Introduction to the Electricity Sector

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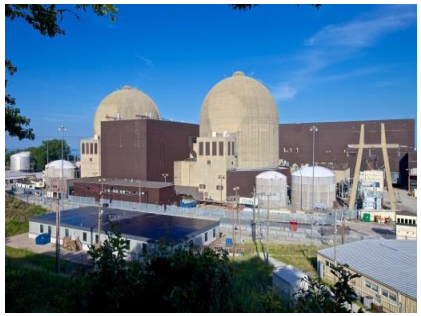


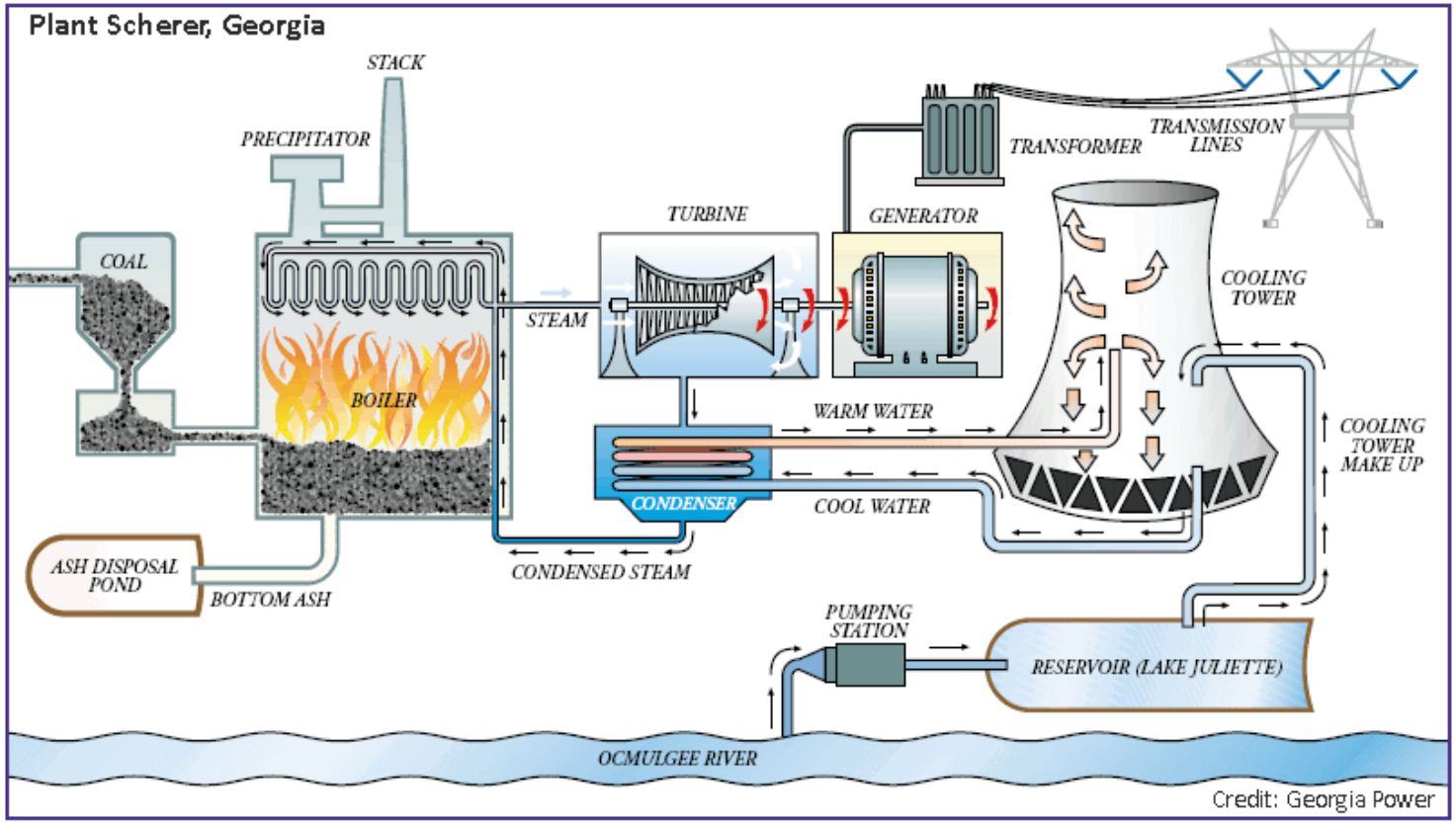

U.S. Energy/Electricity Use

- *About 40% of Energy Used in the U.S. Goes to Generate Electricity (38.5 Quads Out of 95 Quads in 2012). Largest Energy-Using Sector*
- *Transportation Next Largest at 28%*
- *Substantial Losses Between Fuel Used to Generate Electricity (38.5 Quads) and Final Electricity Delivered to Customer (12.5 Quads). In other words, only about 1/3 of the original energy used ends up as electricity delivered to customer.*

