MANCHESTER 1824

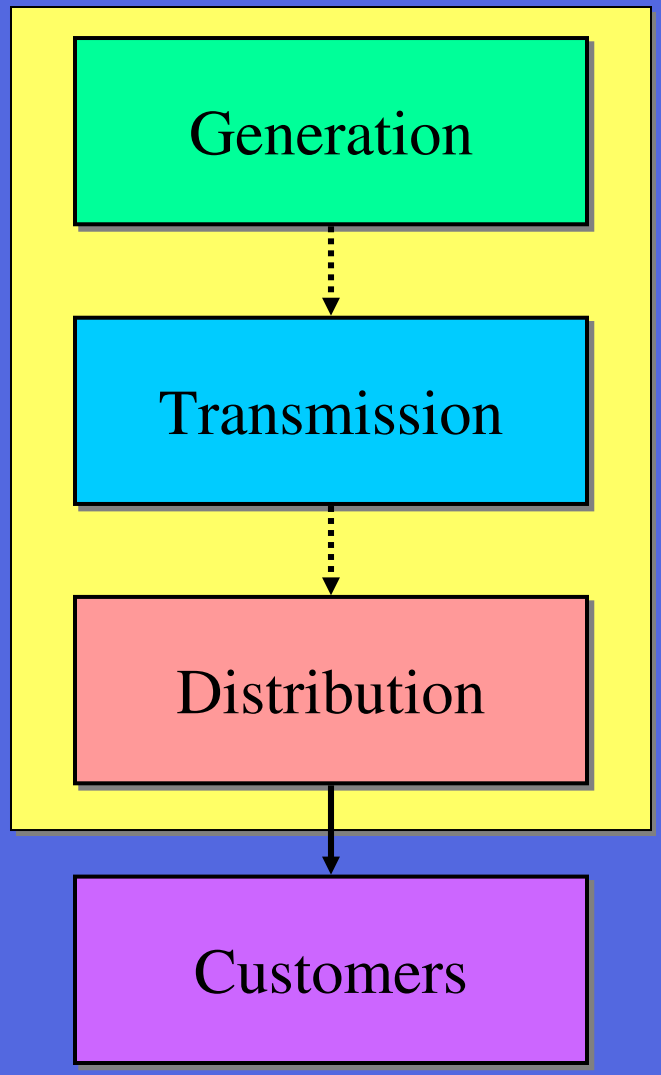
The University of Manchester

Power System Economics: Introduction

** **Important Acknowledgement**:

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

Classification of Competition Models by Hunt & Shuttleworth (1996): Fig. 1.1(a): Traditional Vertically-Integrated Electric Utility



