Overview of Facilities of the New England Electrical System

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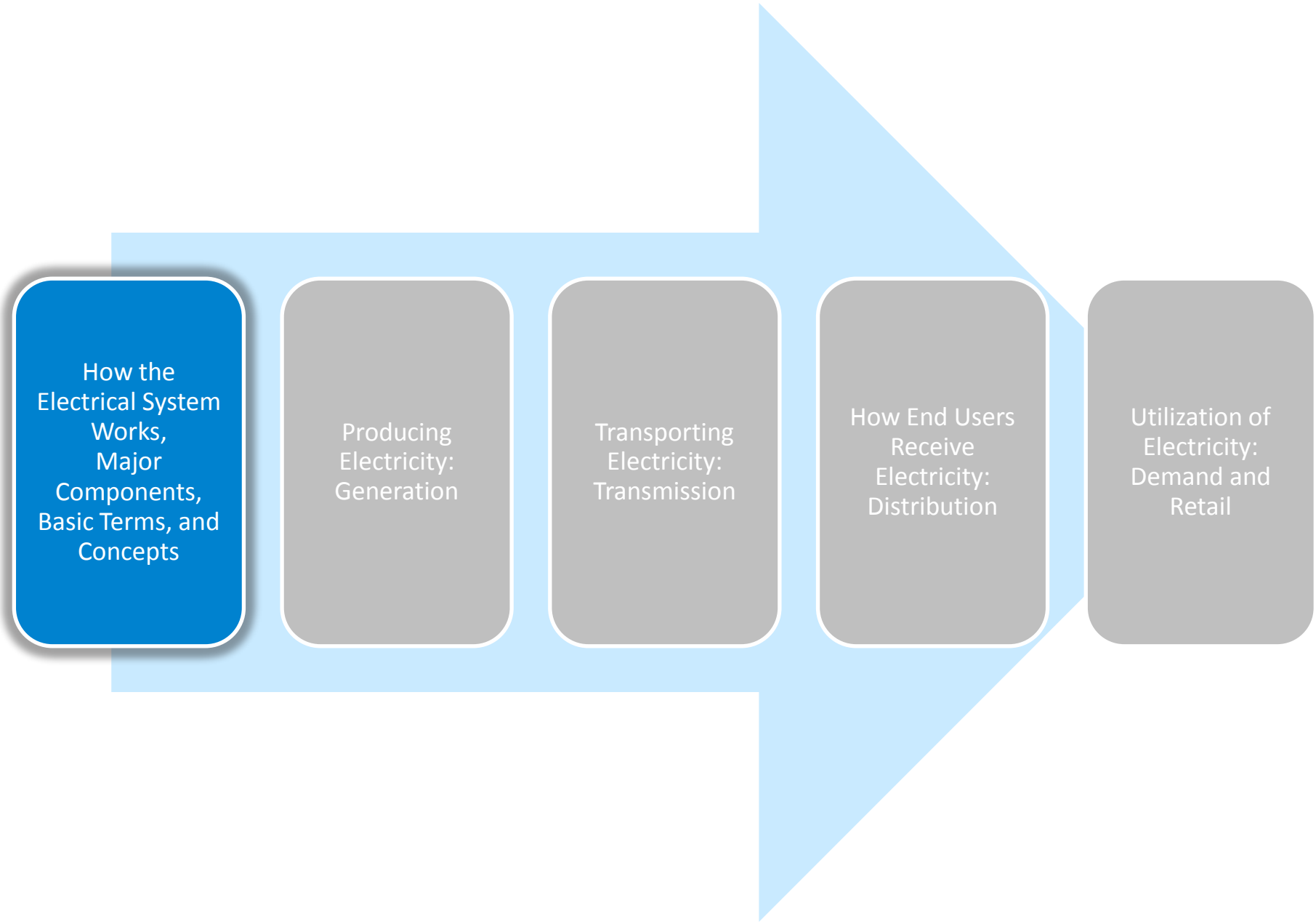
Module Objective

- To provide a high-level overview of the New England electric system by reviewing basic terms and concepts

Topics Covered

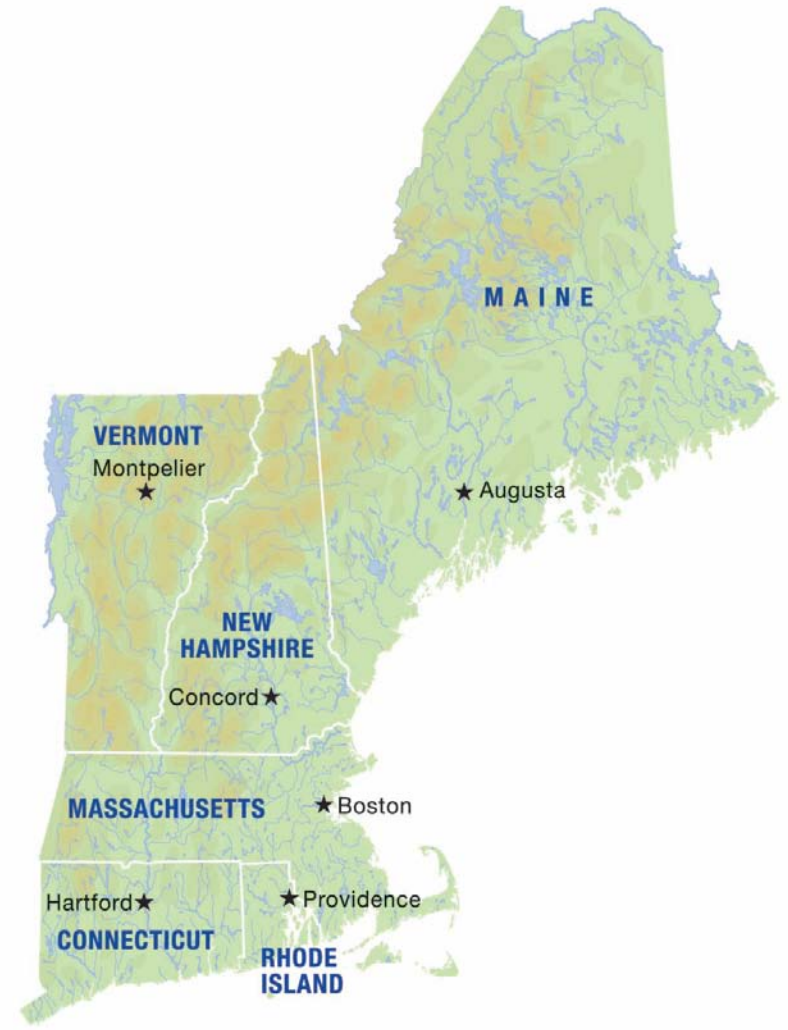
- How the Electrical System Works, Major Components, Basic Terms, and Concepts
- Producing Electricity: Generation
- Transporting Electricity: Transmission
- How End Users Receive Electricity: Distribution
- Utilization of Electricity: Demand and Retail



