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Some Background on the Electric Energy and Natural Gas Industries and their Use of Weather Data

Presented to:

The Alternative Climate Normals and Impacts to the Energy Industry

Presented by:

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Some Background on the Electric Energy Industry

Omnis Electrica Quattuor Partes Divises Est

The electric utility/industry is often divided into 4 parts

1. Generation
   - The production of electricity
2. Transmission
   - The electricity transportation super highway
   - Sometimes known as the 'grid' or 'bulk power system'
   - Some portions also serve the largest customers, typically industrial facilities
3. Distribution
   - The wires to the residential, commercial, and small industrial customers
   - The largest source of unreliability on the electrical system
4. Customers

Units

- Capacity/demand measures

1 kilowatt = 1 kW = 1000 watts

1 megawatt = 1 MW = 1,000,000 watts = 1,000 kW

1 gigawatt = 1 GW = 1,000,000,000 watts = 1,000 MW

- Energy measures

1 kilowatt-hour = 1 kWh = 1000 watt-hours

1 megawatt-hour = 1 MWh = 1,000,000 watt-hours = 1,000 kWh

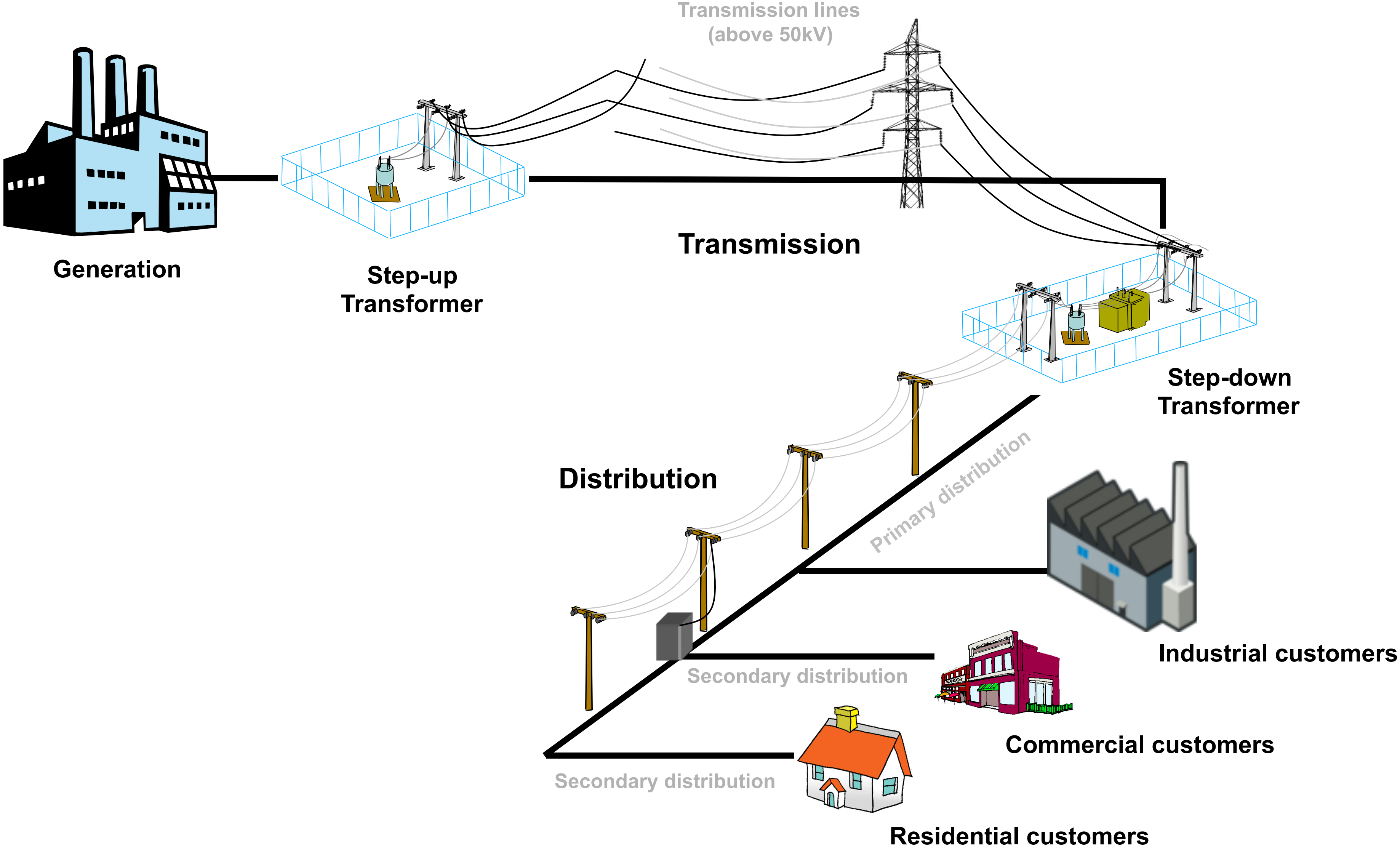
1 gigawatt-hour = 1 GWh = 1,000,000,000 watt-hours = 1,000 MWh

British thermal unit (Btu) = 0.293071 watt-hours

Thus, 1 watt = 3.41214 Btu/hour

1 cubic foot of natural gas (cf) yields approximately 1030 Btus

The Electric Delivery System



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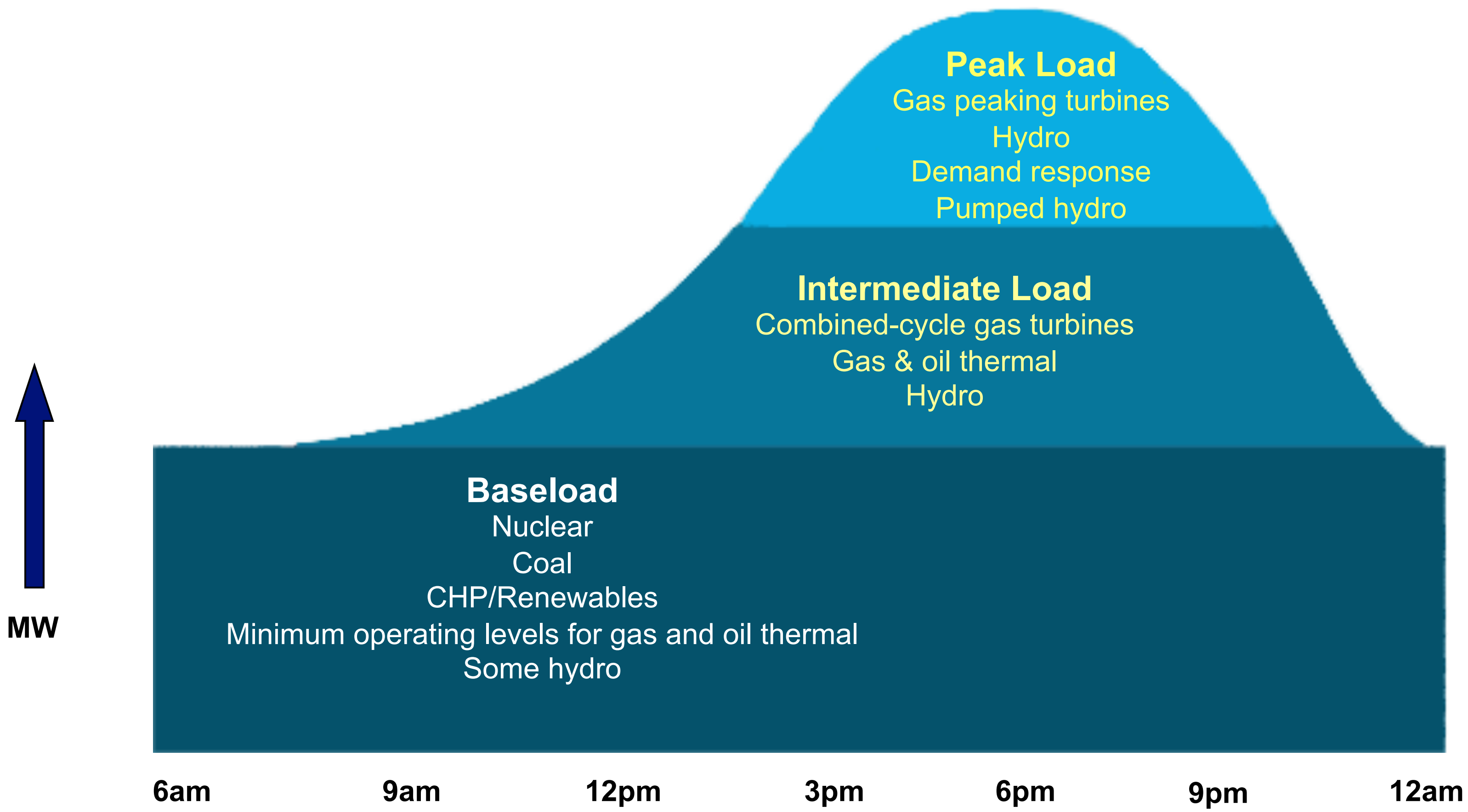
Typical Generation Usage



Three Primary Generation Types

- Baseload
  - Units that will run at or near their maximum level for most of the time
    - High capacity factor
      - Capacity factor = average level of output / maximum potential output [per some time interval]

        = (total output time per time interval/ time interval) / maximum potential output
    - Units designed to produce low-cost energy
      - Low marginal energy costs
      - Heat rates are on the order of 1000Btu/kWh – What is the implied efficiency? What is HHV and LHV?
  - Relatively inflexible in terms of their ability to vary output
    - Slow ramp rates
  - High capital costs, long lead times to build
    - Coal, nuclear typical units
  - Relatively high costs to initiate the operation of the unit, i.e., high start-up costs
    - This implies that you don't want to turn these units off with any frequency
      - For example, if a nuclear generating unit is turned off it may take several days or more to restart it
      - For example, some coal generating units require twenty-four hours to reach their nominal output level

Three Primary Generation Types (cont'd)

♦ Intermediate

- Units that will run a substantial portion, but not all, of the time near their maximum output
- Capital costs lower than baseload, but much shorter lead times
- Higher marginal energy costs than baseload
    - The positioning of such units in the ranking of units to operate depends crucially on the relative prices of fuel
    - At low gas prices, the most efficient CCGTs can produce electricity at lower prices than older coal units.
    - The most efficient CCGTs have heat rates of 6000 Btu/kWh
- Usually fairly flexible in varying output levels
    - Combined cycle gas turbine (CCGT) is typical unit
- Such units often provide ancillary services to support the transmission system
    - Load following, regulation (See FERC's definitions of ancillary services)

Three Primary Generation Types (cont'd)

