Understanding the EPA's Math in the Clean Power Plan

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On this page we hope to break down the EPA's methodology for calculating goals for each state, translated from bureaucratese to more-or-less comprehensible English. The information and data informing the discussion is drawn from several Technical Appendices to the EPA's Clean Power Plan, which can be found as Excel spreadsheets and PDFs on EPA's website.

The formula has many moving parts, but in essence, it begins with a stylized calculation of each state's usage-weighted emissions rate and then applies four alterations, each one labelled a "block." The EPA looks to current usage of both fossil fuel generation sources and renewables and then assumes four different kinds of improvements: making coal more efficient, better utilizing natural gas plant capacity, shifting to renewables, and increasing demand-side energy efficiency. That leaves the EPA with a vision of each state's energy mix in 2030, which implies an overall carbon-intensity (the rate of carbon emissions per unit of energy generated).

The formula to calculate the current emissions rate looks like this, where E_t is the emissions rate in pounds of CO_2 emitted per Megawatt hour (MWh) for each type of generation t, and G_t is the current generation in MWh of type t, using 2012 data.

$$\frac{(E_{Coal} * G_{Coal}) + (E_{Natural\ Gas} * G_{Natural\ Gas}) + (E_{Petroleum} * G_{Petroleum}) + (E_{Other}{}^{*})}{G_{Coal} + G_{Natural\ Gas} + G_{Petroleum} + G_{Other} + G_{Nuclear_{AR+UC}} + G_{Renewable}}$$

Conceptually, it may be easier to think of the formula as the emissions rate for each type of source times generation for that source divided by the combined generation of all sources. For the carbon neutral sources, the emissions rate is zero, so their emissions do not appear in the numerator, even though their generation appears in the denominator.

This formula is used to calculate a baseline emissions rate for 2012 for each state, and is altered as each of the four "blocks" are applied in sequence.

Block One: Coal Efficiency

Applying Block One to each state entails multiplying the coal emissions rate (E_{Coal}), by .94, reflecting a 6% savings for total coal emissions. This is the simplest part of the rule, with the formula changed just a little:

$$\frac{(\mathbf{0.94}\boldsymbol{E_{Coal}} * G_{Coal}) + (E_{Natural\ Gas} * G_{Natural\ Gas}) + (E_{Petroleum} * G_{Petroleum}) + (E_{Other})}{G_{Coal} + G_{Natural\ Gas} + G_{Petroleum} + G_{Other}}$$

[*] In the formula, "Other" contains a variety of different generation mechanisms, such as the emissions from heat generation facilities that are co-located with electricity generating units, and, after Block 2, 55% of the capacity of under-construction natural gas plants.

Block Two: Redispatch to Natural Gas

Block Two is the redispatch block, which entails shifting generation from coal and petroleum to natural gas, resulting in significant CO_2 emissions reductions. Many plants are currently used below 70% of their capacity, as they are used to supplement existing generation during periods of increased demand. Increasing the plants to 70% capacity would make them a more central part of energy generation in some states, and would allow for a decrease in use of other, more carbon intensive energy sources. The natural gas redispatch goal is set by choosing the lower of: (a) 70% generating capacity of existing natural gas plants plus 15% generating capacity of natural gas plants under construction, or, (b) the net generation of coal, petroleum, and natural gas generation combined. The change is then subtracted from the coal and petroleum generation in proportion to their share of generation amongst those three. In other words, after applying Block Two, the EPA recalculates the state's carbon-intensity as if proportional amounts of its coal and petroleum generation now come from natural gas generation instead. This method means also that if there is more underutilized natural gas capacity than generation from coal and petroleum, all coal and petroleum generation is expected to be redispatched.

The updated formula looks like this:

$$\frac{\left(0.94E_{Coal}*\boldsymbol{G_{Coal_{Redispatch}}}\right)+\left(E_{Natural\ Gas}*\boldsymbol{G_{Natural\ Gas_{Redispatch}}}\right)+\left(E_{Petroleum}*\boldsymbol{G_{Petroleum_{Redispatch}}}\right)+\left(\boldsymbol{E_{Other_{Redispatch}}}^{*}\right)}{\boldsymbol{G_{Coal_{Redispatch}}}+\boldsymbol{G_{Natural\ Gas_{Redispatch}}}+\boldsymbol{G_{Petroleum_{Redispatch}}}+\boldsymbol{G_{Other_{Redispatch}}}}$$

Block Three: Renewables and Nuclear

Block Three addresses both nuclear power and renewable energy and can be best understood by treating each component separately.

