AVERT Overview and Step-by-Step Instructions

U.S. Environmental Protection Agency State Climate and Energy Program Updated

April 2016
Overview of AVERT Development for Energy Efficiency and Renewable Energy (EE/RE) Programs

• AVERT (AVoided Emissions and geneRation Tool) translates the energy impacts of EE/RE policies and programs into emission reductions (NO\textsubscript{x}, SO\textsubscript{2}, and CO\textsubscript{2}).
  – It aims to address a key reason states have not implemented previous EE/RE State Implementation Plan (SIP) guidance.

• AVERT has been thoroughly reviewed, well documented and tested. EPA has:
  – Conducted external and internal peer reviews.
  – Benchmarked AVERT against industry standard electric power sector model – PROSYM.
  – Worked with states to beta-tested tool for functionality, appropriate uses, and clarity of user manual.

• AVERT was built to be:
  – user friendly
  – transparent
  – credible

Emission Quantification Methods
Basic to Sophisticated

**Basic Method**
eGRID region non-baseload emission rates

**Intermediate Method**
Historical hourly emission rates

**Sophisticated Method**
Energy Modeling
- Economic parameters
- End use demand
- User defined constraints
- Environmental regulations
- Technology data
- Fuel data
- Emission factors
Applications for AVERT-Calculated Emissions

• SIP credit in a state’s National Ambient Air Quality Standard Clean Air Act Plan
• Identify cohort of electric generating units (EGU) “on the margin” compared to baseline
• Compare emission impacts of different EE/RE programs
• Understand emission reductions during High Electric Demand Days
• This is not a projection tool, not intended for analysis more than 5 yrs from baseline
Examples Using AVERT

• The Clean Air Benefits of Wind Energy (AWEA, May 2014)
• Maine Distributed Solar Valuation Study (Maine PUC, March 2015)
• CarbonCount™ Green Bonds Scores (Alliance to Save Energy, March 2015)
• U.S. EPA’s Ozone Advance Program - Clark County, NV’s Paths Forward
• DOE’s Online Smart Grid Calculator (PNNL, Fall 2015)
• Renewable Portfolio Standard (RPS) Benefits Report (LBNL and NREL, January 2016)
How AVERT Works

• AVERT’s Main Module simulates the hourly changes in generation and air emissions (NO\textsubscript{x}, SO\textsubscript{2}, and CO\textsubscript{2}) at EGU resulting from EE/RE policies and programs.

• User input: MWhs saved from EE programs, or wind and solar generation (MW)
  – Multiple options are built into the tool
  – EPA provides hourly profiles for some states with on-the-books EE programs not included in Energy Information Administration's Annual Energy Outlook (2013)

• User can retire, add and change emission rates of EGU and re-run simulation using AVERT’s Future Year Scenario Template and Statistical Module.
AVERT’s Modules and Data Files

- **Raw Hourly Generation and Emissions Data from Air Markets Program (AMP) Dataset**: Text files
- **Future Year Scenario Template**: User interface for retirements, additions, and retrofits (Excel workbook)
- **AVERT: Statistical Module**: Inputs AMP data, performs statistical analysis, outputs new Regional Data Files (MATLAB Code)
- **Regional Data Files**: Contains annual hourly load data and unit-level statistics on generation and emissions data (Text files)
- **AVERT Main Module**: User interface for creating EE/RE load curves, performs displaced emissions analysis, creates output charts and tables (Excel workbook)

Most users will only need to use the Regional Data Files and AVERT Main Module to calculate emissions.
AVERT’s Data Driven Analysis

- AVERT uses a data-driven analysis to distinguish which EGU respond to marginal changes in load reduction.
  - AVERT analyzes EGU datasets from EPA’s Air Markets and Program Data (hourly, unit-by-unit generation & emissions).
    - Dataset includes EGUs with capacity of 25 MWs or greater.
  - AVERT’s Statistical Module gathers statistics on EGU operations under specific load conditions, and then replicates changes through a Monte Carlo analysis.
  - AVERT’s Regional Data Files contain hourly and unit-level emissions and generation data.
Part I
AVERT Main Module
AVERT Main Module
Step-by-Step Overview

- Enabling Macros
- Using AVERT
- Step 1. Load Regional Data File
- Step 2. Set Energy Efficiency and Renewable Energy Data
- Step 3. Run Displacement
- Step 4. Display Outputs
AVERT Main Module
Enabling Macros

• In Windows, AVERT is compatible with Excel 2007 or newer versions.

