

Overview

- Rural electrification discussion
 - Objectives
 - Lessons
- Pollutant emissions
 - Chapter 5, plus... climate change
- PSERC report – Power System Industry perspective

2

Self-Quiz

- What are the components of a power system?
- Why do we have government policy for energy? What does this policy aim to accomplish?
- What are the relative percentages of fuel types for electricity generation?
- What are typical capacity and energy amounts for
 - A person; a house
 - A power plant
 - For US vs. The-Rest-of-World citizens

3

Rural Electrification Discussion

- What are the objectives of rural electrification?
 - Who benefits, *e.g.*,
 - children, women, men?
 - poor, wealthy?
 - government, private funders, residents?
 - What are the targeted uses for the electricity?
- How are the objectives achieved?
 - How is project performance measured?
- What have been problems with rural electrification projects?

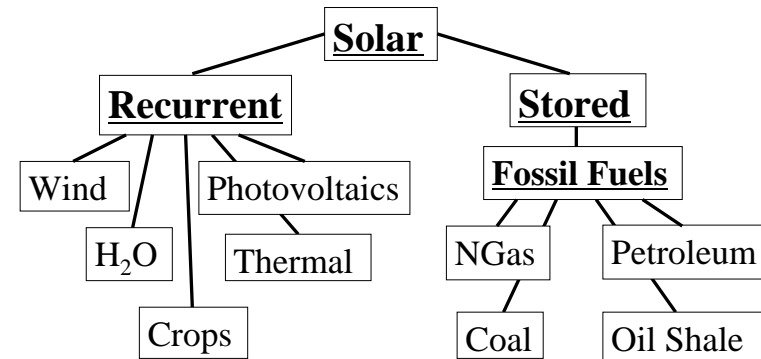
4

Pollutant Emissions from Electric Power

- Which are the pollutants from electric power generation?
- What is their source?
 - Fuel
 - Combustion
 - Other?
- How are the pollutants controlled?
 - Policy
 - Technology
- What is/can the power industry do?

5

Source: Fuel & Combustion



(Nuclear reaction and thermal process also contributes pollutants...)

6

Key problems related to Energy

- Acid Rain
- Nuclear leakage
- Magnetic field radiation
- Fish/animal welfare
- Global warming
- Respiratory illness

7

Pollutants

- SO_x – Sulfur oxides
- NO_x – Nitrogen oxides, esp. N₂O
- O₃ – Ozone
- Carbon, carbon dioxide
- Mercury
- VOC – Volatile organic compounds
- Particulates, ashes

8

Source → Fuel → Coal

Coal types, hardest/least sulfur to softest/most sulfur

– Anthracite → Bituminous → Lignite

1. Anthracite – Pittsburg

- Hardest, oldest coal, most completely converted to coal (most carbon by weight)
- Low/no sulfur → buried in fresh water

2. Bituminous – Appalachia

- High sulfur → buried in salt water

3. Lignite – Montana, Wyoming

- “Brown” soft coal → lower carbon content
- A lot of sulfur
- A lot of this coal

9

Source → Nitrogen Oxides

• Fuel NO_x

- *N in the fuel* reacts with O to form NO and NO_x

• Thermal NO_x

- *N from air* mixes with O at high temperatures,
- Rule of thumb: this will form at around 600 C°

• Prompt NO_x

- N from the air, (some from the fuel); not from processes above...

• Process NO_x

- Dependent upon the manufacturing process
- In processing, agents may be added, there may be N in the agents and N in the process itself
- e.g., KNO₃ – potassium nitrate is a refining agent in glass

