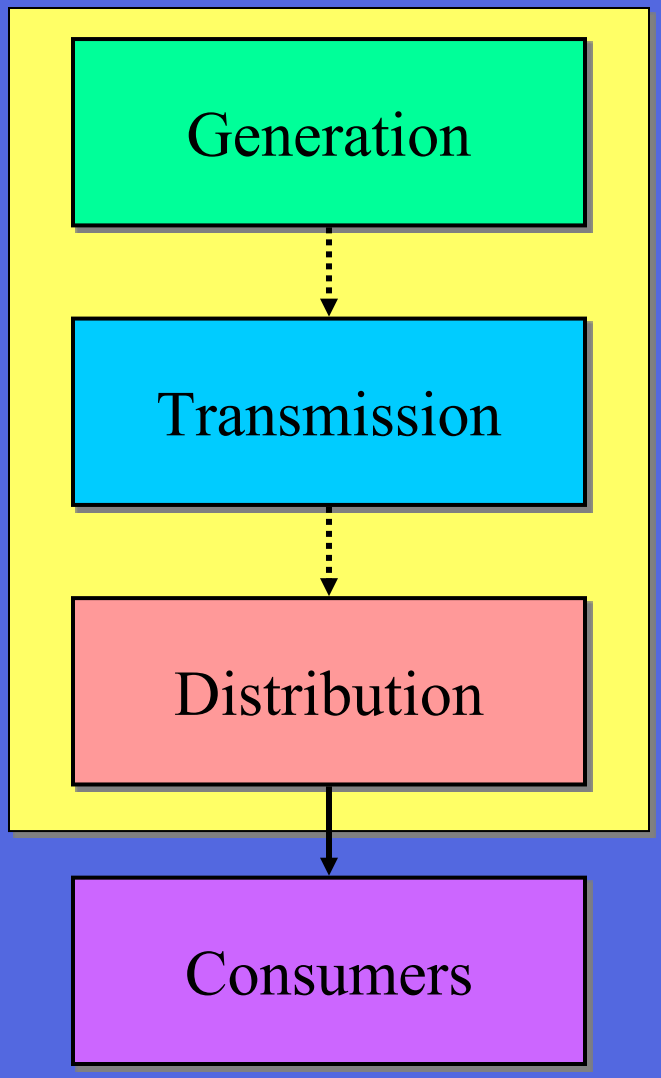
Retail

U.S. High-Voltage Transmission Network



Classification of Competition Models by Hunt & Shuttleworth (1996):

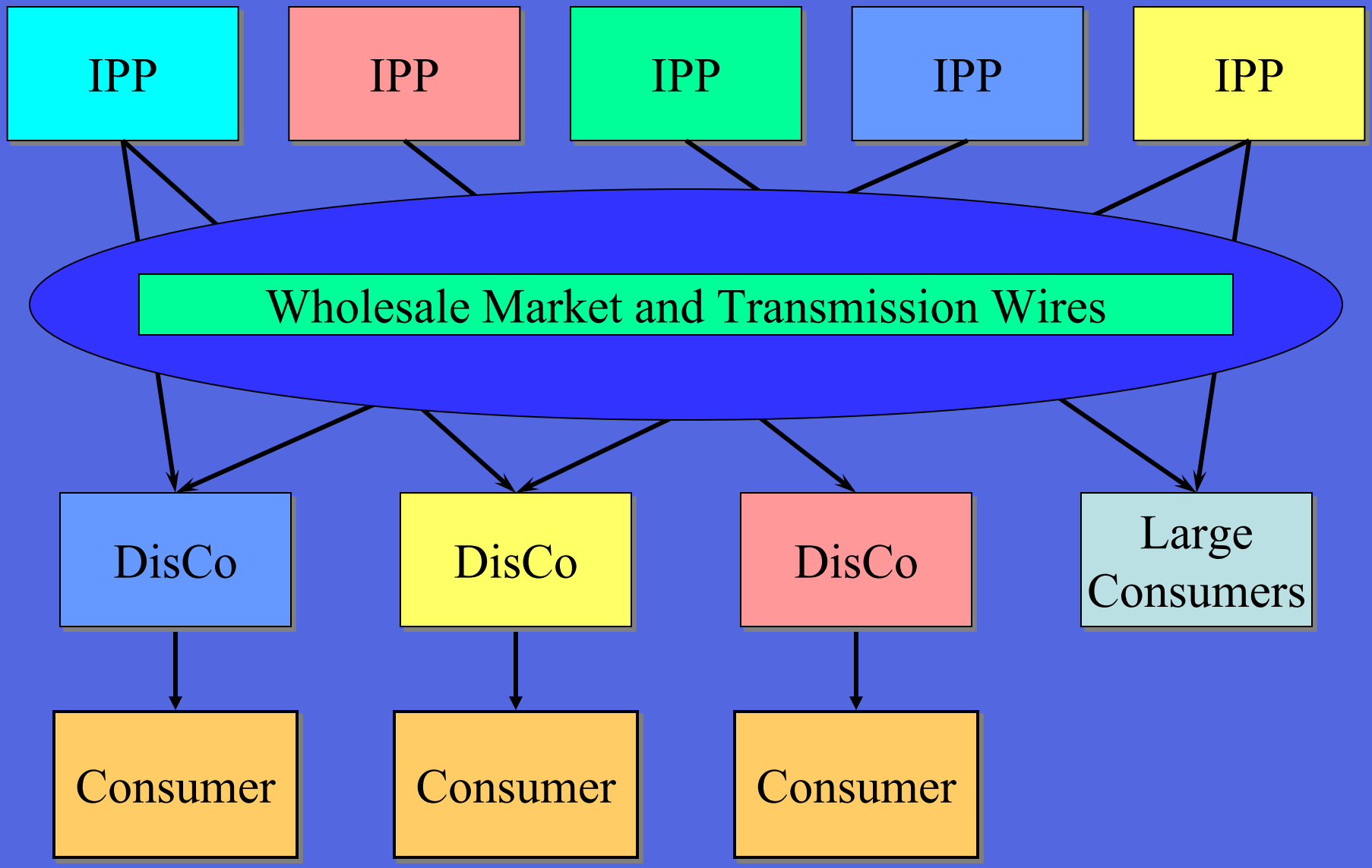
Fig. 1.1(a): Traditional Vertically-Integrated Electric Utility