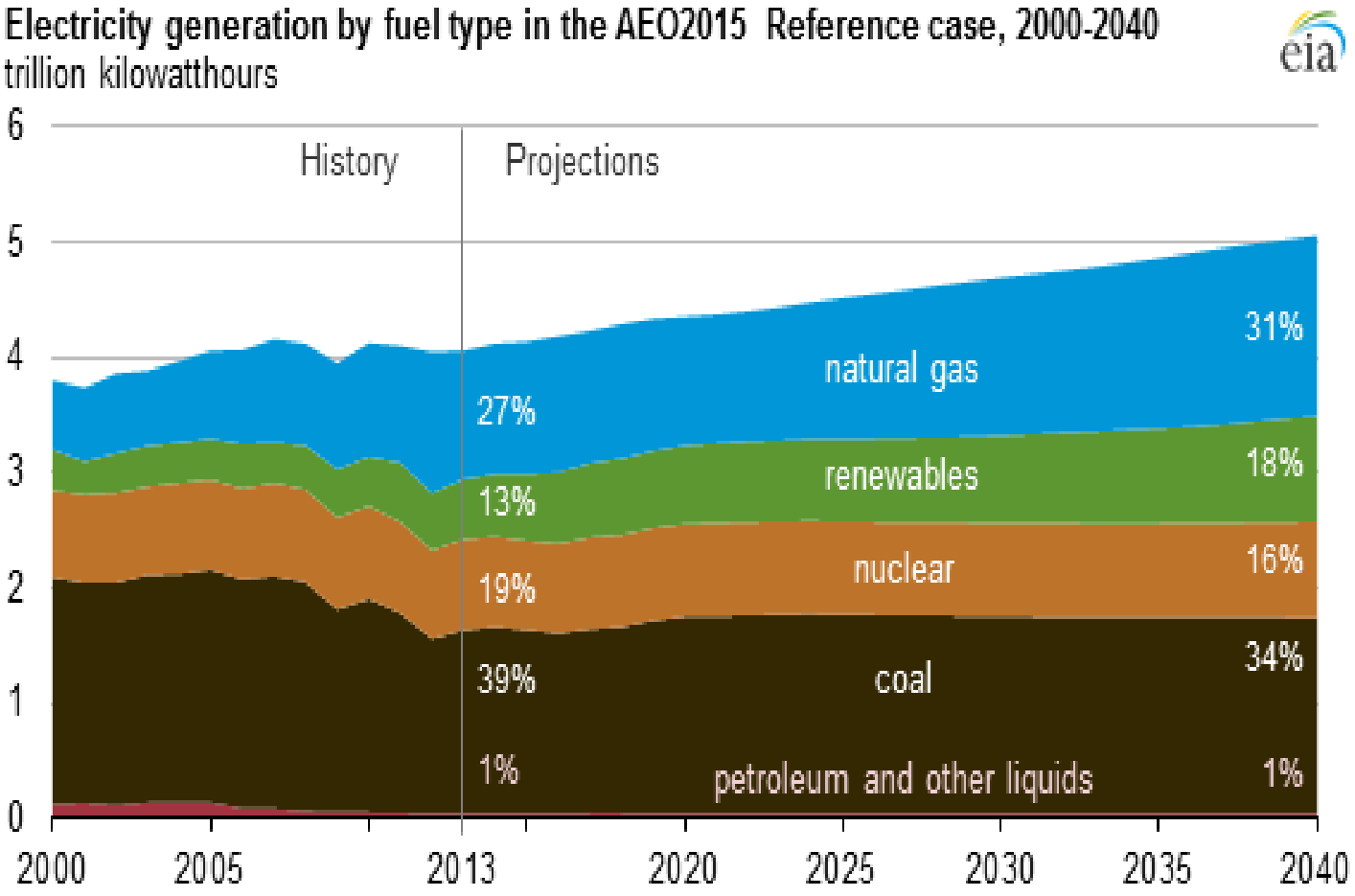
Electricity Generation Basics

- *Most all of US Electricity Generated by Central-Station Power Plants (ex. industrial combined heat/power and rooftop solar)*
- *Steam-Electric (All Coal, Biomass, Nuclear, Some Oil and Gas, some Solar) uses steam turbine (Generally about 30-40% efficient)*
- *Some, smaller, usually natural gas fueled units are Combustion Turbines. These produce electricity directly from the fuel.*
- *Combined-Cycle Gas units use BOTH a steam turbine and a gas turbine to produce electricity. These are the most efficient fossil fueled units (About 50% efficient).*
- *Renewables such as hydro and wind use a mechanical turbine to produce electricity.*
- *Storage is rare in the industry. Thus, plants must be dispatched continuously to meet demand.*