New England's Electric Power Grid

A Tightly Integrated Regional Power System

- 6.5 million households and businesses; population 14 million
- More than 300 generators
- Over 8,000 miles of high-voltage transmission lines
- 13 interconnections to electricity systems in New York, Québec, and New Brunswick
- More than 32,000 megawatts (MW) of total supply
- 2,200 MW of Demand Response
- System peak:
  - Summer: 28,130 MW (August 2006)
  - Winter: 22,818 MW (January 2004)
- More than 400 participants in the marketplace
- $5-11 billion annual total energy market value



Major Components of the Electrical System

Generation

- Production of electricity

Transmission

- Transportation of the electricity to distribution system

Distribution

- Moving electricity to the end-user

Demand

- Amount of electricity consumed by the end-user

Basic Terms and Concepts

Electric System

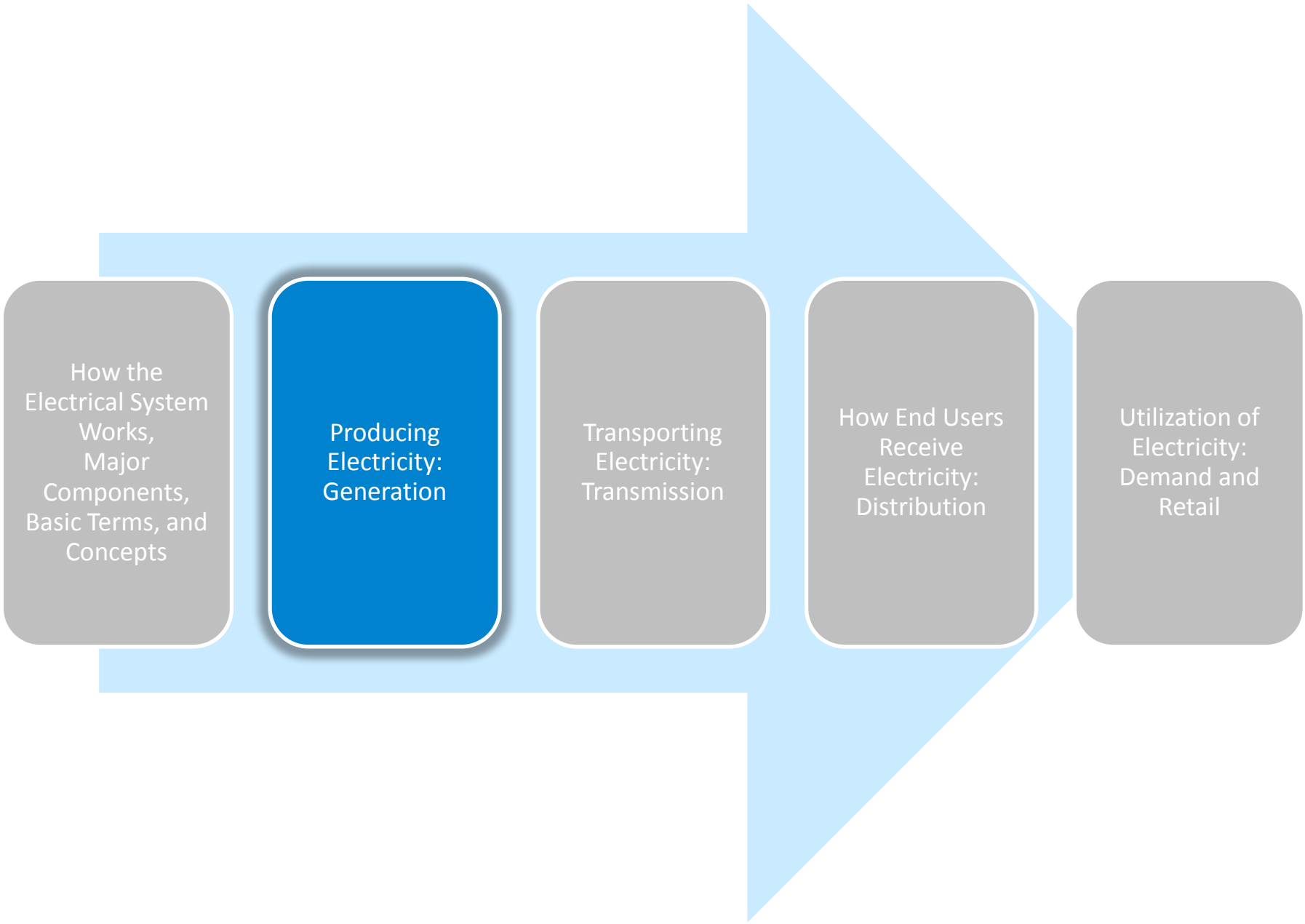
- Electricity - Flow of electrical power or charge
  - Cannot be stored
  - Amount generated must be equal to the customer demand/load
  - Some generator has to produce electricity simultaneously with the need
- Demand/load - Required amount of electrical power needed
  - Terms usually used interchangeably
- Generation - Production of electricity

Energy Basics 101 Energy Information Agency (EIA)

Basic Terms and Concepts

Electric System (cont.)