Monopolistic control of generation, transmission, & distribution

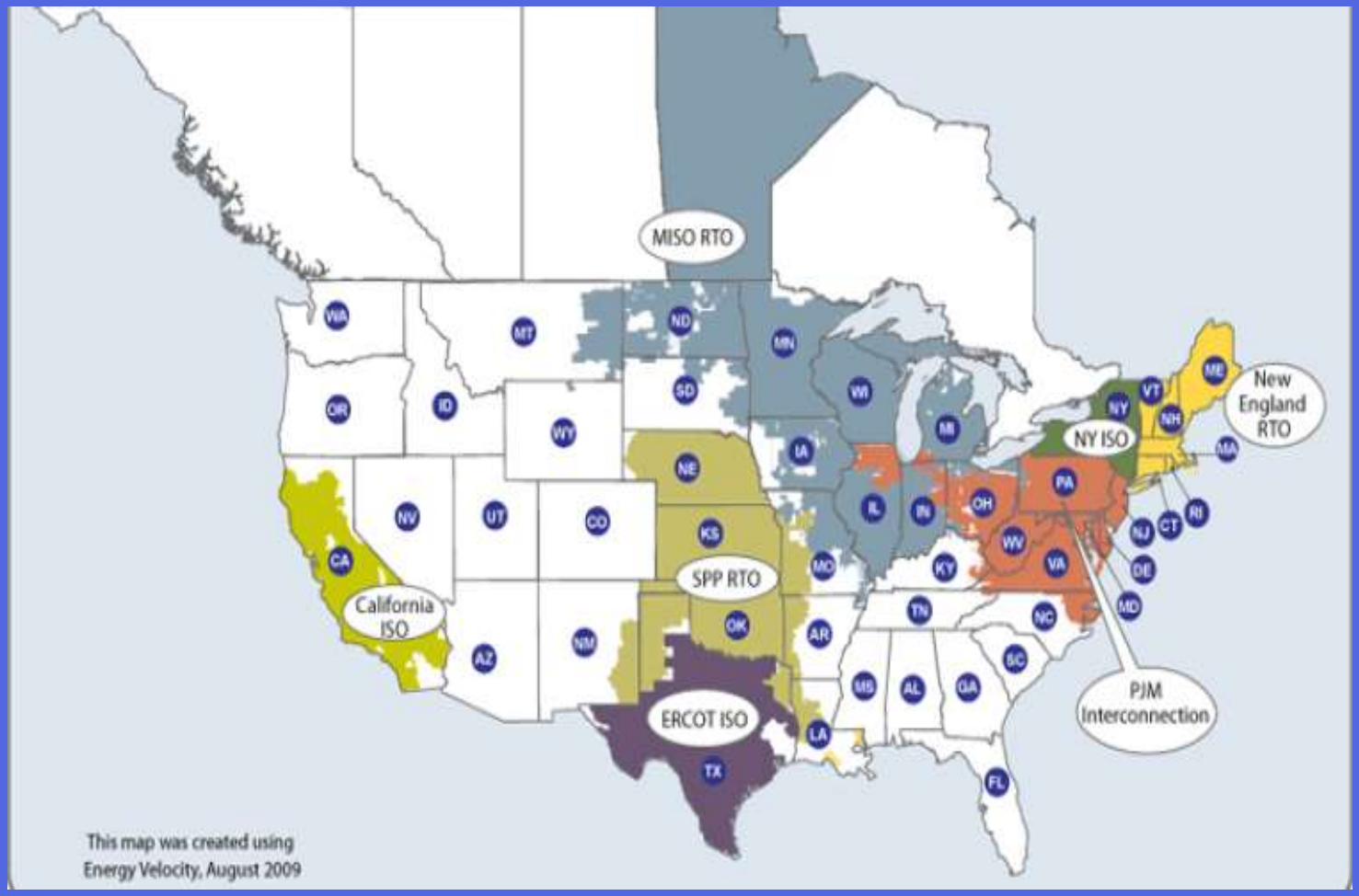
Retail buyers of electrical energy who "use up" (consume) their energy purchases

Figure 1.3: Wholesale Competition Only
(IPP=Independent Power Producer, DisCo=Distribution Company)

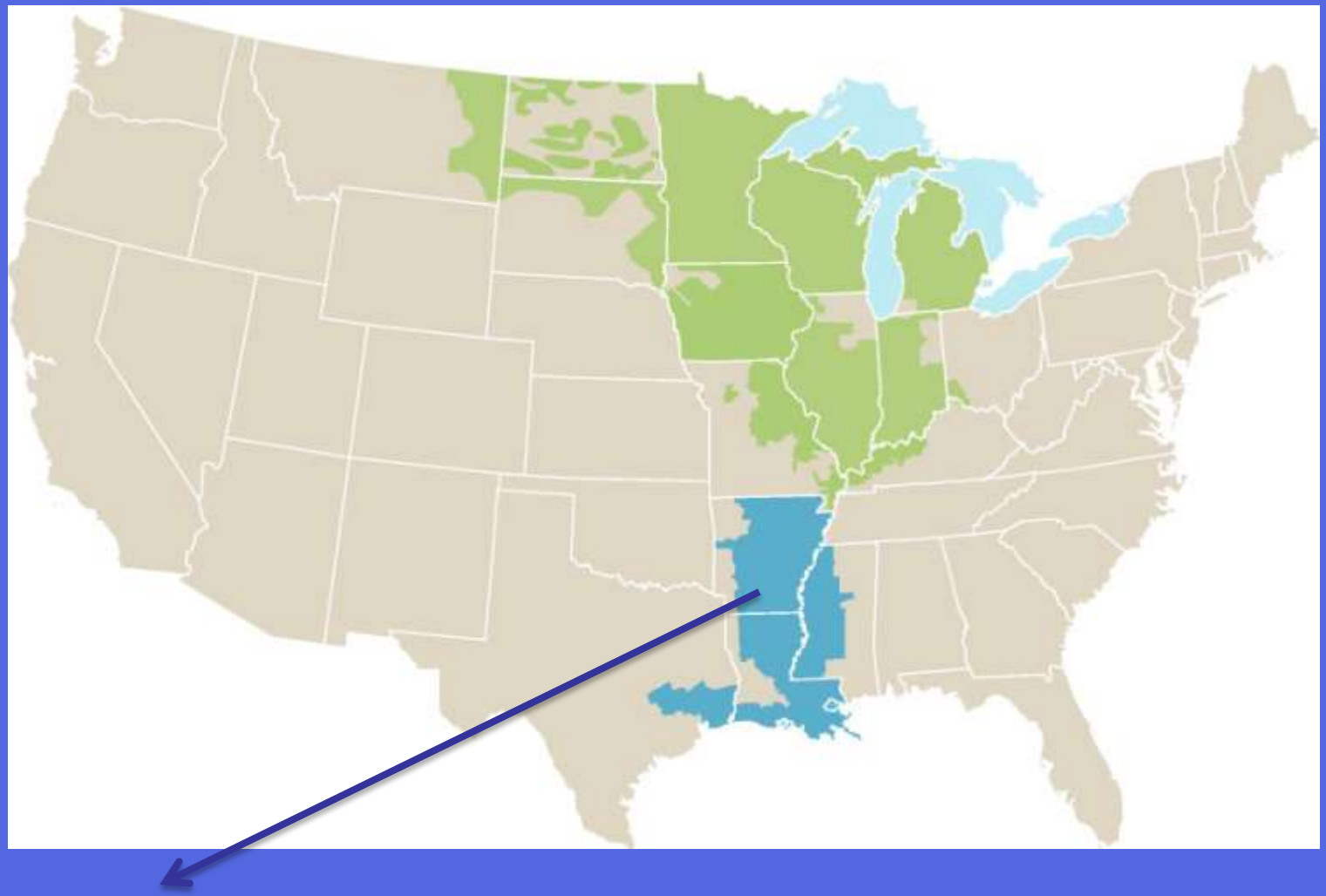


North American energy regions that have restructured their wholesale operations to permit more competition