Power Plants: Scale and Scope



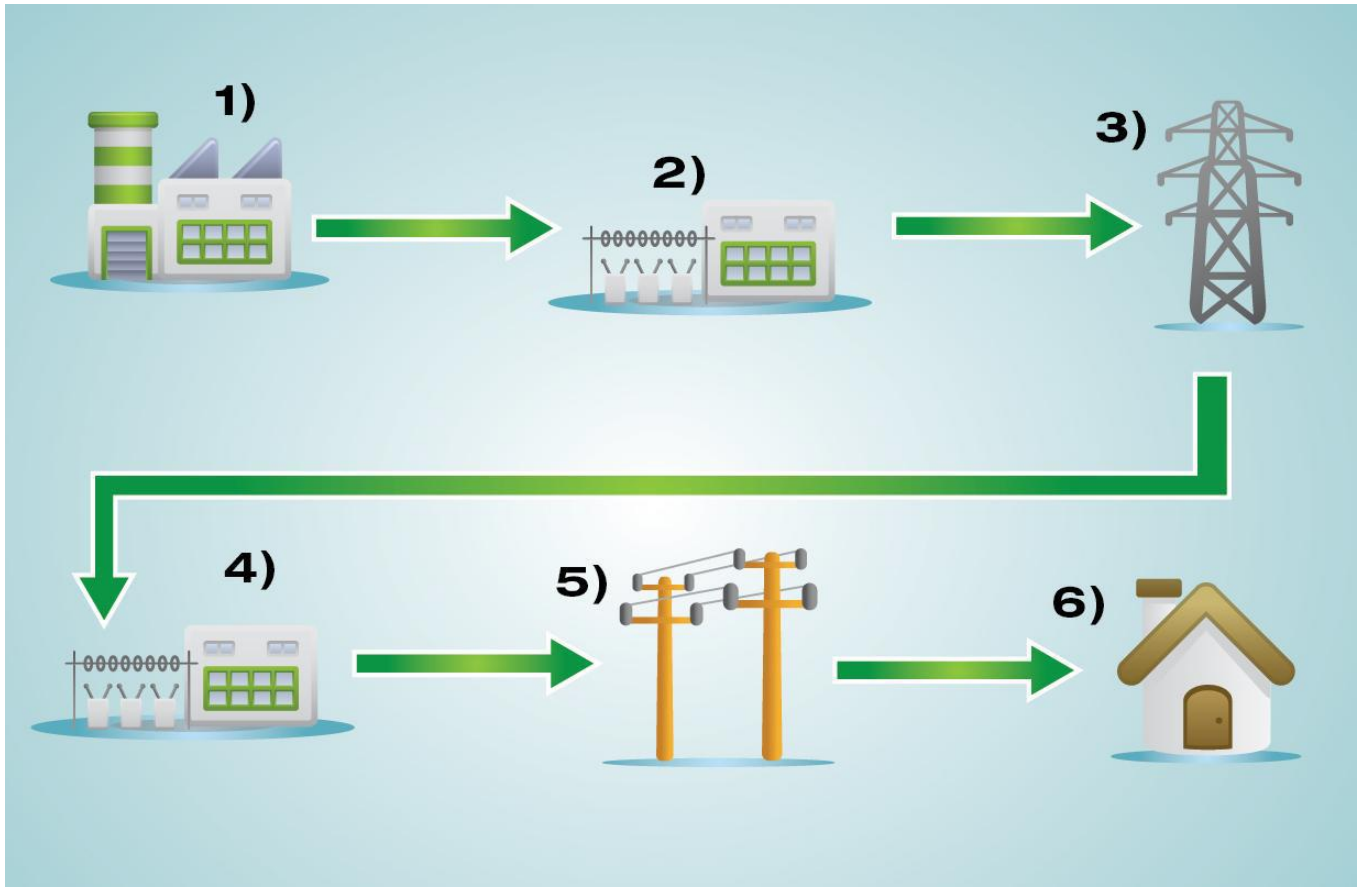
What Fuels are used to Generate Electricity?



Electricity (Physics)101

- ***Electricity Charge (Coulombs)***
- ***Current (Amperes)=*** *Flow rate of electricity charges (Coulomb/sec). This "flow" is carefully regulated by utilities to ensure a household or business gets XX amps all the time.*
- ***Voltage (Joules/Coulomb)= "****force" of electricity flowing thru lines (e.g. garden hose analogy).*
- ***Power (Watts or Joules/Sec) = Voltage X Current.*** *Power is a measure of "Capacity" which indicates how many Watts, Kilowatts or Megawatts are available at a given time.*
- ***Electricity Generation/Sales/Usage (Kilowatt-hours).*** *Power or Capacity of Plant X Hours Operated in a Year = Annual Generation in KWH*