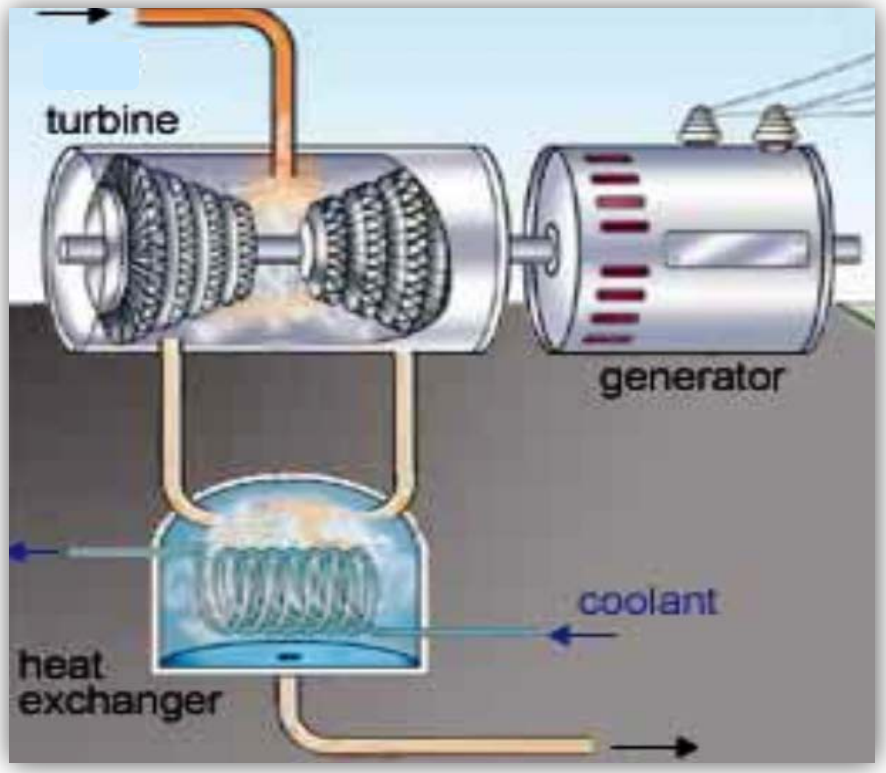
- Transmission - Delivery of electricity through high voltage lines
  - In New England typically ≥ to 69,000 volts (or 69kV) but often 115kV or 345kV
- Distribution - Electricity is distributed to end users via lower voltage electric lines
  - Distribution voltage typically 13-34 kV
  - The line into most homes/small businesses is only 110/220 volts
  - Transformers are used to step-up and step-down voltage



Producing Electricity:

Electric Power Plant

- Electric generator
  - Device for converting mechanical energy into electrical energy
- Uses either a turbine, engine, water wheel, or other similar machine to be the prime mover that drives an electric generator



What is a British Thermal Unit (BTU)?

- A BTU is defined as amount of heat required to raise the temperature of one 1 pound (0.454 kg) of liquid water by 1 °F (0.556 °C) at a constant pressure of one atmosphere.

This is roughly the amount of heat produced by a burning match.

BTU – Why Is This Important?

- BTU is often used to express the conversion-efficiency of heat into electrical energy in power plants.
- Figures are quoted in terms of the quantity of heat in BTU required to generate 1 kWh of electrical energy.
  - 1 KWh equals 3,412 BTU's

BTU – Fast Facts

- A typical coal-fired power plant works at 10,500 BTU/kWh
  - Efficiency of 32-33%
- A Combine Cycle with a heat rate of 6,500 BTU/kWh
  - Efficiency of 48%
- Most efficient Combine Cycle has a heat rate of 5,593 BTU/kWh or about 61% efficient.

BTU Calculations

- The unit MBTU is defined as one thousand BTUs
- The unit MMBTU is defined as one million BTUs
  - Generators deal in MMBTUs
- Strickly speaking, supply offers are expressed in $/MW

So, how do generators develop offer prices?

BTU Calculations

8,000 BTU/kW Generator Example

- Natural Gas

$4.50/MMBTU x 8,000 BTU/kWh x
1 MMBTU/1,000,000 BTU x 1,000 kWh/1 MWh
= $36.00/MWh

- Number #2 Oil

$2.50/gallon x 1 gallon/138,500 BTU x
8,000 BTU/kWh x 1,000 kWh/1 MWh
= $144.40/MWh

Basic Terms and Concepts: Generation

- Power – Rate of producing, transferring, or using energy, most commonly associated with electricity
  - Power is measured in watts and often expressed in kilowatts (kW) or megawatts (MW)
  - Power is measured at a single point in time
- Energy – Capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy)
  - Electrical energy is usually measured in kilowatt/hours (kWh)

Resource: Energy Information Agency (EIA)

Types of Generating Resources

- Thermal Plants
  - Internal combustion
  - Combustion turbine (simple cycle)
  - Steam turbine
  - Combined-cycle plant
- Pumped Storage
- Intermittent Power Resources
  - Biomass (thermal plant)
  - Hydro station/plants
  - Solar
  - Wind

Types of Generating Resources

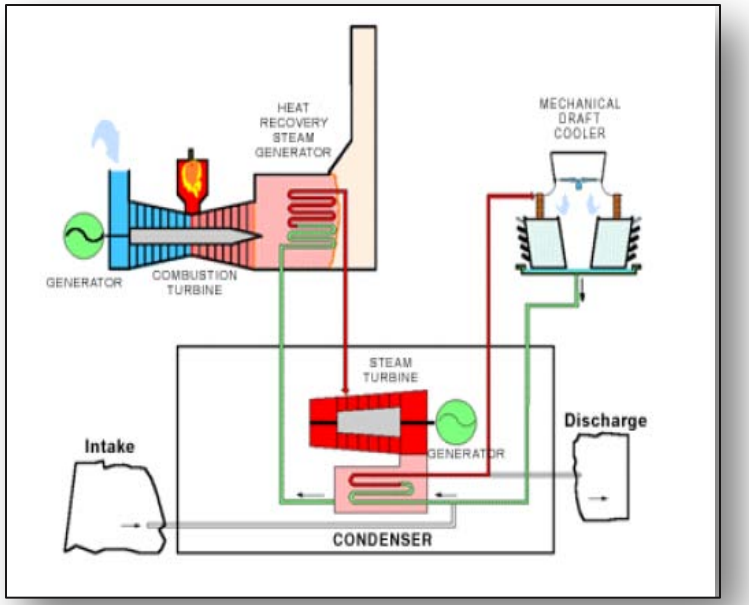
Thermal Plants

- Electric generating stations in which the source of energy for the prime mover is heat
- Generally, steam, hot gases, or air drives the turbine
- Fuel types
  - Oil
  - Gas
  - Coal
  - Nuclear