- Peaking
  - Low capital costs and short lead times to build
    - Have been brought in, at least on a temporary basis, on barges and even on the back of trucks (big rigs)!
  - High marginal energy costs
    - Natural gas combustion turbine (CT) is typical unit
    - Heat rates on the order of 8,500 Btus/kWh for new units (Where would you go to see if this true?)
  - How they are operated depends on design
    - Some CTs are block loaded, i.e., only operate at full output, by some of the independent system operators (ISOs)
    - Other CTs are designed for very rapid changes in output
      - Tens of MWs/minute for the fastest

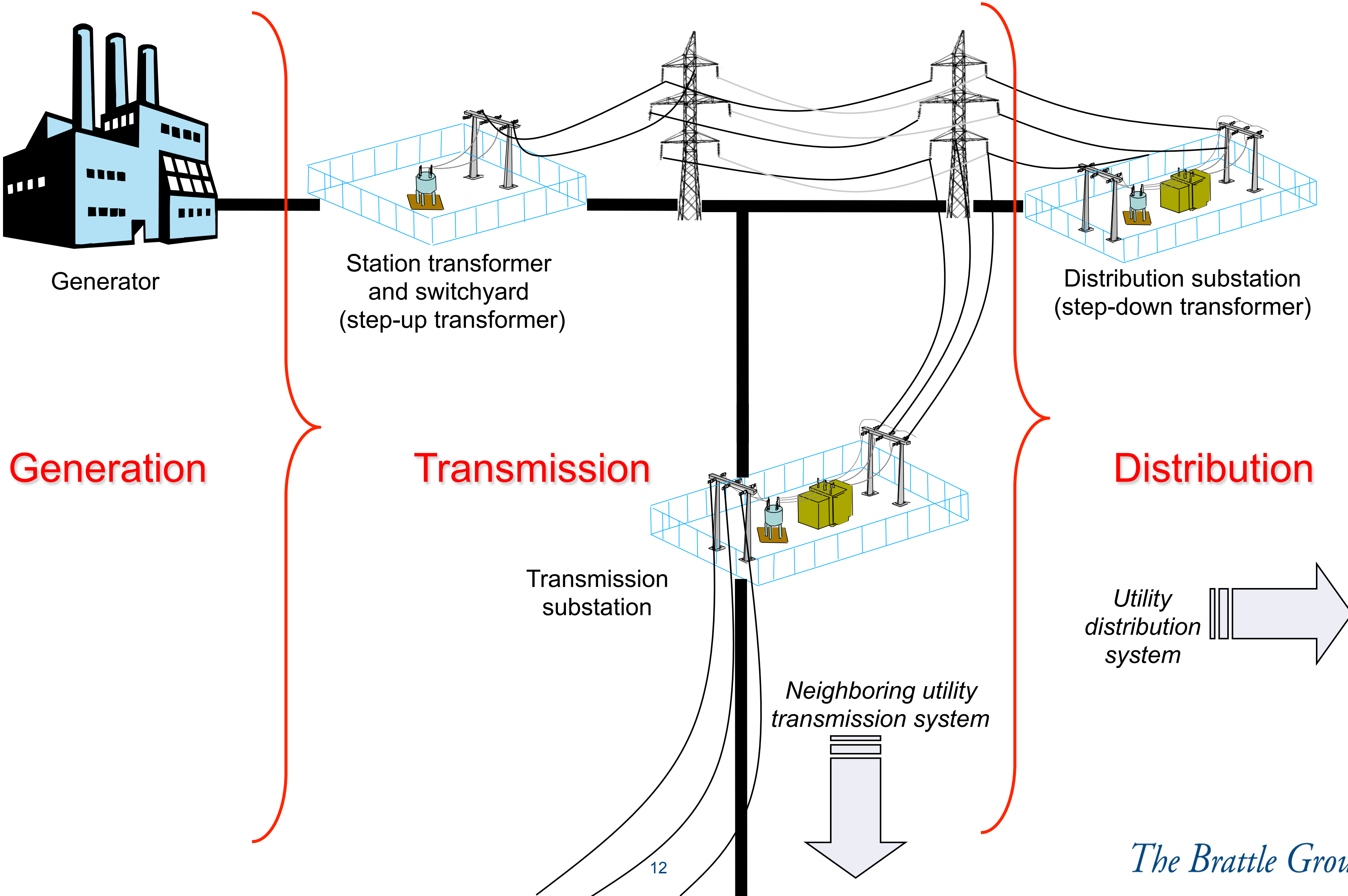
Other Generation

- Large scale hydroelectric
  - Big dams
    - 000's MW
    - Pondage provides storage
  - Very expensive to build, but very low marginal costs (How would this be defined?)
  - Depending on the water system, can be energy-constrained, i.e., cannot operate at full output all of the time
  - Very flexible in varying output
    - Often provides ancillary services
- Smaller scale hydroelectric
  - Run-of-river
    - Little or no controllability
    - Potential for large variations in output depending on water source conditions
  - Typically small MW's – a few to 100
    - Often left over from mills that self-supplied power

Other Generation (cont'd)

- Biomass – waste-to-energy – primarily cogenerators selling power to utility
  - Paper mills are frequent sources of such generation
  - Municipal waste facilities
- Renewable resources
  - Typically characterized as high capital costs, but very low marginal energy costs, sometimes zero
  - Characterized by intermittency of output
    - Predictable, but largely controllable
    - Geographic-specific
    - Wind, solar thermal, solar PV
  - Geothermal is exception to intermittency issue, but very geography-specific
    - Not much geothermal in Florida, but Hawai'i has potential

The Transmission System



Transmission System, i.e. 'The Grid'

The electrical system's super highway

- Connect distant generation to loads
  - Lines connecting generation to transmission
  - grid are often treated as part of the generation
  - station's cost, not a transmission system cost
- The network capabilities are key
  - Redundancy!
- Voltage levels as high as 765kV
  - Highest voltage levels are sometimes DC, denoted as HVDC
  - HVDC lines are sometimes employed for inter-area connections to provide protection against large scale blackout
    - Transmission reliability is termed 'security'
  - Higher voltage levels yield lower losses
    - Typically 2%
    - HVDC has lower losses than high voltage AC (HVAC - not to be confused heating, ventilation, and air conditioning, also HVAC)

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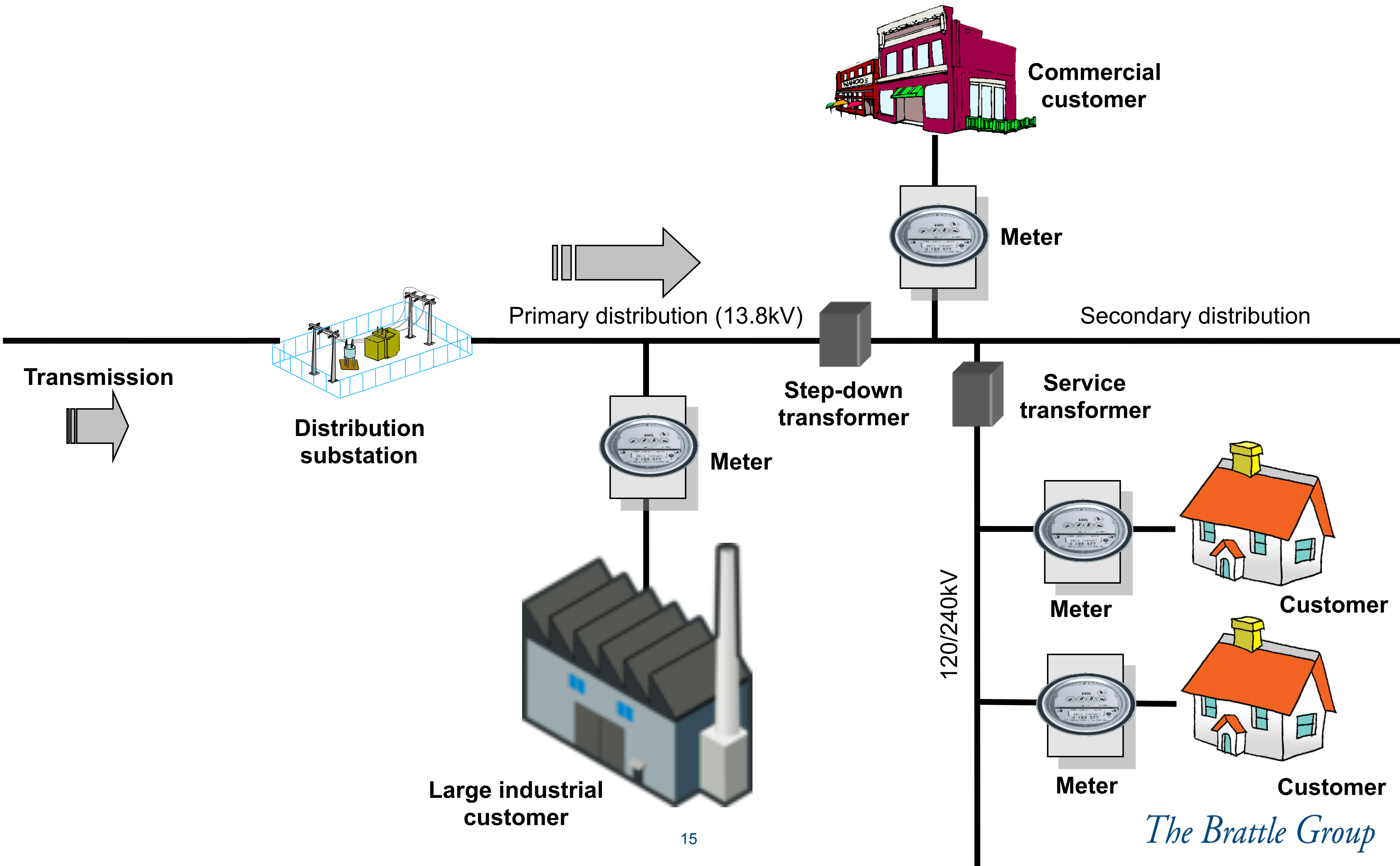
Transmission System, i.e. ‘The Grid’ (cont’d)

- Lowest voltage levels typically around 115kV
  - Depends on system as to classification
    - Some include 69kV, although some classify this as sub-transmission
      - Why should we care?
- Almost all lines are above ground
  - Air acts as insulator
    - When lines heat up they sag, can arc to ground (‘fault to ground’) if sag low enough – very, very bad
  - Undergrounding and underwater cables are about 10X as expensive to construct as above ground, higher maintenance for them, too
- Interconnection point for the largest of customers, mostly industrial

