Approaches for Quantifying Emission Impacts of Clean Energy Policies and Programs

Robyn DeYoung
August 15, 2011
U.S. EPA
State Climate and Energy Program

Overview of Process & Today's Presentation

- Quantifying the emissions impacts of clean energy policies requires understanding:
  1. How clean energy policies reduce emissions at electric generating units
  2. Which clean energy policy will be analyzed and estimates of the energy impacts
  3. Where to access data on electricity generation and emissions of electric generating units in a State or Region
  4. The range of available quantification methods and when to use them:
     - eGRID subregion nonbaseload emission rates
     - EGU capacity factor emission rates approach
     - Historic hourly emission rate approach
     - Energy modeling

EPA
State and Local Climate and Energy Program

Common Terms and Abbreviations

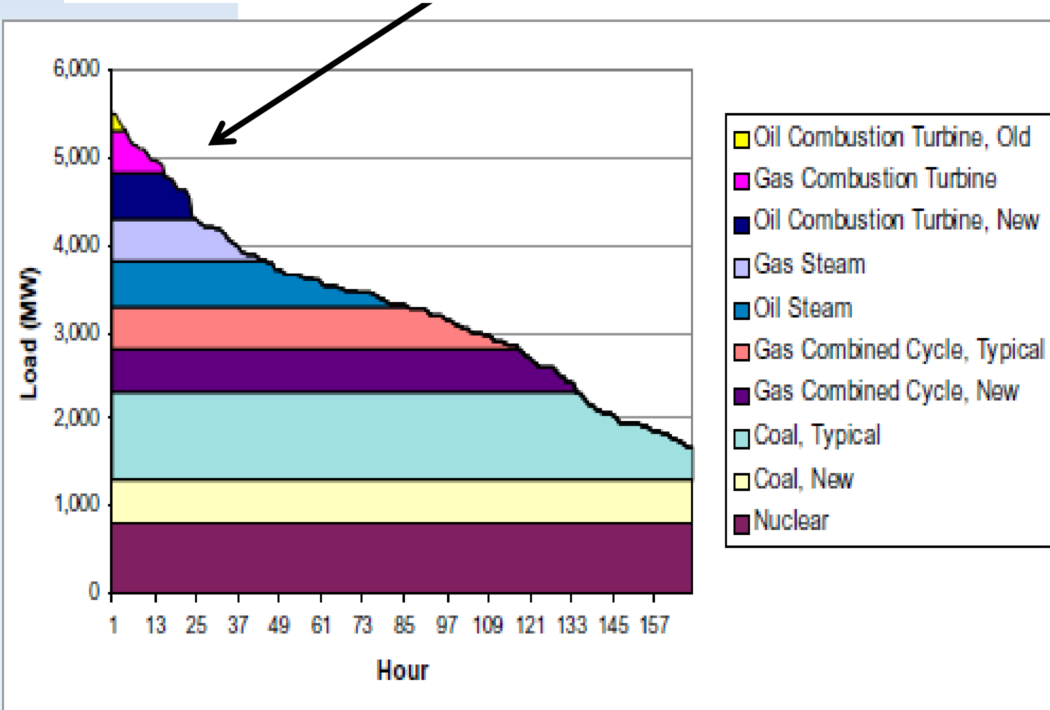
- Clean Energy: no-to-low emitting options to meet energy demand, such as energy efficiency, combined heat and power, and renewable energy
- Electric generating unit: (EGU) a power plant or generator that produces electricity and is connected to the grid.
- Baseload EGUs: operate near maximum capacity most hours of day. (E.g., nuclear, in most cases coal & hydro plants)
- Nonbaseload EGUs: fluctuate generation based on changes in demand (E.g., gas combined cycle, gas turbines, oil-fired plants)
- Peaking EGUs: only operate during the highest demand periods (older oil combustion turbines, gas combustion)
- Marginal Unit: the last (or next) EGU called upon to meet demand