• On a Mac, AVERT is compatible with Excel 2011.
  – Only the Main Module has been optimized for Mac. Other components (e.g., the Statistical Module) require Windows.

• You may want to revert to the default macro settings after using the model. Enabling macros in other Excel files may allow potentially dangerous code to run.
AVERT Main Module
Enabling Macros in Windows*

In Excel 2010 or 2013, click **File > Options**

Next, click **Trust Center > Trust Center Settings > Macro Settings > Enable all macros**

*If using Excel 2007, click the Microsoft Office Button: .
*If using Excel on a Mac, select “Enable macros” in the dialog box that appears when opening the file.
AVERT Main Module

Using AVERT

- Add details about the user, the date, and the EE/RE program for which displacements are to be estimated.
- Click on the button labeled “Click here to begin”.

Welcome to AVERT's Main Module

AVERT is an EPA tool that quantifies the emission impacts of energy efficiency and renewable energy policies and programs within the continental United States. Please refer to the AVERT user manual for details on step-by-step instructions, appropriate uses and assumptions built into the tool.

NOTE

Please ensure macros are enabled on your computer. AVERT requires Excel 2007 or newer to run.

AVERT v.1.0

Use the blue entry to describe each scenario and keep track of multiple versions of AVERT.
AVERT Main Module
Step 1. Load Regional Data File

Regions represent relatively autonomous electricity production zones, and are based on electricity market module regions.

Regions include
- California
- Great Lakes/Mid-Atlantic
- Lower Midwest
- Northeast
- Northwest
- Rocky Mountains
- Southeast
- Southwest
- Texas
- Upper Midwest
AVERT Main Module
Step 1. Load Regional Data File

• Select a region for analysis by either using the dropdown or clicking the map.

  – Selecting a region loads region-specific data for wind and solar capacity factors, and dynamically creates a hyperlink to that region’s data on EPA’s website.

• After selecting a region, click the link under the map to download it from EPA’s website.
AVERT Main Module
Step 1. Load Regional Data File

• In the box labeled “Enter filepath,” double-click the blue area to navigate to the location of the downloaded regional data file.
AVERT Main Module
Step 1. Load Regional Data File

- Click the button under “Load data” entitled:

Clicking this button loads the following information from the regional data file:

- Hourly fossil load
- EGU information (e.g., location, fuel type)
- Typical EGU performance for generation and emissions at a given regional load
AVERT Main Module

Step 1. Load Regional Data File

- A popup will indicate when the file has finished loading and remind you how to handle states that are split across multiple AVERT regions.
AVERT Main Module
Step 2. Set EE and RE Data

• This page leads you through the process of creating a load impact profile depicting the load reductions expected from an EE/RE program.
AVERT Main Module

Step 2. Set EE and RE Data

- If the hourly load reductions expected from a particular EE/RE policy, program, or measure are known, a manual stream of load reduction values can be entered for every hour of the year by clicking the “Enter hourly data manually” button.

```
<table>
<thead>
<tr>
<th>Date</th>
<th>Hour</th>
<th>Day of Week</th>
<th>Regional Fossil Load (MW)</th>
<th>Manual EE RE Profile (MW)</th>
<th>Total Change (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1/2012</td>
<td>1</td>
<td>Sunday</td>
<td>9,182</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>2</td>
<td>Sunday</td>
<td>8,084</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>3</td>
<td>Sunday</td>
<td>7,072</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>4</td>
<td>Sunday</td>
<td>6,666</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>5</td>
<td>Sunday</td>
<td>6,726</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>6</td>
<td>Sunday</td>
<td>6,986</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>7</td>
<td>Sunday</td>
<td>7,330</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>8</td>
<td>Sunday</td>
<td>7,051</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>9</td>
<td>Sunday</td>
<td>7,401</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>10</td>
<td>Sunday</td>
<td>7,841</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>11</td>
<td>Sunday</td>
<td>8,135</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>12</td>
<td>Sunday</td>
<td>8,445</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>13</td>
<td>Sunday</td>
<td>8,581</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1/1/2012</td>
<td>14</td>
<td>Sunday</td>
<td>8,615</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
```
AVERT Main Module
Step 2. Set EE and RE Data

This page also allows you to estimate a load reduction from basic characteristics:

- Reduce fossil-fuel generation by a percent in some or all hours
- Reduce fossil-fuel generation by total GWh
- Reduce each hour by a constant MW
- Renewable energy proxy
- Combination of EE/RE programs including combining pre-set options with manual entry