The Distribution System



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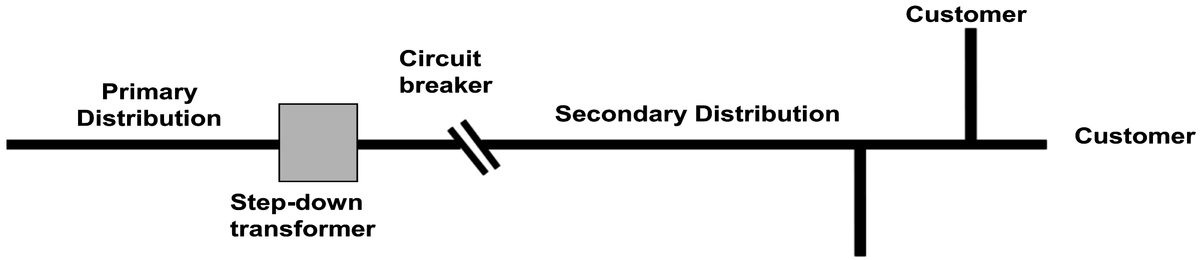
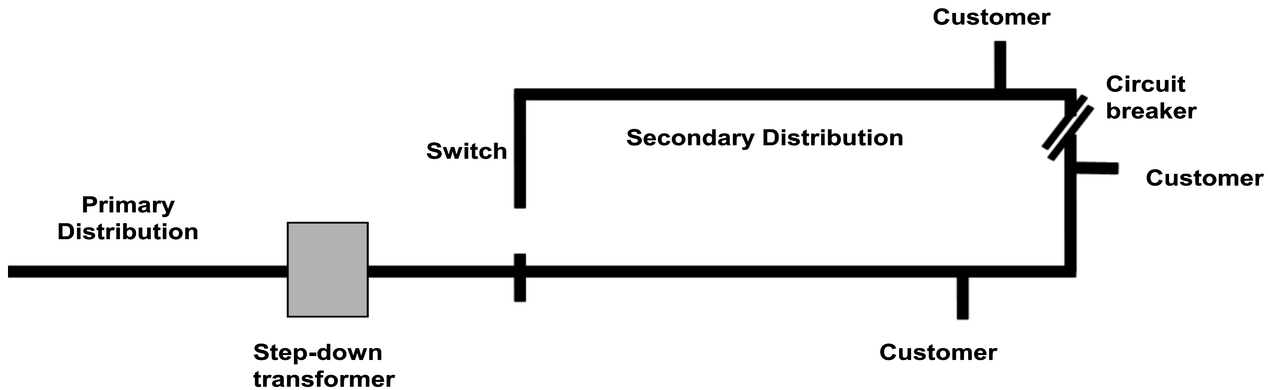
Types of Distribution Systems

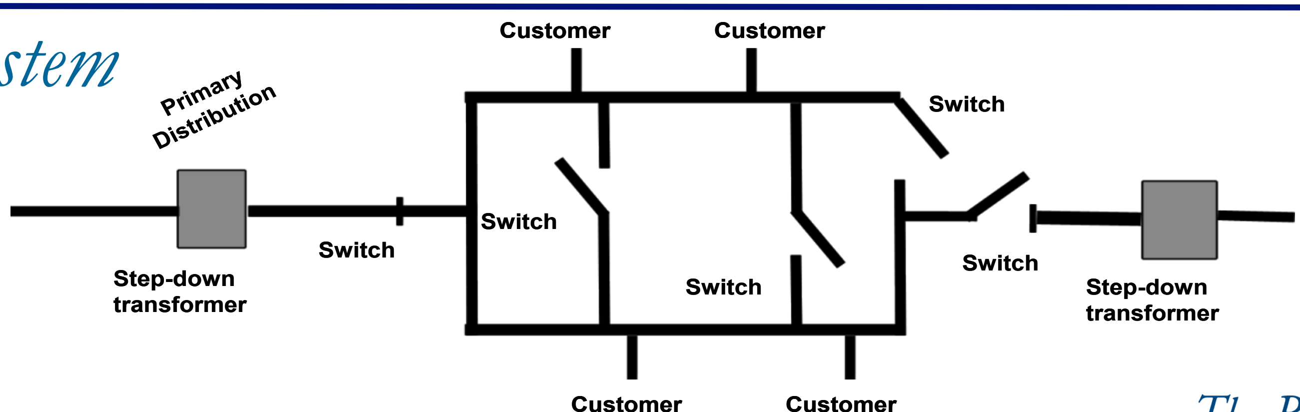
Radial Feed



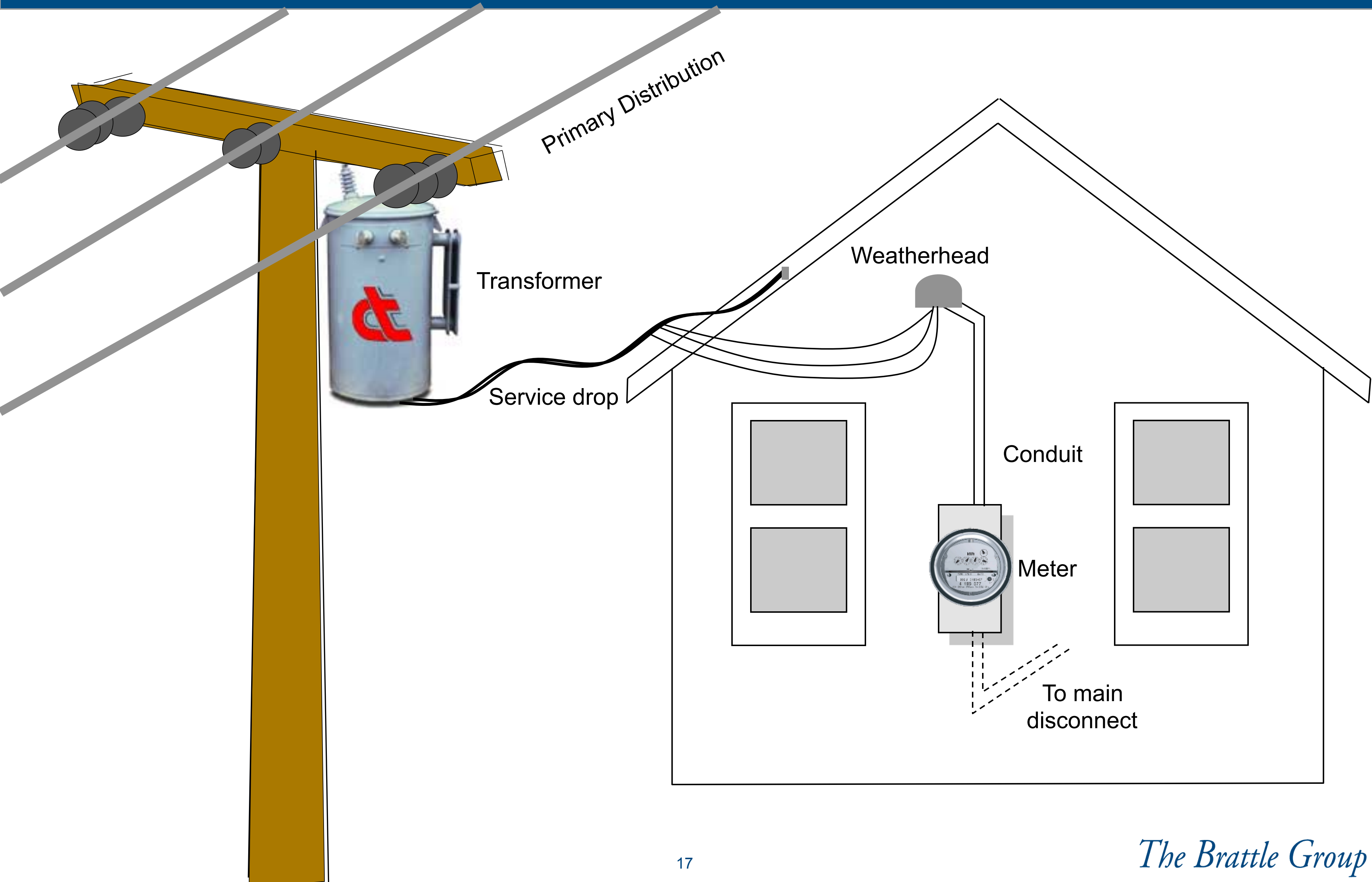
Loop Feed



Network System



Service Drop



Distribution System – Power to the People!

The ultimate delivery point for the majority of customers

- Voltage usually 69kV and below
- Distribution lines are connected to customers typically
- in one of three configurations
    - Loop feed
    - Radial feed
    - Network system
- Connection to the customer is known as a 'service drop'
    - Usually includes pole top transformer, the line from the transformer ('service drop') to the home and through the customer's meter
- The lower the voltage at which the customer receives service, the greater the losses
    - Typical distribution system losses are 2-6%
- Urban distribution systems mostly underground by necessity
    - Expensive to construct and maintain
- Suburban distribution systems mixture of above ground and underground
    - New suburban divisions are often underground with conduit for wires laid by developer
- Rural systems are usually above ground

Some Background on the Electric Market Organization

Electric Energy Market Organization

Very broadly, electric energy markets come in two flavors

- Traditional markets
- Restructured markets

Traditional Electric Markets And Their Organization

Traditional Markets

- Traditional Markets
  - Comprised of primarily integrated utilities
  - Price formation is entirely through regulation by public utility commissions.
- Utility performs the following functions
  - Distribution
    - Low voltage wires providing service to ultimate customer – residential, commercial, small industrial
  - Transmission
    - Bulk power system
      - Provides "highway" connecting generation to distribution system
      - Largest customers connect at the voltage levels of transmission system
      - Interconnection to other utilities provides reliability enhancement and potential for economic interchange
  - Generation
    - Owned by utility
    - Economic dispatch

Who are the market participants?