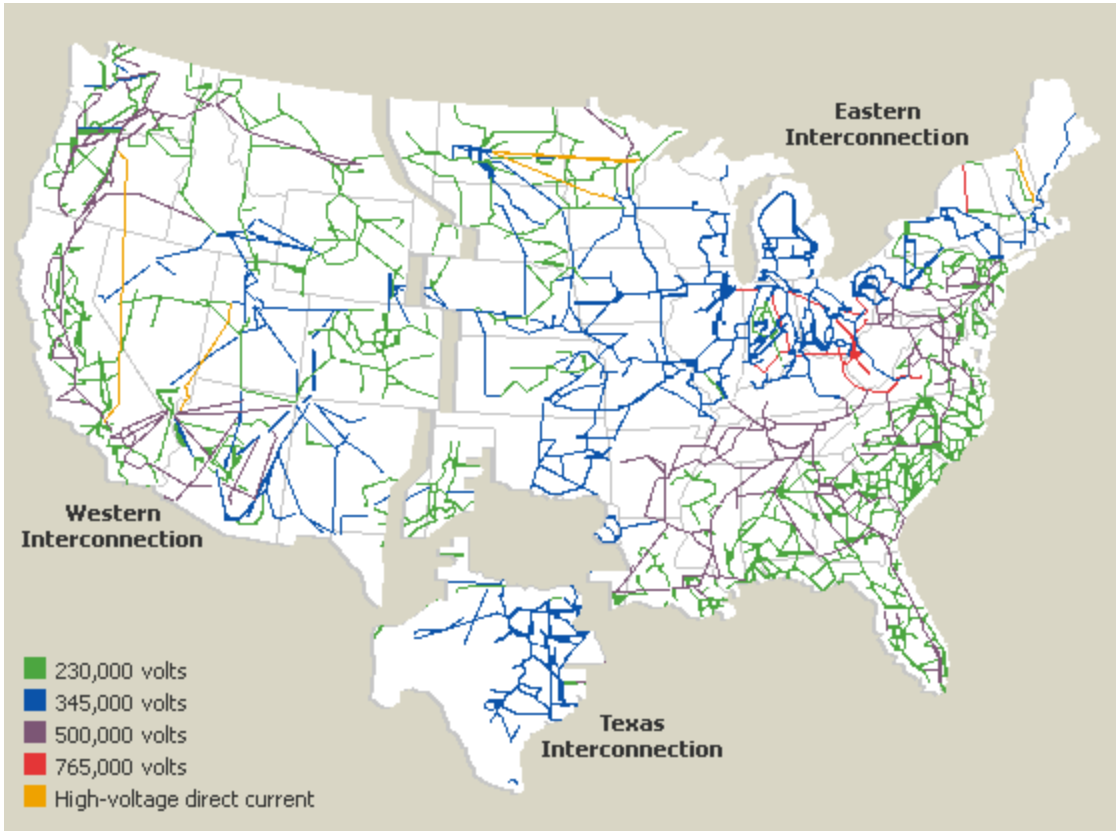
Electricity Delivery Business



1. Electricity is generated and leaves power plant. (GENERATION)
2. Voltage is increased at a "step-up" substation.
3. Power travels along transmission lines to area where it is needed. (TRANSMISSION)
4. Voltage is then decreased or "stepped-down" at a substation.
5. Distribution power lines carry the electricity. (DISTRIBUTION)
6. Electricity reaches your home or business. (RETAIL)

Source: Edison Electric Institute

Transmission Grid



Electricity Flows are Very Complicated

- *Electricity Generated at a Plant Does NOT follow a linear path to customer.*
- *Enters Grid and then follows "path of least resistance" or Ohm's Law i = V/R or Current= Voltage/Resistance.*
- *Current flows along multiple electrical lines in grid proportional to voltage and inversely proportional to resistance.*
- *Means Location of Plant and Customer Matters A LOT. Not just a simple balancing of supply and demand in region.*

A Brief History of the Electric Industry

- *1900-30s –Electricity technologies develop. Electric Utilities develop as "natural monopolies"; prices are regulated by states*
- *1935- (PUHCA) Public Utilities Holding Company Act—limit utility holding companies to states or regions; to keep prices regulated by states*
- *1970s—Inflation and Higher Energy Prices For First Time Cost of Electricity is Increasing*
- *1978- (PURPA) – Public Utilities Regulatory Policy Act- Non-utility generation development begins*
- *Late 1980s/1990s —Natural Gas Price Deregulation—Lower Prices lead to many new gas plants*
- *1996 - FERC Order 888 – Open Access Non-discriminatory Transmission*
- *Late 1990s/Early 2000s –Retail Competition/Industry Restructuring in a Number of States*
- *2001-2002 California Experience and Enron – California's broken system leads to Suspension of Restructuring/Competition in Many States*

