Get Energized: Interactive Generate! Game Explores Energy Choices and Environmental Quality

Rebecca Dodder, PhD

U.S. EPA Office of Research and Development

Get Energized!

- What is the U.S. energy system?
- Energy and the environment
- Introduction to Generate!
- Changing the rules and other twists
- Make your own version
- Other great energy “resources”

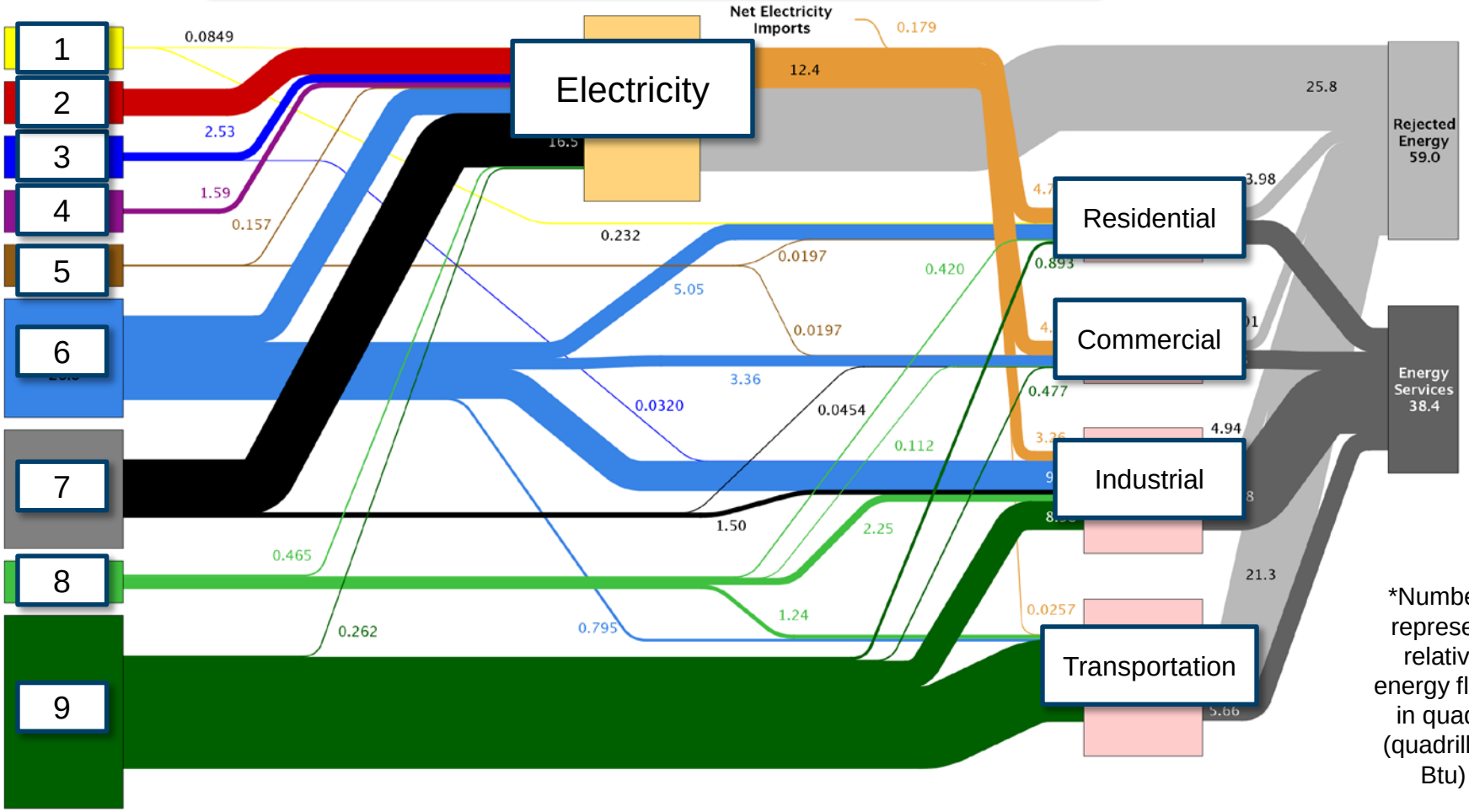
PART 1: WHAT IS THE U.S. ENERGY SYSTEM?

What is the U.S. energy system?

- **Primary energy resources:**
  - Fossil: coal, natural gas, petroleum
  - Renewable: wind, solar, hydro, geothermal, biomass
  - Other: uranium
- **Technologies to convert primary resources to useable energy like electricity, gasoline, etc.**
  - Petroleum/oil refineries
  - Electric power generation
- **End-use sectors that use electricity and fuels**
  - Residential
  - Commercial
  - Industrial
  - Transportation

U.S Energy Flows from Resource to End Uses

Lawrence Livermore National Laboratory



*Numbers represent relative energy flows in quads (quadrillion Btu)

Coal	Solar	Biomass
Natural Gas	Wind	Geothermal
Petroleum (Crude Oil)	Hydropower	Nuclear

U.S Energy Flows from Resource to End Uses

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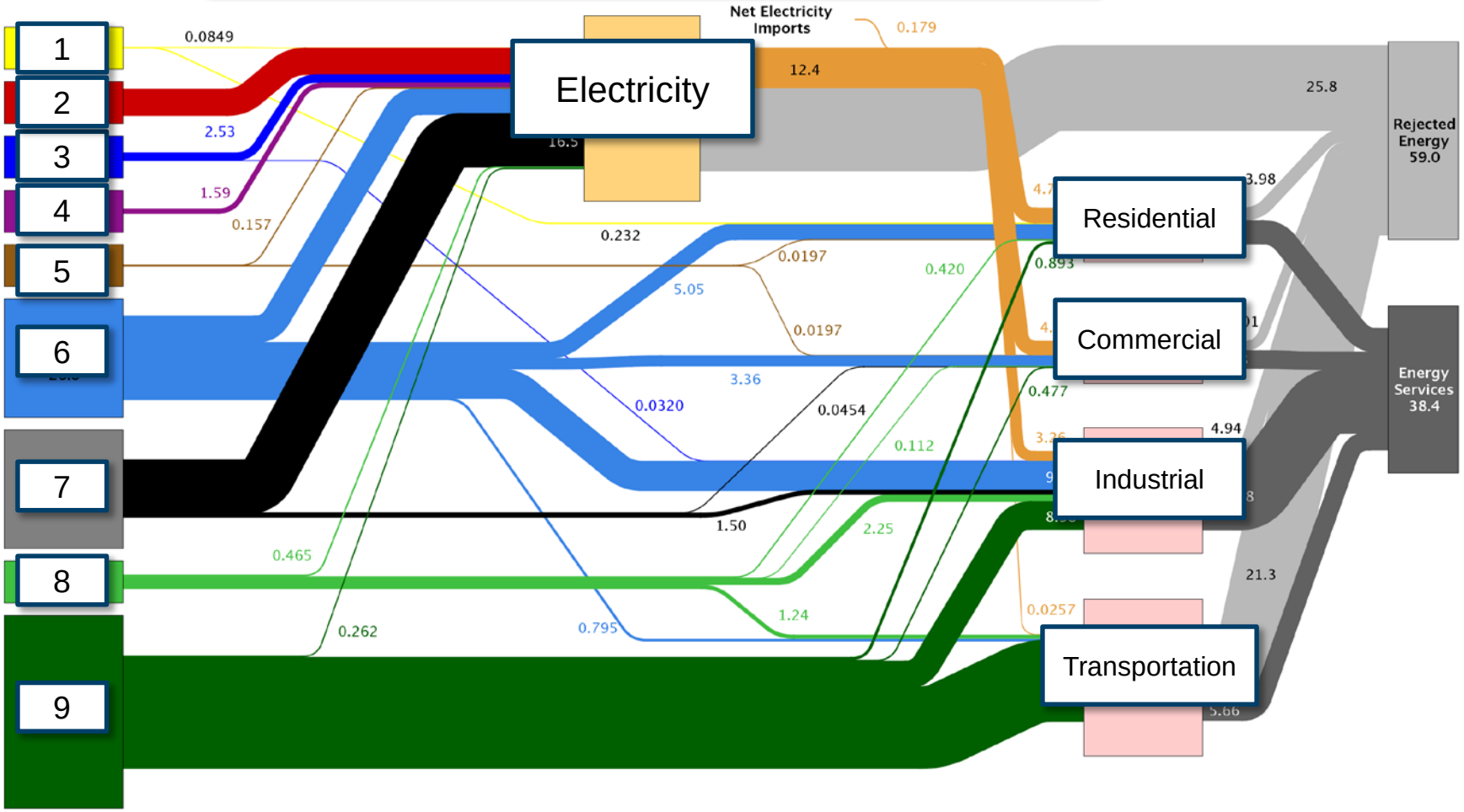
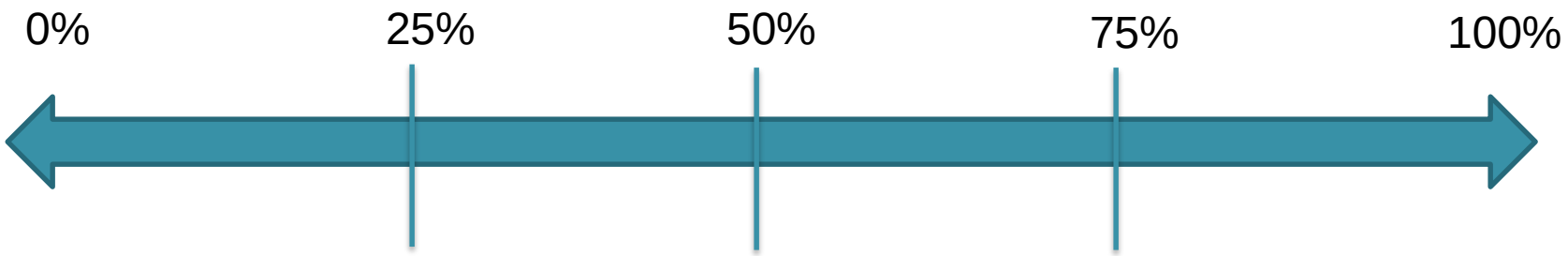