Investor-owned Utilities (IOUs)

- For-profit corporations owned by either public or shareholders
- Franchised service territory, usually exclusive
- Almost always fully integrated, i.e., generation, transmission, and distribution
- Serve approximately 70% of all customers
- Retail business is regulated by public utility commissions (PUCs), wholesale by the **Federal Energy Regulatory Commission** (FERC) (formerly the **Federal Power Agency** (FPA)
- **Edison Electric Institute** (EEI) is their lobbying arm

Who are the market participants? (cont'd)

Municipal utilities (Munis) and public utility districts (PUDs)

- Munis are either local government departments (such as Los Angeles Department of Water and Power (LADWP)) or created as special agencies by the state (such as Salt River Project)
- Groups of Munis and PUDs may form **Public Power Agencies** which may own and operate generation and transmission
- PUDs predominate in the Pacific Northwest
- Nonprofit, although will often include a measure of 'profitability' in calculation of rates
- Federal income tax exempt, interest on bonds they issue are also Federal income tax exempt
- Often do not own generation or transmission, but rely on local IOUs to provide power, so-called transmission dependent utilities (TDUs)
- Typically only regulated by local government or boards, but not PUCs
- **American Public Power Association** (APPA) is their lobbying arm

Who are the market participants? (cont'd)

Rural Electric Cooperatives (RECs) (not to be confused with Renewable Energy Credits, which are also RECs)

- Created by New Deal when the Rural Electrification Administration was established
  - Aim was to provide power to rural areas where IOUs would not necessarily provide service
  - Many are now suburban power providers as cities grew and farming was reduced
- Have similar financial status as munis and PUDs – nonprofit and tax-exempt
- Two types – distribution cooperatives and generation and transmission cooperatives (G&T Co-op).
  - Distribution co-ops are distribution only entities
  - G&T co-ops formed to serve distribution co-ops
  - Besides G&T co-ops, some distribution co-ops are served by federal power agencies and IOUs
- REA became Rural Utilities Service and is under the Department of Agriculture
- Some co-ops operate under some form of PUC supervision

Who are the market participants? (cont'd)

Federal Power Agencies

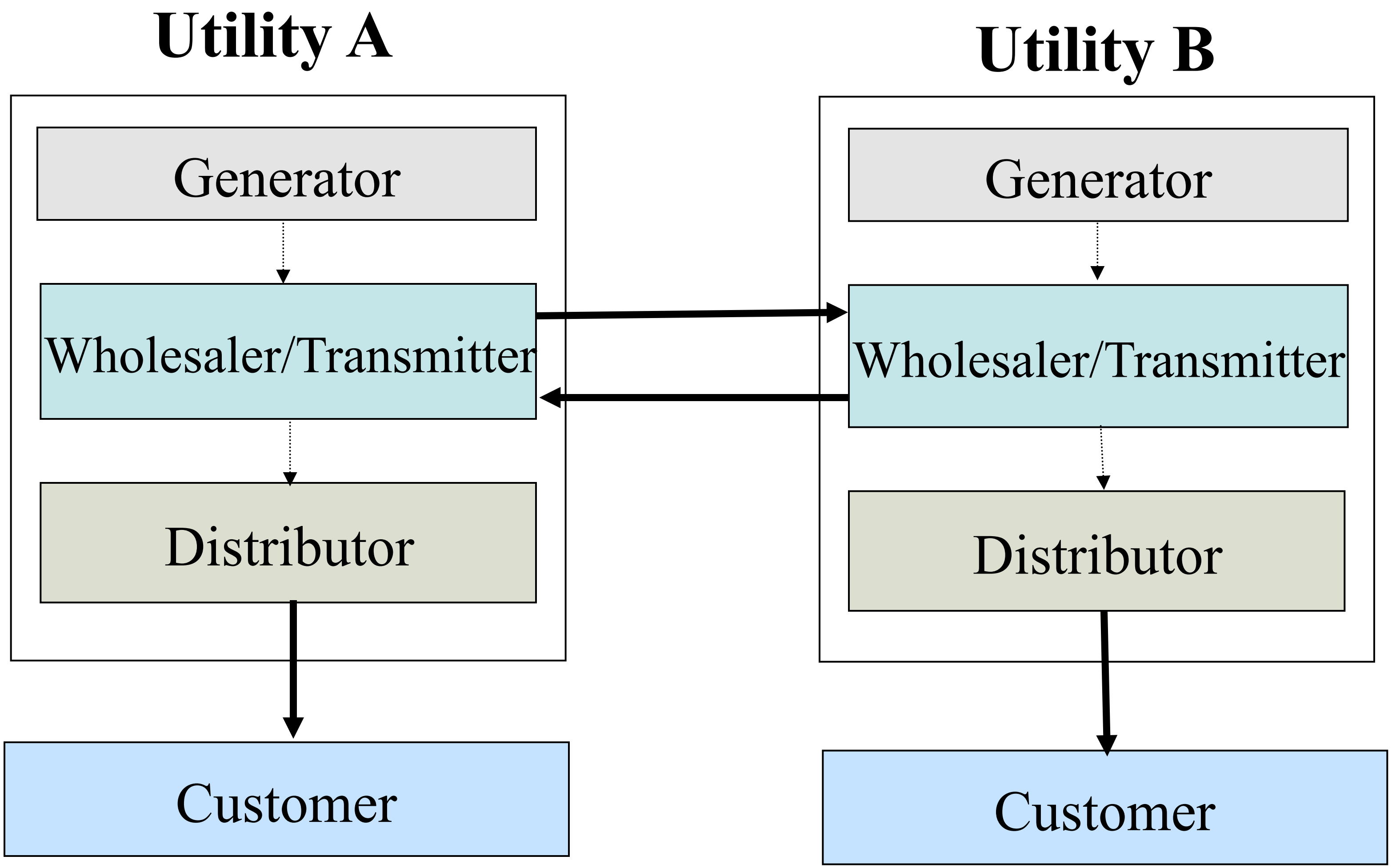
- Entities created by the U.S. to market the power output of federal projects, usually from hydroelectric power from large dams
- Agencies
  - Bonneville Power Administration (BPA)
  - Southwestern Power Administration (SWPA)
  - Southeastern Power Agency (SEPA)
  - Western Area Power Administration (WAPA)
- Tennessee Valley Authority (TVA) is not a federal power agency, but largely behaves as if it were one
- Generally provide power to munis, PUDs, and co-ops

Who are the market participants? (cont'd)

Other participants

- ♦ **Power pools**
  - Created by groups of utilities which then subsumes the responsibility for scheduling and dispatch of their power plants
  - Eventually become **regional transmission organizations** (RTOs) / **independent system operators** (ISOs)
- ♦ **Energy Service Companies** (ESCOs)
  - Offer services that are not necessarily provided utilities – bill evaluation, appliance maintenance
  - May also be contracted by regulated entity such as IOU to provide services such as energy audits, demand-side management, power quality
    - May be unregulated subsidiary of a regulated entity
- ♦ **Independent Power Producers** (IPPs)
  - Often a result of Public Utilities Regulatory Policy Act of 1978 (PURPA) which encouraged the development of co-generation
  - **Exempt Wholesale Generator** (EWG)
- ♦ Electric Marketers
  - Entities that buy excess generation and resell to other market participants

Traditional Markets



Decentralized Bilateral Trade

Restructured Markets
Market Organization

FERC Orders 888 and 889

Goal

- ♦ Protect and promote generation competition and enforce fair treatm of external users of the transmission system
  - Issued on April 24, 1996
  - Although the Energy Policy Act of 1992 (EPAct) formally began the process of restructuring, Orders 888 and 889 really began the ball rolling
- ♦ Order 888, the "Standards of Conduct" order
  - Establish and promote competition in the generation market, by ensuring fair access and market treatment of transmission customers
  - Six steps
    - Require all jurisdictional utilities (within the United States) to file an open-access transmission tariff (OATT)
    - Require investor-owned utilities (IOU's) to functionally unbundle wholesale generation and power marketing from transmission services
    - Create **independent system operators** (ISOs) and operating guidelines
    - Encourage reciprocity for non-jurisdictional (Canadian and Mexican) utilities
    - Allow utilities to recover stranded costs
    - Identify ancillary services and comparable services to properly operate the bulk power system

FERC Orders 888 and 889 (cont'd)

Order 889, the "Open Access" order

- Details exactly how all participants in the electricity market should interact with transmission providers
- Laid out the structure and function of what became known as **Open Access Same-Time Information System** (OASIS) "nodes"
  - Secure, web-based interfaces to each transmission system's market offerings and transmission availability announcements
  - Single point of information dissemination to the market
  - Customer portal for transmission service requests, even for affiliated power marketers desiring access to their own parent company's transmission
    - Available Transmission Capacity/Capability (ATC) posted for varying time intervals – hourly, daily, weekly, monthly, annual, both firm and non-firm, and associated rates permits customers to secure transmission
    - Also posts transmission service request queue
- **Order 890** clarifies issues raised by market participants after the implementation of Orders 888 and 889

Restructured Markets

- Restructured Markets – Regional transmission organizations (RTOs)/ Independent System Operators (ISOs)
  - Aggregated transmission system operated by ISO whose primary function is to provide open access to the transmission system and balance supply and demand
    - Utilities retain TX ownership, requirement for maintenance, expansion
    - Federal Energy Regulatory Commission (FERC) sets rate and regulates
  - Generation bid into market
    - Some utilities have retained generation ownership
    - New entrants
      - Merchant generators
      - Transmission companies (Transcos)
      - Financial service companies
      - Electric marketers
    - Very loosely regulated by FERC
  - Residual traditional utility, now known as Load-Serving Entity (LSE) or Local Distribution Company (LDC), operates and maintains the wires to retail customers
    - Under wholesale competition
      - Retains supplier role, purchasing on behalf of customers
    - Under retail competition
      - Residual obligations, Provider of Last Resort (POLR)
    - In both approaches, regulated by state public utility commissions