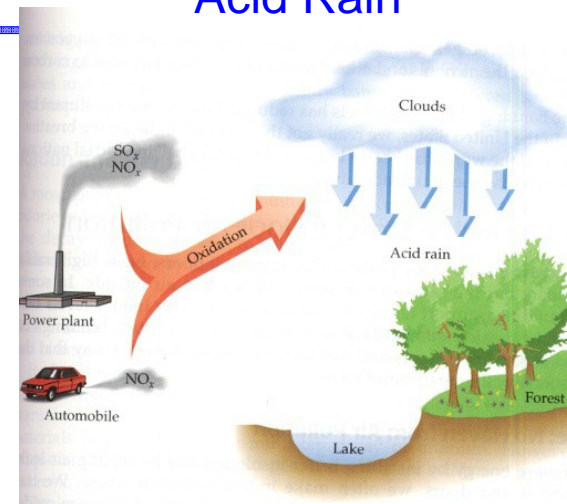
10

Damage

- Acid rain
- Global warming
- Human health
- Animal and environmental health

11

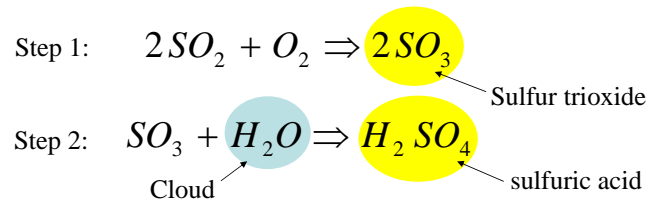
Acid Rain



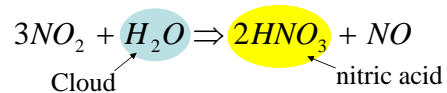
12

Ingredients of Acid Rain

- **Sulfuric Acid**



- **Nitric Acid**



13

Control – Technology

- Sulfur and acid rain
 - “Scrubbers” =
 - SCR – selective catalytic reduction
- Policy solution created “cap and trade” permit scheme
- A regional, not global, issue

14

Greenhouse Effect

- The earth temperature depends on
 - solar energy reaching the earth
 - radiated energy from earth back to space.
- Increased CO₂ concentration absorbs infrared radiations (7-12 μm).
- Part of this energy is reradiated back to earth, thus increasing the Earth temperature

15

Greenhouse Gases, GHGs

- CO₂ is one of the greenhouse gases
- Other greenhouse gases
 - Water vapor
 - Methane
 - Nitrous oxide
 - Ozone

16

Industrial Greenhouse Gases

- **Carbon dioxide:** burning fossil fuels, solid waste, and wood
- **Methane**
 - Emitted during the production of coal, natural gas, and oil
 - Also as a result from the decomposition of organic wastes in landfills, and the raising of livestock
 - Methane traps over 21 times more heat per molecule than carbon dioxide

17

Industrial Greenhouse Gases

- **Nitrous oxide** is emitted during
 - combustion of fossil fuels and solid waste
 - agricultural and industrial activities
- **Nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide**
- **(Ozone** from CFCs and automobile exhaust)

18

Pollutant Emissions (lb/MWh)

Pollutant	Fuel Type		Effect
	Coal	Natural Gas	
Sulfur Oxides (SO _x)	14 lb/MWh	0.01 lb/MWh	Acid rain & respiratory

Pollutant	Fuel Type		Effect
	Coal	Natural Gas	
Nitrogen Oxides (NO _x)	4.8 lb/MWh	4.3 lb/MWh	Acid rain & Smog

Pollutant	Fuel Type		Effect
	Coal	Natural Gas	
Carbon Dioxide (CO ₂)	2,100 lb/MWh	1,200 lb/MWh	Global warming Greenhouse Gas

19

Control – Policy

- **Legislation: 1990 CAA – Clean Air Act**
 - Defines “criteria pollutants,” “criteria species”
 - Based on threshold concentrations, which are ill-defined
 - Note that we regulate
 - NO₂, not NO_x in general, e.g. not N₂O
 - SO₂ not SO_x
 - CO not CO₂

20

Control – Policy

- **1990 CAA Amendments**
 - National ambient air quality standards
 - New concept is that of a threshold – scientifically defined to be that level below which no harm is done
 - Two thresholds
 - One for humans
 - One for the environment
- ***Note that the national legislation does not account for***
 - Storage/accumulation of the pollutants in the environment with/over time
 - Transport of pollutants to other geographic areas

21

Control – Policy

- New policies needed to address climate change...

22

Recent Power Industry Response

- The Electric Power Industry and Climate Change: Power System Research Possibilities
 - Research report from PSERC
 - 13 major power system universities
 - Regional power system operators
 - Transmission system owners
 - Power system equipment and software manufacturers