Coal = 7	Solar = 1	Biomass = 8
Natural Gas = 6	Wind = 4	Geothermal = 5
Petroleum (Crude Oil) = 9	Hydropower = 3	Nuclear = 2

POLL

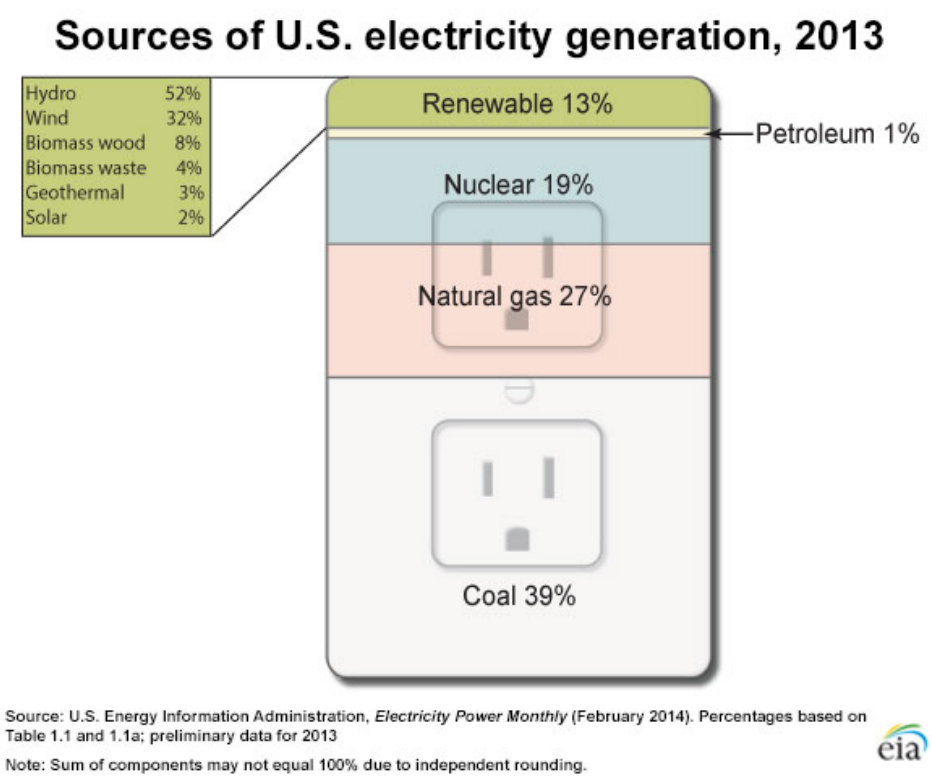
- What share of our total electricity production in the U.S. comes from **renewable power**?



- Place a marker!

Snapshot of our Energy System

Renewables are 13%

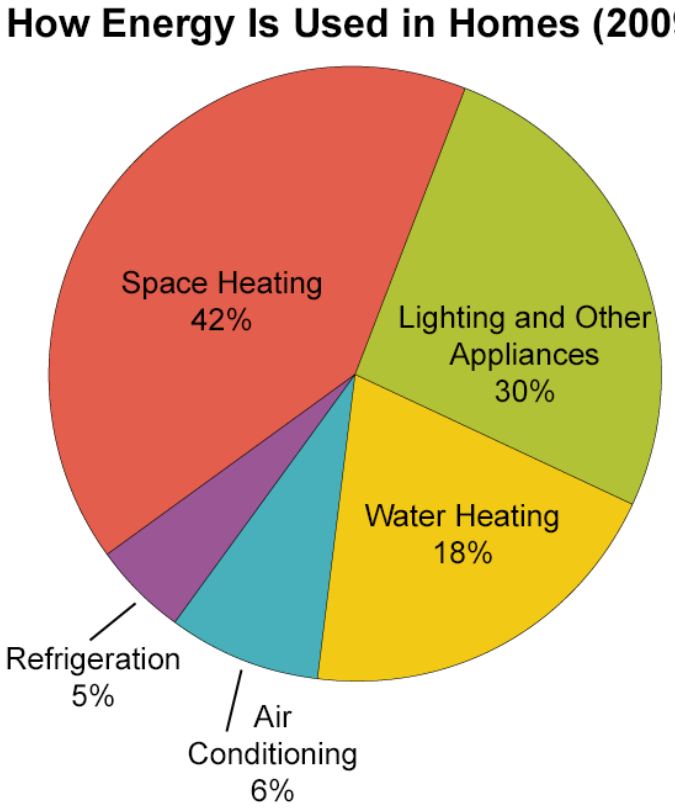


Source: U.S. Energy Information Administration, *Electricity Power Monthly* (February 2014). Percentages based on Table 1.1 and 1.1a; preliminary data for 2013

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

eia

Space heating is top use



* 2009 is the most recent year for which data are available.

Source: U.S. Energy Information Administration, *Residential Energy Consumption Survey (RECS) 2009*.

PART 2: ENERGY AND THE ENVIRONMENT

Energy and its role in air, climate and water

Air Pollutant Emissions

- Contributions to U.S. anthropogenic emissions
  - Nitrogen Oxides (NO_X) ~ 95%
  - Sulfur Dioxide (SO_2) ~ 89%
  - Carbon Monoxide (CO) ~ 95%
  - Mercury (Hg) ~ 87%