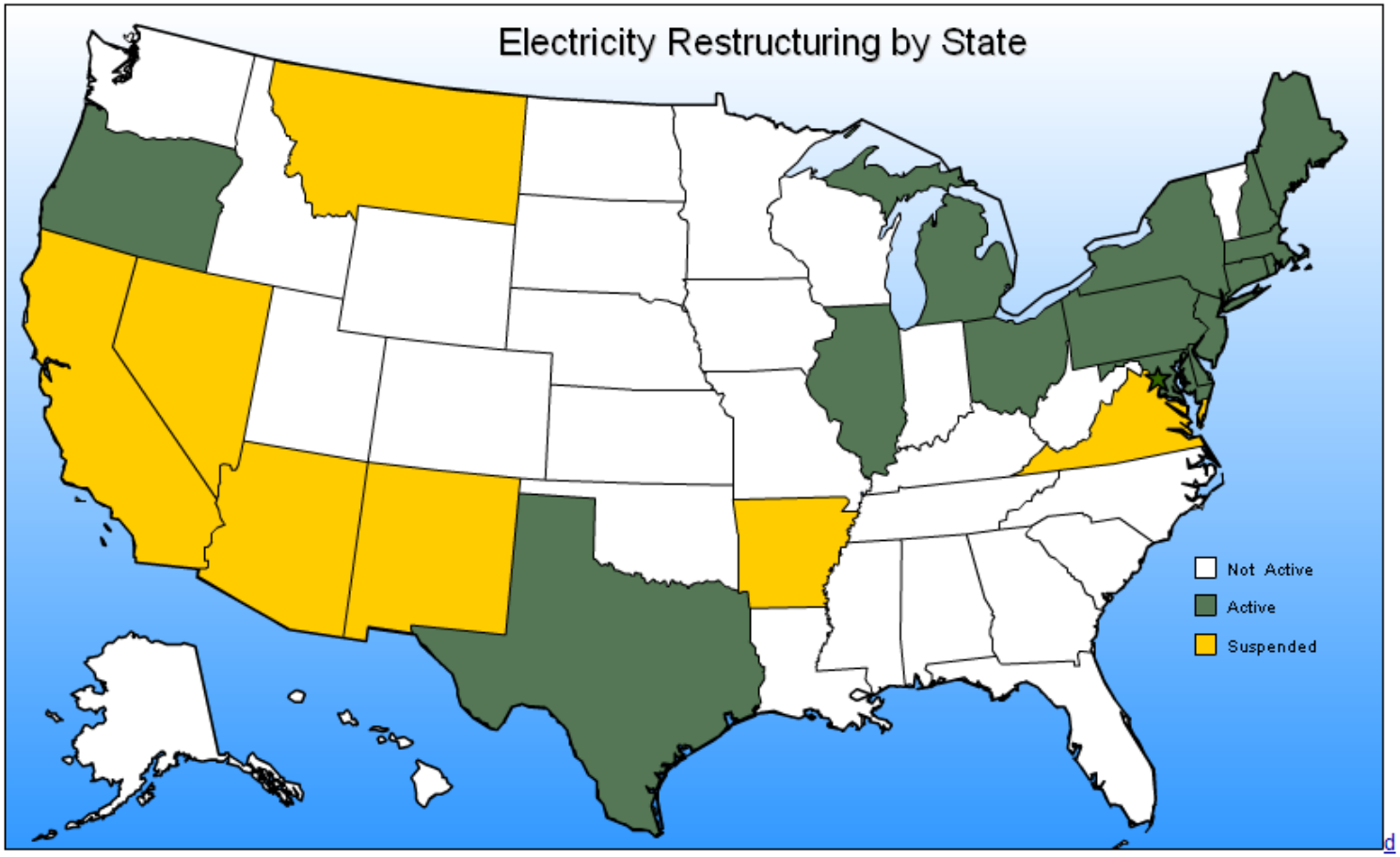
Electricity Businesses

- *"Wires" (Transmission and Distribution) Regulated "Cost of Service" Business.*
- *Generation:*
  - *Wholesale—Generally deregulated*
  - *Retail– Varies by State:*
    - *Some are "restructured" and have retail competition.*
    - *Others are "cost of service" but include pass thru of wholesale power purchases and sales.*

Electric Restructuring Fundamentals

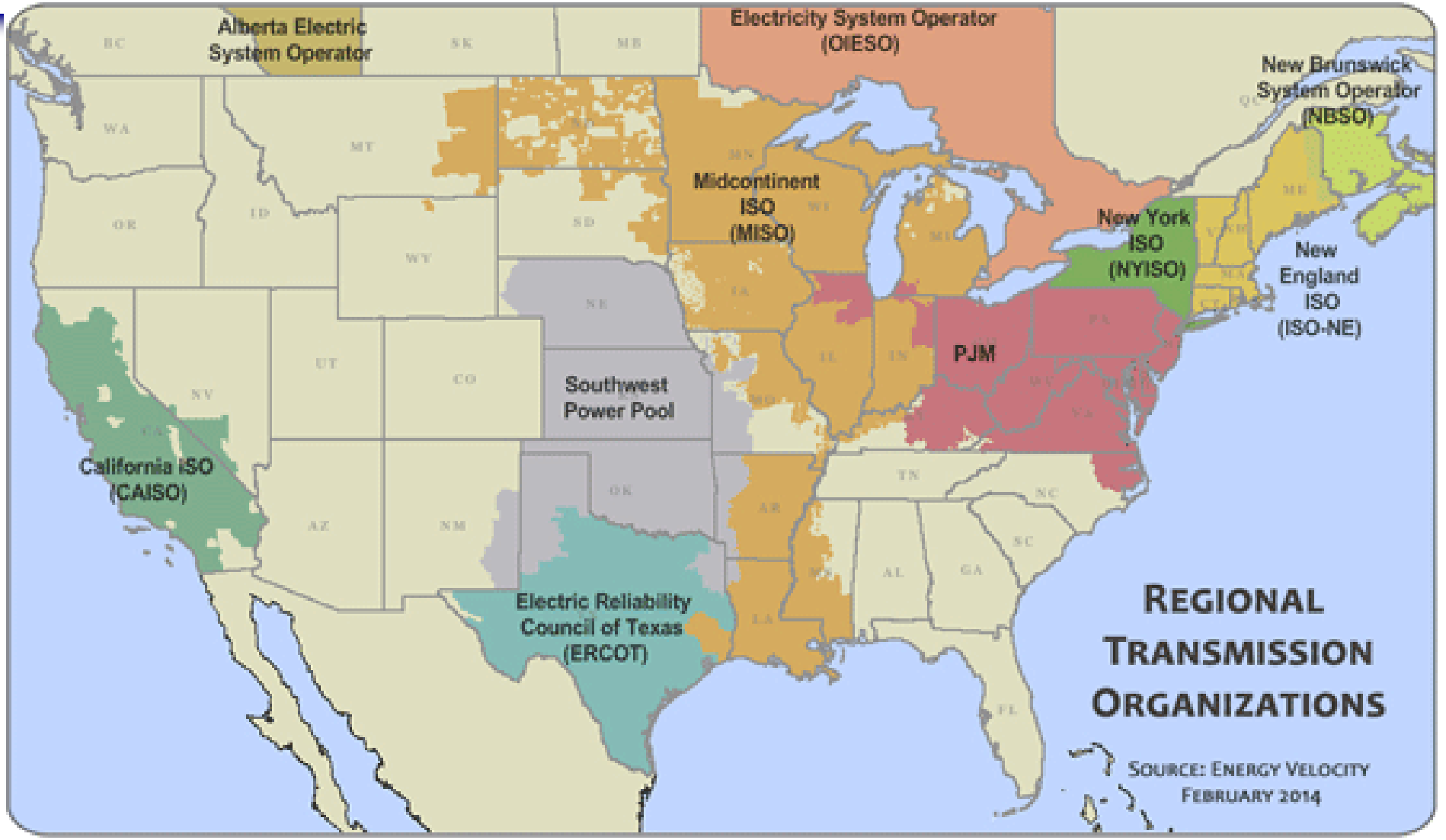
- *Traditionally, "integrated" (G&T&D) electric utilities were granted monopoly status with electric rates set by state regulators based on "cost of service." FERC helped create "competition" for new generation services in 1980s-1990s.*
- *Over past two decades, many states have switched to a restructured or "competitive" model in which alternative "generation" and "retail" suppliers compete for customers.*
- *Competitive model usually required some form of "unbundling" of generation from still regulated T&D.*
- *Impetus of state "restructuring" was desire for lower rates. Late 1990s/early 2000s put damper on state restructuring.*
- *Today's lower price natural gas and increasing capital expenditures on existing coal-fleet could drive additional states to restructuring.*