Types of Generating Resources

Combined-Cycle Plant

- Produces electric power in two stages or cycles
  1. The first stage runs a turbine and generator driven by the direct burn of gas, like a jet engine
  2. The second stage uses the heat from the burning fuel to make steam that drives a steam turbine and generator



Combined-cycle facilities tend to have a higher capital cost per megawatt of capacity compared with single or simple-cycle power plants, such as combustion turbines, but are significantly more efficient in power output per unit of fuel burned.

Types of Generating Resources

Pumped Storage

- Water is pumped up to a storage pond during periods of low demand and lower energy costs
- Water is stored until the electrical power is needed
- Water is then released to drive the turbine generator, usually during peak-load periods
- Helps utilize excess generating capacity during off-peak hours

Types of Generating Resources

Hydro Stations/Plants

- Use water flow to turn a turbine that drives a generator
- Output dependent upon adequate source of water

Types of Generating Resources

Solar

- Photovoltaic (PV) is a solar power technology that uses solar cells or solar photovoltaic arrays to convert light from the sun directly into electricity

Types of Generating Resources

Wind

- Wind drives the turbine
- Turbine must have adequate source of wind
- Currently around 100 units representing approximately 200 MW of capacity in New England

Hull, Massachusetts

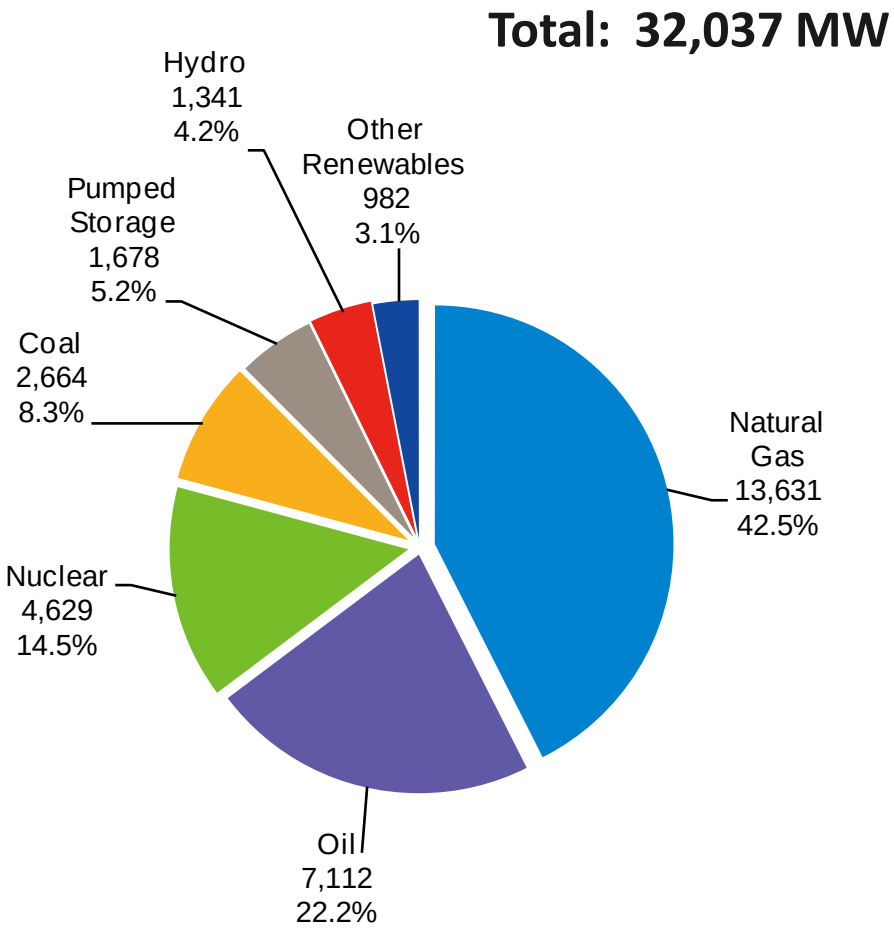
Types of Generating Resources

Biomass

- Biomass - Organic non-fossil material of biological origin (thermal unit)
- Biomass waste - Organic non-fossil material of biological origin that is a byproduct or a discarded product
  - Note: EIA “biomass waste” data also include energy crops grown specifically for energy production, which would not normally constitute waste