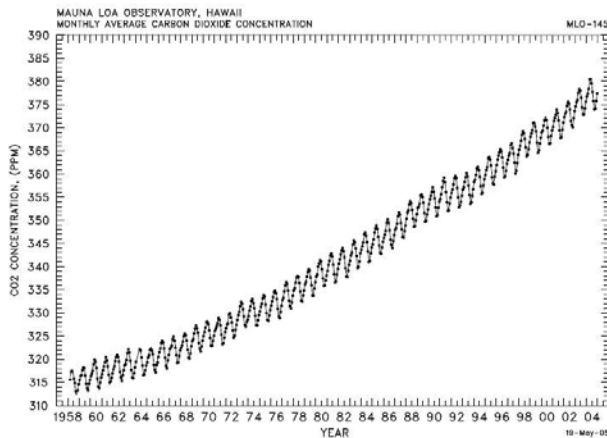
23

White Paper Introduction

- The Power Industry and Climate Change
 - How climate change affects the power industry
 - Equipment impacts
 - Fuel supply impacts (primarily hydro)
 - Changes in other industries
 - How the power industry may affect climate change
 - Primarily carbon dioxide emissions

24

What is Known: CO₂ in Air is Rising



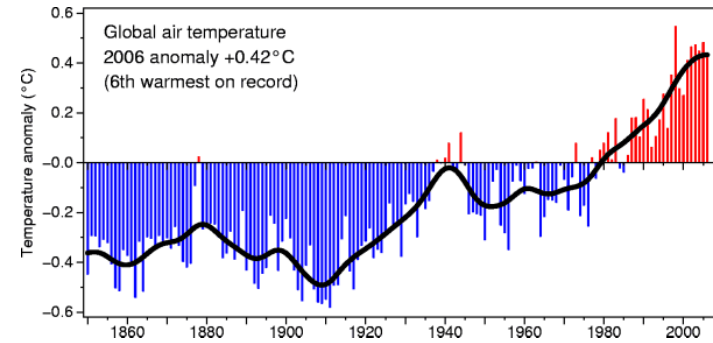
Value was about 280 ppm in 1800, 384 in 2007

Rate of increase is about 3ppm per year

Source: <http://cdiac.ornl.gov/trends/co2/sio-mlo.htm>

25

As is Worldwide Temperature



Baseline is 1961 to 1990 mean

Source: <http://www.cru.uea.ac.uk/cru/info/warming/>

26

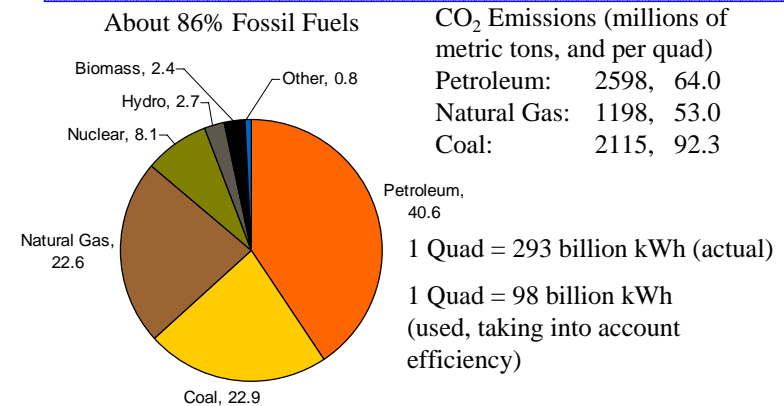
CO₂ and Global Warming

- “Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.”

Quote from Intergovernmental Panel on Climate Change, Climate Change 2007: The Physical Science Basis, Summary for Policymakers, p. 10

27

US Energy Pie: Total of 100 Quad



Source: EIA Energy Outlook 2007, Table 1, 2005 Data

28

Activity: Pair discussion and Report

- Select one of the following topics, discuss with your partner
 - General power system topics
 - Extreme weather
 - Government policies
 - Market mechanisms
 - Industry planning
- ...And bring questions and summary to the class

29

Some CO₂ Reduction Options

- Energy efficiency and conservation: Use less energy in total
- Biofuels: Convert all our corn to ethanol?!
- Nuclear: Build new reactors
- Coal: Practicality of sequestration is unknown
- Wind: A significant increase would require a lot of new transmission system capacity
- Pluggable Hybrids: Will transfer issues from transportation sector to electricity sector

30

Science & Technology Research Topics

1. Develop and analyze methods to improve energy conservation and efficiency.
2. Analyze the effects on system load shape and transmission system expansion in response to an increased use of plug-in hybrid vehicles.
3. Analyze the impact of an expansion of nuclear energy, in terms of impacts on the transmission system and power system operation, and in GHG reductions.
4. Analyze system impacts and control needs of a significant penetration of large, remote wind farms.