Source: www.ferc.gov/industries/electric/indus-act/rto/rto-map.asp

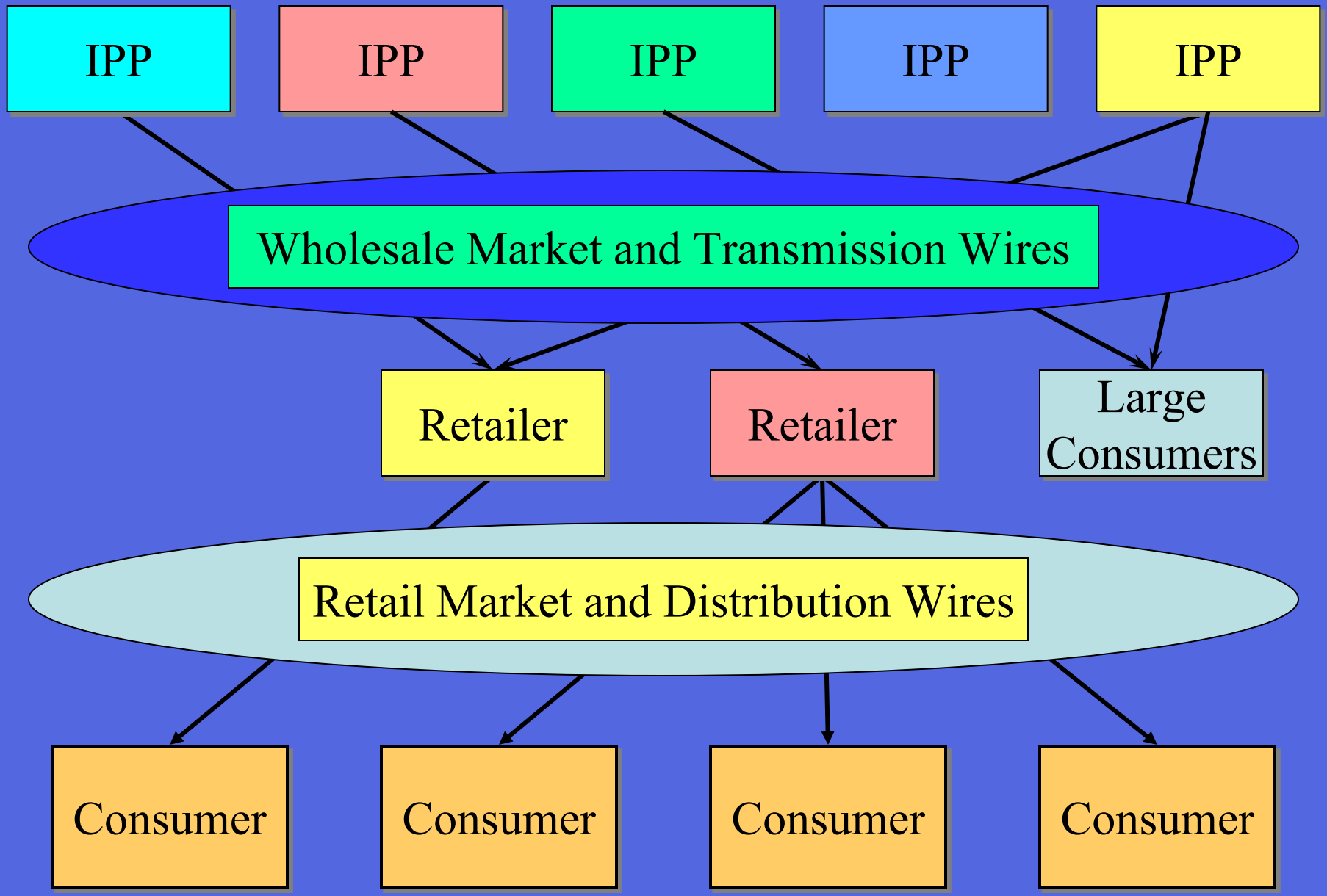


MISO Extended Market Footprint: August 2011

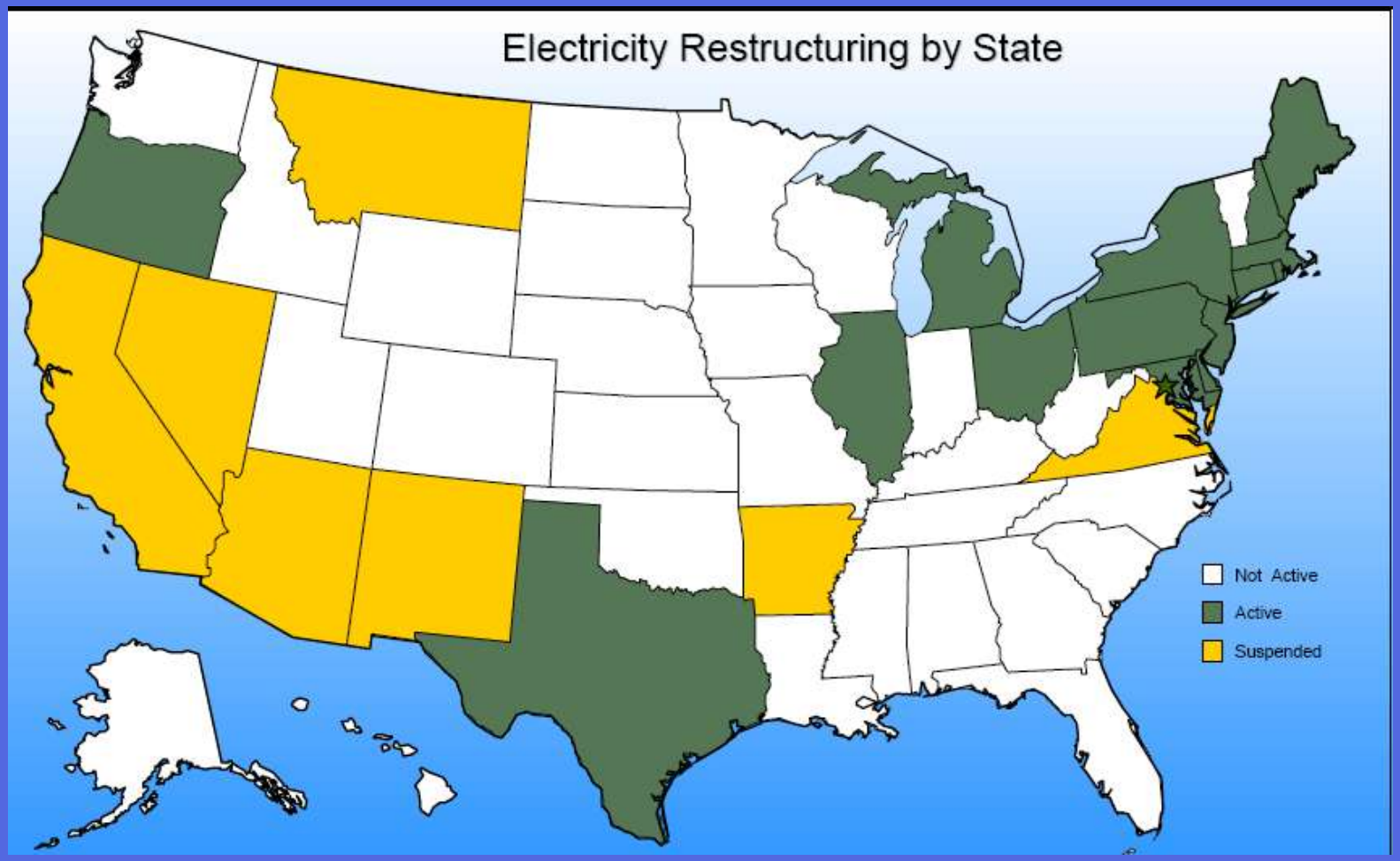


Entergy Electric Territory to join MISO!