Monopolistic control of generation, transmission, & distribution

Retail Consumers

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

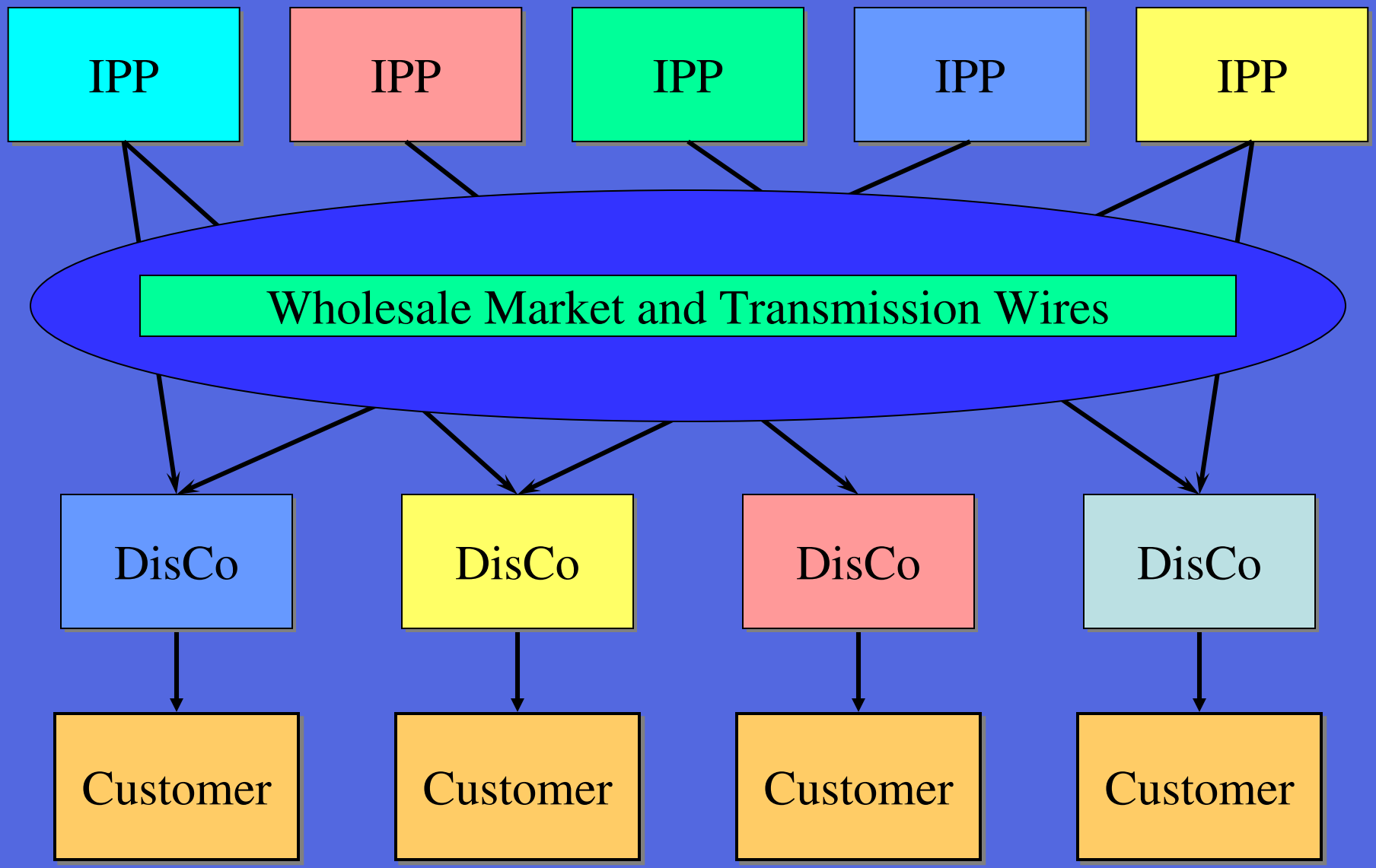
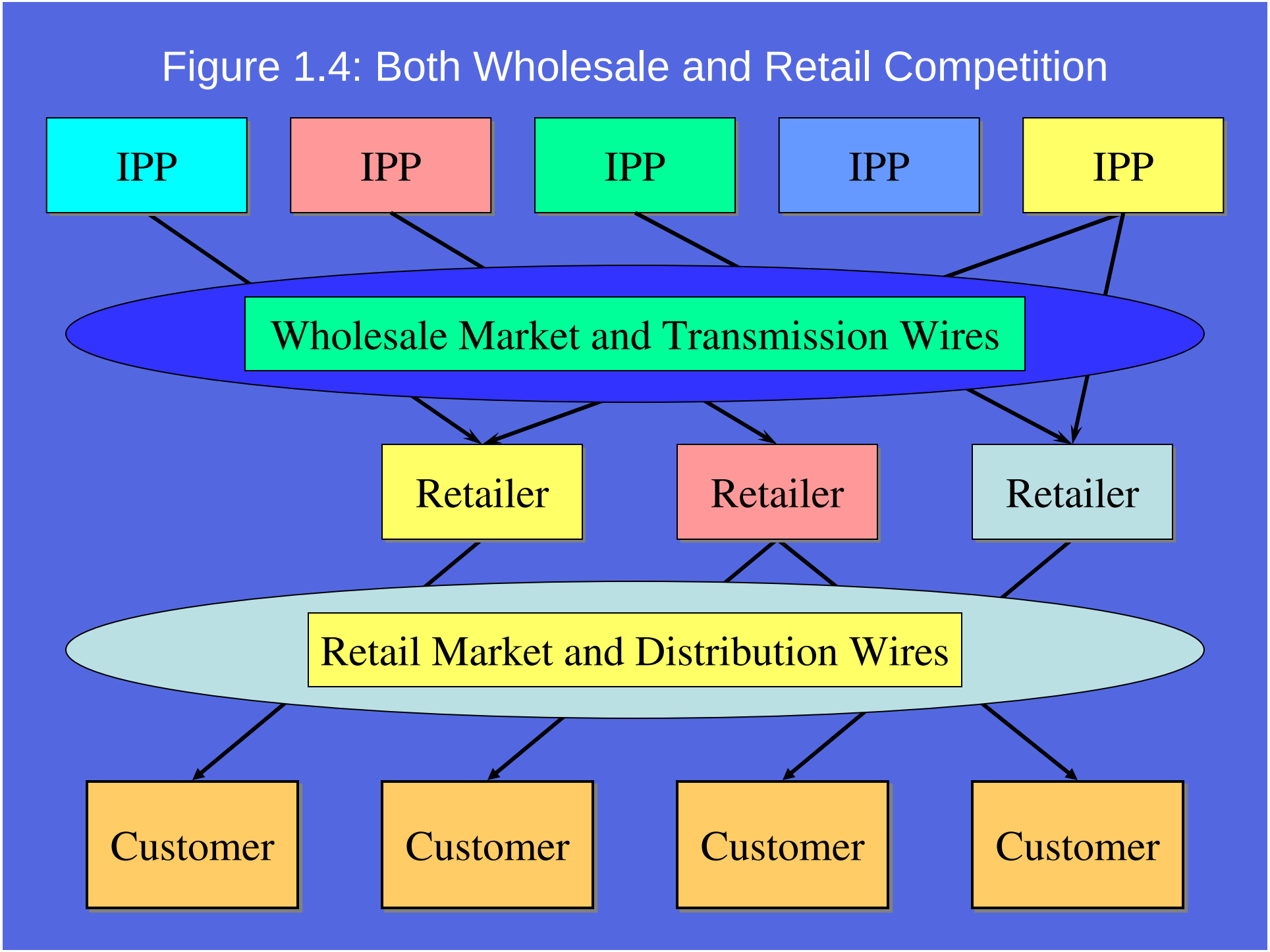