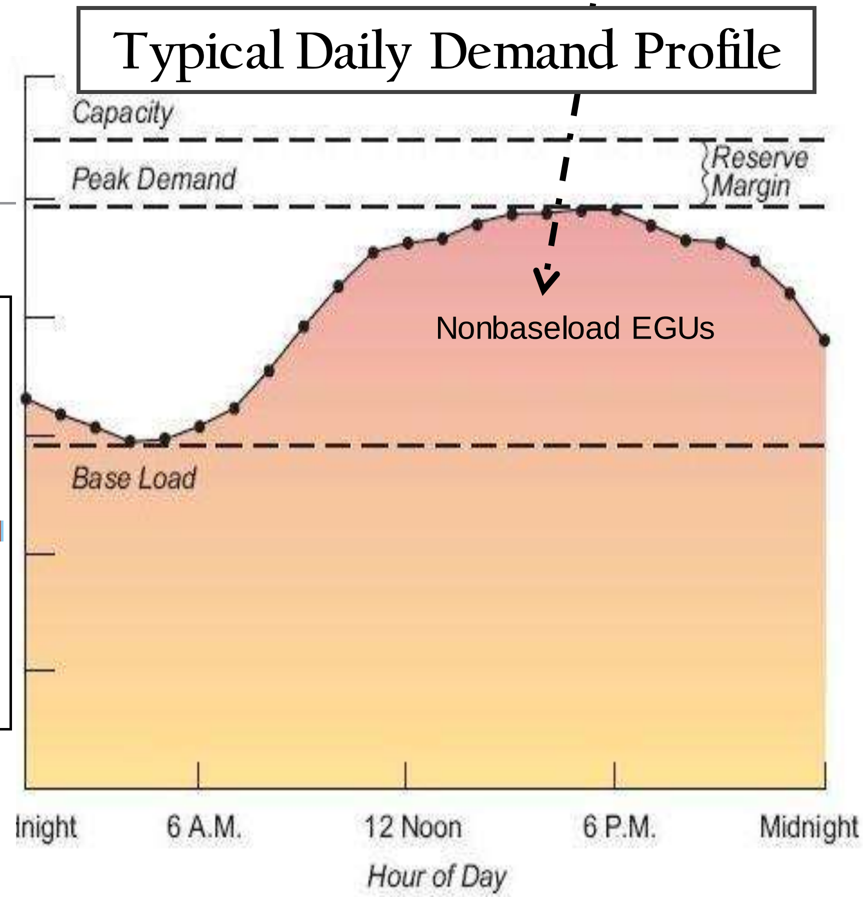
EPA
State and Local
Climate and Energy Program

How do Clean Energy policies reduce emissions?

Generally, CE policies reduce emissions at nonbaseload EGUs, and the most expensive units are dispatched last

Hypothetical EGU Dispatch Curve (1 week)





Types of Clean Energy Policies and Their Impacts

Examples of State Energy Efficiency Policies:

- Energy Efficiency Resource Standards
- Public Benefits Funded EE programs

Example s of State Renewable Energy Policies:

- Renewable Portfolio Standards (RPS)
- Renewable Energy Incentives (E.g., rebates)

Clean Energy policy impacts are estimated in Megawatt-hours (MWh).

- Capturing energy impacts of CE policies will provide the most emissions benefits.

EPA

State and Local Climate and Energy Program

The *Clean Energy-Environment Guide to Action: Policies, Best Practices, and Action Steps for States* (April 2006) http://www.epa.gov/statelocalclimate/resources/action-guide.html

Available Data Sources for EGU generation and emissions

- EPA's eGRID (Emissions Generation Resource Integrated Database)
  - Annual emissions for NOx*, SO_2, Hg, CO_2, CH_4 and N_20
  - Different aggregation levels – boiler to subregions
  - Capacity factors – the ratio between generation and max capacity
- EPA's Clean Air Markets Division (CAMD) database
  - Monitored NOx, SO2, CO2 emissions for EGUs reporting to EPA
  - Emission unit level
  - Temporal scales – 5min – hourly - annual emissions data
- State emissions inventories
  - Emissions for EGUs permitted by State DEPs
  - Includes units not captured in EPA data collection
  - Scale of emissions varies depending upon permitting requirements

