Welcome to Conesville Power Plant

Electricity from coal
Conesville Plant

177 employees

Retired Units:
Unit 2 (125 MW): 1957 – 2005
Unit 1 (125 MW): 1959 – 2005
Unit 3 (165 MW): 1962 – 2012

Active Units:
Unit 4 (780 MW): 1973 + 2009 scrubber retrofit
Unit 5 (410 MW + scrubber): 1976
Unit 6 (410 MW + scrubber): 1978

Active Total Output = 1,600 MW

27 million 60 W light bulbs
People run the processes that make the power
Learning Objectives

• Electric system - “the grid”
• Types of generation – pros vs. cons
• Coal fired generation
• Environmental protection

Conflicts & Constraints
Electricity
Electricity

Definition

What is electricity?
Matter is made of very small particles called atoms.

- proton [positive charge (+)]
- electron [negative charge (-)]

When electrons move from one atom to another atom, it produces electricity.

Useful

Uncontrolled

Controlled

Diagram: Direction of electric current and potential difference (V).
AC Power

U. S. generators spin at 60 revolutions / sec. (60 Hz) causing a sinusoidal wave form
Power System

- A giant network
- More stable if large
- Economy of scale
- 24/7 operation
- Instantaneous
- On demand - no storage
Supply vs. Demand

Power Generation must match Load Demand

- System frequency changes
- Adjustment made to supply to match demand
- Frequency rebalances

Supply Changes: Generation, Transmission, or Distribution disruption
PJM Pool Locational Marginal Pricing Map As of 2/20/15 (12:00p EST)

LMP Values (USD)
- $0-$20
- $20-$40
- $40-$70
- $70-$100
- $100-$150
- $150-$200
- $200-$500
- $500-$1000

Source: PJM
Regional Transmission Organization (RTO)

- Control the system (GRID)
- Conesville produces power that is fed into the GRID

**Variable** revenue to power producers – prices can be volatile based on supply and demand

**Fixed** revenue to power producers for being available to run
Energy Types

Pros  Cons
World Energy – Fossil Fuels 86%

1.3 billion people (19%) have no electricity

U.S.A. - 25% of the world’s energy
- 5% of the world’s population

Fossil Fuels
• Protect people from the climate
• Lift people out of poverty
• Power the world
US Energy – 81% Fossil Fuels

U.S. energy consumption by energy source, 2016

Total = 97.4 quadrillion British thermal units (Btu)

- Petroleum: 37%
- Natural gas: 29%
- Coal: 15%
- Nuclear electric power: 9%
- Renewable energy: 10%

Total = 10.2 quadrillion Btu

- Solar: 6%
- Wind: 21%
- Biomass waste: 5%
- Biofuels: 22%
- Wood: 19%
- Hydroelectric: 24%
- Geothermal: 2%

Note: Sum of components may not equal 100% because of independent rounding.

Source: U.S. Energy Information Administration, Monthly Energy Review, Table 1.3 and 10.1, April 2017, preliminary data

Environmentalists oppose these
Typical Household Consumption

Energy consumption of a typical household

- 38% Space heating/cooling
- 13% Water heating
- 11% Lighting
- 5% Clothes washer/dryer
- 5% Cooking
- 7% Refrigeration/freezer
- 2% Personal computers
- 1% Dishwashers
- 15% Other uses
Electricity Cost Comparison

Aug. 2016 - Average Electricity Cost ($/kwh)

- Washington: $0.08
- Ohio: $0.10
- USA: $0.11
- New York: $0.16
- California: $0.17
- Japan: $0.23
- UK: $0.24
- Hawaii: $0.24
- Germany: $0.33

50% wind, 17% solar
6% wind, 1% solar
Electricity from Coal

**Pros:**
- **Electricity on demand** (>90% typical)
- **Economical** (½ of wind, ¼ of solar cost)
- **Abundant fuel** (250+ years)
- **Mature technology**
- **Solid fuel inventory**

**Cons:**
- Air pollution
- Coal mining invasive to environment
- Waste disposal of by-products
- Large use of water

30.4%

2016 World Coal Consumption (million ton)

<table>
<thead>
<tr>
<th>Country</th>
<th>Consumption (million ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>3,546</td>
</tr>
<tr>
<td>India</td>
<td>922</td>
</tr>
<tr>
<td>United States</td>
<td>661</td>
</tr>
<tr>
<td>Germany</td>
<td>226</td>
</tr>
<tr>
<td>Russia</td>
<td>210</td>
</tr>
<tr>
<td>South Africa</td>
<td>194</td>
</tr>
<tr>
<td>Japan</td>
<td>191</td>
</tr>
<tr>
<td>South Korea</td>
<td>126</td>
</tr>
<tr>
<td>Poland</td>
<td>124</td>
</tr>
<tr>
<td>Australia</td>
<td>114</td>
</tr>
<tr>
<td>Turkey</td>
<td>106</td>
</tr>
<tr>
<td>Indonesia</td>
<td>100</td>
</tr>
</tbody>
</table>
Change of U.S. Coal Generation

May, 2015 – E.P.A. MATS law to reduce mercury, 6,000-8,000MW of coal units predicted to retire

1980 – 51%
2014 – 39%
2015 – 33%
2016 – 30%

Natural gas prices are beating coal

Business Reality
72,000 MW of coal retiring (enough to power 45 million homes)

1997 - predicted that by 2040 coal would still be 50% of the mix.
2018 - predicting that by 2050 coal would still be 11% of the mix worldwide.
So, what expert opinions today will be proven wrong in the future?