Figure 1.4: Both Wholesale and Retail Competition



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 electric power
  - **Retail level:** Consumers choose from whom they buy electric power
  - **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 marketable commodity as far as possible.

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

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

- A Volt?
- An Ampere?
- A MW?
- A MWh?

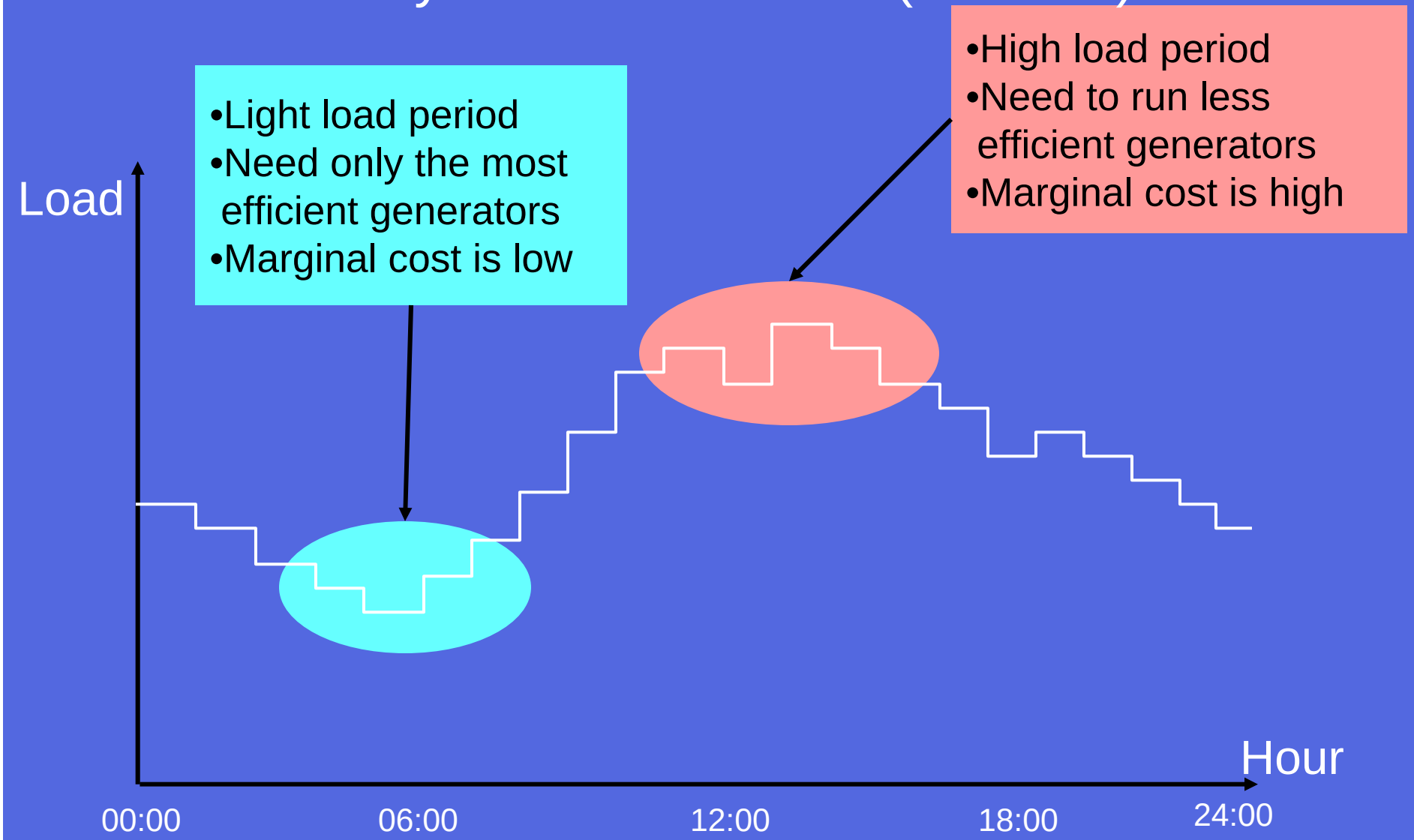
Important characteristics of electrical energy:

- Electrical energy cannot be stored economically
- Electrical energy must be produced when it is consumed
- Load (demand) for electrical energy varies over time
- Cost of producing electrical energy changes with the load

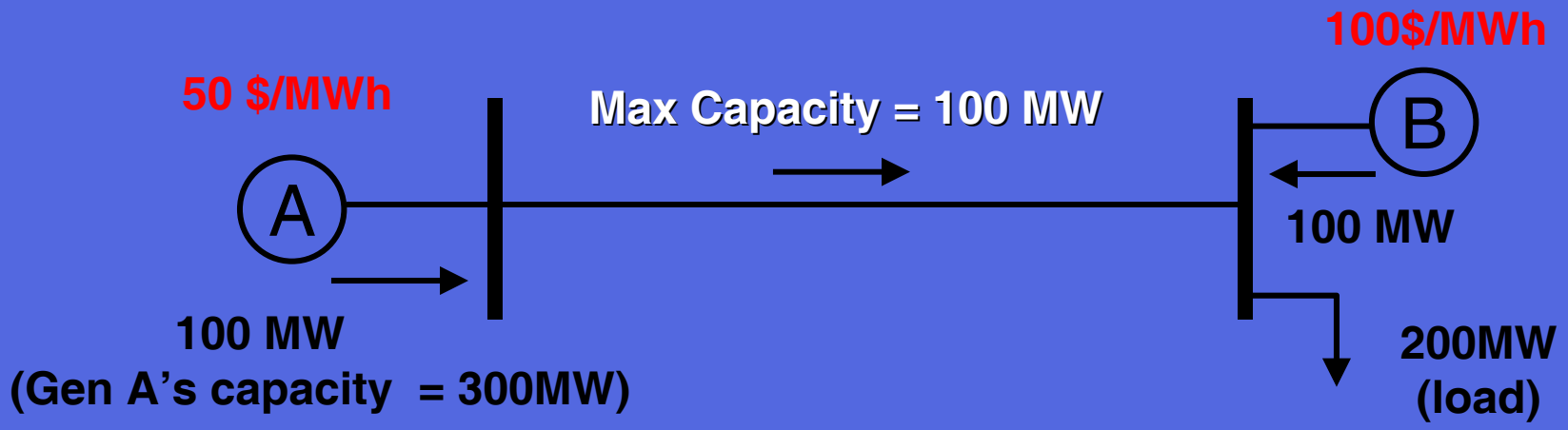
➔ Value of a MWh varies over the course of a day, e.g., a MWh corresponding to a peak hour for load doesn't have same value as a MWh for an off-peak hour.