EPA
State and Local Climate and Energy Program

*Ozone season emissions available for NOx

Summary of Emission Quantification Approaches

Four Emission Quantification Approaches

Approach	Emission Rate	Temporal Scale	Geographical Scale
eGrid subregion nonbaseload approach	lbs/MWh	Annual and ozone season	Regional averages of nonbaseload EGUs
EGU Capacity factor approach	lbs/MWh	Annual and ozone season	EGU specific
Reported Hourly emissions approach	Lbs/MWh	Hourly, daily, monthly, annual	EGU and emission unit level specific
Energy modeling approach	lbs.MWh Or lbs	Varies depending upon model	EGU and emission unit level specific

Deciding which approach to use depends on policy objectives, analytical questions as well as time and resource constraints

* Note: This does not cover the full scope of all possible approaches

State and Local Climate and Energy Program

eGRID subregion nonbaseload emission rates approach

- **How it works:**
  - Uses emission rates that represent average emissions of nonbaseload units in an eGRID subregion.
- **Examples for when to use:**
  - Estimate emission reduction potential
  - Captures average emission reductions
- **Advantages:**
  - Requires low resources – easy calculation
  - Great for annual emissions reductions, regional and national estimates
- **Limitations:**
  - Does not specify which power plant is reducing emissions
  - Based on historical data

eGRID Subregions

CALCULATION USING eGRID

Energy saving of EE (MWh)

✖

eGRID nonbaseload emission rate (lbs/MWh)
(Account for Grid loss factor)

=

emissions avoided by EE (lbs)

State and Local Climate and Energy Program

eGRID subregion nonbaseload emission rates approach

Informational resources:

- eGRID website:
  - http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
- eGRID summary tables:
  - http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2010V1_1_year07_SummaryTables.pdf
- eGRID overview presentation:
  - http://www.epatechforum.org/documents/2010-2011/March%2031/Diem-eGRID-2011-03-11.pdf
- New Mexico example using eGRID:
  - http://www.epatechforum.org/documents/2010 2011/March%2031/DeYoung_eGRID_3.31.11.pdf

eGRID Subregions

USERS of eGRID

- EPA's Power profiler
- EPA's CHP calculator
- Energy Star Portfolio Manger
- EPA's Personal GHG calculator
- EPA's GHG equivalency calc.
- EPA's Wastewise GHG calc.

(The emission rates may vary within each tool depending upon the purpose)

EPA

State and Local Climate and Energy Program

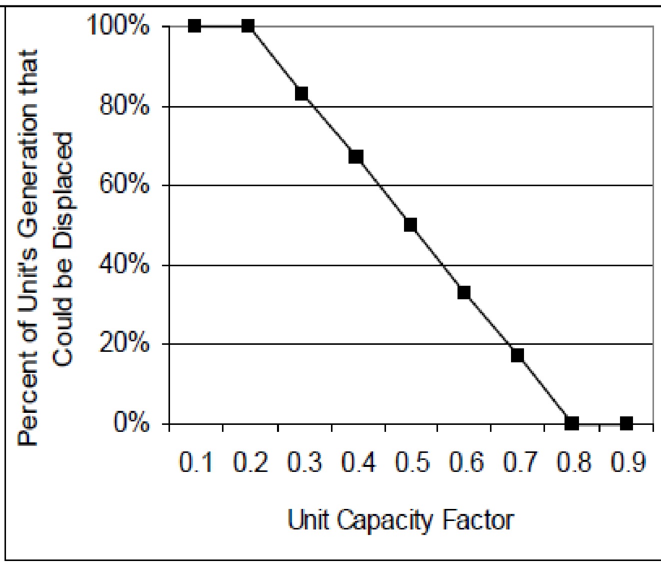
EGU Capacity Factor Emission Rates Approach