Greenhouse Gas Emissions

- Contributes 94% of US anthropogenic carbon dioxide (CO_2) emissions

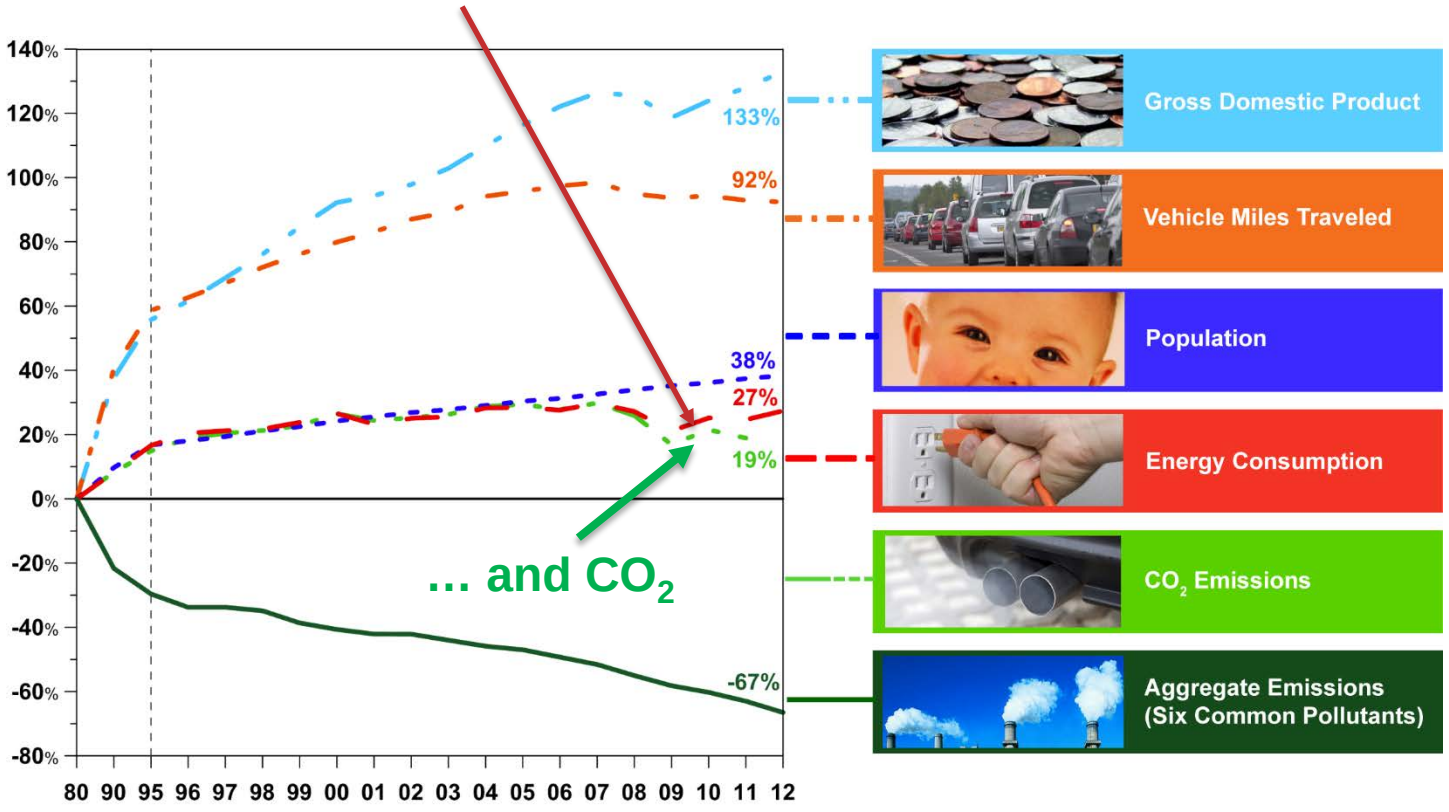
Water Supply, Use and Quality

- 41% of US water withdrawals (agriculture ~ 37%; public supply ~ 13%)
- ~200 billion gallons of water per day are required for power plant cooling
- Water quality issues for energy resource extraction and processing

Measures of growth and emissions in the U.S.

Air pollutant emissions have fallen at the same time that GDP, vehicle miles and population have grown.

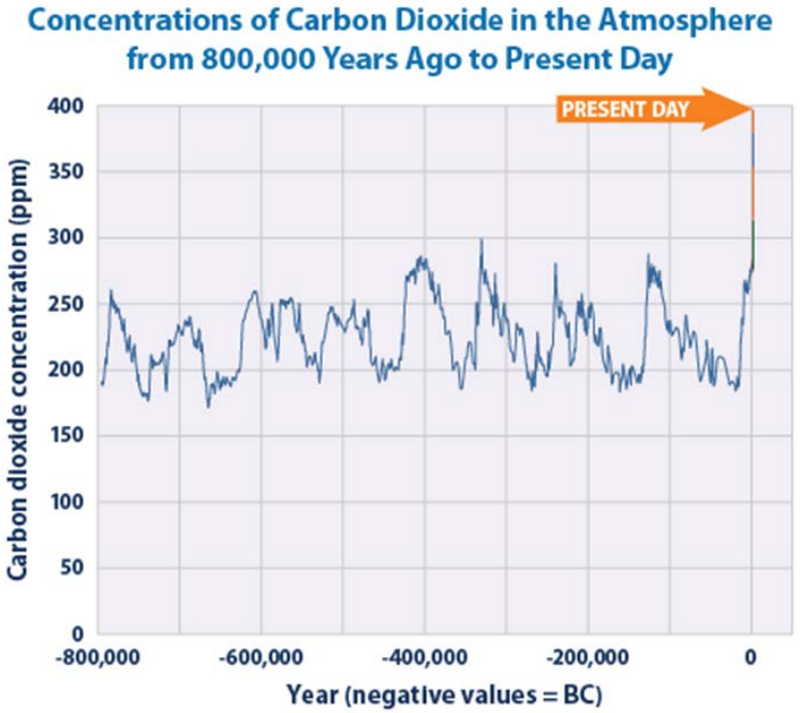
Energy and CO_2 are still closely related.



www.epa.gov/airtrends/aqtrends.html#comparison

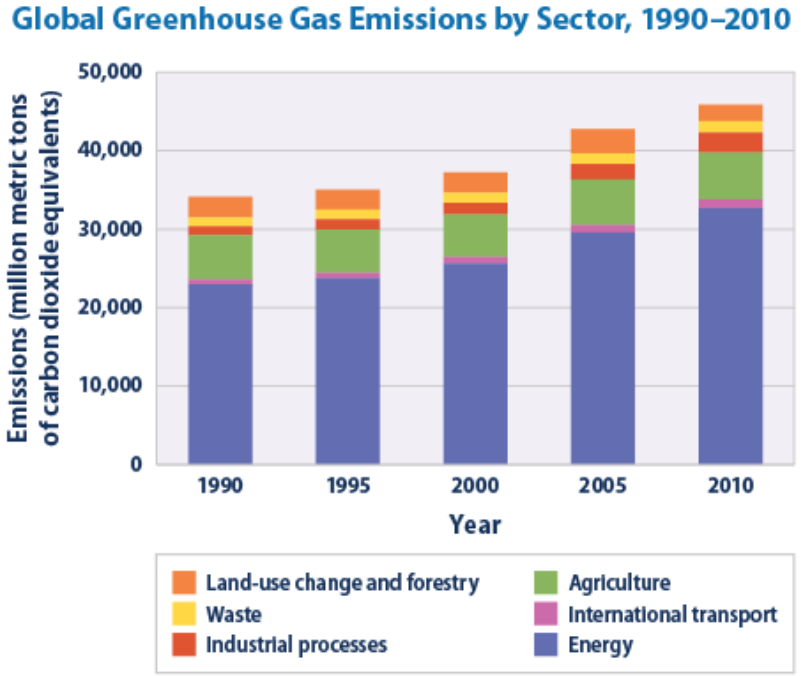
Energy and Climate Change

CO_2 concentrations (parts per million, ppm)



Data source: Compilation of 10 underlying datasets
http://www.epa.gov/climatechange/science/indicators/ghg/ghg-concentrations.html

CO_2 emissions (million metric tons)



Data sources: World Resources Institute, 2014; Food and Agriculture Organization, 2014

CO_2 can stay up in the atmosphere for nearly a century!

Energy and Greenhouse Gas Emissions

The EPA's proposed Clean Power Plan

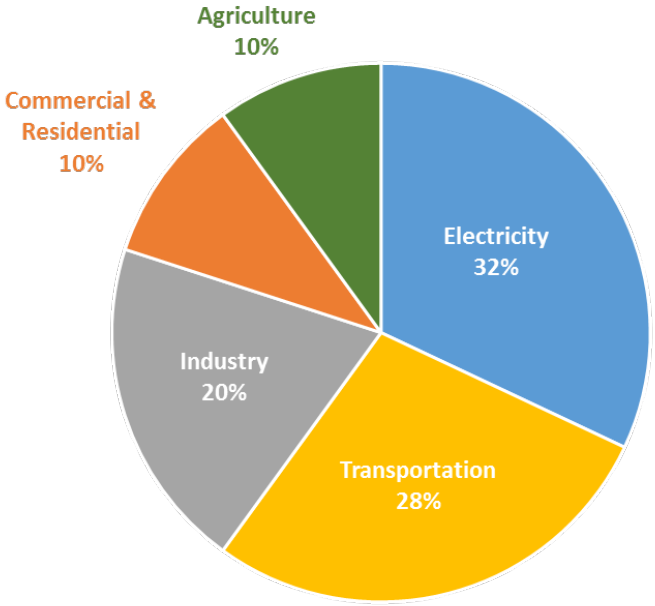
- Focus is on the **electric sector**, both new and existing facilities
- Flexibility in how states achieve their targets
- Target is to cut carbon from the power sector by 30% below 2005 levels

http://www2.epa.gov/carbon-pollution-standards/regulatory-actions

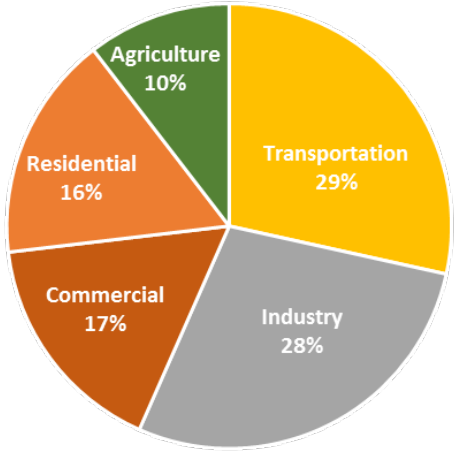
Transportation GHG emissions also falling with new CAFÉ/GHG standards for 2017-25 model years

http://www.epa.gov/otaq/climate/documents/420f12051.pdf

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2012



Total U.S. Greenhouse Gas Emissions with *Electricity Emissions Distributed*



Total Emissions in 2012 = 6,526 Million Metric Tons of CO_2 equivalent
Source: U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012*
http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html#about

Where do we go from here?