- 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 load (demand):



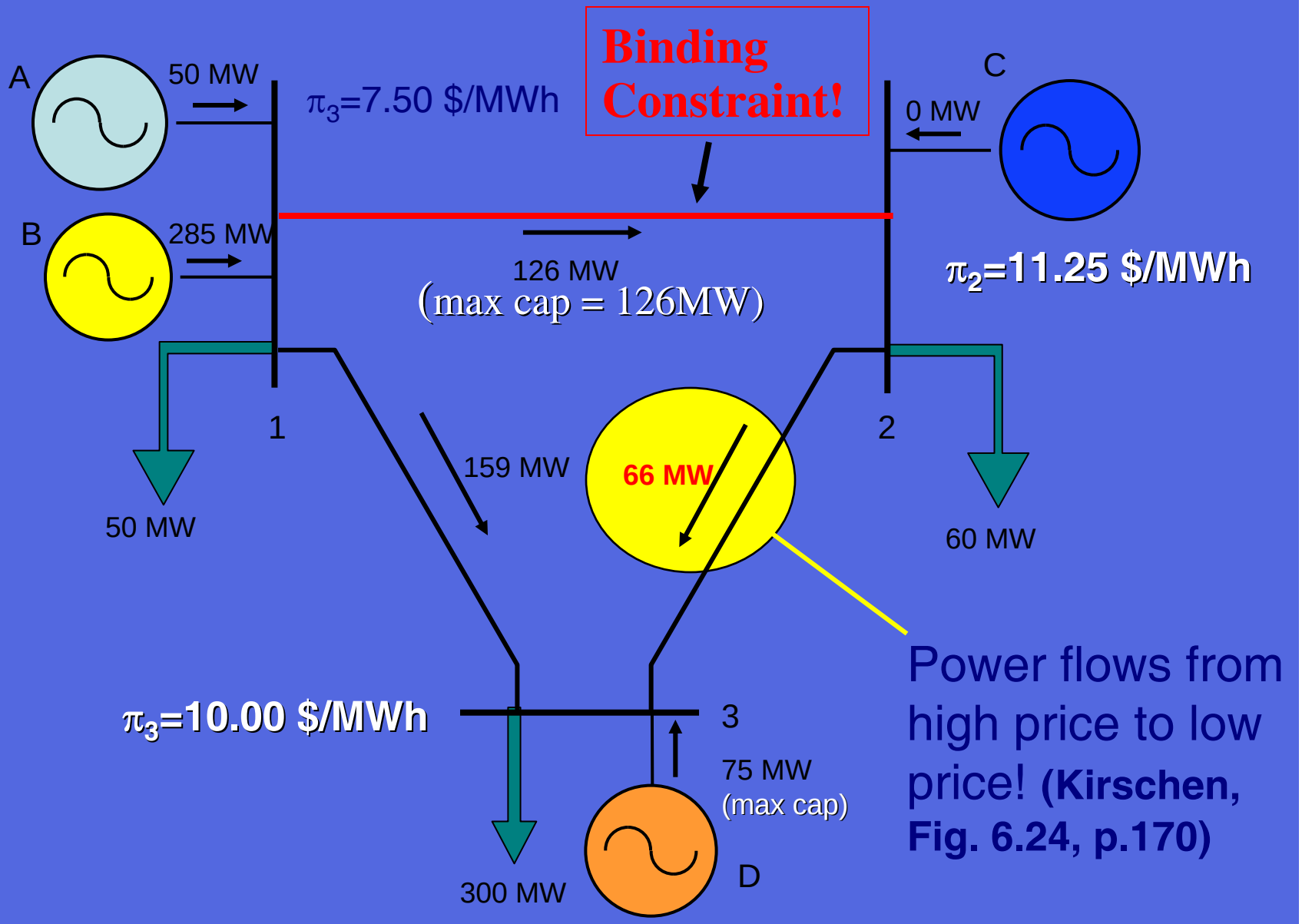
Effects of binding transmission constraints:



- Price of electricity at A = marginal cost at A = 50$/MWh
- Price of electricity at B = marginal cost at B = 100$/MWh
- Different prices persist at busses A and B