- **How it works:**
  - An EGU's capacity factor is indicative of how much emissions could be displaced
    - EGUs with ~ high capacity factors are generally baseload EGUs
    - EGUs with ~ low capacity factors are generally nonbaseload EGUs
- Distribute emissions reductions to each EGU based on 1) displaceability 2) CE impacts 3) annual EGU emission rates
- **Examples for when to use:**
  - Approximate EGU dispatch order
  - Understand which EGUs are nonbaseload and where emissions could most likely be displaced

AN EGU's CAPACITY FACTOR IS A RATIO:

$$\frac{\text{The actual electricity produced}}{\text{The available electricity production at maximum capacity}}$$

Capacity Factors Relationship to Emissions Displacement



EPA
State and Local Climate and Energy Program

EGU Capacity Factor Emission Rates Approach

- **Advantages:**
  - Emissions can be distributed to each EGU
  - Relatively easy calculation
  - Great for preliminary analysis
- **Limitations:**
  - Capacity factors are approximate and don't account for maintenance, outages, etc.
  - Dynamics of electric grid not captured (E.g., exports, imports)
  - Based on historical data - future generation not represented
- **Examples using this approach:**
  - Energy efficiency policy analysis in Texas (S.B. 5)
    - Estimated how much and where emission reductions occur within TX
  - (See illustrative example at the end of presentation)

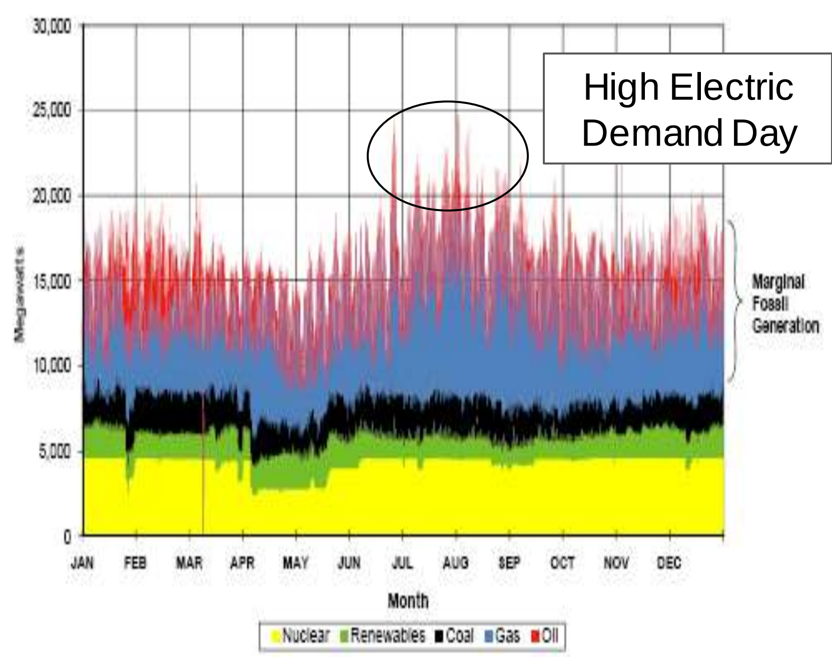
Capacity Factors can be found in eGRID's excel workbooks

EPA State and Local Climate and Energy Program

Historical Hourly Emission Rates Approach

- **How it works:**
  - Use reported hourly generation and emissions information to derive hourly emission rates.
  - Historical hourly emissions rates can be aggregated to any temporal scale to answer policy questions.
- **Examples for when to use:**
  - Regulatory analysis
  - Analyze emission impacts during high electric demand days
  - Analyze how RE technologies reduce emissions

Figure 3.1: New England 2007 Hourly Generation



Reported Hourly Emissions information can be found at EPA's Clean Air Market's Division website: http://camddataandmaps.epa.gov/gdm/index.cfm?fuseaction=iss.progressresults