New England Generation Capacity for 2011

By Fuel Type

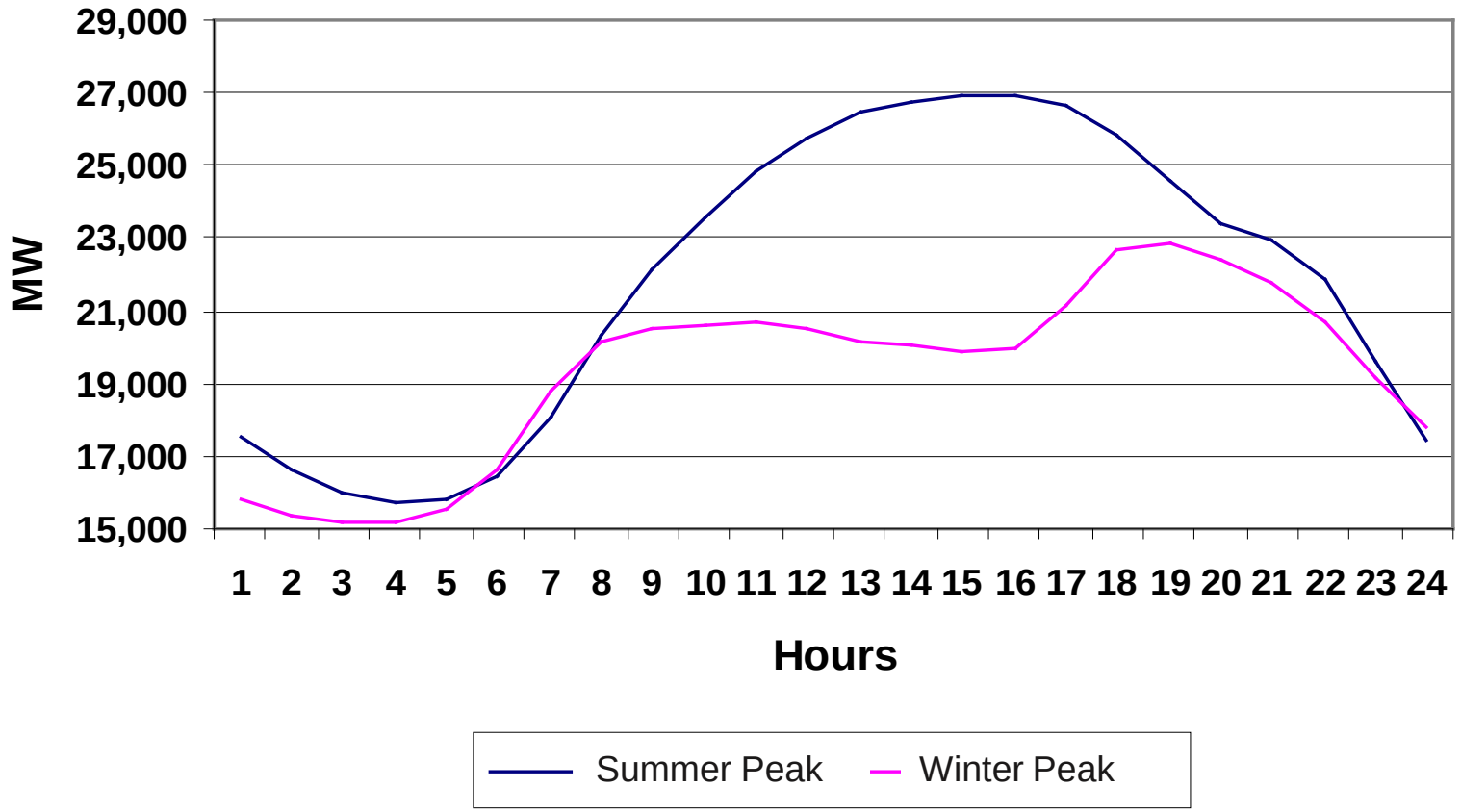


Source: April 2011 CELT Report. "Other" includes landfill gas, other biomass gas, refuse, wood and wood waste, wind solar and misc. fuels

Major Classification of Generators

- Generators can be used:
  - Different times of the day
  - Different seasons
  - Depending on their fuel costs and the needs of the electric system
  - For quick response situations (reserves)
    - Fast Start Generator
  - For blackout conditions (little or no power in the system)
    - Black Start Unit
- Major classifications of generators are:
  - Base load
  - Intermediate
  - Peaking