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

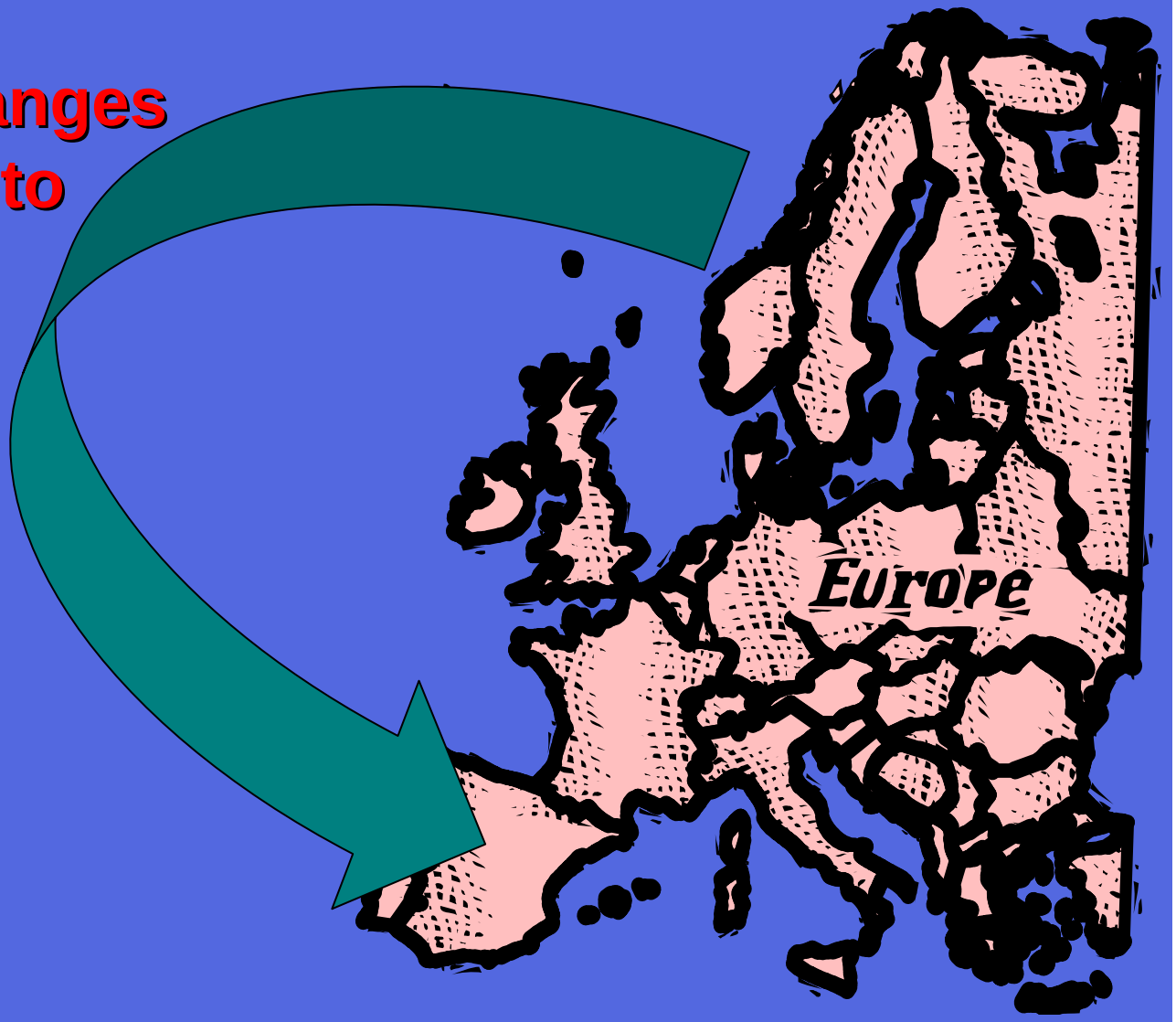
Effects of laws of physics in presence of binding transmission & capacity constraints:



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?