When theory collides with reality, reality wins!
Electricity from Natural Gas
80-95% methane (CH₄)

**Pros:**
- Cleaner emission,
  No fly ash, SO₂, or mercury, CO₂ 45% < coal
- More efficient at energy conversion than coal
- Low cost due to fracking
- Large supply due to fracking

**Cons:**
- Methane
  21x more powerful than CO₂
- Pipelines
  Explosive, Large infrastructure
- People oppose new lines
- Fracking problems
  Water pollution
  Water – large usage
  Earthquakes
Electricity from Nuclear

**Pros:**
- Generation on demand
- Economical
- Little pollution

**Cons:**
- Radioactive release fear
  - 1979 - Three Mile Island
  - 1986 – Chernobyl
  - 2011 - Fukushima
- Radioactive nuclear waste has an extremely long life
**Pros:**
- Renewable
- Green (no pollution)
- Economical
- Reliable – on demand
- Safe

**Cons:**
- Environmental effect on river
- Expensive capital cost
- Need large vertical drop for large output
If opponents had their way ....

<table>
<thead>
<tr>
<th>No Nuclear Power</th>
<th>No Dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.4%</td>
<td>6.5%</td>
</tr>
<tr>
<td>19.7%</td>
<td>33.8%</td>
</tr>
</tbody>
</table>

STOP Fracking

= 90.4%

We want our electricity back!

Conflict - a prosperous society relies on a robust electric system.
Wind Power

**Pros:**
- No pollution (almost)

**Cons:**
- No wind – no power
  - 20-50% capacity factor
  - Very low when temps are hot
- High cost (heavily subsidized)
- Not aesthetic
- Kills birds
- Noisy
Solar Power

Pros:
• Renewable
• Abundant
• No pollution to operate
• Silent
• Low Maintenance

Cons:
• High cost (heavily subsidized)
• Intermittent
• Fossil fuel footprint to mine materials, manufacture, transport, construct, and maintain
• Large use of rare earth metals
• Requires large footprint
  Environmentalists tried to stop a plant in Nevada due to the rare desert tortoises
Future?

• Less coal & nuclear
• More natural gas & renewables
• Distributed battery storage
• Micro grids (DC in large buildings)
• Electric vehicles
• Energy efficiency
• Demand response
• Smart metering
• System automation and sensor
• Smart appliances
Coal to Electricity
Energy Conversion

Chemical Energy in coal

Thermal Energy in boiler

Kinetic Energy in turbine

Electrical Energy out of generator

Coal supply

Water supply

Steam line

Turbine

Generator

Condenser

Transformer

Transmission lines
A giant steam producing plant............
uses the steam to drive a turbine-generator.
Eastern Bituminous Coal
From Eastern and Southern Ohio
About 2-3 million tons per year

Delivered by rail & truck

30 day inventory
Moved by conveyors

4-6 hour storage in silos near boilers
Air blown through mill

Powdered coal & air blown to boiler
Crushed in mills
Boiler

- Produces high energy steam
  - Unit 4 is 1005 def F, 3500 psi
  - Unit 5, 6 is 1005 def F, 2700 psi

- Hot flue gas out
- Pressurized and preheated water
- Powdered coal & air blown from mills
- Water Wall – pipe welded together to form solid wall with water flowing in it.
- Steam to turbine
- Suspended fireball at 2700 deg F
- Secondary air added for combustion
- Pressurized and preheated water
High voltage transmission lines are necessary to flow AC power long distance.

Steam moves turbine blades, which turn the shaft. The turning shaft creates a wave of flowing electrons (AC power), which is then utilized to generate electricity. Exciter electrifies the rotor, creating a magnetic field between the stator and rotor, allowing for AC power generation.
Environmental Protection
United States

Reductions:
69% - Carbon Monoxide (CO)
99% - Lead (Pb)
55% - Nitrogen Oxides (NOx)
53% - Volatile Organic Compounds
58% - Particulate Matter (PM)
81% - Sulfur Dioxide (SO2)

Source: http://www.epa.gov/airtrends/aqtrends.html
UK - Air pollution now leading cause of lung cancer. Air pollution has been named as the leading cause of lung cancer, the World Health Organization's cancer agency said.