Part One: Nuclear

The EPA estimates that 5.8% of the current nuclear power fleet is "at risk" of being retired between now and 2030.† To encourage states not to close these plants, EPA includes this 5.8% as part of the denominator of the formula, allowing states that choose to keep nuclear plants open to be credited for maintaining this zero-emissions power source. That means that states with nuclear plants but no plans to retire them are essentially treated as already having made progress. The EPA adds megawatt hours reflecting 5.8% of a state's nuclear fleet, along with any megawatt hours for under construction nuclear plants, to the denominator of the formula, resulting in the following version of the formula, where the subscript AR means nuclear generation at risk and UC means nuclear generation under construction.

$$\frac{\left(0.94E_{Coal}*G_{Coal_{Redispatch}}\right)+\left(E_{Natural\ Gas}*G_{Natural\ Gas_{Redispatch}}\right)+\left(E_{Petroleum}*G_{Petroleum_{Redispatch}}\right)+\left(E_{Other_{Redispatch}}\right)}{G_{Coal_{Redispatch}}+G_{Natural\ Gas_{Redispatch}}+G_{Petroleum_{Redispatch}}+G_{Other_{Redispatch}}+\boldsymbol{G_{Nuclear_{AR+UC}}}}$$

* After Block Two, "Other" includes 55% of natural gas generation capacity that was under construction (and therefore not yet operational) in 2012

† As explained in the GHG Abatement Technical Support Document, 4-32 to 4-35.

Part Two: Renewables

The EPA's renewable energy growth expectations for states are based on regional averages of states' Renewable Portfolio Standards (RPS), which are goals set by states for what percentage of their energy mix will come from renewables by a certain date. RPSs reflect both the reality of growth potential for the state and aspirations that the state's elected officials have for the green economy.

All states, excluding Hawaii and Alaska, are assigned to a region, and then the average of the 2020 Effective Renewable Level (the EPA's 2020 extrapolation of each state's RPS, which usually target other years) for all RPSs in that region is set as the regional renewable generation target. The EPA then determines at what rate the region would need to grow its renewable capacity in order to meet that target, and then applies that growth rate to each state. Assuming growth at that pace, most states do not actually have to meet the regional renewable target, but instead must achieve 13 years of growth at the prescribed rate from 2017 to 2029. For example, Illinois, in the North Central region, has a regional target of 15%. However, the growth rate imposed on them by their regional membership, 5.98% per year, determines that they will only be expected to have 9% of their generation from renewable sources by 2030.

The regional targets and growth rates are below:

Region	Regional Renewable Generation Target	Regional Growth Rate
East Central	16%	17.26%**
North Central	15%	5.98%**
Northeast	25%	12.59%**
Southeast*	10%	13.43%**
South Central*	20%	8.35%**
West	21%	6.09%**
Alaska	10%	11.43%**
Hawaii	10%	9%

After applying the relevant growth rates, a final renewable generation level for 2029 is generated, and this number is added to the denominator of the formula, resulting in the following version of the formula.

$$\frac{\left(0.94E_{Coal}{*}G_{Coal_{Redispatch}}\right)+\left(E_{Natural\,Gas}{*}G_{Natural\,Gas_{Redispatch}}\right)+\left(E_{Petroleum}{*}G_{Petroleum_{Redispatch}}\right)+\left(E_{Other_{Redispatch}}\right)}{\left(G_{Coal_{Redispatch}}+G_{Natural\,Gas_{Redispatch}}+G_{Petroleum_{Redispatch}}+G_{Other_{Redispatch}}+G_{Nuclear_{AR+UC}}+\boldsymbol{G_{Renewables_{2029}}}\right)}$$

It is worth briefly noting that the EPA's expectations for state renewable provision and growth suffer from a lack of tailoring to individual states, which will likely present challenges if and when states attempt to meet the goals set under Block 3. The current approach in no way takes into

* In the South Central and Southeast regions, each has only one state that has Renewable Portfolio Standards. These states, Kansas and North Carolina, set the pace for the rest of the regions, so they are the determining factor in their region's renewable goals under the EPA rules.