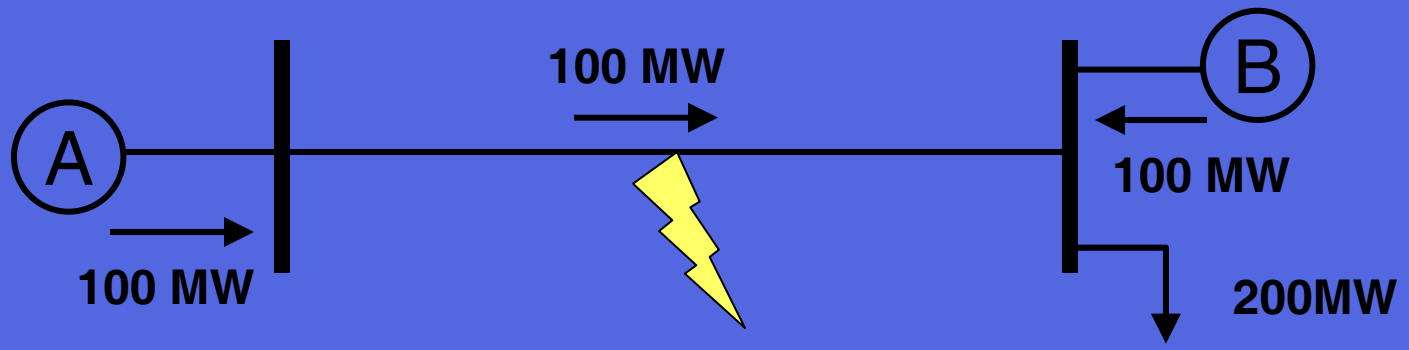
Given these characteristics of electrical energy….

- 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 (= MWh/per h) at bus K during hour H

- Sometimes, however, it is taken to be the total energy (accumulation of power) during a particular time interval at a particular location on the transmission grid.
- ***Example:*** 6 MWh at bus K during hour H.

However, security of supply can also affect value:



- Consumers expect a continuous supply of electricity
- 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 operators, independent system operators (ISOs), 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
  - Portfolio of plants with different technologies
- Often called an Independent Power Producer (IPP) when coexisting with a vertically integrated utility

Objective:

- Maximize the profit it makes from the sale of energy and other services

Distribution Company (DisCo):

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

Objective:

- Maximize regulated profit

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

- Buys electrical energy on wholesale market
- Resells this energy “downstream” to retail customers
- The customers of any one retailer can be spread over multiple distinct distribution networks
- Does not own large physical assets
- Occasionally a subsidiary of a GenCo or a DisCo

Objective:

- Maximize profit earned from the difference between wholesale and retail prices ***(buy low, sell high)***

Market Operator (MO):

- Runs the computer system that matches bids and offers submitted by buyers and sellers of electrical energy in the “day-ahead market” (DAM)
- Runs the market settlement system
  - Monitors delivery of energy
  - Transmits payments from buyers to sellers

Objective:

- Run an efficient market to encourage trading

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”)
  - Balances the generation and load in real time
- Owns only computing and communication assets

Objective:

- Ensure system security

Transmission Company (TransCo):

- Owns transmission assets such as lines, cables, transformers, and reactive 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 regulated profit (TransCo) or profit (ITC)

Regulators:

- Government bodies
- Determine or approve market rules
- Investigate suspected abuses of “market power”
- Set the prices for products and services provided by monopolies

Objectives:

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

Small Consumer (Typically Residential):

- Buys electricity from a retailer
- Leases a connection from the local DisCo
- Participation in markets is usually limited to choice of retailer

Objectives:

- Pay as little as possible for electrical energy
- Obtain a satisfactory quality of supply

Large Consumer (Commercial, Industrial):

- Often participates actively in electricity markets
- Buys electrical energy directly from wholesale market
- Sometimes connected directly to the transmission grid
- May offer load control ability to the ISO to help control the system

Objectives:

- Pay as little as possible for electrical energy
- Obtain a satisfactory quality of supply

Outline of the Remainder of the Course

- Micro Basics for Power Markets (markets, firms, costs, game theory)
- Optimization Basics for Power Markets
- Organization of Power Markets
- Power Market Trading Subject To Transmission Constraints
  - Power Systems and LMP Fundamentals
  - Bid/Offer-Based Optimal Power Flow
- Real-World Examples: Policy Concerns
- Financial and Operational Risk Management (Reliability, FTRs)
- Investment in New Generation
- Investment in New Transmission
- Environmental Issues
- Future Prospects for Restructuring