Figure 1.4: Both Wholesale and Retail Competition

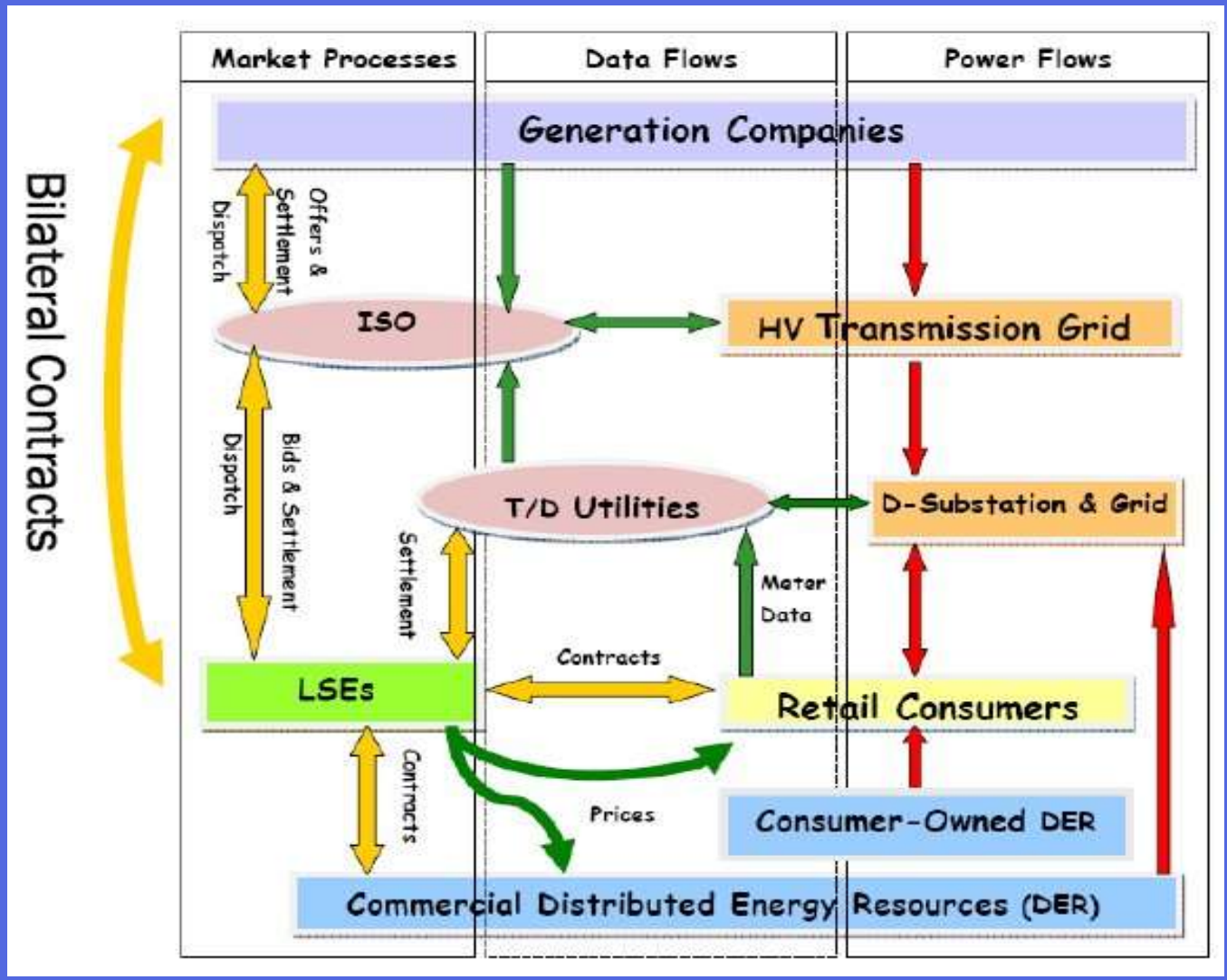


Retail Restructuring in U.S. by State in 2010



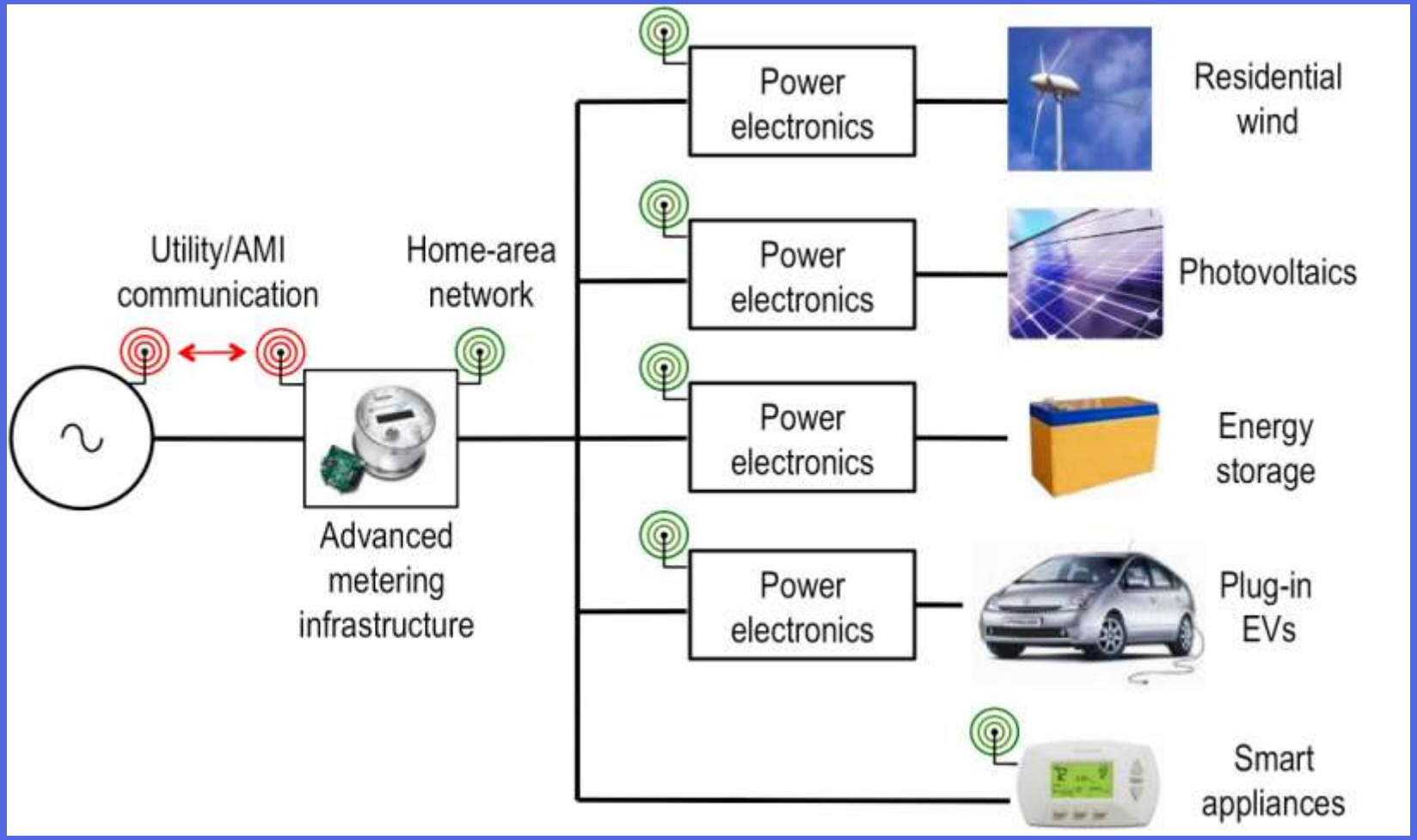
Source: ***http://www.eia.doe.gov/***

Integrated Retail/Wholesale Power Market Operations in the ERCOT (Texas) Energy Region with Retail Competition



Consumer-Owned Distributed Energy Resource Possibilities

Source: Slide by Prof. Dionysios Aliprantis (ECpE, ISU)



Why introduce competitive electricity markets?

- Vertically integrated utilities operating under regulated rates ensuring costs & “normal” profit tend to be inefficient
  - No incentive to operate efficiently
    - Operation costs are higher than they could be
  - No penalty for planning mistakes
    - Costs of unnecessary or poorly considered investments are passed along to consumers
- Potential benefits of introducing competition
  - Increased efficiency in generation and distribution of electric power
  - Lower electric power prices for consumers
  - Promotion of economic growth through appropriate investment in new generation and new transmission

Restructuring Movement: Structural Goals

- Privatization/Unbundling
  - As far as possible, generation and distribution should be separately carried out by multiple private for-profit companies that have to compete with each other for business.
  - Vertically integrated utilities should be broken up by “divestiture” into separate companies
- Competition