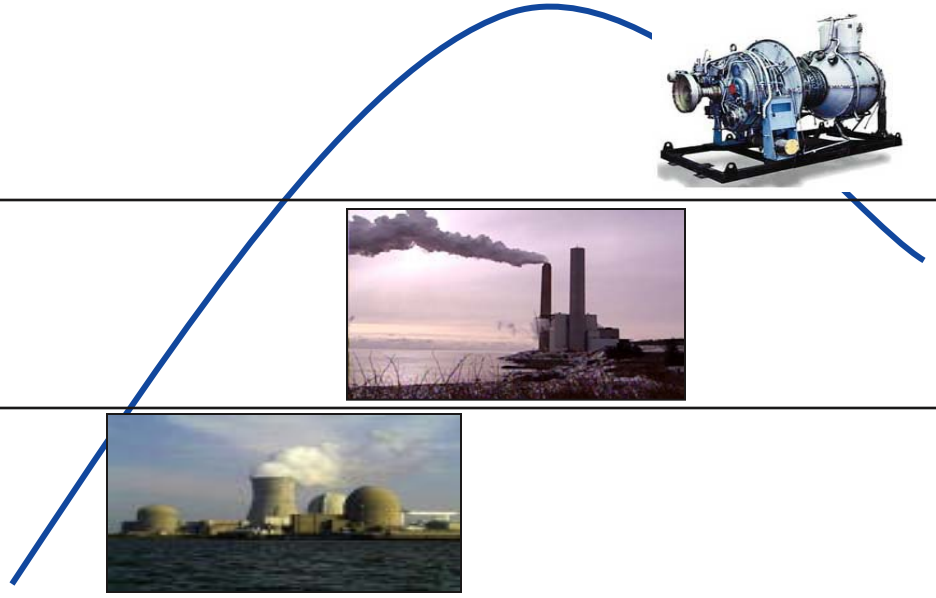
ISO New England Seasonal Peak Days



Classification of Generators

Matching Demand with Generation

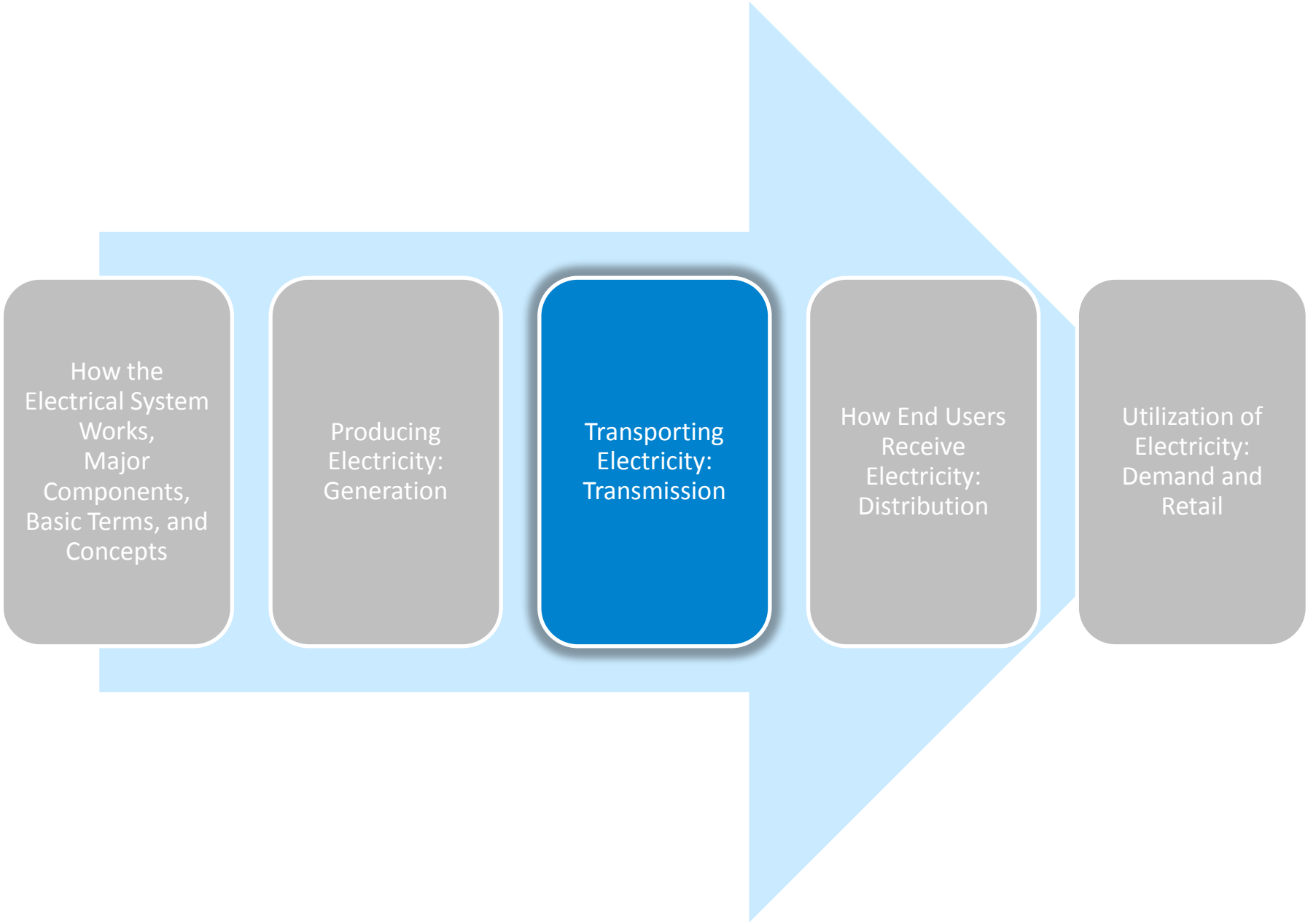
Type of Unit	
Peaking Spring: 17,000 - 31,000 MW Summer: 20,000 - 31,000 MW	
Intermediate Spring: 9,500 - 17,000 MW Summer: 10,000 - 20,000 MW	
Base load Spring: up to 9,500 MW Summer: up to 10,000 MW	



Morning **Noon** **Mid Afternoon** **Evening**

Demand Resources (DR)

- Installed measures resulting in additional and verifiable reductions in end-use demand on the electricity network
  - Energy efficiency
  - Load management
  - Distributed generation
  - Compensates electricity users for reducing use when reliability is at risk
  - Can provide system operators with operational flexibility
- Serve to reduce the peak demand in the system and maintain operating reserves
- Displace load permanently, over pre-defined hours or in real-time when dispatched by the ISO



Basic Terms and Concepts

Transmission

- Transmission
  - Means to transfer electricity in large quantities at high voltage, usually over long distances, from resources to electrical substations that distribute electricity to end users
- High voltage lines
  - Electric lines that transfer large quantities of power at high voltage, usually over long distances ≥ 69 kV
  - Minimize losses

Basic Terms and Concepts

Substation

- Substation
  - A facility on an electricity generation, transmission and distribution system where voltage is transformed from high to low or the reverse using transformers
- Electric power may flow through several substations between generating plant and consumers, and may be changed in voltage in several steps

VELCO- Queen City 115 kV Substation Breaker

Basic Terms and Concepts

Transmission (cont.)

- Types of Electrical Current
  - **Alternating Current (AC)** - Electric current whose magnitude and direction vary cyclically
    - AC is the most common current because an AC system is cheaper to build and is more flexible
    - Voltage can be stepped up or stepped down through the use of transformers
  - **Direct Current (DC)** - Electrical current that flows in one direction
    - It is easier to control power flows in emergency situations.
    - Higher power ratings for lines
    - Power is converted at both ends to alternating current