<table>
<thead>
<tr>
<th>Enter EE impacts based on the % reduction of regional fossil load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce generation by a percent in some or all hours</td>
</tr>
<tr>
<td>Apply reduction to top X% hours:</td>
</tr>
<tr>
<td>Reduction % in top X% of hours:</td>
</tr>
<tr>
<td>% of top hours</td>
</tr>
<tr>
<td>% reduction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>And/or enter EE impacts distributed evenly throughout the year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce generation by annual GWh:</td>
</tr>
<tr>
<td>OR</td>
</tr>
<tr>
<td>Reduce each hour by constant MW:</td>
</tr>
<tr>
<td>% of top hours</td>
</tr>
<tr>
<td>% reduction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>And/or enter annual capacity of RE resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Capacity:</td>
</tr>
<tr>
<td>Utility Solar PV Capacity:</td>
</tr>
<tr>
<td>Rooftop Solar PV Capacity:</td>
</tr>
<tr>
<td>2000</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>MW</td>
</tr>
<tr>
<td>MW</td>
</tr>
<tr>
<td>MW</td>
</tr>
</tbody>
</table>
AVERT Main Module

Step 3. Run Displacement

- Run displacement by selecting the button entitled “Click here to calculate displaced generation and emissions.”
AVERT Main Module
Step 3. Run Displacement

• This step calculates hourly displaced generation and emissions (SO₂, NOₓ, CO₂) for each fossil EGU within the selected region.

• Note that this is a processor-intensive step. When using an older computer, or when analyzing regions with many fossil EGU, this step may take up to ten minutes.
AVERT Main Module

Step 4. Display Outputs

- The data generated in Step 3 are aggregated in two groups of charts and tables in Step 4.
AVERT Main Module
Step 4. Display Outputs

Annual regional displacements

- This table displays the total annual generation and emissions as reported for the region in the base year (“Original”) and as calculated by AVERT’s Main Module after the EE/RE reduction (“Post-EERE”).

<table>
<thead>
<tr>
<th></th>
<th>Original</th>
<th>Post-EERE</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation (MWh)</td>
<td>245,694,500</td>
<td>235,514,500</td>
<td>10,180,000</td>
</tr>
<tr>
<td>Total Emissions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO₂ (lbs)</td>
<td>956,871,300</td>
<td>921,132,200</td>
<td>35,739,100</td>
</tr>
<tr>
<td>NOₓ (lbs)</td>
<td>416,259,200</td>
<td>400,349,300</td>
<td>15,909,900</td>
</tr>
<tr>
<td>CO₂ (tons)</td>
<td>246,098,700</td>
<td>236,856,400</td>
<td>9,242,300</td>
</tr>
<tr>
<td>Emission Rates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO₂ (lbs/MWh)</td>
<td>3.895</td>
<td>3.911</td>
<td></td>
</tr>
<tr>
<td>NOₓ (lbs/MWh)</td>
<td>1.694</td>
<td>1.700</td>
<td></td>
</tr>
<tr>
<td>CO₂ (tons/MWh)</td>
<td>1.002</td>
<td>1.006</td>
<td></td>
</tr>
</tbody>
</table>

All results are rounded to the nearest hundred. A dash (“—”) indicates a result greater than zero, but lower than the level of reportable significance.
AVERT Main Module
Step 4. Display Outputs

Annual displacement data by county

- This table presents a summary of the displaced generation and emissions for each of the counties from each of the states contained within the region. A line for each county containing an EGU is displayed.

For each county, annual output statistics are given for:

- Peak Gross Generation Post-EE/RE
- Annual Gross Generation Post-EE/RE
- Capacity Factor
- Annual Change in Generation
- Annual Change in Heat Input/\text{SO}_2/\text{NO}_x/\text{CO}_2
- Ozone Season Change in \text{SO}_2/\text{NO}_x
- Ozone Season, 10 Peak Days Change in \text{SO}_2/\text{NO}_x
AVERT Main Module
Step 4. Display Outputs

Displacement data for top ten peak days

- This table displays a summary of the ten days in the region featuring the highest level of fossil fuel load.