Projected global temperature range

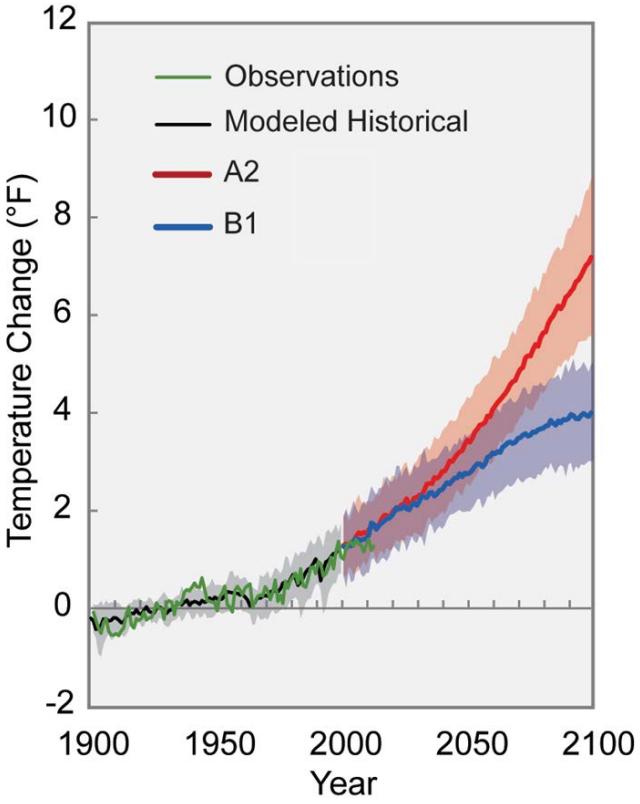
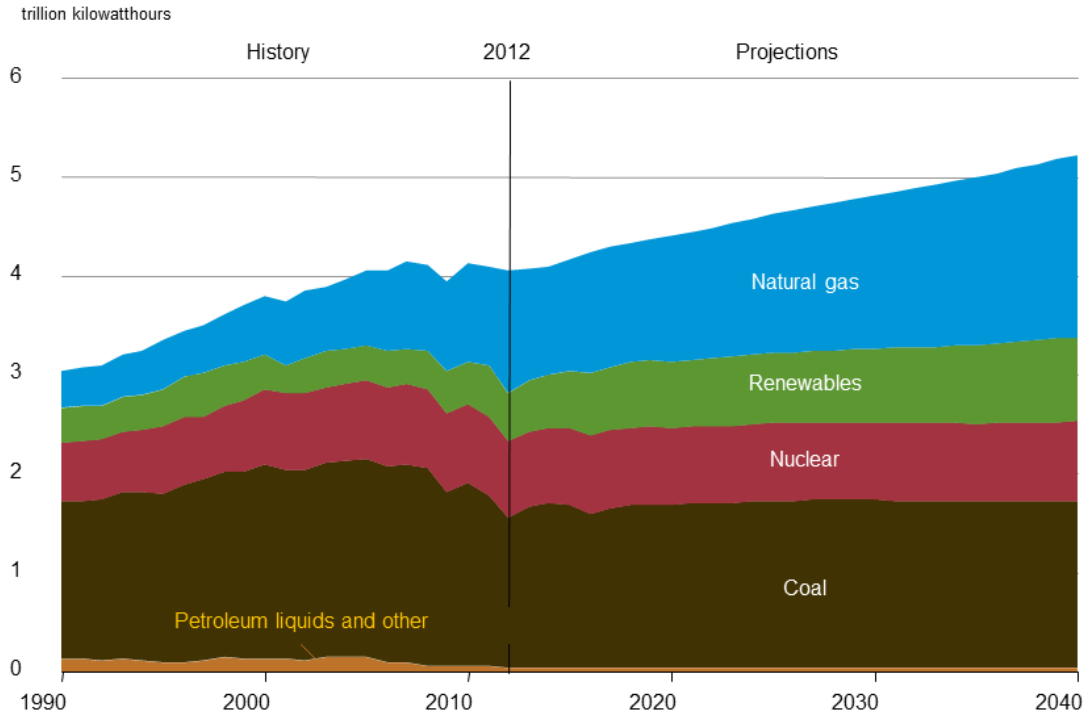


Figure source: NOAA NCDC / CICS-NC

Energy choices over next several decades

One version of 2040

Figure ES-5. Electricity generation by fuel in the Reference case, 1990-2040



Annual Energy Outlook 2014, Energy Information Administration (EIA)

- A “Reference Case” will give you roughly more of the same.
- But what if it looked totally different?
- What would make it look different?

Different choices with very different impacts

What resources does it use?

How will it affect our climate?

How much does it cost?

What are the air emissions?

What are the other environmental impacts?

How much water does it require?

Free Response

- What are other environmental impacts of energy production and use I haven’t covered?

EPA's Air, Climate, and Energy (ACE) Research Program

- The Air, Climate, and Energy Research Program (ACE) provides the critical science to:
  - Develop and implement the National Ambient **Air Quality** Standards under the Clean Air Act.
  - Foster innovative approaches to ensure clean air in the context of a changing **climate** and **energy** options.
  - Provide scientific information and tools to adapt and reduce the impact from a changing climate.

- Learn more about Climate Change Research: http://www.epa.gov/research/climatescience/index.htm
- Learn more about Air Quality Research: http://www.epa.gov/research/airscience/index.htm

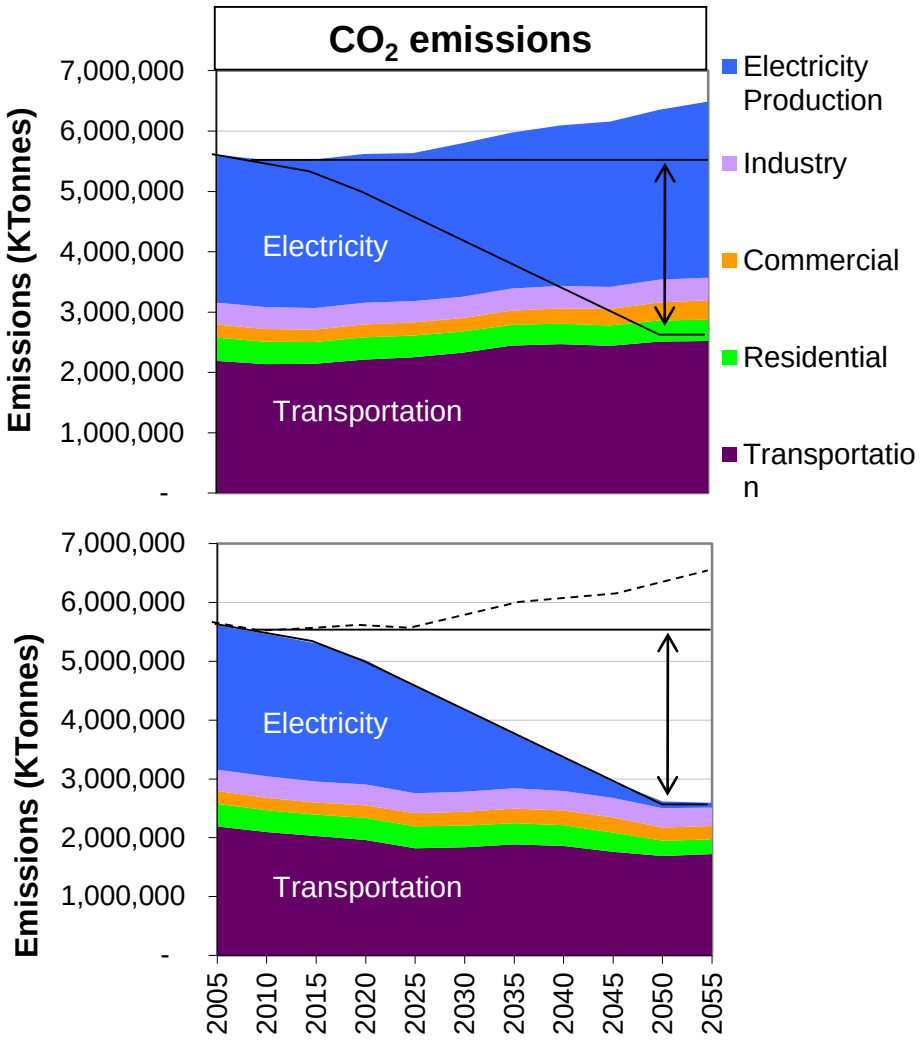
EPA research with energy-environmental modeling tools