North American Electric Reliability Regions

NERC Regional Entities

FRCC

Florida Reliability Coordinating Council

SERC

SERC Reliability Corporation

MRO

Midwest Reliability Organization

SPP RE

Southwest Power Pool Regional Entity

NPCC

Northeast Power Coordinating Council

TRE

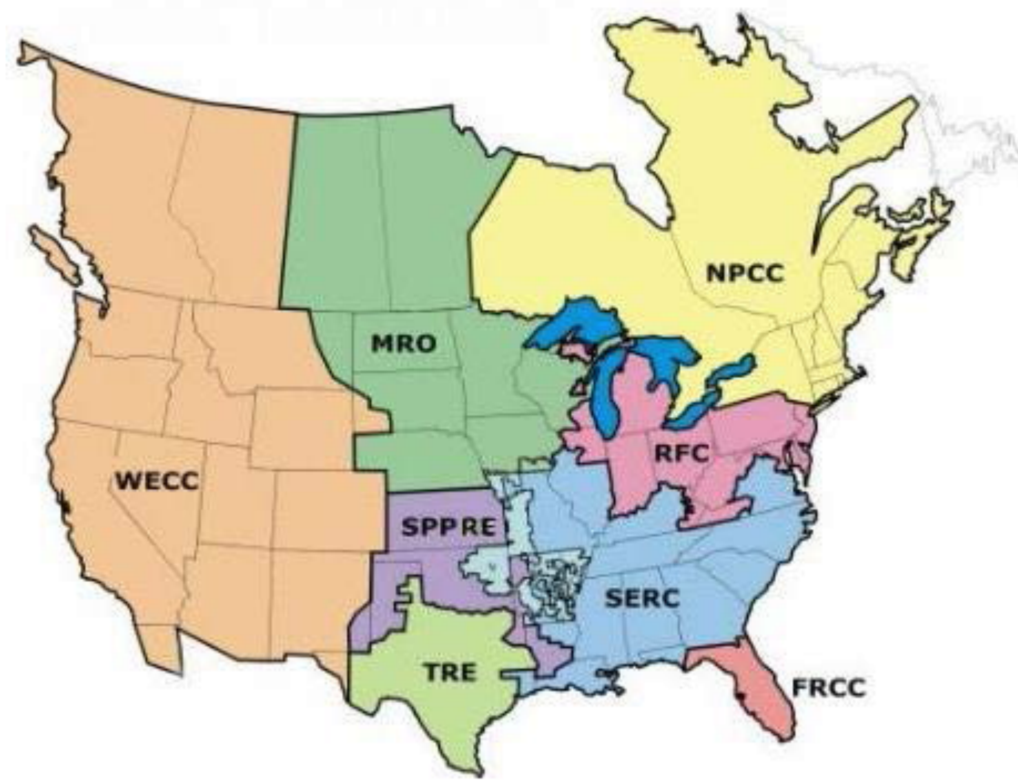
Texas Reliability Entity

RFC

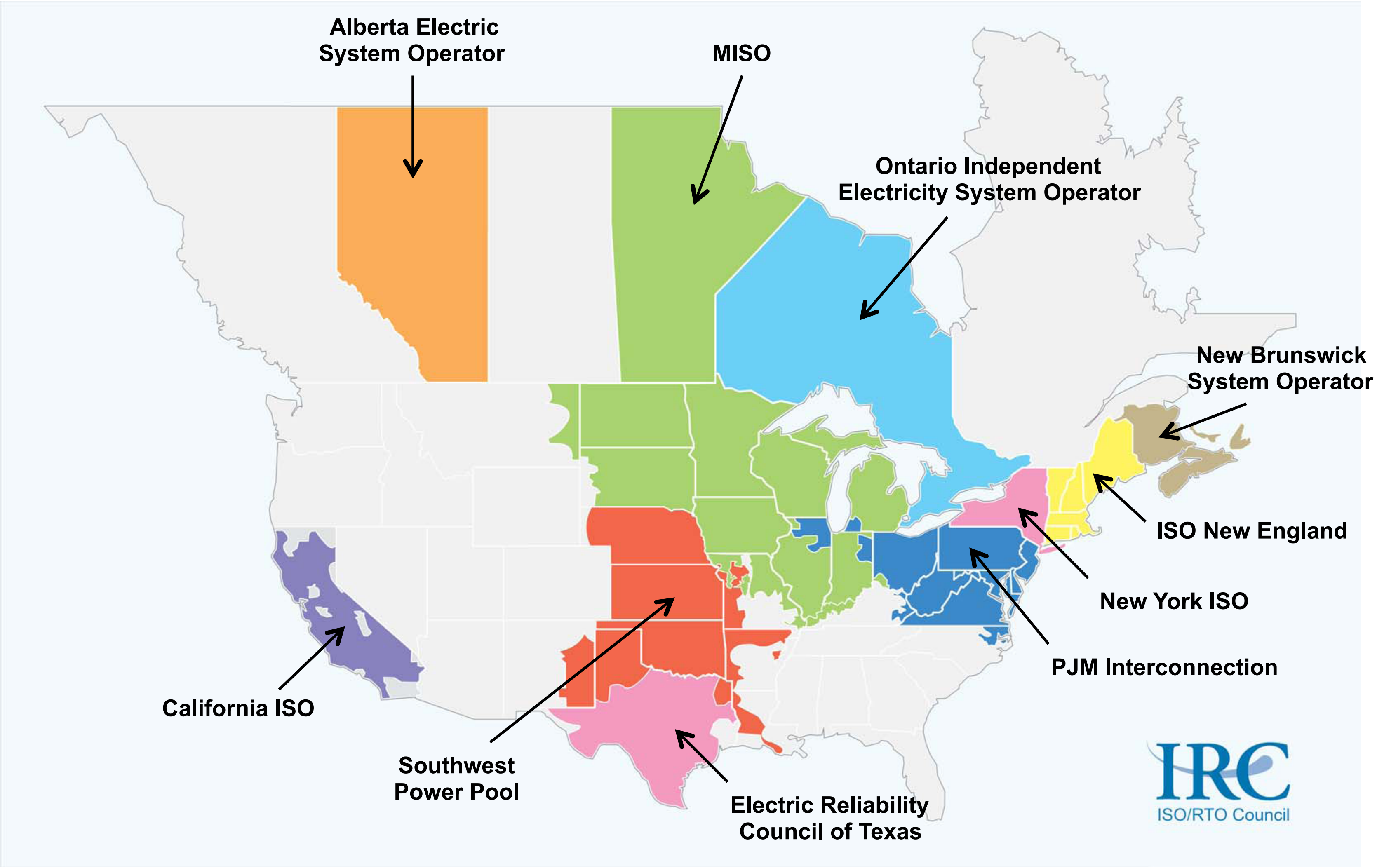
Reliability*First* Corporation

WECC

Western Electricity Coordinating Council



The Regional Transmission Organizations

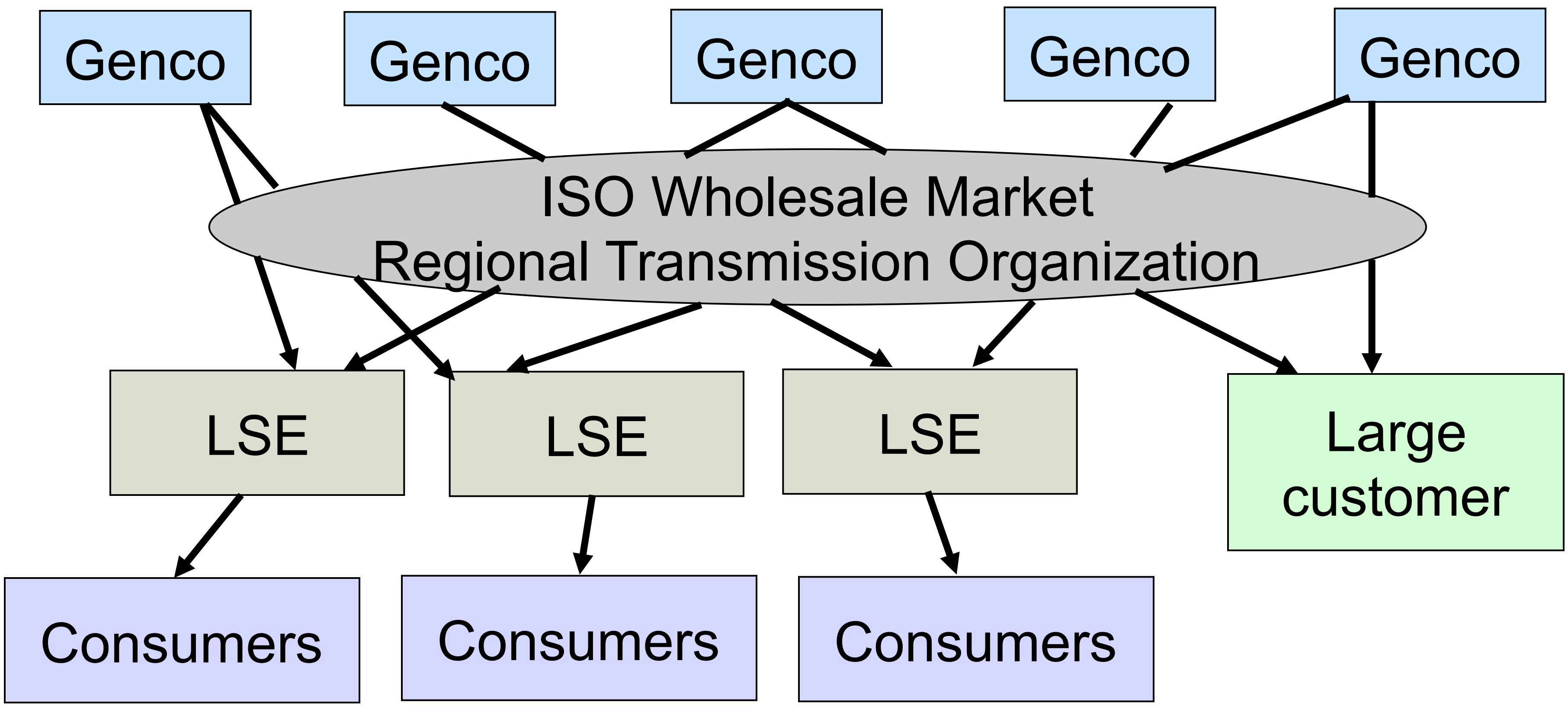


Restructured Wholesale Market

- ISOs are also market-makers
- Multi-settlement market
  - Day-ahead hourly market (DAM)
  - Real-time
    - Deviations from generation schedules (unscheduled outages)
    - Deviations from forecasted bids or demand
  - Day-after
    - Generators paid based on schedule, LSEs pay based on projected or bid demands
    - Suppliers and demanders charged for increased costs resulting from deviations from schedule by settling at real time prices
- Ancillary services markets
  - Operating reserves
  - Transmission-related
    - VARs
  - Capacity/Forward reserves market