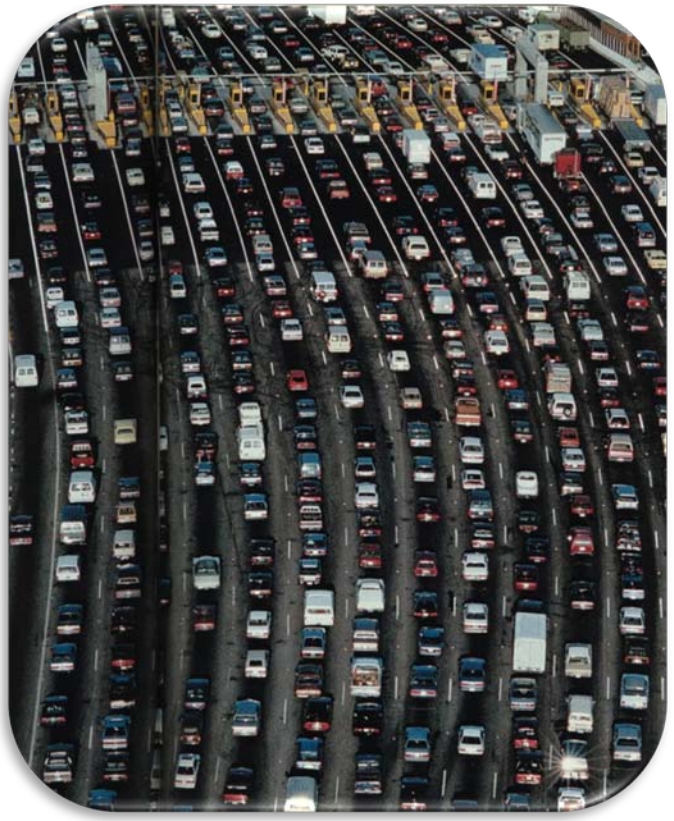
Basic Terms and Concepts

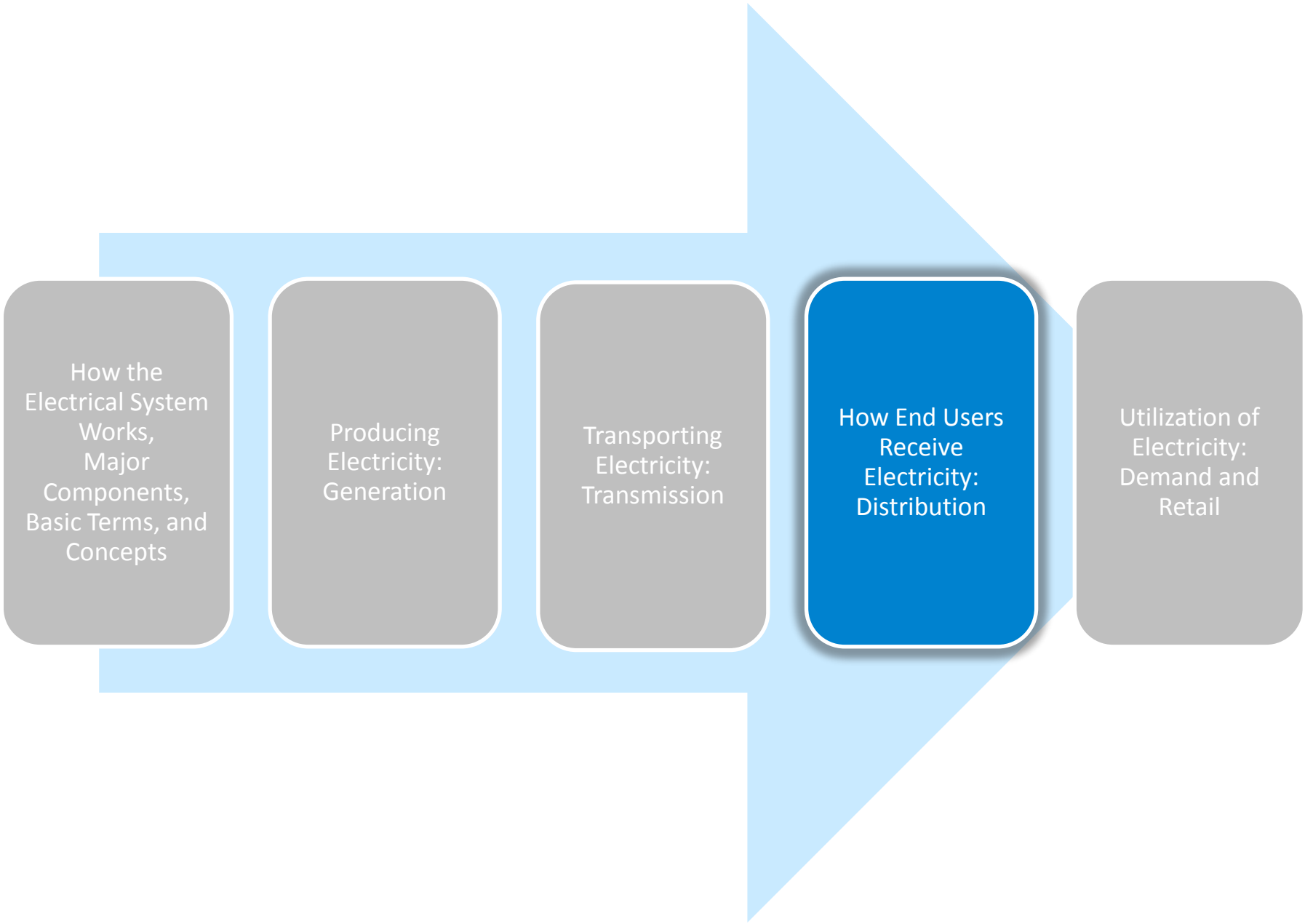
Transmission (cont.)

- Transmission and distribution loss
  - Electric energy lost due to the transmission and distribution of electricity. Much of the loss is heat
- Transmission Line Ratings
  - Ratings are determined by physical characteristics of transmission circuits and can be affected by environmental factors
  - Summer temperatures cause ratings to be lower when compared to winter ratings

Congestion on the Transmission System

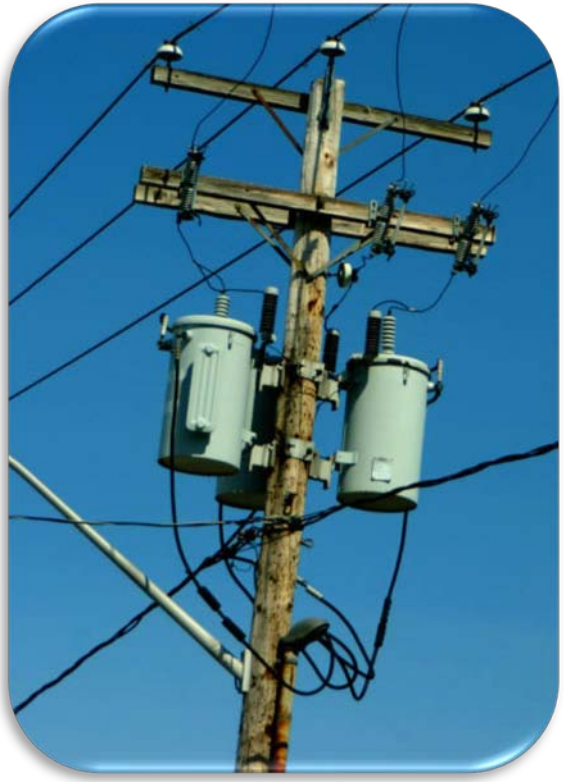
- Congestion
  - A condition that occurs when insufficient transfer or power carrying capacity is available to implement all of the preferred schedules for electricity transmission simultaneously