By Tom Rawle  PUBLISHED: 16:53, Thu, Oct 17, 2013
Circulating Water

- Cooling water loop
- Protects river from over heating

Water pumped to boiler

Cold cooling water

Air blow up discharging heat in water vapor

Warmer cooling water

Water distributed on tower and diffused to fine mist through nozzles

Make-up water to system

Steam condenses to water
Cooling Towers

Protects river wildlife from hot water discharge thermal pollution (over heating)

Fan blades
- pulls air from side
- water cascades down tower
- air cools water
Combustion Residue - Ash

- Fly ash captured in precipitator
- 80% of ash flows with boiler draft (fly ash)
- 20% of ash to hoppers (bottom ash)
- Fly ash blown from soot hopper to STP
- Bottom ash sluiced to ash pond
Electrostatic Precipitator (ESP) cleans flue gas - removes 99.95% of flyash

1. Dirty flue gas
2. Electrified wires charge particles (inside box)
3. Particles stick to metal plates (inside box)
4. Rappers shake plates
5. Collected fly ash blown to STP
6. Clean flue gas to scrubber
Combustion Residue – FGD & Gypsum

Scrubbers mitigate **acid rain**

- Flue gas with SO2
- Scrubber removes SO2
- Solid material hauled to Landfill or AML
Wet Spray Tower Scrubber – unit 5 & 6 prevents acid rain - removes > 96-98% of $SO_2$

1-Dirty flue gas
2-Spray crushed limestone + water
3-Calcium (Ca) in limestone reacts with $SO_2$ to form calcium sulfite ($CaSO_3$)
4-Scrubbed flue gas to stack – white plume is water
5-Solids + water pumped to thickener tank
Scrubber Process (continued)

6-Slurry pumped to STP

5-Solids + water pumped to thickener tank

Thickener tanks

Sludge Treatment Plant (STP)
6-Slurry pumped to STP

7-Vacuum filters remove water

8-Dried filter cake mixed with fly ash + lime

9-FGD by-product conveyed to stacker pad

10-FGD by-product excavated, hauled to landfill
JBR Scrubber – unit 4
prevents acid rain – removes > 96-99% of SO\textsubscript{2}

1-Limestone sent to ball mills and crushed

6-Scrubbed flue gas to stack

2- CaCO\textsubscript{3} + water

4-Oxidation (O\textsubscript{2}) blowers add air

7-Solids + water pumped to filters

5-Flue gas bubbles in reagent
Gypsum Pad

9-Gypsum (CaSO₄) from filters

8-filters dry material in building

7-Solids + water pumped to filters

10-Gypsum excavated, haul to landfill
Selective Catalytic Reduction (SCR) – unit 4

>> cleans air >> removes > 90% of NO\textsubscript{x}

NO\textsubscript{x} effects the ozone layer of the atmosphere and is GHG 310x stronger than CO\textsubscript{2}

- Urea makes ammonia (NH\textsubscript{3}) on demand

- Ammonia (NH\textsubscript{3}) with catalyst breaks nitrous oxide (NO\textsubscript{x}) into Nitrogen (N\textsubscript{2}) and water (H\textsubscript{2}O)

- **Unit 5 & 6** use Low-NO\textsubscript{x} burners to reduce NO\textsubscript{x} by 60%
Gore Technology – unit 5&6 cleans flue gas - removes 90% of mercury

- Named for Gortex, not Al Gore
- Gortex absorbs mercury into filter basket layers.
- Baskets are disposed in landfill after many years of use.
- MATS limit is 1.2 #Hg / trillion BTU
  - A golf ball size for 42,000 tons of coal or 8 train loads.
- Unit 4 meets mercury compliance with JBR.
Coal Is Called Dirty, however......

<table>
<thead>
<tr>
<th>Unit</th>
<th>Problem</th>
<th>Pollution Control Equipment</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,5,6</td>
<td>Hot water to river</td>
<td>Cooling Tower</td>
<td>100%</td>
</tr>
<tr>
<td>4,5,6</td>
<td>Electrostatic precipitator</td>
<td>particulate matter (flyash)</td>
<td>&gt; 99.95%</td>
</tr>
<tr>
<td>4,5,6</td>
<td>Sulfur dioxide (SO2)</td>
<td>Scrubber</td>
<td>&gt; 96%</td>
</tr>
<tr>
<td>4</td>
<td>Nitorous oxide (NOX)</td>
<td>SCR</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>5,6</td>
<td>Nitorous oxide (NOX)</td>
<td>Low NOX burners</td>
<td>&gt; 60%</td>
</tr>
<tr>
<td>5,6</td>
<td>Mercury in air</td>
<td>Gore Technology</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>all</td>
<td>Mercury in water discharge to river</td>
<td>various</td>
<td>&lt; 12 ng *</td>
</tr>
</tbody>
</table>

* Equivelen of 12 drops of water in 22 Olympic size swimming pools

27 million 60 W light bulbs
Let’s go see the plant