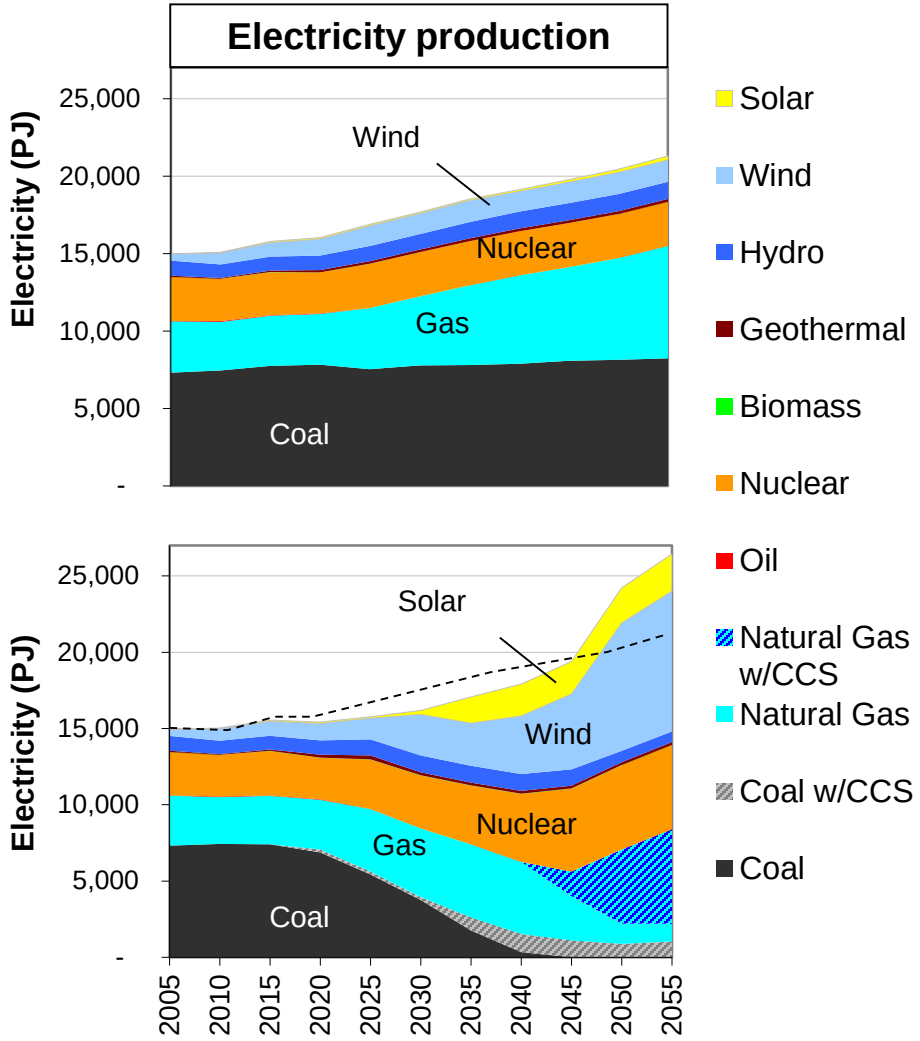
- Learning from energy system models
  - Develop and examine scenarios, *not predicting the future!*
  - Assess the potential roles of specific technologies in meeting policy goals
  - Identify important system interactions and potential unintended consequences
  - Consideration of uncertainties in fuel prices, technologies, and policy
- Quantify how the energy system may evolve and its effect on our environment and human health

A few EPA research projects

- Energy scenarios and impacts on climate and air quality
- Water demands for the electric power sector
- The role of breakthrough energy technologies

Alternative future scenarios for 2055 "Reference" vs. "Low carbon"

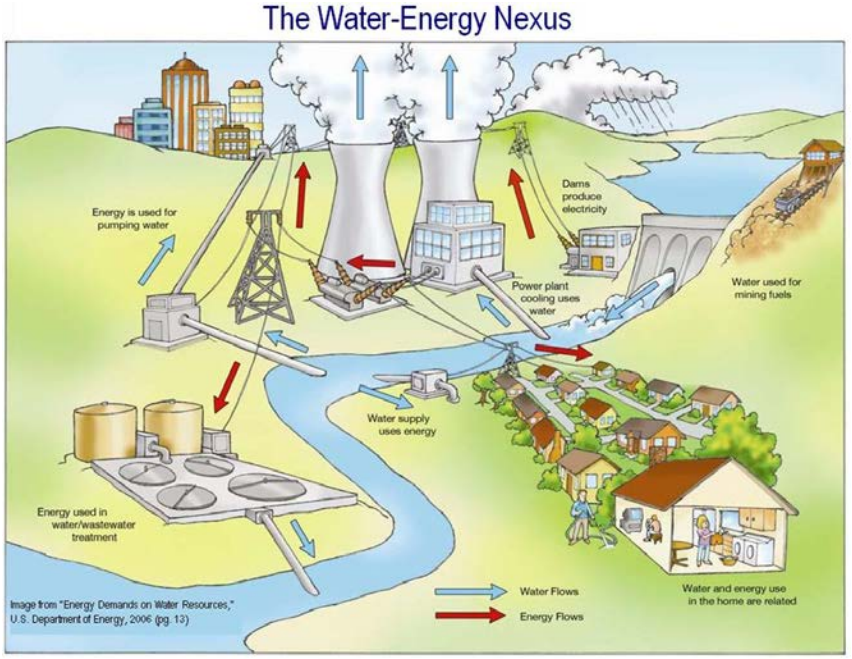


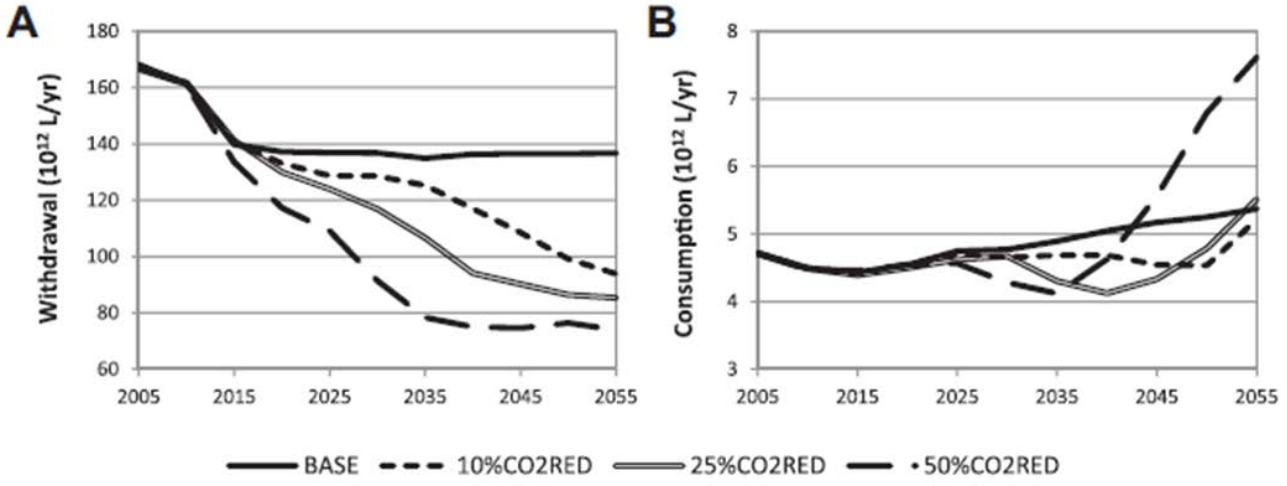


Research on the water demands of the energy sector

Reducing carbon generally lowers the **(A) water withdrawals** (total water intake) for the electricity sector

But, reducing carbon can lead to higher long term **(B) water consumption** (evaporative losses)





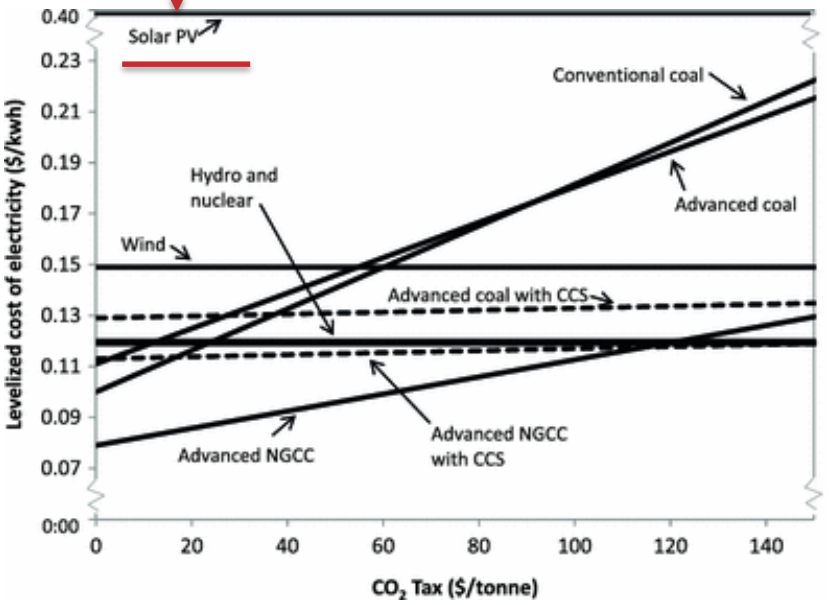
Source: C. Cameron, W. Yelverton, R. Dodder, J. West (2014) "Strategic responses to CO2 emission reduction targets drive shift in U.S. electric sector water use" *Energy Strategy Reviews.*

The role of *breakthroughs* in energy technologies

Centralized Solar PV

Photos: Nellis AFB, http://www.nellis.af.mil/

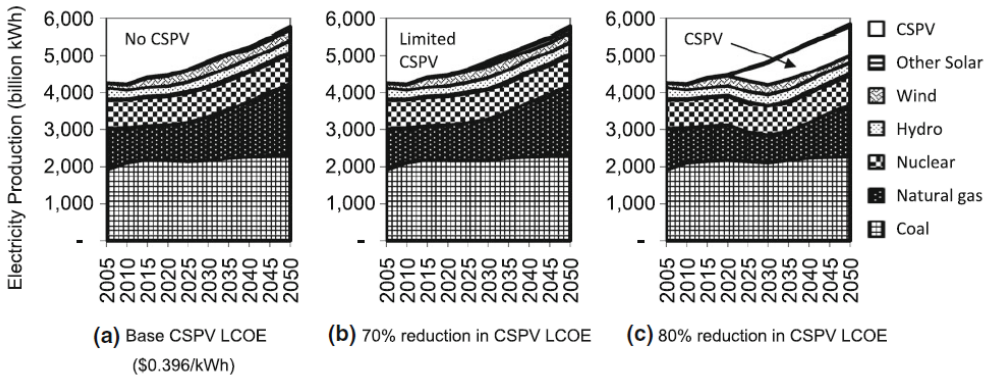
too expensive?