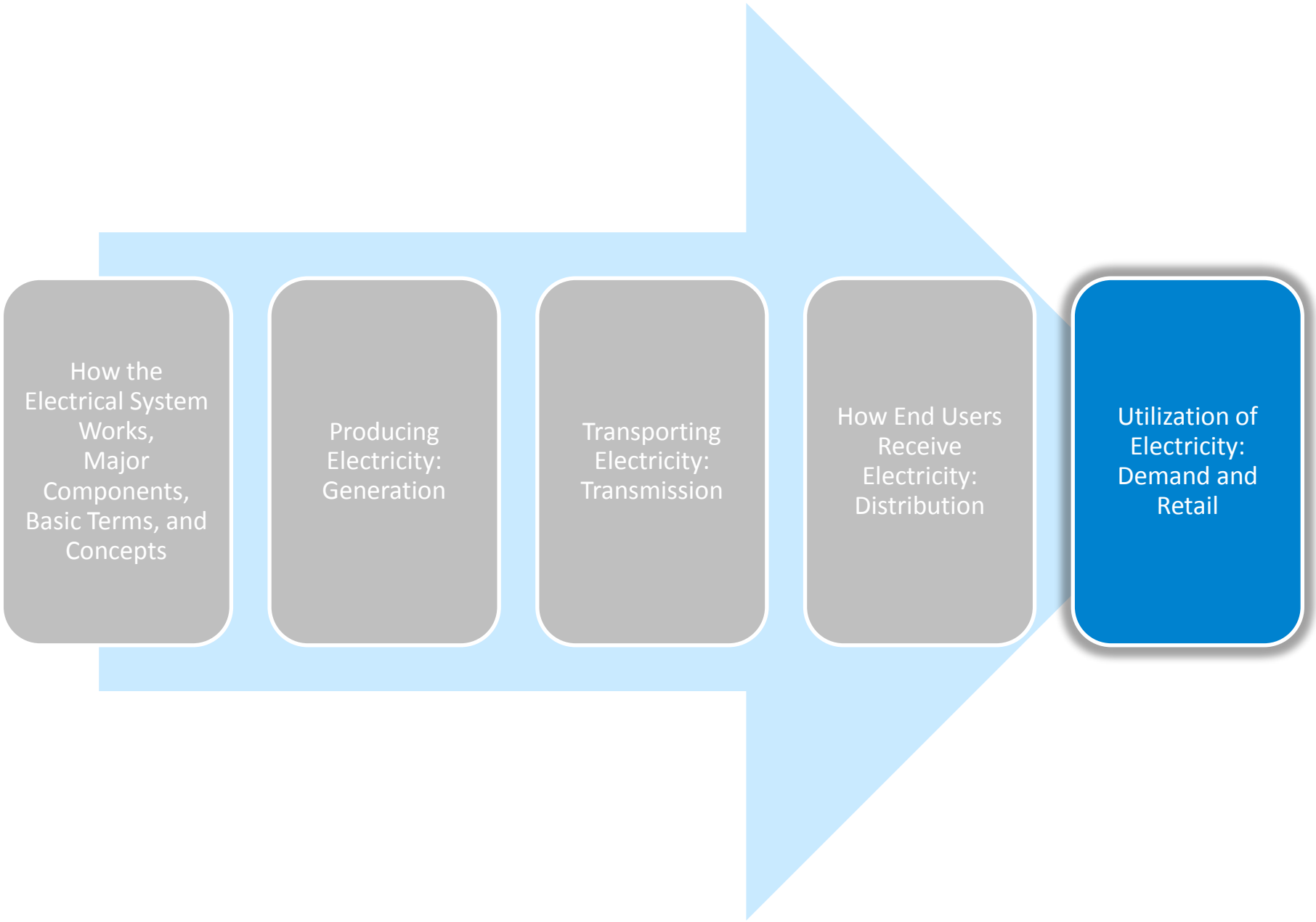




Distribution

- The delivery of energy to retail customers
- Involves moving electricity from the high voltage (≥ 69 kV) transmission system to the lower voltage lines (<69 kV) at substations (e.g., 15 to 23 kV)
- Operated by Local Control Centers in coordination with the ISO





Retail

- Retail - The sale of power from the wholesale market for use by end-users
- Utilization of electric power by sector
  - Percent of energy

Sector	United States	New England
Residential	35%	38%
Commercial	34%	44%
Industrial/Other	31%	18%

- Some large end-users may be able to purchase electricity at wholesale rates

Resource: Energy Information Agency (EIA)

Residential

- Includes private households and apartment buildings where energy is consumed primarily for:
  - space heating
  - water heating
  - air conditioning
  - lighting
  - refrigeration
  - cooking
  - drying clothes
  - computers
  - televisions

Resource: Energy Information Agency (EIA)

Commercial

- Includes non-manufacturing business establishments such as:
  - hotels
  - motels
  - restaurants
  - wholesale businesses
  - retail stores
  - health, social, and educational institutions
- Includes small manufacturing facilities

Resource: Energy Information Agency (EIA)

Industrial

- Includes:
  - manufacturing
  - construction
  - mining
  - agriculture
  - fishing
  - forestry establishments
- Other :
  - Includes municipal uses such as street lights, miscellaneous items

Resource: Energy Information Agency (EIA)

Module Review: Topics Covered