  - **Wholesale level:** Generators compete to sell electrical energy
  - **Retail level:** Consumers choose their electrical energy suppliers
  - **Grid:** Regulated to ensure open access for all potential users

Is Unbundling (Divestiture) Really Needed?

- Competitive market will work only if it is fair
- Market participants should not be able to prevent others from competing
- Should management of the transmission/distribution ***networks*** be independent from electrical energy trading?
  - A company should not be able to keep others from competing for energy trades by inducing congestion that prevents power inflow
  - “Open access” to transmission and distribution networks is needed
- More generally, should “wires businesses” be separated from “energy businesses”?
  - Energy businesses can become part of a competitive market
  - Wire businesses must remain regulated (public goods)

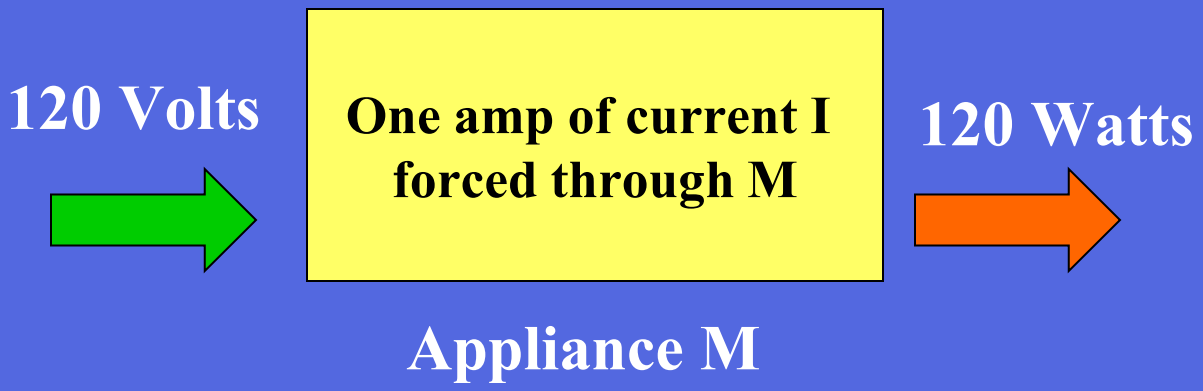
Fundamental underlying assumption:

- Electrical energy should be treated as an ordinary commodity as far as possible.

- Examples of commodities:
  - A bushel of wheat
  - A metric barrel of crude oil
  - A cubic meter of natural gas

How should we define the “unit” for electrical energy as a commodity?

- Volt V (unit of voltage = “electrical pressure”)
- Amp A (unit of electrical current flow I)
- Watt W (unit of power = rate of flow of energy)
- Watt-Hour Wh (unit of energy = accumulation of power)
- **For direct current (DC) systems, Power = V * I :**