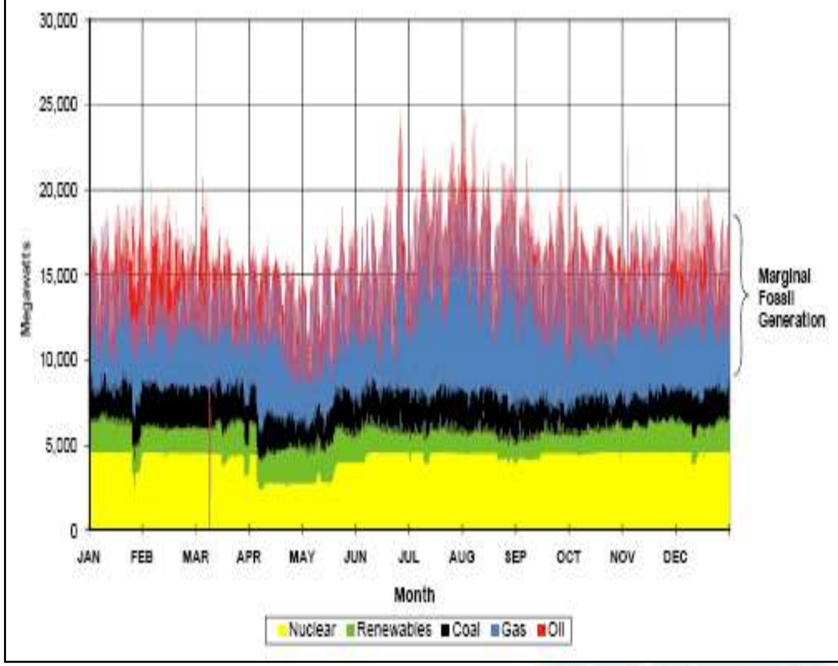
State and Local Climate and Energy Program

Historical Hourly Emission Rates Approach

- Advantages:
  - Approach uses monitored emissions data
  - Can select emission rates for any group of hours
- Limitations:
  - Data intensive w/out infrastructure
  - Based on historical data
- Examples of this approach:
  - Washington Council of Governments calculator
  - http://www.mwcog.org/environment/air/EERE/default.asp
  - Mid-Atlantic Regional Air Management Association Report

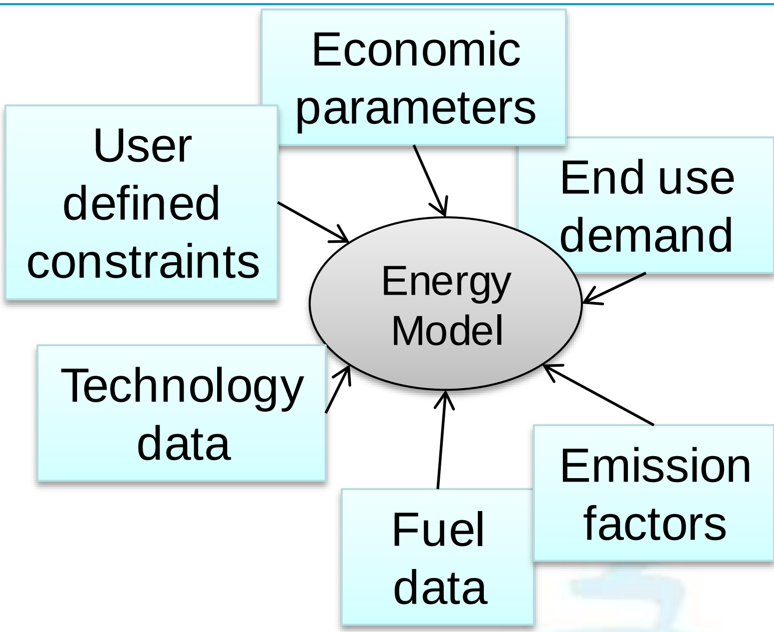
    http://www.marama.org/RegionalEmissionsInventory/2007hourlypoint/FinalDoc_mar2011_Analysis_of_Hrly_CAMD_Emissions_Data.pdf.