** Calculated using the data provided by the EPA in Appendix 1 and 2 to the Goal Computation Technical Support Document.

consideration the specific resources available to each state, the potential for growth, or whether certain resources have already been "tapped out" using currently available technology, which raises serious questions about states' ability to meet these goals.

Block Four: Demand Side Energy Efficiency

Block Four demands emissions savings through the demand side of the energy market: lower demand leads to lower overall generation, and thus lower emissions. To calculate the final energy efficiency savings that for its formula, the EPA uses a complicated multi-step process. Unfortunately, the EPA does not provide the data necessary to follow along in those steps, so the process is somewhat mysterious even to those of us who have spent a great deal of time trying to understand it.

But the important takeaway from this block is the number that is used as the total megawatt hours saved, which can be obtained much more easily. To do this, take the "2029 EE Potential (%)" given in the EPA's technical appendix, and multiply it times the "2012 Total MWh (sales x 1.0751)", which is , according to the EPA's explanation, the total amount generated, including what is sold and what is lost in transmission." For states that are net importers of energy, the result of the first calculation is multiplied by the state's generation as a percentage of its sales, to ensure that it is only responsible for what it generates, and not what it imports. This results in a total amount of Megawatt hours that are then added to the denominator as "Energy Efficiency Savings. This block results in similar levels of savings across most states, at approximately 10% of 2012 generation, which are added to the denominator of the formula.

The final formula with energy efficiency factored in is below, where S stands for Savings:

$$\frac{\left(0.94E_{Coal}*G_{Coal_{Redispatch}}\right)+\left(E_{Natural\,Gas}*G_{Natural\,Gas_{Redispatch}}\right)+\left(E_{Petroleum}*G_{Petroleum_{Redispatch}}\right)+\left(E_{Other_{Redispatch}}\right)}{G_{Coal_{Redispatch}}+G_{Natural\,Gas_{Redispatch}}+G_{Petroleum_{Redispatch}}+G_{Other_{Redispatch}}+G_{Nuclear_{AR+UC}}+G_{Renewables_{2029}}+\boldsymbol{S_{Energy\ Efficency}}}$$

To make things more concrete, we present the formula and goal for Michigan:

$$\frac{(2{,}120\ lbs/MWh*41{,}091{,}564MWh)+(810\ lbs/MWh*30{,}795{,}650\ MWh)+(1{,}586\ lbs/MWh*598{,}388MWh)+(3{,}044{,}925{,}860\ lbs)}{41{,}091{,}546\ MWh+30{,}795{,}650\ MWh+598{,}388\ MWh+4{,}299{,}173\ MWh+1{,}827{,}909\ MWh+8{,}055{,}859MWh+13{,}262{,}541MWh}=$$
$$1{,}161\,\frac{lbs}{MWh}$$

The Meaning of the Blocks

The EPA's Four-Block calculation process does *not* oblige states to attempt to produce efficiencies to match each step. The bottom line of EPA's rule is that each state is given an efficiency standard and can devise its own plan to ensure that power generated within its borders is, on average, no more carbon-intensive than that standard. Hypothetically, it might do that entirely through expanding its renewable energy capacity or, in some cases, simply by building more natural gas plants to replace heavier-emitting coal ones.

In practice, however, it is difficult to see how states will satisfy EPA's standards without making at least some of the choices implied by EPA's blocks. This is especially true of states starting from low carbon-intensity baselines which are nevertheless asked to achieve significant improvements, sometimes by completely phasing out their coal generation. For some states, the savings EPA requires by some blocks may turn out to be unachievable, especially renewable growth, but it remains to be seen whether and how EPA would adjust its expectations of a state if it made a persuasive showing of impossibility (or prohibitive cost) for one of the blocks.

At this stage in the rulemaking process, EPA must respond to all concerns raised about its calculation methods. Over the next months, interested observers should look to see whether EPA decides to alter its formulas to address critics.