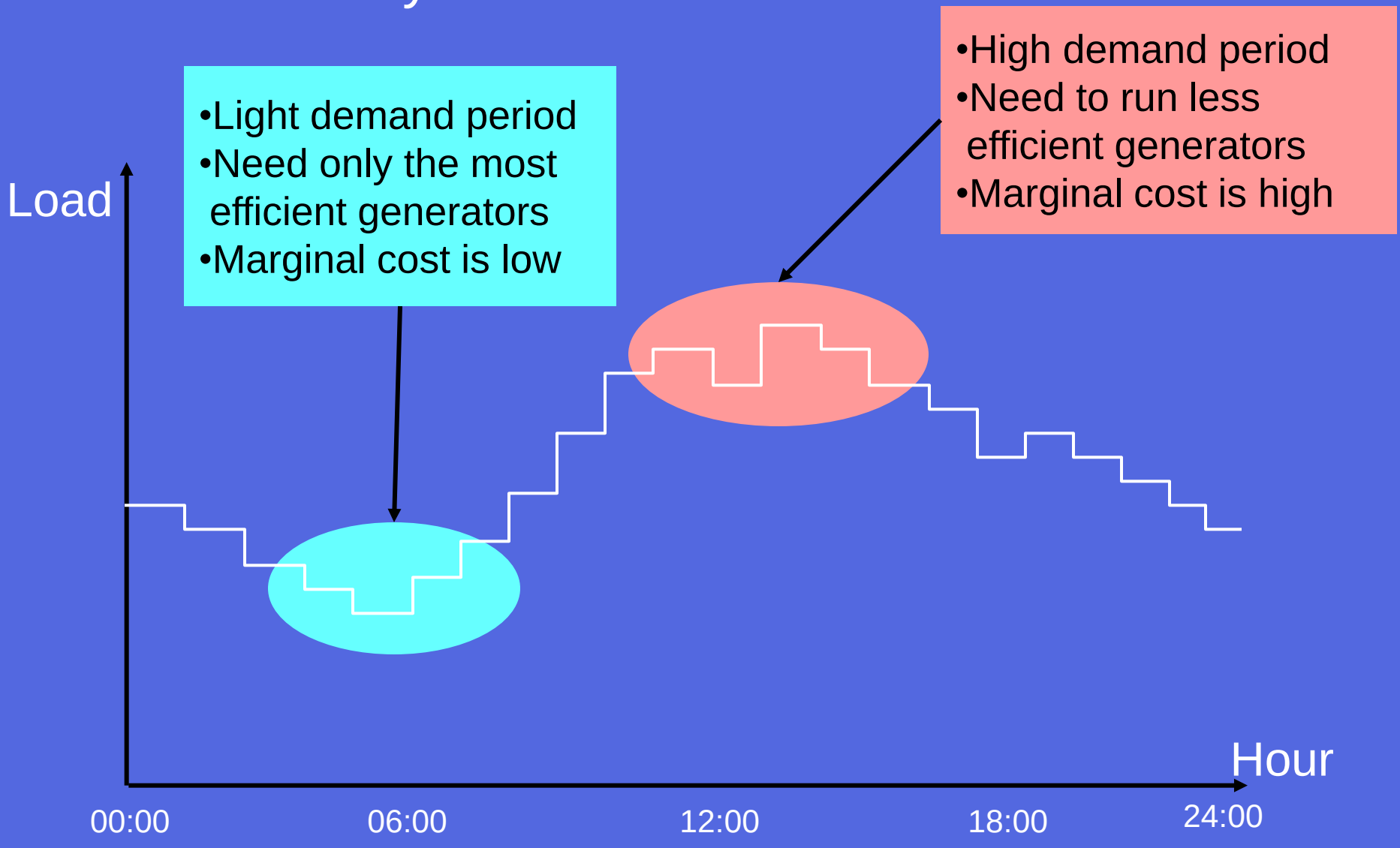
Important characteristics of electrical energy:

- Electrical energy is difficult to store economically
- Electrical energy injections and withdrawals/losses on the HV transmission grid must be balanced at all times
- The demand for electrical energy varies over time
- Cost of producing electrical energy changes with demand

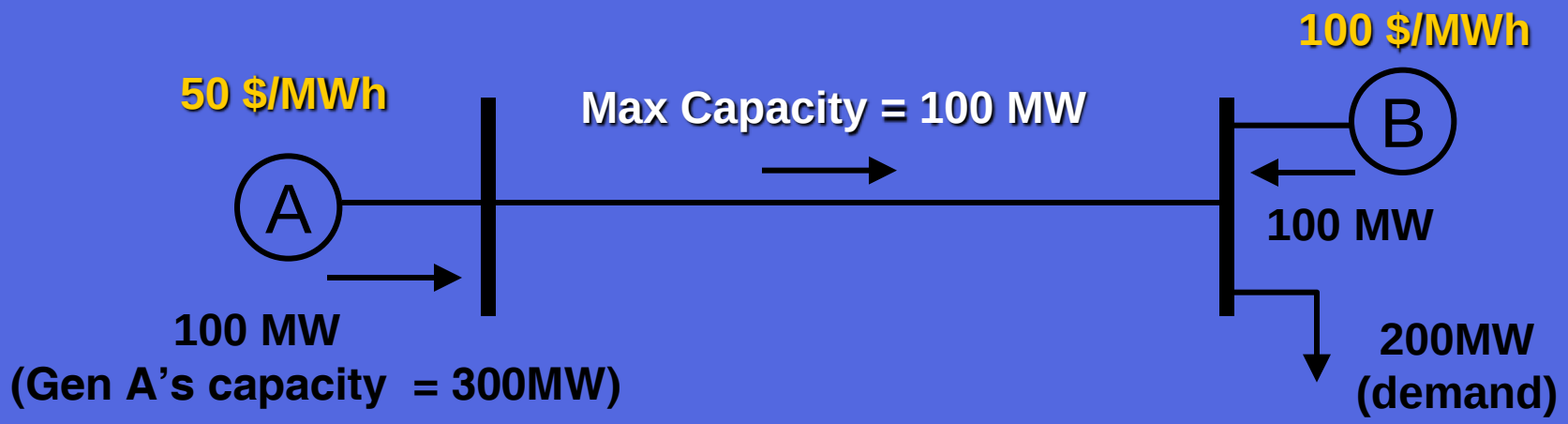
➔ Value of a megawatt-hour (MWh) varies over the course of a day, e.g., a MWh corresponding to a peak demand hour doesn't have same value as a MWh for an off-peak hour.

- Value of a MWh can vary depending on the location of its injection into or withdrawal from the transmission grid.

Effects of daily variations in demand:



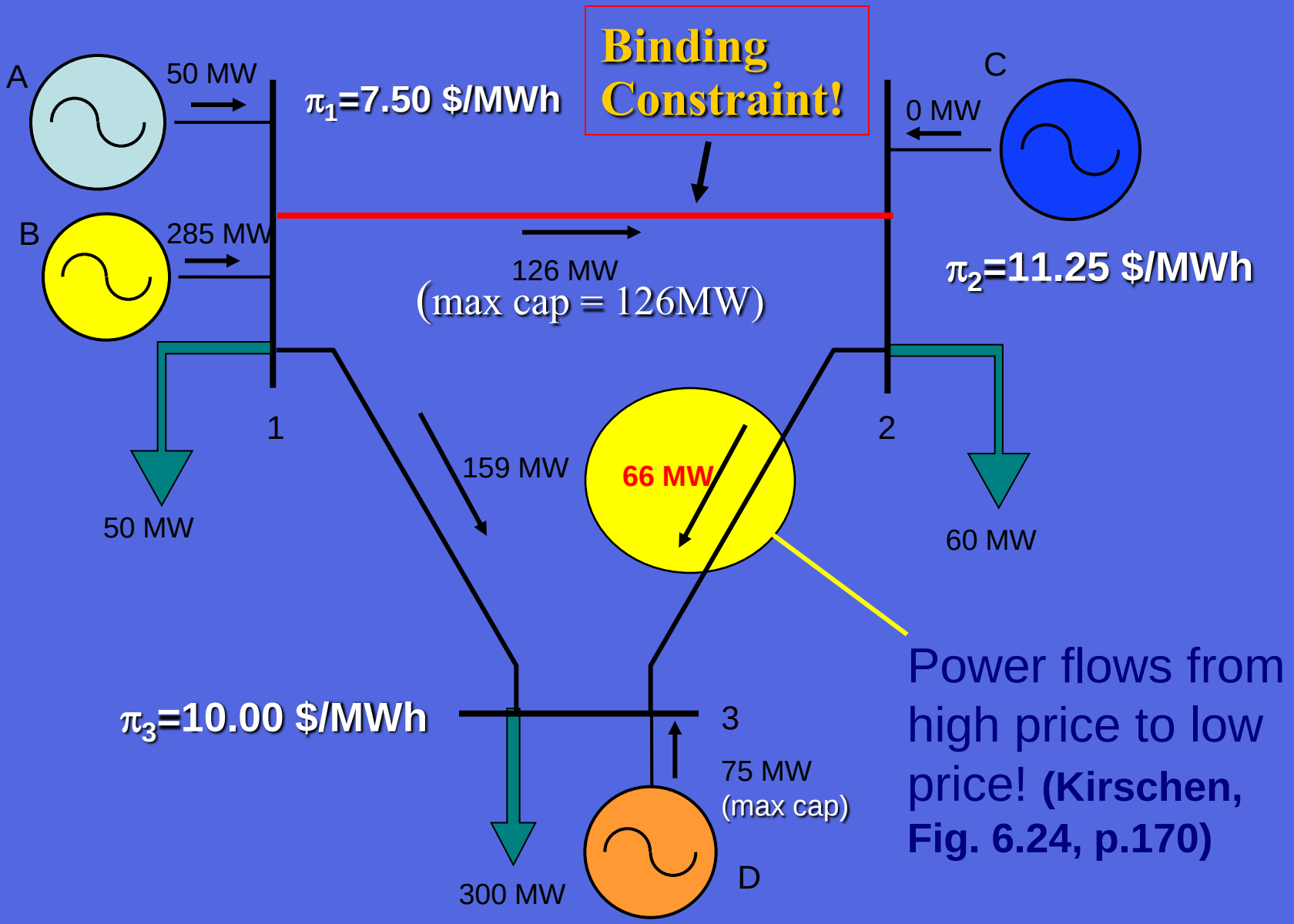
Effects of binding transmission constraints:



- Price of electrical energy at A = marginal cost at A = 50$/MWh
- Price of electrical energy at B = marginal cost at B = 100$/MWh
- Different prices persist at buses A and B because not enough power can flow from A to B to fully service the 200MW demand at B

➔ Binding transmission constraints can segment the market (different energy prices at different buses)

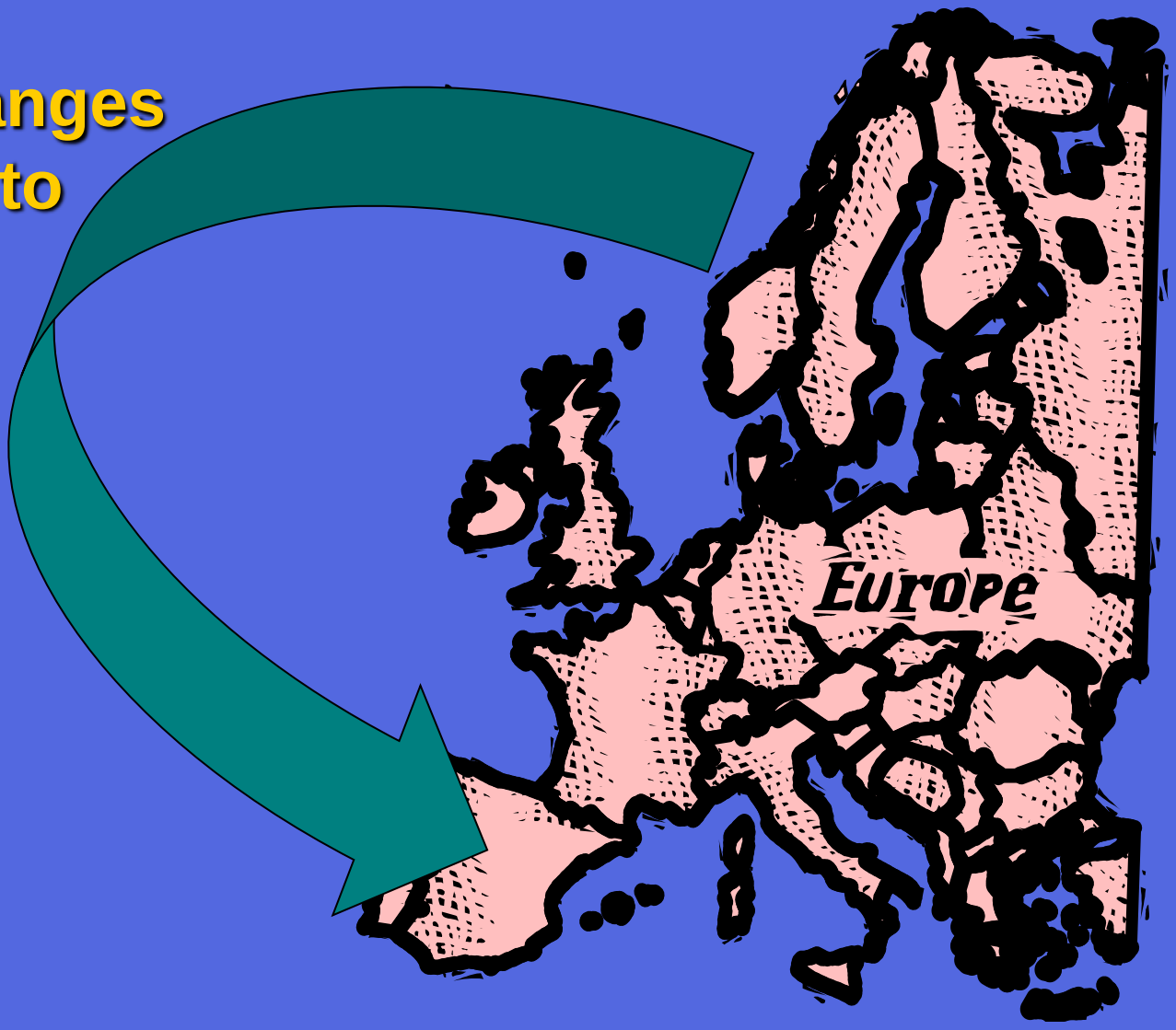
Effects of laws of physics in presence of binding transmission & capacity constraints:



Power flows from high price to low price! **(Kirschen, Fig. 6.24, p.170)**

Effect of the laws of physics

Exporting oranges from Norway to Spain?