Levelized costs of electricity production technologies ($/kWh), including a CO_2 tax for CO_2 emitting technologies.

Source: D. Loughlin, W. Yelverton, R. Dodder, C. Miller. (2013) *Clean Technology & Environmental Policy*

What happens as costs come down?



Questions so far?

We've covered:

- Our energy system
- Its environmental impacts
- How we study future trends and impacts

PART 4: INTRODUCTION TO GENERATE!

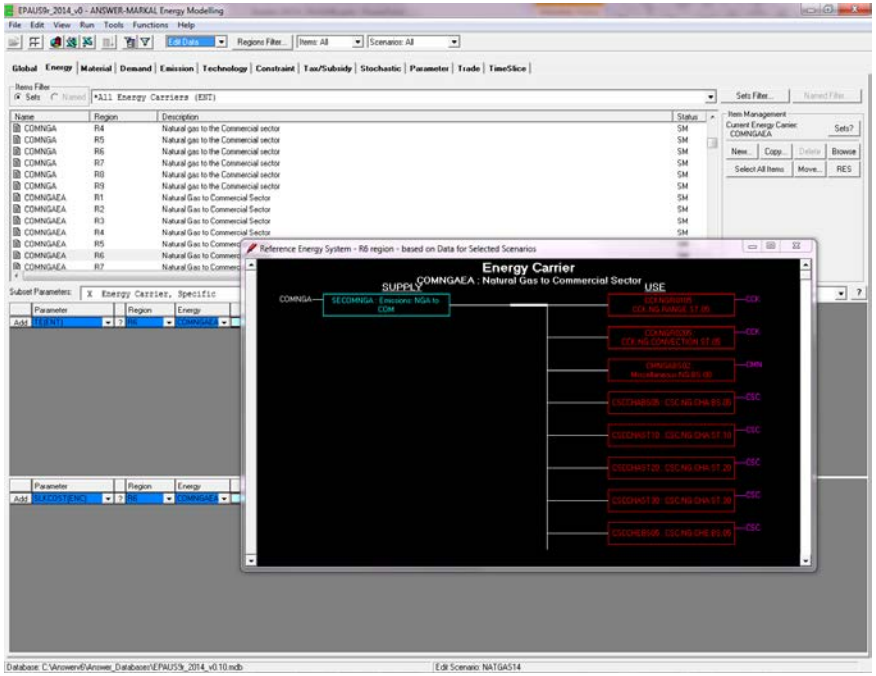
Why make a game?

Questions:

- How do we communicate the link between climate change and energy choices to students?
- How do we make it fun and interactive?
- How do we make it complex (challenging) but still accessible to students

Answer: Turn our complex energy system model into a game board!

A complex model

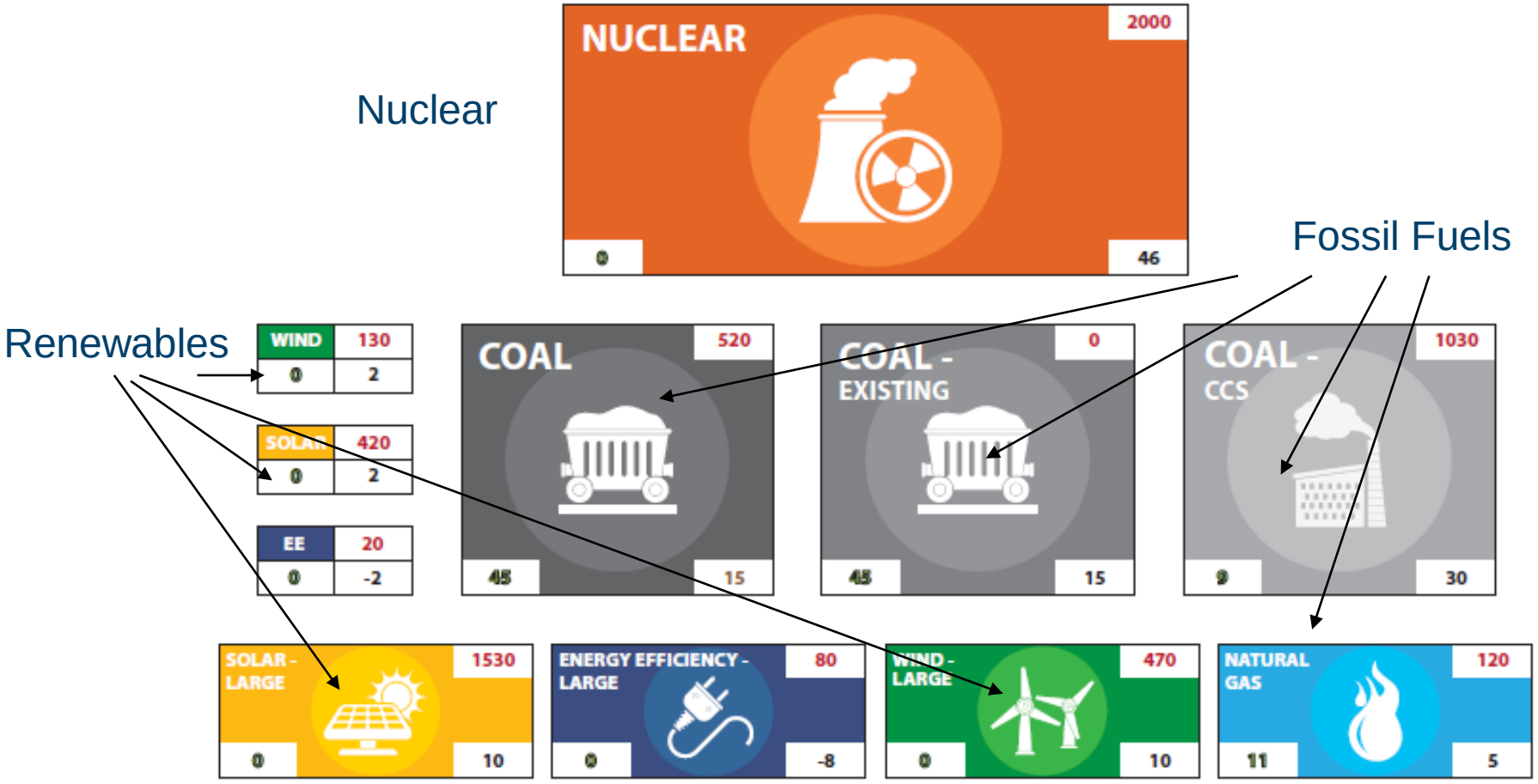


A model uses mathematical language to describe the behavior of a system

The game board = the “grid”

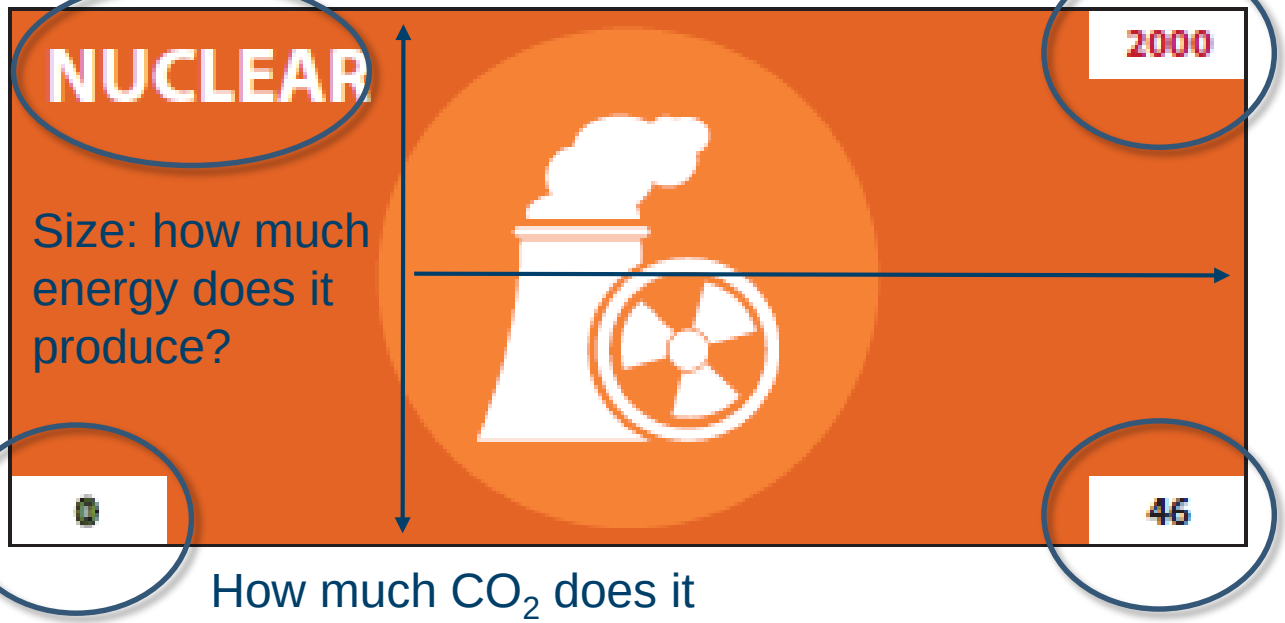
- This is the student teams’ grid
- Students are the decision makers for how they want to produce energy
- They will use this board for multiple rounds of game play
- Each team can be thought of as a town, state, region or country

Types of energy pieces



Parts of the energy pieces

What primary energy resource does it use?



