Concepts, Data Sources, and Techniques
Handbook of Energy Modeling Methods

World Energy Projection System (WEPS): Convergence Module

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1. Introduction

The WEPS Convergence Model evaluates and facilitates convergence of WEPS. WEPS is a modular system that comprises a series of separate energy models that communicate and work with each other. The Convergence Model uses an iterative solution technique, in which energy prices are successively adjusted until the the various demand and supply models of WEPS converge to a simultaneous economic equilibrium solution of prices and quantities of fuels consumed.

2. Description of the Convergence Check

The Convergence Model is the last model run by the WEPS system. WEPS comprises several models. A single run of every model in WEPS is referred to as one WEPS iteration. A complete WEPS run typically comprises multiple iterations (the iterative process) as the system attempts to converge to a simultaneous equilibrium solution.

The sequence of model execution in WEPS is important because each model uses the results from the models that have been run before it to calculate a new projection. The WEPS system uses a common, shared database for communication between the models. The Residential Model, for instance, calculates residential sector energy consumption projections based on the prices imported from the shared file. In the first iteration of the Residential Model, the prices in the shared file are the result of a previous WEPS run, but as iterations are made, these prices are adjusted based on the results of executing the supply models. In turn, the supply models use the energy consumption projected by the Residential Model to re-calculate prices. Also, transformation models, such as the World Electricity Model, use both the consumption projected by the demand models and the fuel prices adjusted in the supply models to project fuel consumption, and then the supply models use those projections. This exchange of data is like a set of demand curves and supply curves that are brought to an equilibrium solution through a series of successive approximations.

At the end of a WEPS iteration, the Convergence Model imports all of the consumption and price projections returned by the other WEPS models in that iteration along with the consumption and price projections that were in the shared file *before* the iteration began. The Convergence Model compares the two sets of consumption and price projections and computes the proportional change for each consumption and price value by fuel, region, and year:

$$\text{Proportional Consumption Change} = \left(\frac{\text{Consumption Before Iteration}}{\text{Consumption After Iteration}}\right) - 1.0.$$

$$\text{Proportional Price Change} = \left(\frac{\text{Price Before Iteration}}{\text{Price After Iteration}}\right) - 1.0$$

The Convergence Model imports a set of convergence tolerance levels determined by the analyst's judgment. These tolerances specify, for each consumption and price value, the *reasonable* proportional change from iteration to iteration. These convergence tolerances are specified for each fuel in each region. Tolerances are typically set to be 0.02 (or about 2%) for both quantities and prices.

The Convergence Model measures the degree to which the proportional change for each of the consumption and price values comes close to its tolerance level by the grade point average (GPA). This concept comes from our National Energy Modeling System (NEMS), although the way the Convergence Model uses the calculation differs in some cases. If the proportional change is equal to or less than the tolerance, then the GPA for that value is set at 4.0. Otherwise, the Convergence Model calculates it as follows (bounded to be no greater than 4.0 and no less than 0.0)

$$\text{Consumption GPA}=5.0-\left(\frac{\text{Proportional Consumption Change}}{\text{Consumption Change Tolerance}}\right)$$

$$\text{Price GPA}=5.0-\left(\frac{\text{Proportional Price Change}}{\text{Price Change Tolerance}}\right)$$

For example, if the tolerance is 0.02 and the proportional change is 0.02 or less, the GPA is 4.0. On the other hand, if the proportional change is 0.04, then the GPA would be 3.0. Any proportional change greater than or equal to 0.10 would have a GPA of 0.0.

The GPAs are a convenient way to determine the degree to which the WEPS has converged to equilibrium projected price and consumption levels, given the specified tolerance levels. The Convergence Model calculates aggregate summary GPAs for consumption and for prices, ignoring categories for which that we are not considering (e.g., renewable energy sources' prices and consumption that are driven more by government policy than by market dynamics). The summary GPAs provide an overall measure of convergence.

The Convergence Model uses the summary GPAs to determine whether the current iteration has achieved convergence. If average GPAs for consumption and price (over regions and years) have reached a score of 3.5 or higher, then WEPS has converged, and one additional iteration will occur solely for report writing. If the model has not achieved convergence, then it will continue with further iterations until it has converged or until it reachesthe maximum number of iterations allowed.

3. Adjusting Prices to Facilitate Convergence

If, after an iteration, WEPS has not achieved convergence, the Convergence Model applies an adjustment to the prices to facilitate convergence. The rationale behind the adjustment is that because the model has not reached equilibrium, another set of prices must exist that would shift the demand closer to the equilibrium point. The prices are *relaxed* by re-estimating them to be values halfway between the value at the start of the iteration and the value at the end of the iteration:

$$\text{Adjusted Price}=\frac{\text{Price Before Iteration}+\text{Price After Iteration}}{2.0}$$

After the model adjusts the prices, another iteration of WEPS is initiatied. This iterative process contines until WEPS has either converged or until the maximum number of iterations has been executed.