31

Extreme Weather

- Slow increase in *average* global temperature not an issue.
- But increases in *extremes* of heat, rain, winds and changes in water runoff could be significant for power system design and operation.
- Key is the rate of change in extremes versus the rate of power system upgrade.

32

Extreme Weather Research Topics

1. Use predictions of regional climate change to estimate the rate of change of power system design parameters.
2. Robust monitoring and control techniques for harsh weather and increased load demand.
3. Combine climate predictions of extreme weather with emerging blackout risk assessment.
4. Better system restoration in case of natural disasters.

33

State Government Policies

- RGGI – Regional Greenhouse Gas Initiative
 - Mandatory cap-and-trade beginning in 2009
 - Nine northeast and mid-Atlantic states
- WRCIA – Western Regional Climate Action Initiative
 - Regional emissions market and monitoring
 - To begin summer 2008
- California Assembly Bill 32
 - Reduce GHG to 1990 levels by 2020
 - Reduce to 80% below 1990 levels by 2050
 - Mandatory reduction beginning 2012

35

Government Policies

- International
 - United Nations Kyoto Protocol, 1997
 - President Bush disengaged in 2001
 - US goal would have been to reduce CO₂ emissions to 7% below 1990 levels by 2008-2012
- Federal
 - 1990/92: CO₂ monitoring
 - Four mandatory limit bills now in Congress
- Carbon Capture and Sequestration
 - Probable technology for coal
 - Cost for retrofitting plants could affect dispatch
 - Issues with locating plants near sequestration site

34

Government Policies

- Investigate how potential and actual government policies will affect power system operations and electricity market operations.

36

Government Policies Research Topics

1. Analyze the effect on system operations from changing the use of generators that result from production caps and emissions regulations.
2. Analyze the impact on both existing generating plants and the power system from possible government regulations constraining the use of specific types of generators.
3. Analyze the effect of bills such as AB32 on power system operations.
4. Analyze the effect of inconsistent/conflicting regional emissions policies (in conjunction with an analysis of inconsistent/conflicting regional permit markets) in contrast to uniform, national policies.

37

Market Mechanisms

- Responsive demand and conservation
 - Price-, Incentive-, Reliability-based
 - Manual and automatic response
- Carbon tax
 - Economist support for a carbon tax
 - Transparent mechanism
- Cap-and-trade emissions trading
 - Emissions limits; permits to produce pollutants; permits can be traded
 - Significant market design and permit allocation issues

38

Market Mechanisms

- Renewables portfolio standards, RPS
 - State based initiatives, with discussion on developing a federal RPS
 - Mandate MW, MWh or % energy from renewables
 - 4% by 2009 (MA) v. 30% by 2020 (MN)
 - Trading allowed via renewable energy certificates (RECs)
 - ‘Tier 1’ and ‘Tier 2’ resources
- Market design for issues for cap-and-trade, responsive demand and portfolio standards

39

Market Mechanisms Research Topics

1. Research the effect of conflicts and/or inconsistencies between regional cap-and-trade markets, and conflicts with renewable portfolio standards (RECs).
2. Analyze the effect on system and market operations if automated control systems are installed at customer locations.
3. Develop new planning and risk management tools, focusing on the risk introduced by uncertainty in climate change and government policies designed to address climate change issues.

40

Industry Planning

- Demand reduction and conservation
- Improved efficiency of the electricity infrastructure
- Increase emphasis on renewables (wind, solar, biomass, biofuel) and distributed generation
- Nuclear generation
- CO₂ reduction, capture, transformation and sequestration.
- Other industries are making long range plans.
 - (Market share, Anticipate Regs, Avoid \$ Loss, Avoid Litigation)

41

Industry Planning Research Topics

1. Analyze the efficiencies of market structures where carbon trading is allowed within the electric power industry and between the electric power industry and other GHG producing industries.
2. Evaluate the consequences on system stability and responsiveness that is lost by reducing hydro-generation.

42

Conclusions

- The power industry has mixed interest in addressing climate change issues
- Communication necessary between engineers and policy makers
- PSERC report at
 - http://www.pserc.org/cgi-bin/pserc/getbig/publicatio/reports/2007report/pserc_climate_change_final_rpt_june07.pdf

43

Summary

- Early efforts
 - Acid rain, ozone hole
- Current issue
 - Climate change
- Continuing concerns
 - Mining
 - Heating of rivers, lakes, shoreline
 - All pollutant emissions

44