How much does it cost to build/purchase?

How much does it cost each year to run/operate?

How much CO_2 does it produce?

Total Score	= 2000 + (46 * 30) + (0 * 30) * CO_2 cost
(over 30 years)	= 3380

** Units are generic, but represent relative costs of energy sources*

Filling in the “grid”

Set up: Up to 5 teams

- Each team has a game board, a “grid” to fill, and a bag of energy pieces
- Each team has the same total energy (area of pieces)
- Each team does not have the same mix of energy pieces
- Goal is to fill the game board with energy types to achieve the lowest total score

Score = purchase cost + operating cost + CO_2 cost

EPA GENERATE

Team ___

Instructions: When your grid is complete, fill in the number of pieces for each type of energy. After the score is calculated by the instructor, fill in your score and rank for each round.

	Round 1	Round 2	Round 3	Round 4	Round 5
Nuclear	1				
Coal	4				
Coal-Existing	2				
Coal-CCS	0				
Natural Gas	4				
Small Wind	8				
Large Wind	0				
Small Solar	0				
Large Solar	0				
Small Efficiency	0				
Large Efficiency	0				
Score					
Rank					

Notes

POLL: Which one is cheapest (per unit of energy)?

Here are your choices

A: Coal

B: Wind

C: Solar

D: Natural Gas

E: Nuclear

Score = Purchase + (Operate * 30) + ~~(CO_2 * 30) * CO_2 cost~~

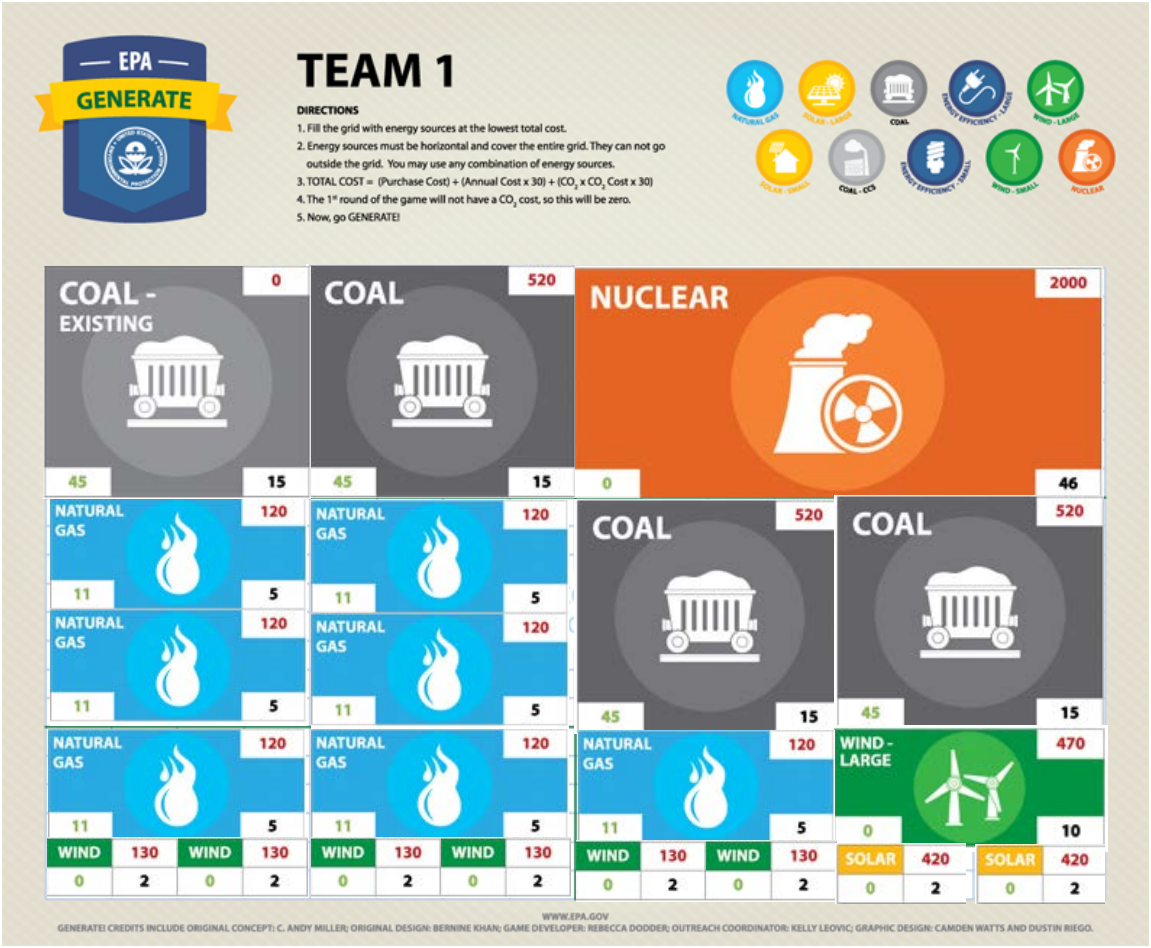
- Hint 1: Piece size matters!
- Hint 2: CO_2 cost is zero!

A typical result for Team 1

This would be a typical result for Team 1

- Using the “cheapest” pieces first
- Then… the next cheapest
- Then finding out they need the small pieces to fill up the bottom row

NOTE:
Each team will have a different outcome!



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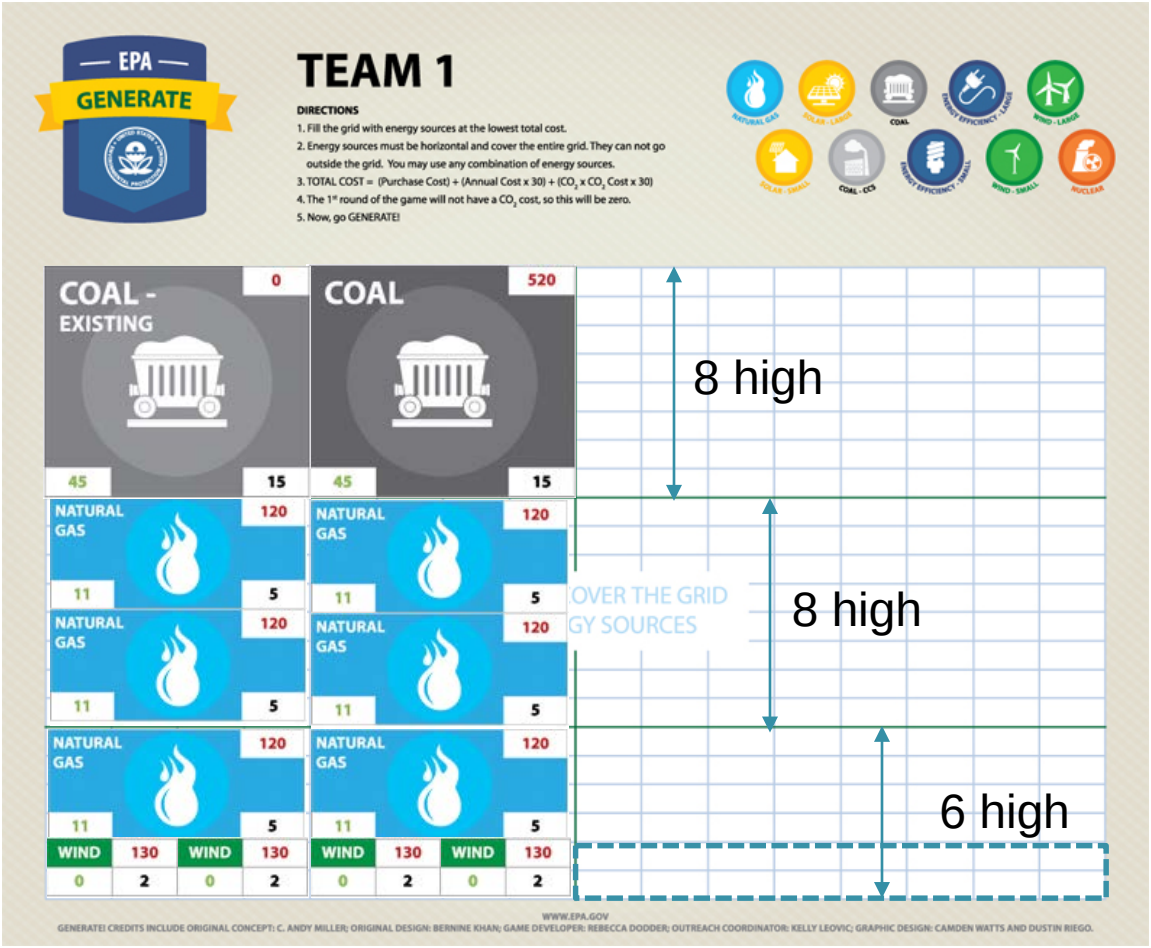


Follow-on issues and questions

- **Types of energy resources**
  - What are the different types of energy?
  - How can we classify them?
  - How do they differ?