Electricity Restructuring

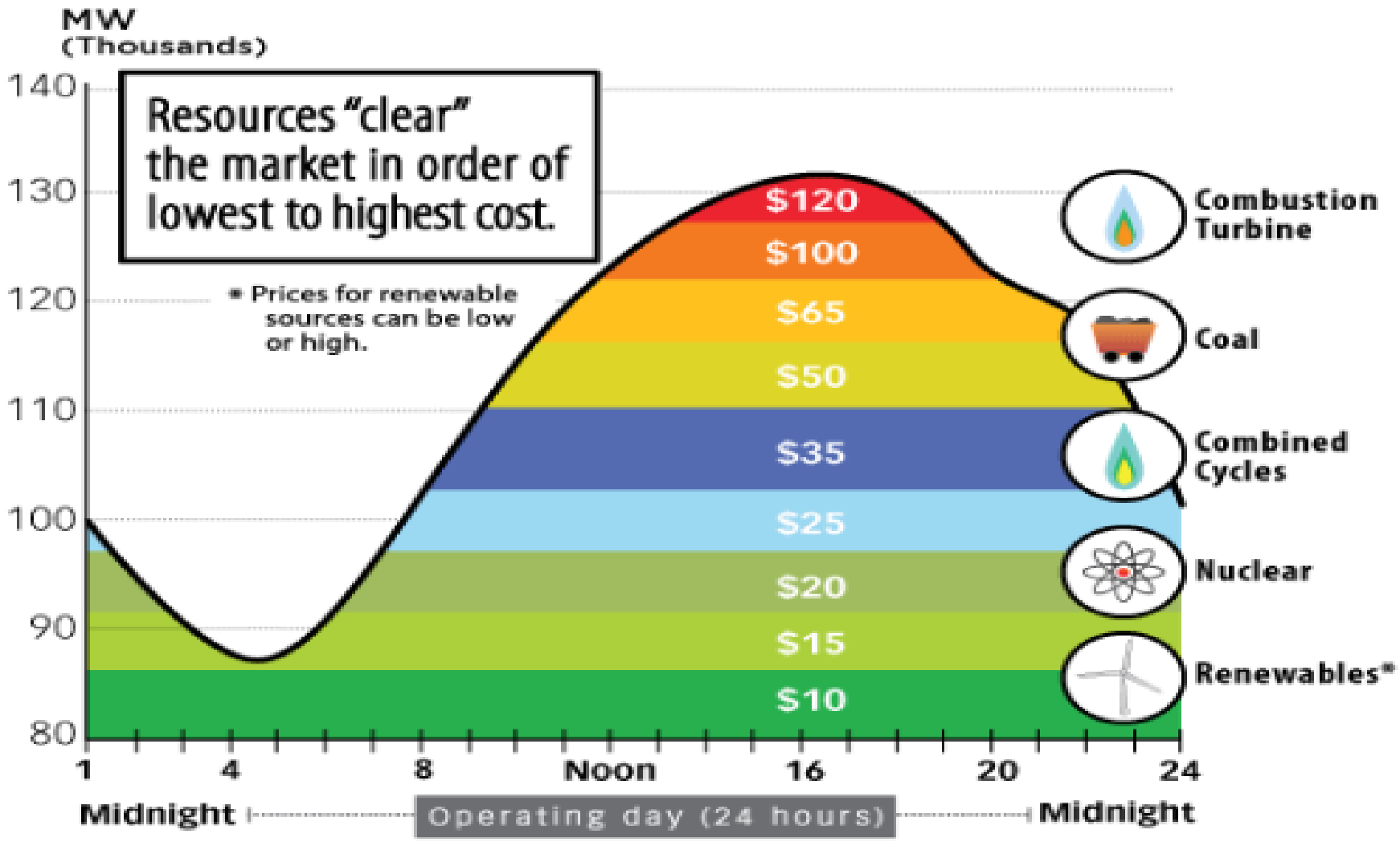


Source: Energy Information Administration

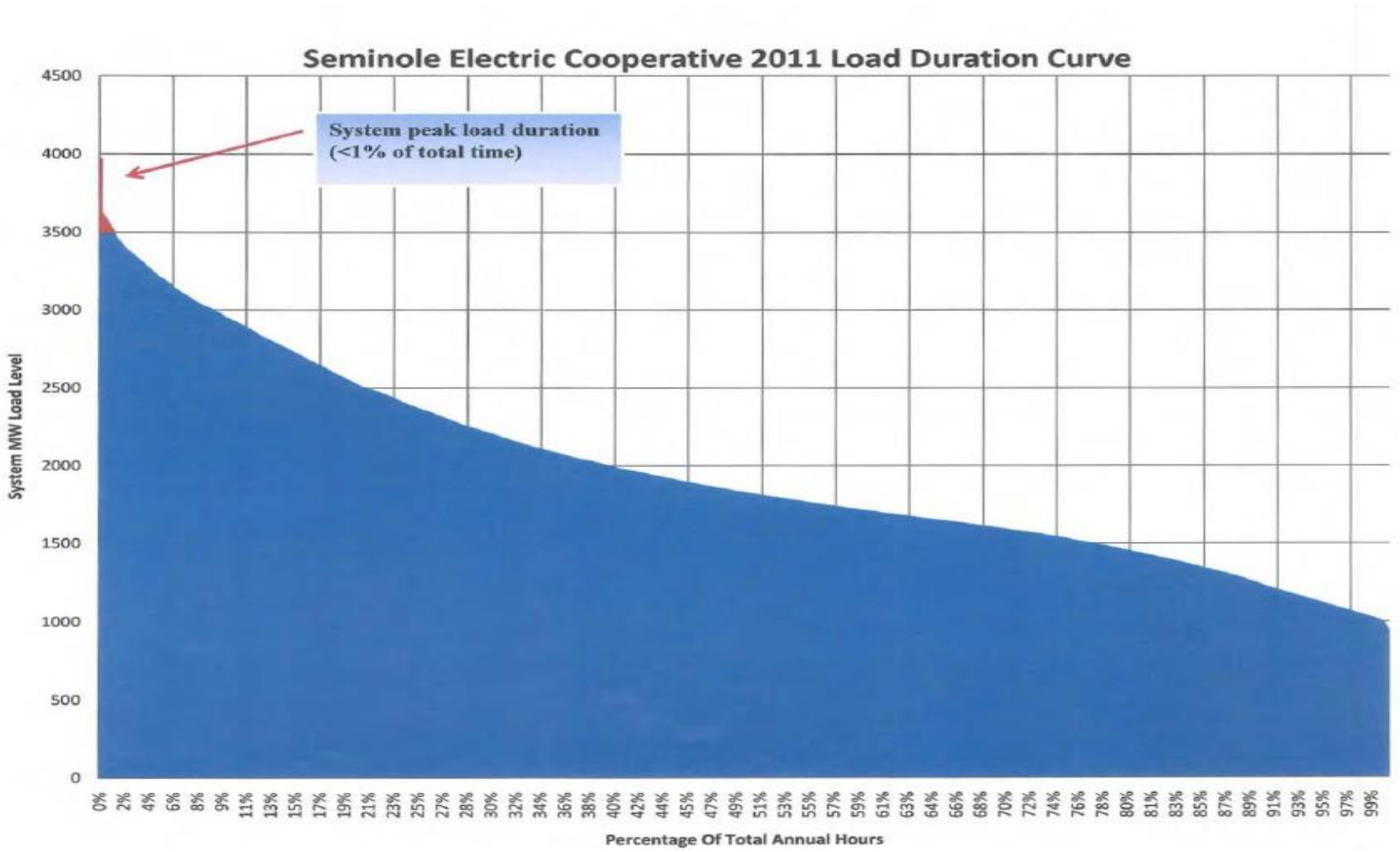
Regional Transmission Organizations



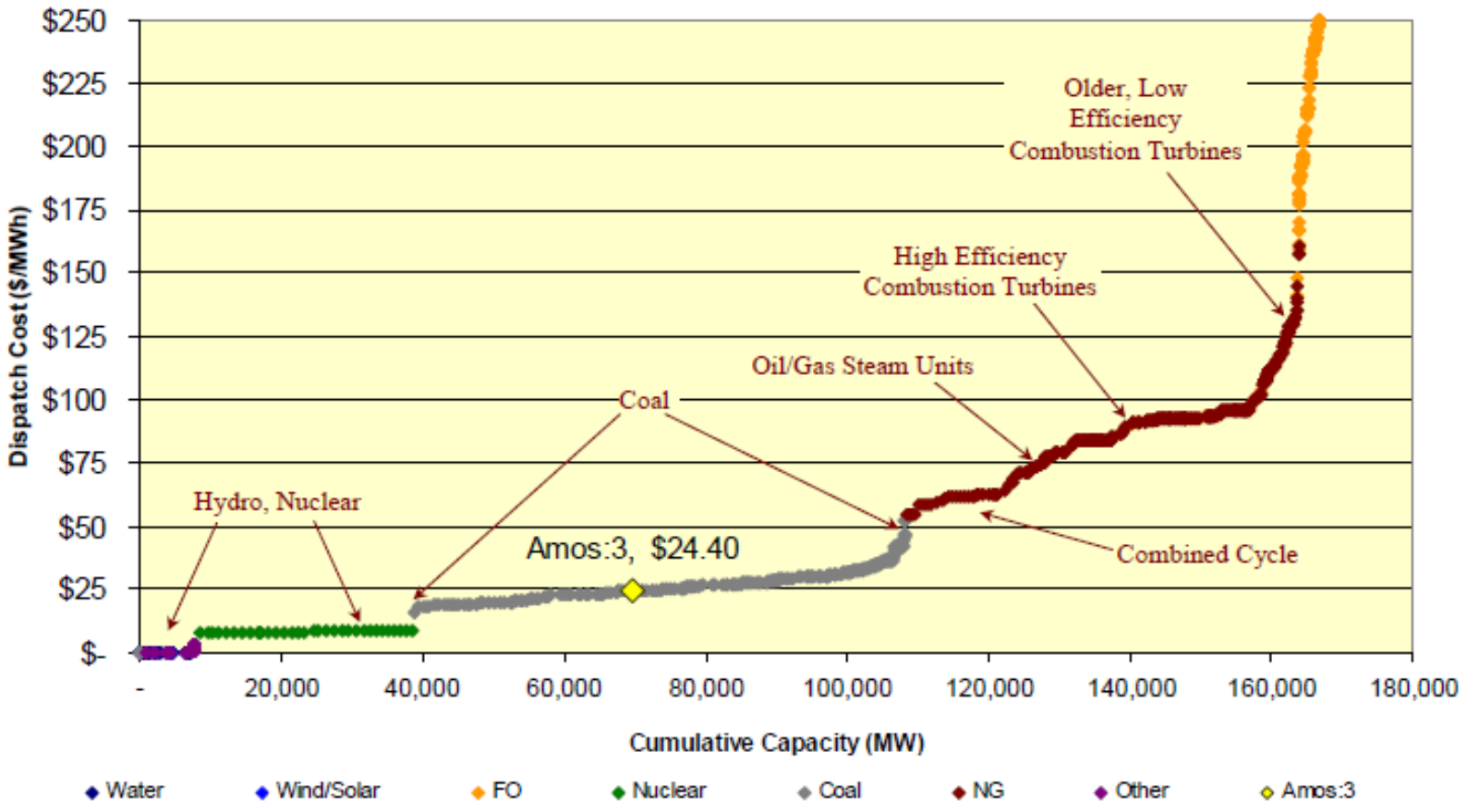
Typical Chronological Load Curve



Annual Load Curves



Electric Energy Market: Supply/Demand/Prices



PJM market example from 2008. Dispatch Cost is the Variable Cost of Units. Marginal Cost to Meet Hourly Demand = Price in that Hour

Capacity vs Energy Markets and Prices

- *Under traditional Cost-of-Service Regulation, utilities were required to hold "reserve margins". Typically, this amounted to holding excess generating capacity equal to 15-20% above estimated peak demand (Typically occurring in the summer).*
- *"Reserve Margin" designed to assure electricity reliability in the event of plant outages and/or unexpected demand increases (often due to weather).*
- *Some regional markets, most notably PJM, have developed "capacity markets" where generators bid in a capacity price and distribution utilities (responsible for serving customer load) can buy capacity several years ahead of time.*
- *Other markets (e.g. ERCOT) have NO formal capacity market.*

Capacity ≠ Energy

Capacity

- Annual Auction
- Paid to "be ready"
- Price = $/MW-day (e.g. $120/MW-day for 2017/18)

Energy

- Hourly Dispatch
- Paid only if produce
- Price = $/MWH (e.g. $40/MWH average in 2014)

"Levelized" Cost of Electricity