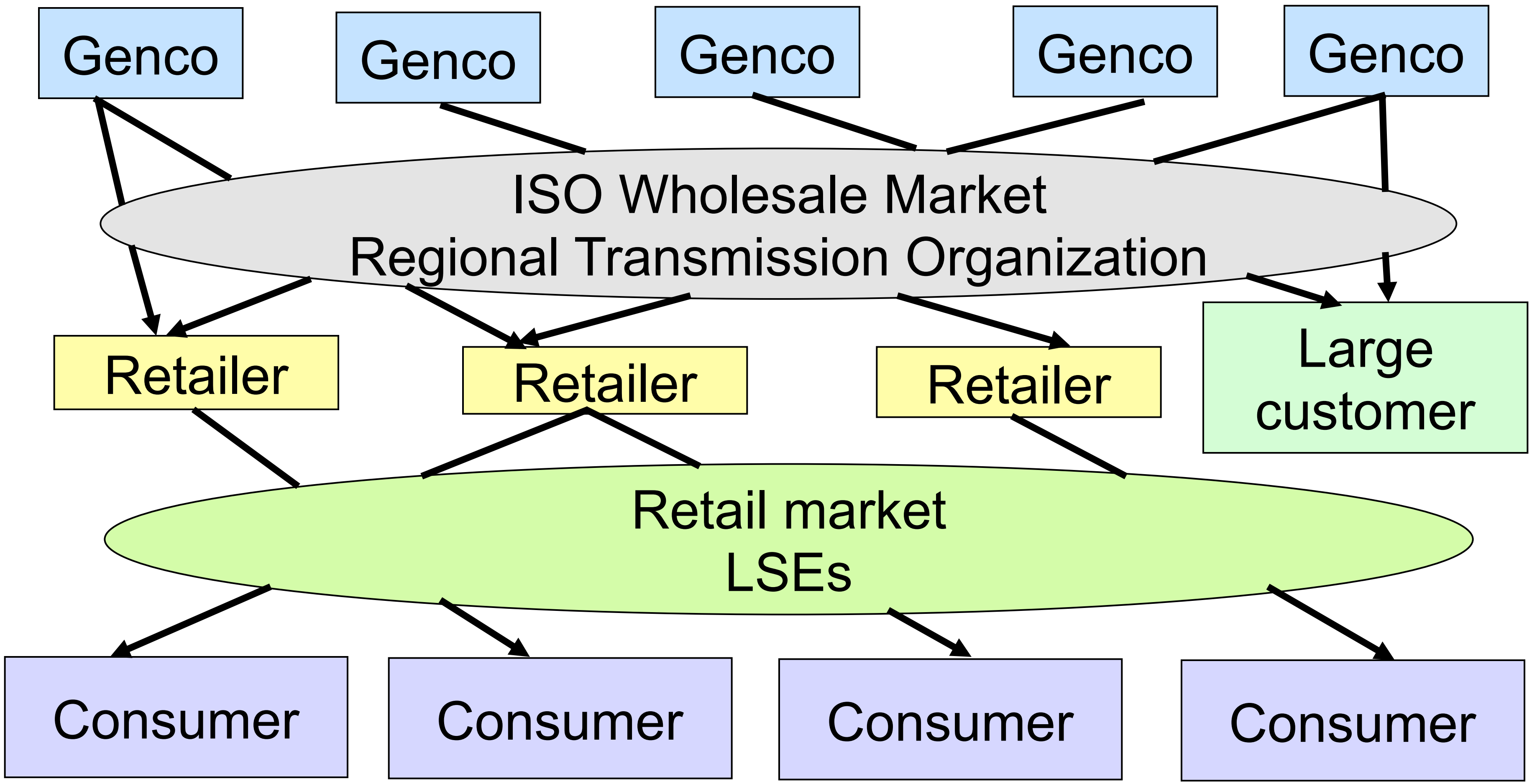
Restructured Markets

Wholesale competition - Centralized Market Design



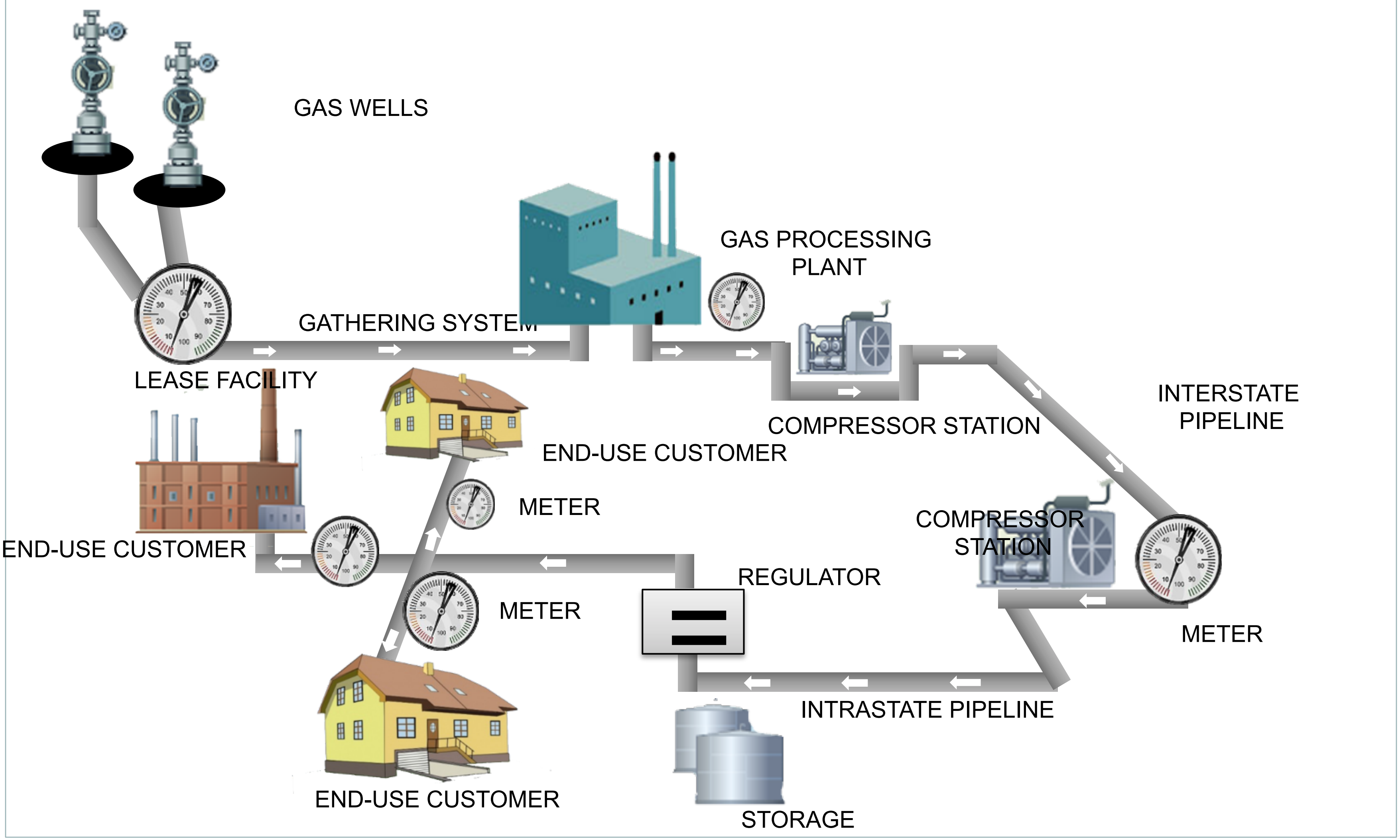
Restructured Markets

Centralized Wholesale Market/Decentralized Retail Market



Some Background on the Natural Gas Industry

The Natural Gas Delivery System



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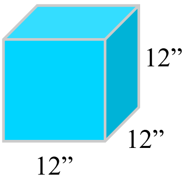
Common Units of Measurements

- NG is composed of approx. 1,000 Btus* per 1 cubic foot. Thus,
  - 1 cf = 1,000 Btu.

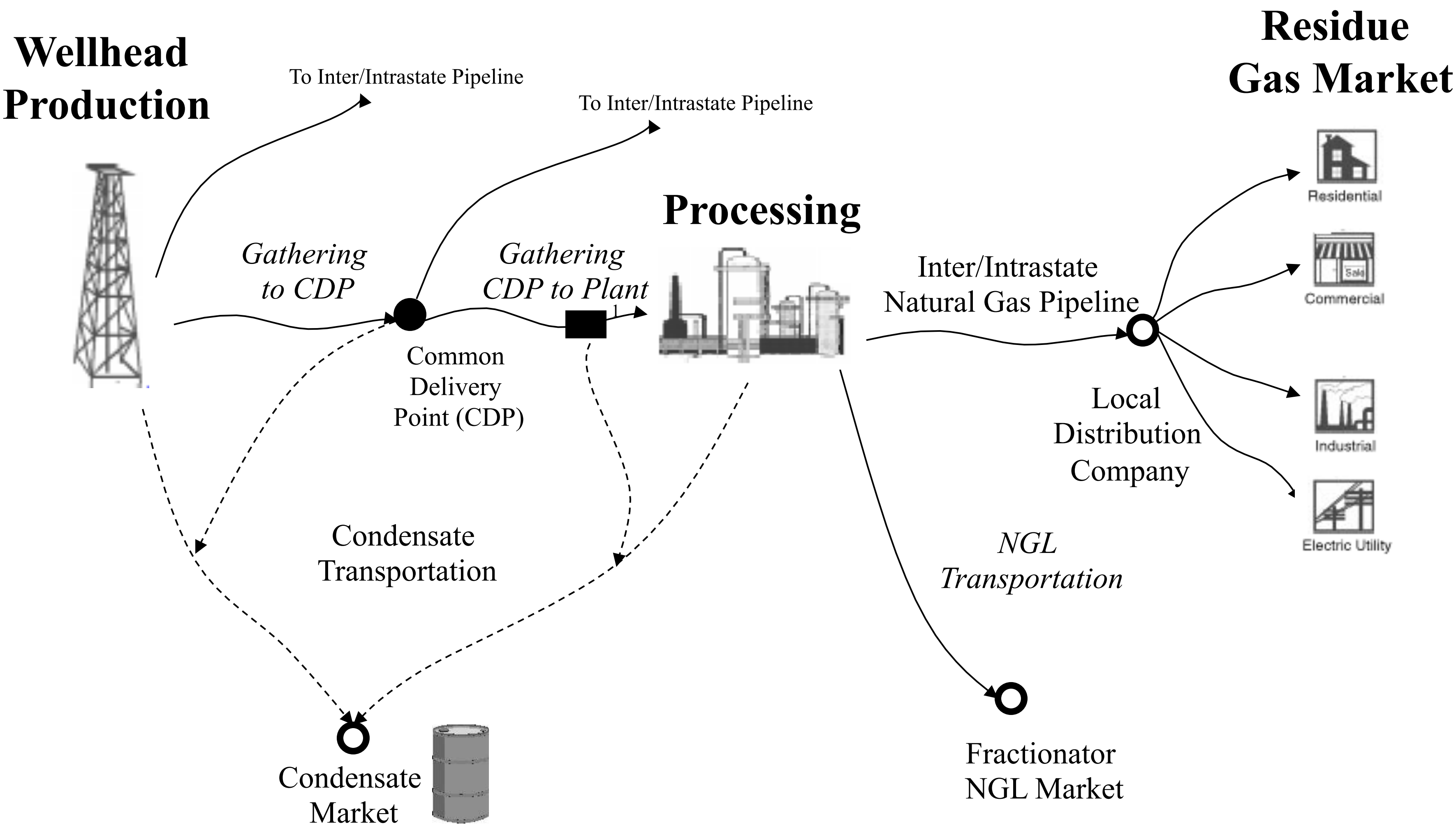
- 1 Mcf ≈ 1 MMBtu** = 1 Dekatherm (Dth)
  - 1 Dekatherm = 10 therms
  - 1 therm ≡ 100,000 Btus
- 1 Bcf*** = 1,000 MMcf



- We often like to look at gas units on a “per day” basis. For e.g., Bcf/d, Dth/d etc.

*Btu = British thermal unit = quantity of heat required to raise the temperature of one pound of water from 62°F to 63°F.
**In the gas industry, M is the Roman numeral representing one thousand. In electric, M is usually shorthand for “mega,” representing one million.
*** Bcf = Billion cubic feet. Similarly, TCF will be Trillion cubic feet.