Figure 3.1: New England 2007 Hourly Generation



Energy Modeling Approach

- **How it works:**
  - Dynamic simulation models are used to forecast emissions
  - Models account for complex interaction of the electric grid
    - Dispatch Models
    - Capacity Expansion Models
- **Examples of when to use:**
  - Regulatory analysis
  - When policy assumptions are well defined, detailed input data



EPA uses the Integrated Planning Model (IPM) for all electric sector regulatory analysis

EPA
State and Local Climate and Energy Program

*NEMS - National Energy Modeling System
**IPM - Integrated Planning Model includes dispatch capabilities
*** MARKAL - Market Allocation Model

Energy Modeling Approach

- Examples of this approach:
  - Energy Information Administration's (EIA) Annual Energy Outlook (AEO) Projections (NEMS) http://www.eia.gov/forecasts/aeo/
  - U.S. EPA's Regulatory Analysis (IPM) http://www.epa.gov/airmarkets/progsregs/epa-ipm/index.html
  - Emission reductions of clean energy policies in California's Air Management Districts (PROSYM)
    http://www.epatechforum.org/documents/2010 2011/June%2014/Fisher%206-14 2011%20EPA%20Tech%20Forum.pdf

Advantages and Disadvantages of Energy Models

Energy Model	Advantages	Disadvantages
Dispatch Models ■ Prosym, ■ Promod, ■ Ventyx	■Provides very detailed estimations about specific plant and plant-type effects within the electric sector. ■ Provides highly detailed, geographically specific, hourly data.	■Often lacks transparency. ■Requires technical experience ■Labor- and time- intensive. ■Often high labor and software licensing costs. ■Requires establishment of specific operational profile of the clean energy resource.
Capacity Expansion Models ■ NEMS, ■ IPM, ■ Energy 2020, ■ MARKAL	■Model selects optimal changes in generation mix based on assumptions and energy system (10–30 years). ■ Captures emission changes from new power plants and retirements ■May provide plant specific detail and perform dispatch simultaneously (IPM).	■Often lacks transparency ■Requires significant technical experience ■Labor- and time- intensive. ■Often high labor and software licensing costs. ■Requires assumptions that have large impact on outputs (e.g., future fuel costs).

Choosing an Emission Quantification Approach

- Basic approaches are useful when:
  - time or resources are short
  - High-level, preliminary analyses are needed
  - A long list of options need to be shortened
- Sophisticated approaches are useful when:
  - Policy options are well-defined
  - high degree of precision and analytic rigor is desired
  - sufficient time, data and financial resources are available.

EPA
State and Local
Climate and Energy Program

Contact Information

Robyn DeYoung
U.S. EPA's State Climate and Energy Program
202-343-9080
Deyoung.robyn@epa.gov

EPA
State and Local
Climate and Energy Program

Capacity Factor Approach - Example

There are seven generating units in this hypothetical power system, labeled A - G.

- Column [2] shows the % of each unit's production that could be displaced by the EE program (based on and EGU's capacity factor relationship to displacement)
- Column [3] shows each unit's actual generation in the historical year
- Column [4] shows the amount of energy that could be displaced [2] x [3]
- Column [5] shows the % of the energy saved by the EE program (1,000 MWs)
- Column [6] shows the MWhs displaced at each generating unit.

- Last step: multiply emission rate of each EGU by column [6] to get displaced emissions (not shown below)

Unit (1)	Percentage Displaceable (2)	Historical Generation (MWh) (3)	MWhs Displaceable (4)	Percentage of Energy Saved Allocated to Unit (5)	MWhs Displaced (6)
A	100%	50,000	50,000	7%	65
B	82%	65,000	53,000	7%	69
C	79%	120,000	94,800	12%	123
D	48%	500,000	240,000	31%	312
E	22%	1,500,000	330,000	43%	430
F	0%	1,800,000	0	0%	0
G	0%	2,000,000	0	0%	0
Totals		**6.035,000**	**768,100**	**100%**	**1,000**

State and Loca
Climate and Energy P