- ***Which New Power Plant Choice is Least Cost?***
- ***Capital ($/kw) X CCR= Ann. Capital ($/kw-yr.)***
- ***Fixed O&M ($/kw-yr.) (Annual fixed maintenance and labor that doesn't vary with plant operation)***
- ***Variable O&M ($/MWH) (varies with plant output , includes plant consumables)***
- ***Fuel Price ($/mmBtu) X Heat Rate(Btu/kwh)= Fuel Cost ($/Mwh)***
- ***Convert Ann. Cap. And Fixed O&M in $/kw-yr To $/Mwh Using Capacity Factor (Hrs. Operated/Year)***
- ***Sum All Costs in $/mwh for Total Levelized Costs.***

Example of Levelized Cost Calculation: New Gas CC

New CC Combined Cycle – Utilization = 68.5% Cap. Factor or 6000hrs./yr.; CCR = 0.1; Gas Price $4.00/MMBTU; Heat Rate = 7000 BTU/kwh

- *Capital $1200/kw –Annual Cap.=1200 x0.1= $120/kw-yr.*
- *Fixed O&M $30/kw-yr.*
- *Total Cap & O&M Fixed Charges =(120+30)=$150/kw-yr. Convert to $/MWh -- $150/kw-yr. x Yr./6000 Hrs. X 1000 kw/MW = $25/MWh.*
- *Variable O&M = $2/MWh*
- *Fuel = $4.00/MMBTU X 7000 BTU/kwh X 1000 kwh/MWh= $28/MWh*

- ***Total Cost of Electricity = $55/MWh OR 5.5 cents/kwh***

Example of Levelized Cost Calculation: New Gas CT

New CT (Combustion Turbine) – Utilization = 5.7% or 500 hrs./yr.; CCR = 0.1; Gas Price $4.00/MMBTU; Heat Rate = 10000 BTU/kwh

- *Capital $400/kw –Annual Cap.=400 x0.1= $40/kw-yr.*
- *Fixed O&M $10/kw-yr.*
- *Total Cap & O&M Fixed Charges =(40+10)=$50/kw-yr. Convert to $/MWh -- $50/kw-yr. x Yr./500 Hrs. X 1000 kw/MW = $100/MWh.*
- *Variable O&M = $2/MWh*