Given these characteristics of electrical energy….

- The “unit” for electrical energy as a commodity should be conditioned on both time and location.

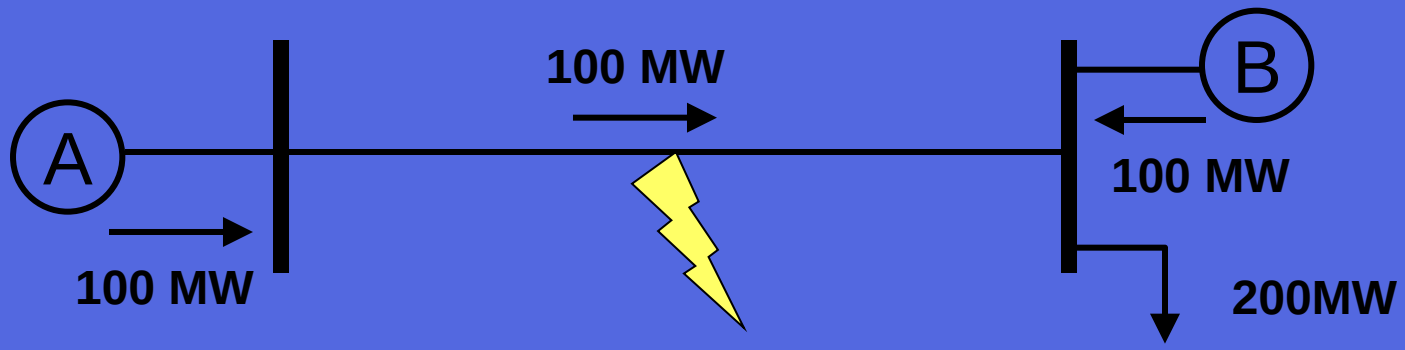
- The basic unit for electrical energy as a commodity is often taken to be the average power (flow of energy) during a particular interval of time at a particular location on the transmission grid.

  Example: 4 MW (= 4 MWh/per h) at bus K during hour H

- Sometimes, however, it is taken to be the energy (accumulation of power) during a particular time interval at a particular location on the transmission grid.

- ***Example:*** 6 MWh of energy withdrawn at bus K during the course of an hour H.

However, security of supply can also affect value:



- Consumers expect a continuous supply of electrical energy
- Electrical energy commodity should be conditioned on security of supply (risk) as well as on time and location.
- Operational risk management through imposition of “security constraints” is an important topic, to be addressed later in the course.

Challenges Posed by Restructuring

- Traditional Organization (Vertically-Integrated Utilities)
  - Each VIU has operational control over gen, trans, & dist in its franchised area, subject to regulatory oversight
  - Regulatory focus on reliability of system operations, not efficiency
- Restructured (Unbundled) Competitive Electricity System
  - Many actors, each controlling one aspect
  - Different perspectives, different objectives
  - Participants include private trading companies (GenCos, DisCos, Retailers), market and transmission operators (ISOs, RTOs), private transmission companies (TransCos), regulators (e.g., FERC, NERC), and consumers
- How to make the system work so that all participants are satisfied (i.e. objectives achieved to satisfactory degree)?

Generating Company (GenCo):

- Produces and sells electrical energy in bulk
- Owns and operates generating plants
  - Single plant
  - Or a portfolio of plants with possibly different technologies
- Often called an Independent Power Producer (IPP) when coexisting with a vertically integrated utility

Objective:

- Maximize the long-run profits it makes from the sale of electrical energy and other services
- ***Note:*** As will be clarified later in the course,

  Profits = [Revenues - Total Costs]

Distribution Company (DisCo):

- Owns and operates distribution network
- Traditional environment:
  - Monopoly for the retail sale of electrical energy to consumers in a given geographical area
- Competitive environment:
  - Operation and development of distribution network separated from the retail sale of electrical energy to consumers
  - Operation of distribution network remains a regulated monopoly

Objective:

- Maximize long-run profits

Retailer (or “Load-Serving Entity” = LSE):

- Buys electrical energy on wholesale market
- Resells this energy “downstream” to retail consumers
- The consumers contracting with any one retailer can be spread over multiple buses & multiple distribution networks
- Typically does not own large physical assets
- Occasionally a subsidiary of a GenCo or a DisCo

Objective:

- Maximize long-run profits by “buying low and selling high”

Market Operator (MO):

- Manages the computer system that matches demand bids and supply offers submitted by buyers and sellers of electrical energy in the **day-ahead market (DAM)**

- Manages the market settlement system
  - Monitors delivery of energy
  - Transmits payments from buyers to sellers

Objective:

- Ensure market efficiency (i.e., avoid wastage of resources)

Independent System Operator (ISO):

- Maintains the security of the system
- Should be independent from other participants to ensure the fairness of the market
- Usually runs the market of last resort (“real-time market”)
  - Ensures generation and load balanced in real time (adequacy)
- In U.S., an ISO typically also acts as a market operator, managing the operation and settlement of a day-ahead market (DAM)
- Owns only computing and communication assets

Objective:

- Ensure system reliability (security and adequacy)
- Ensure efficient market operation (if also an MO)

Transmission Company (TransCo):

- Owns transmission assets such as lines, cables, transformers, and reactive power compensation devices
- Operates these assets according to instructions of an ISO
- TransCos are sometimes subsidiaries of companies that also own generating plants.
- An ***Independent Transmission Company (ITC)*** is a TransCo that does not own generating plants and that operates its own assets (acts as its own ISO)

Objective:

- Maximization of long-run profits

Regulators:

- Government bodies
- Determine or approve market rules
- Investigate suspected “market power” abuses (manipulation of prices for one’s own gain)
- Set or constrain the prices for products and services provided by monopolies

Objectives:

- Make sure that the overall electrical energy sector operates in a ***fair and economically efficient*** manner
- Make sure the overall electrical energy sector operates in a ***reliable*** manner (security and adequacy)
- Ensure quality of supply

Small Retail Consumer (Typically Residential):

- Buys electrical energy from a retailer
- Leases wire connection from the local DisCo
- Market participation is usually limited to choice of retailer

Objectives:

- Maximize net benefits (i.e., benefits minus costs) from use of electrical energy
- Obtain a satisfactory quality of supply

Large Retail Consumer (Commercial, Industrial):

- Often participates actively in electrical energy markets
- Buys electrical energy directly from wholesale market
- Sometimes connected directly to the transmission grid
- May act as a “demand response” resource for the ISO to help control the system (e.g., agree to have its demand curtailed under certain stated conditions)

Objectives:

- Maximize long-run profits
- Obtain a satisfactory quality of supply