Schematic of Product Markets



[1] Indicates free liquids/condensate separator prior to delivery to processing plant

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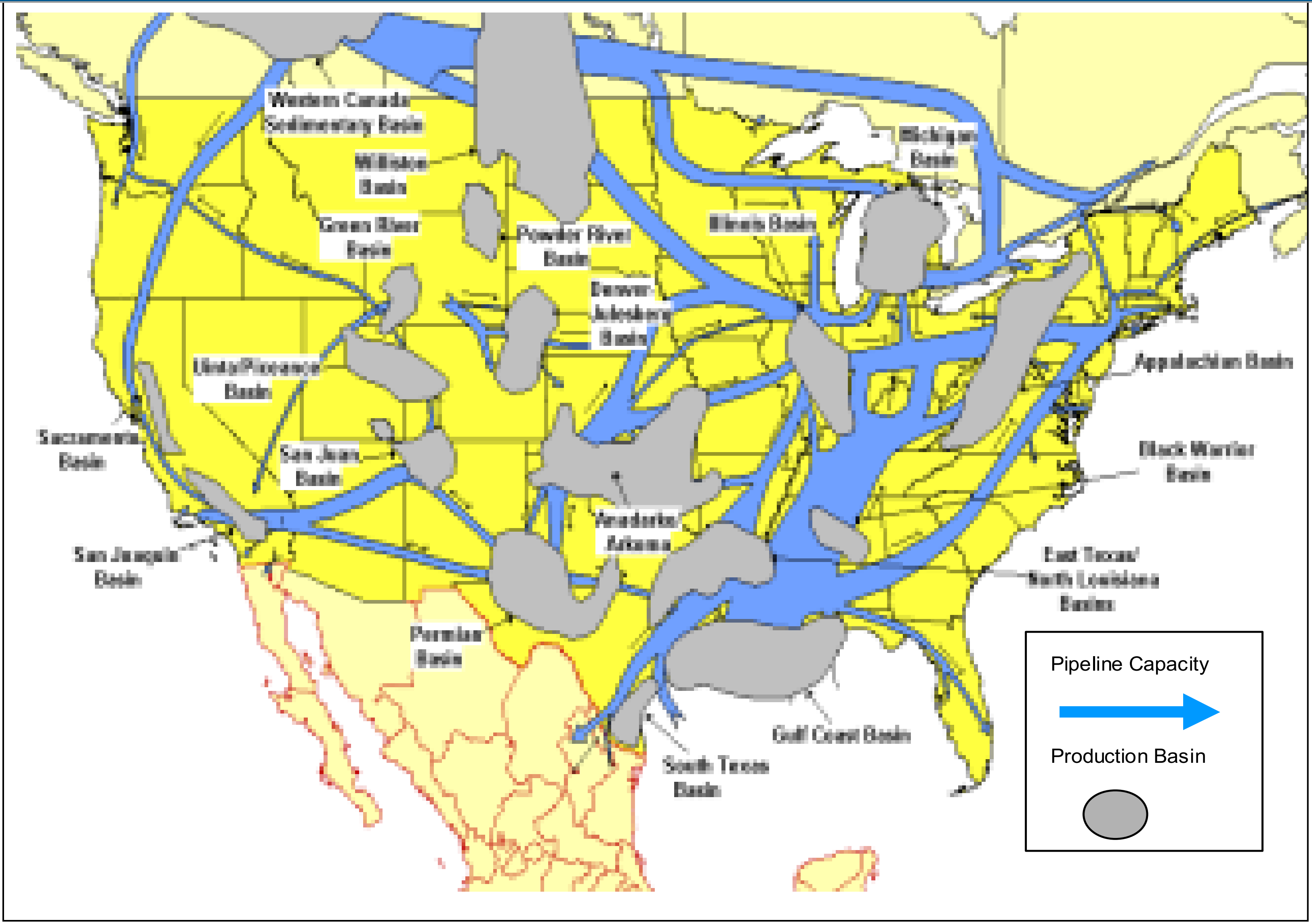
Major Supply Basins and Pipeline Capacity



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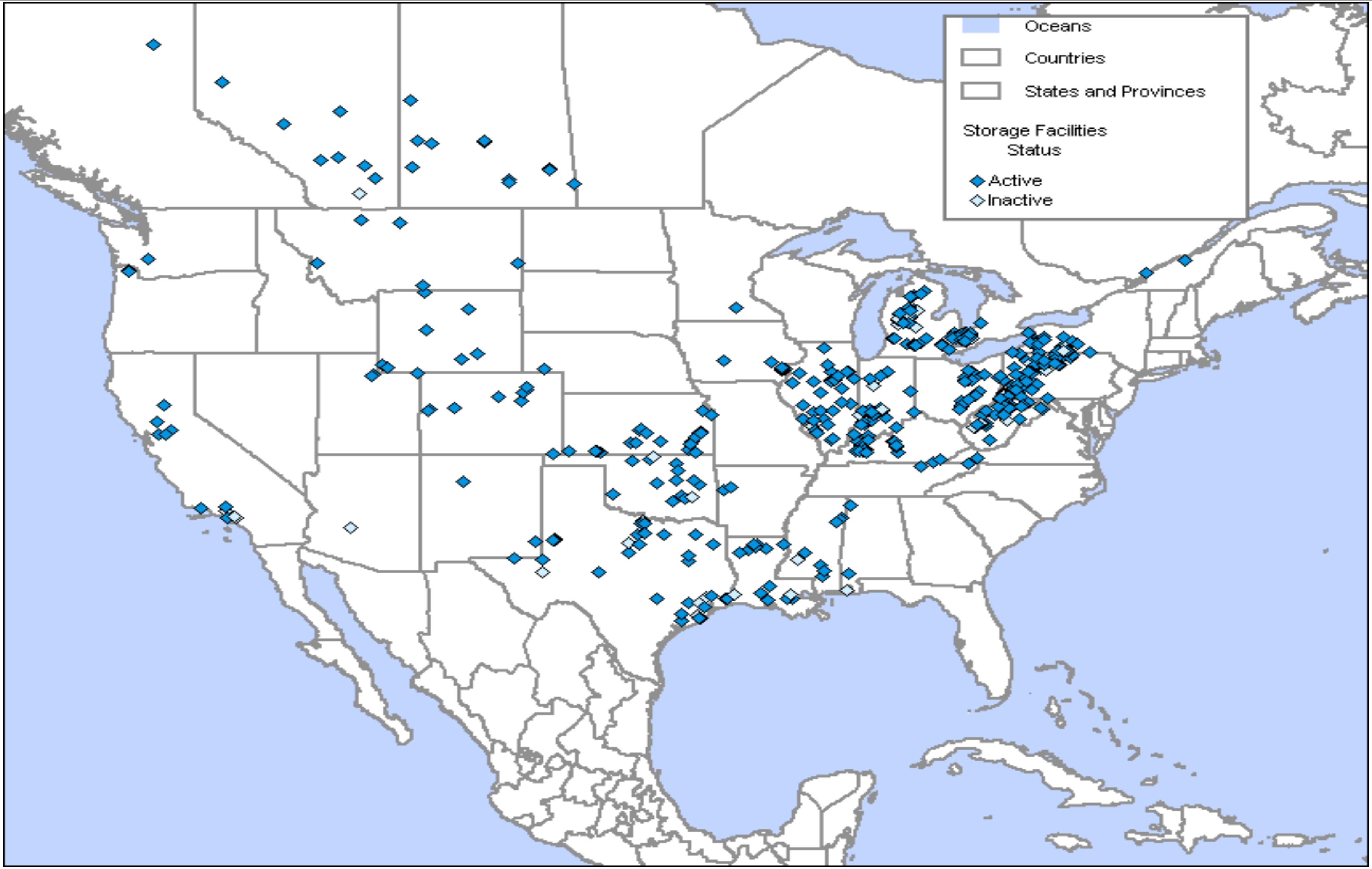
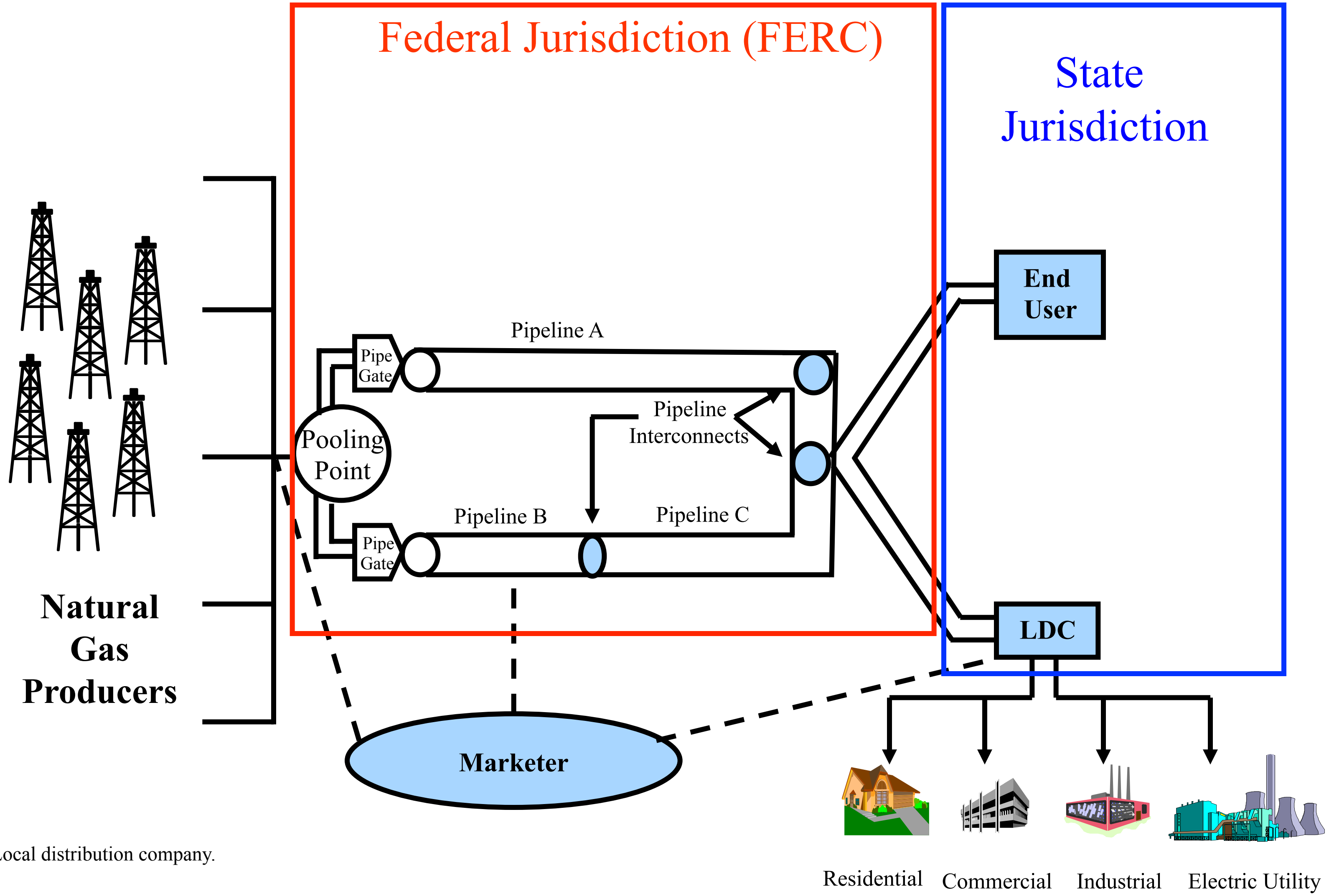
NG Storage Facilities: Not Evenly Scattered