- *Fuel = $4.00/MMBTU X 10000 BTU/kwh X 1000 kwh/MWh= $40/MWh*
- ***Total Cost of Electricity = $142/MWh OR 14.2 cents/kwh***

Why Would You Ever Build A CT if its Cost of Electricity is almost 3 times a Gas CC?

Levelized Electricity Cost Comparison

- ***Why Would You Ever Build A CT if its Cost of Electricity is almost 3 times a Gas CC?***
- ***ANSWER:*** ***You have to also consider the importance and value/cost of capacity (at peak). CT is much cheaper $/kw cost than a CC.***
- ***BEST TO DO APPLES-APPLES Comparions with same capacity factors for power plants.***

Distributed Generation & Net Metering

- ***Distributed generation (DG) is small-scale, on-site power (e.g. solar panels) located at or near customers' homes or businesses.***
- ***Many DG customers are in states with "net metering" --allows them to sell any excess electricity at the full retail electric rate.***
- ***The retail electricity rate (in cents/kwh) includes not only the cost of the power but also the fixed costs of poles, wires, meters etc. to keep the grid safe/reliable AND to accommodate DG systems.***
- ***Through the credit, net-metered customers avoid paying some of these fixed costs of electricity service to their home/business.***
- ***Thus, All OTHER customers including those with low income and seniors, are subsidizing those with distributed generation.***
- ***Some states have begun revising tariffs to deal with this problem.***
- ***MORE DISCUSSION TO COME DURING RENEWABLES SECTION***