- **Where we get our electricity**
  - Does the first round approximate our resource mix in the U.S.?
  - What electricity mix would *you like to see*, and why?
  - What are the challenges with getting to that outcome?
  - How could those challenges be met?

  - **But, we have ignored one crucial part of the equation: CO_2**

Check in?

- I’ll take 2-3 questions on the game basics before we ramp it up

PART 4: CHANGING THE RULES AND OTHER TWISTS

Now things get interesting

Changing the rules of the game

- *What if*… in our cost of electricity, we included costs associated with CO_2 emissions?
- How would that change the mix?

Total Score = Purchase + (Operate * 30) + (CO_2 * 30) * CO_2 cost
Total Score = 120 + (5 * 30) + (11 * 30) * 2

POLL: Which one is cheapest (per unit of energy)?

Here are your choices, again

A: Coal

B: Wind

C: Solar

D: Natural Gas

E: Nuclear

Score = Purchase + (Operate * 30) + (CO_2 * 30) * CO_2 cost

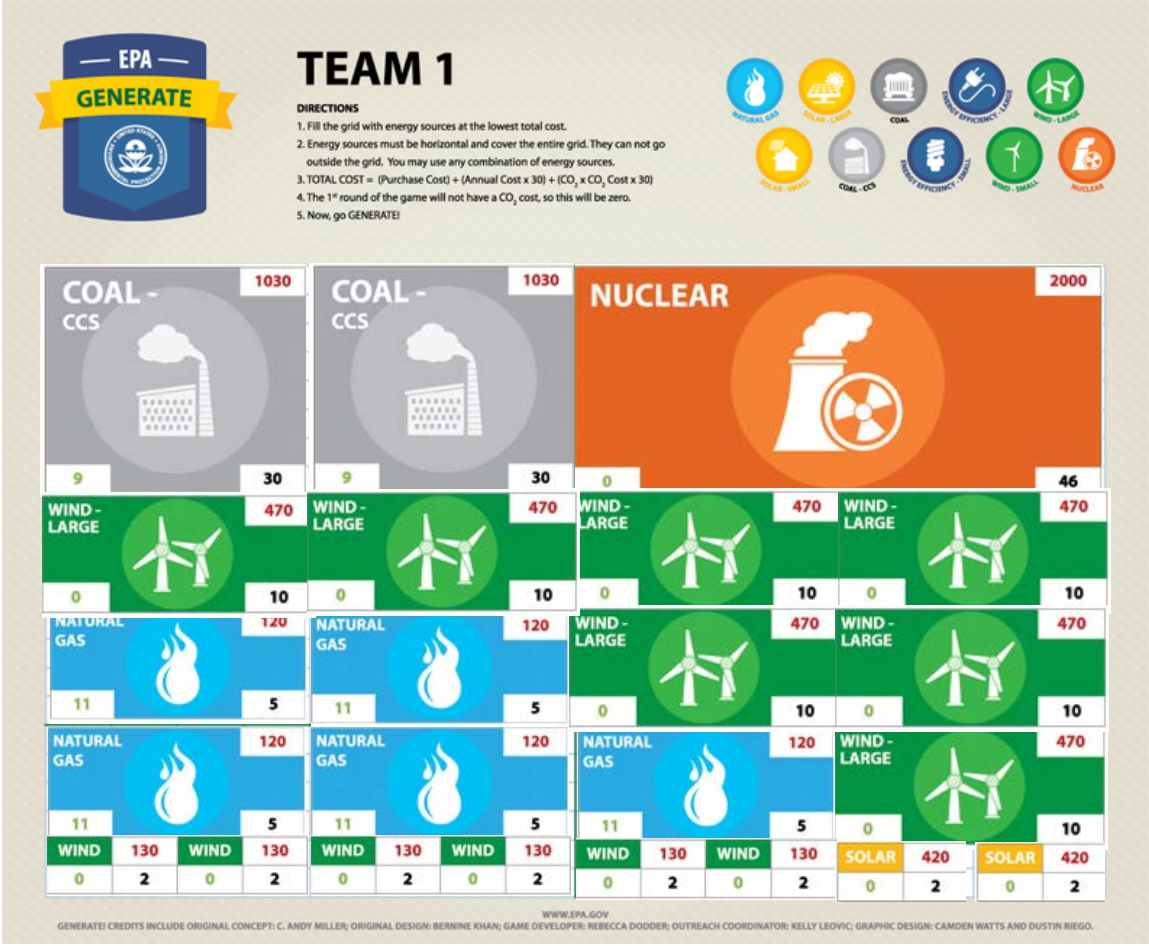
- Hint 1: Piece size matters!
- **Hint 2: CO_2 cost is now 2!**

A typical “low carbon” result for Team 1

This would be a typical result for Team 1

- Swapping out coal for coal with Carbon Capture and Storage (CCS)
- Bringing in some additional wind power
- Leaving nuclear or adding it to the mix, if they have it

- *Additional rounds can be run at higher and lower CO_2 costs*



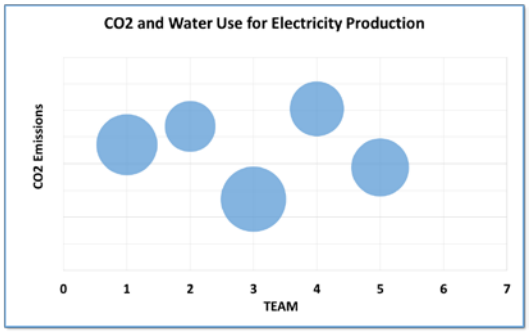
Keep playing it up!

Energy efficiency round

These prized pieces will bring down CO_2 and save costs!

EE	20
0	-2

Thirsty energy



Size of bubble shows total water use

Set a maximum total water use.

Student provided with water use per piece.

*Renewables are zero water use!

Other game extensions

- *Budget Breakers*
  - Set a max cost
- *Climate Friendly*
  - Set a max CO_2 limit
- *Pure Optimization*
  - Start all students with same sets of pieces
- *Energy Traders*
  - Let students “trade” pieces

PART 6: GENERATE AND OTHER “RESOURCES”

The GENERATE Package

- Printable boards and pieces: color and black and white
- Files for score sheets and calculation sheets
- Excel file for quickly calculating team scores and ranks for multiple rounds
- Introductory power point presentation
- Teachers Instruction Guides
  - Middle School – Susan Randolph, Wayne School of Engineering, Goldsboro, NC
  - High School – Kristen Thomas, Athens Drive High School, Raleigh, NC
  - Materials highlight alignment to Next Generation Science Standards, Common Core Middle School ELA/Math, and North Carolina Essential Standards

Resources available at:

www.epa.gov/research/airscience/hands-on.html

In the words of 6 grade students

It was cool, funny and angering at times!

The game was complicated and fun… so many ways to put the pieces.

I think you should put geothermal in.

I liked the CO_2 factor.

Solar energy is not used as much as we thought.

Can you add Velcro?

It was a good competition.

We think that there shouldn't be so much math.

We also think that the game makes us think hard and learn more about the impact that we have on the environment.

This is the best science board game EVER!

I think solar and nuclear should have been cheaper.

We thought it was unfair that all the different teams had different pieces, but for the most part we liked your game.

I applaud how you can learn and have fun.

Could you have given us energy efficiency before?

Excellent resources for energy and climate materials

Energy

Energy Information Administration
www.eia.gov

- State energy comparisons www.eia.gov/state/
- Interactive mapping of ALL energy resources and facilities www.eia.gov/state/maps

Open Energy Information

- http://en.openei.org/wiki/Main_Page

Climate

EPA Climate Change Resources
http://epa.gov/climatechange/

- Mapping GHG emissions from large facilities http://ghgdata.epa.gov/
- 30 Indicators for climate change http://epa.gov/climatechange/science/indicators/index.html
- Students guide to global climate change www.epa.gov/climatestudents/

Any Final Questions or Feedback?

Thank you so much for your time and interest!

Rebecca Dodder

Dodder.Rebecca@epa.gov

(919) 541-5376

Website for materials:
www.epa.gov/research/airscience/hands-on.html