Unregulated Production; Regulated Transmission/Distribution

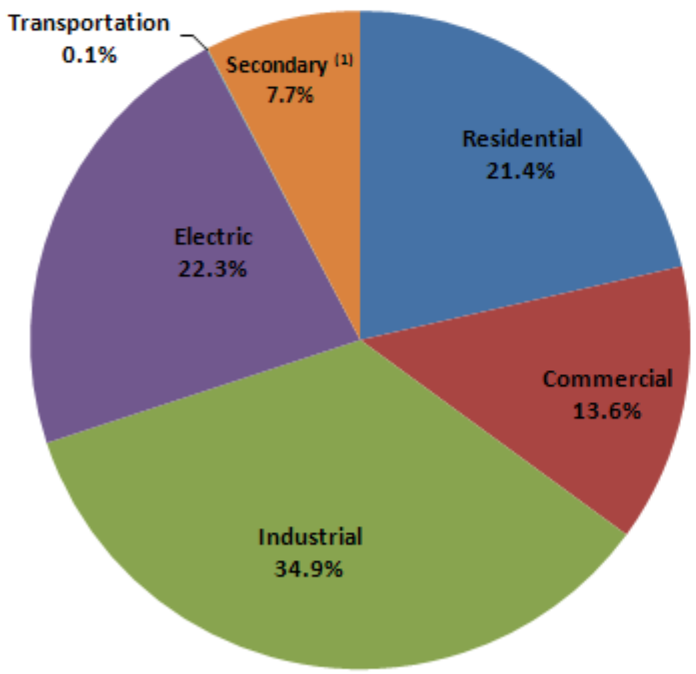


LDC= Local distribution company.

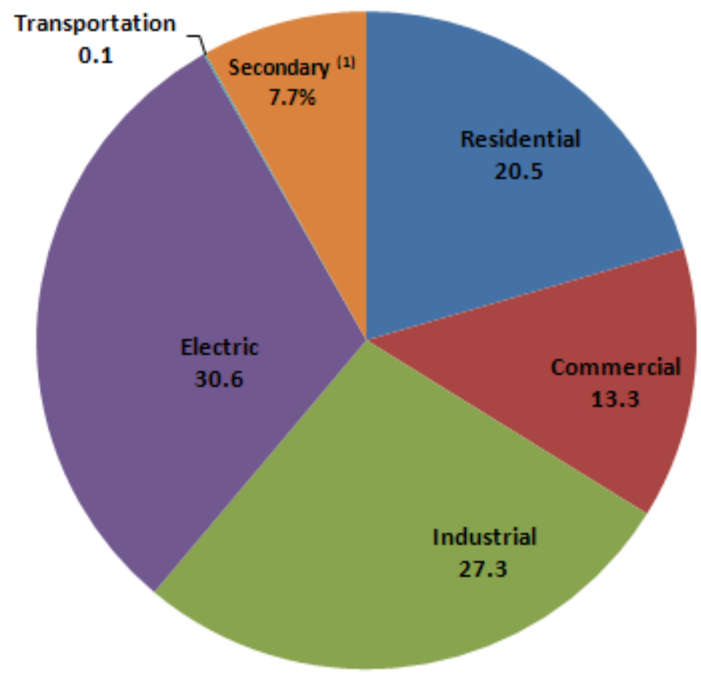
How Weather Data (Normal and otherwise) is Used

Natural Gas Demand by Sector

2000 Natural Gas Demand by Sector



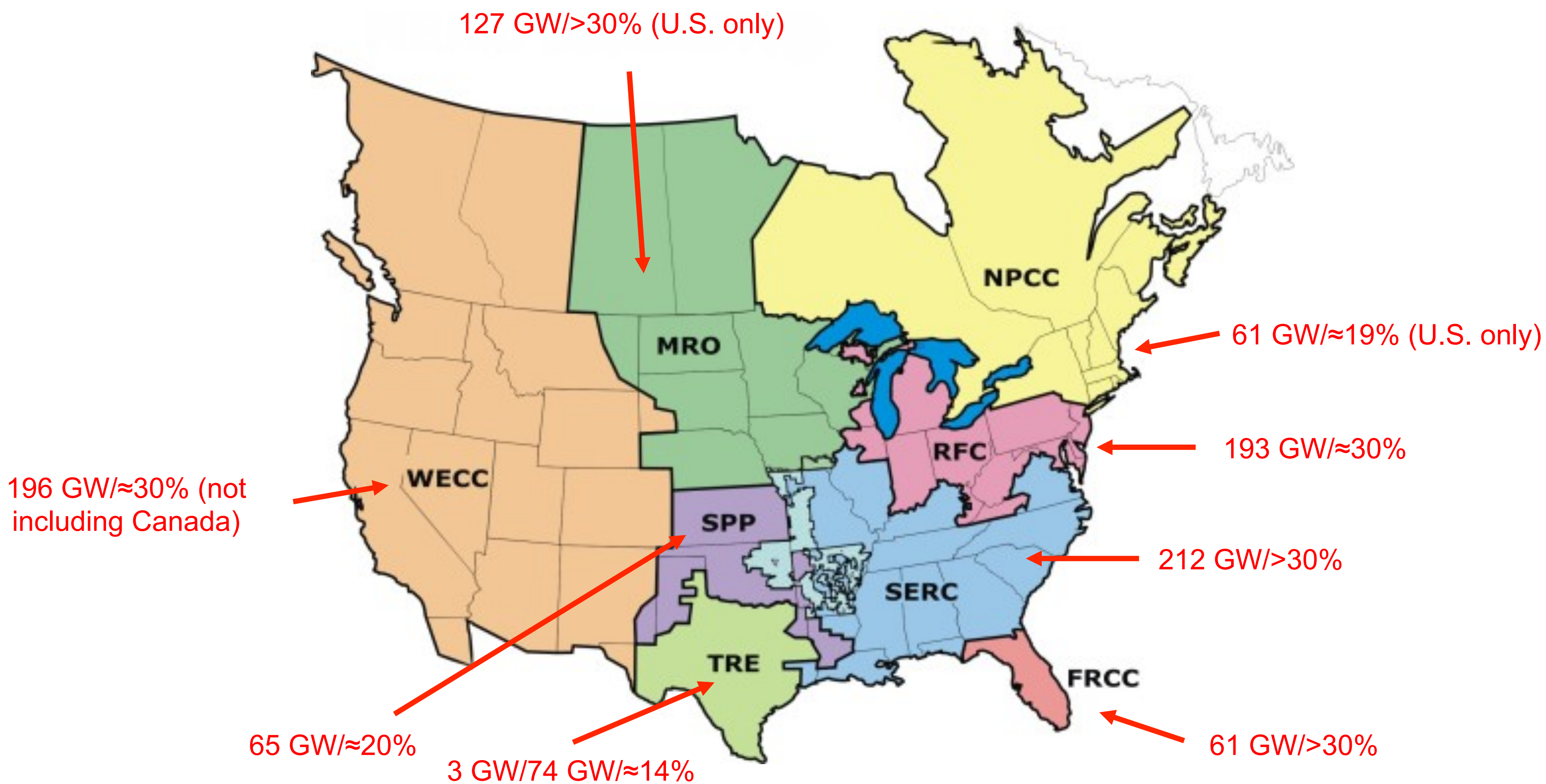
2010 Natural Gas Demand by Sector



1. Secondary Demand includes Lease and Plant Fuel, and Pipeline Fuel

Source: EIA

Capacity/reserve margins as of Summer, 2011



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Resource Requirements Forecasting

Electric energy and natural gas requirements are forecast on a variety of time scales

- Hour, day, month, season, year
  - Hour
    - Affects electric resources in place and their operation
    - Affects electric resources that can be brought to bear in short time periods, typically from 10 minutes to a few hours
  - Day
    - Affects non-electric resource natural gas demands and, thus, natural gas pipeline and distribution system requirements
    - Affects the choice of electric resources to be used – baseload, intermediate, peaking
    - Affects the fuel requirements of electric resources and, thus again, natural gas pipeline and distribution requirements

Resource Requirements Forecasting

Electric energy and natural gas requirements are forecast on a variety of time scales

- Hour, day, month/season/year, multi-year
  - Month/season/year
    - Affects storage requirements for natural gas
    - Affects scheduling of electric resource maintenance
    - Affects inventory control of large hydroelectric generation resources
  - Multi-year
    - New electric resource choices
    - New electric transmission/distribution
    - Sizing and positioning of natural gas storage facilities
    - New pipeline capacity
    - Local distribution company expansion

Resource operations

Electric resources

- Thermal generation
  - Efficiency (ambient temperature)
- Renewables
  - Wind velocity affects wind resources
  - Sun affects solar
- Transmission system
  - Higher temperatures increase sag and potential for ground faults
    - Tree trimming
  - Higher ambient temperatures increase losses for transmission lines and transformers
    - Also true for distribution system

Speaker Bio and Contact Information

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Mr. Hanser assists clients in issues ranging from market structure and market power and associated regulatory questions, to specific operational and strategic issues, such as transmission pricing, resource planning, and retail tariff strategies. He also has expertise in fuels procurement, environmental issues, forecasting, marketing and demand-side management, renewables integration, and other complex management and financial matters.

Over his thirty years in the industry, Mr. Hanser has appeared as an expert witness before the Federal Energy Regulatory Commission (FERC), numerous state public service and siting commissions, arbitration panels, and in federal and state courts. He served six years on the American Statistical Association's Advisory Committee to the Energy Information Administration (EIA) and serves as a referee for both IAEE and IEEE journals.

Prior to joining *The Brattle Group*, Mr. Hanser held teaching positions at the University of the Pacific, University of California at Davis, and Columbia University, and has served as a guest lecturer at the Massachusetts Institute of Technology, Stanford University, and the University of Chicago. He was the manager of the Demand-Side Management Program at the Electric Power Research Institute (EPRI) before joining Brattle. He has published widely in leading industry and economic journals.

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Our services to the electric power industry include:

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- Cost of Capital
- Demand Forecasting and Weather Normalization
- Demand Response and Energy Efficiency
- Electricity Market Modeling
- Energy Asset Valuation
- Energy Contract Litigation
- Environmental Compliance
- Fuel and Power Procurement
- Incentive Regulation
- Rate Design, Cost Allocation, and Rate Structure
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