<table>
<thead>
<tr>
<th>Day Rank</th>
<th>Date</th>
<th>Total Fossil Generation (MWh)</th>
<th>Expected Displaced Generation (MWh)</th>
<th>Displaced Generation (MWh)</th>
<th>Displaced NOₓ (lbs)</th>
<th>Displaced SO₂ (lbs)</th>
<th>Displaced CO₂ (Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jul 26</td>
<td>990,200</td>
<td>-32,600</td>
<td>-32,000</td>
<td>-56,500</td>
<td>-58,900</td>
<td>-23,200</td>
</tr>
<tr>
<td>2</td>
<td>Jul 27</td>
<td>966,700</td>
<td>-26,200</td>
<td>-26,200</td>
<td>-57,000</td>
<td>-42,500</td>
<td>-19,800</td>
</tr>
<tr>
<td>4</td>
<td>Jul 14</td>
<td>963,400</td>
<td>-21,800</td>
<td>-21,800</td>
<td>-42,400</td>
<td>-36,800</td>
<td>-16,500</td>
</tr>
<tr>
<td>5</td>
<td>Aug 01</td>
<td>954,200</td>
<td>-16,500</td>
<td>-16,400</td>
<td>-35,900</td>
<td>-27,700</td>
<td>-12,800</td>
</tr>
<tr>
<td>6</td>
<td>Jul 06</td>
<td>953,600</td>
<td>-16,000</td>
<td>-16,000</td>
<td>-37,400</td>
<td>-26,700</td>
<td>-12,600</td>
</tr>
<tr>
<td>7</td>
<td>Jul 13</td>
<td>950,100</td>
<td>-17,000</td>
<td>-16,400</td>
<td>-37,800</td>
<td>-29,900</td>
<td>-12,100</td>
</tr>
<tr>
<td>8</td>
<td>Jul 07</td>
<td>926,900</td>
<td>-19,000</td>
<td>-19,100</td>
<td>-41,100</td>
<td>-29,600</td>
<td>-14,600</td>
</tr>
<tr>
<td>9</td>
<td>Jul 10</td>
<td>927,500</td>
<td>-18,400</td>
<td>-18,500</td>
<td>-42,700</td>
<td>-31,400</td>
<td>-14,400</td>
</tr>
<tr>
<td>10</td>
<td>Aug 12</td>
<td>923,200</td>
<td>-15,500</td>
<td>-15,500</td>
<td>-34,200</td>
<td>-21,500</td>
<td>-12,000</td>
</tr>
</tbody>
</table>

Negative numbers indicate displaced generation and emissions.
All results are rounded to the nearest hundred. A dash (—) indicates a result greater than zero, but lower than the level of reportable significance.
AVERT Main Module
Step 4. Display Outputs

*Displaced generation and emissions map*

- This dynamic map allows the user to view where emissions have been displaced within the selected region. Users can view changes in generation, heat input, SO$_2$, NO$_X$, and CO$_2$. 

![Annual Change in CO2 (tons)](image)
AVERT Main Module
Step 4. Display Outputs

*Displacement data by month*

Monthly output can be viewed over the entire region, or a specific state or county within the region.

- First select region, state, or county in the top dropdown menu.
- If selecting a state, choose the state in the next dropdown menu.
- If selecting a county, choose both the state and the county in the next two dropdown menus.
AVERT Main Module
Step 4. Display Outputs

**Hourly displacements by week**

- This graph displays a dynamic representation of hourly displacement from each EGU in a region. Individual plants are stacked as gradated bar plots.
AVERT Main Module
Step 4. Display Outputs

*Hourly displacements by week*

- The second figure shows the same week-long load impact profile, but presents the displaced load in reference to the total fossil-fuel load to illustrate the degree of change represented by the EE/RE program relative to the baseline.
AVERT Main Module
Step 4. Display Outputs

*Signal-to-noise diagnostic*

- This chart is a scatterplot of every hour of the year, showing calculated total generation reduction in each hour (y-axis) against the user-input EE/RE load reduction in each hour (x-axis).
- Ideally, AVERT perfectly matches unit generation reductions to the amount of EE/RE load reduction requested by the user.
- This graphic shows where that assumption holds, where it does not hold, and to what extent.
Part II
AVERT Statistical Module
Operation
AVERT Statistical Module
Overview

• Purpose
  – Basis of AVERT analysis
  – Processes raw CAMD data to determine behavioral characteristics of fossil-fired EGU
  – Returns expected generation and emissions behavior to AVERT Main Module
  – Allows users to alter EGU characteristics, retire and add EGU with Future Year Template

• Advanced use of AVERT
  – Most users will not require the Statistical Module
  – Based in MATLAB
  – Executable version available for public use
  – Requires MATLAB Compiler Runtime (MCR) to be installed (free from Mathworks)
  – Requires Windows

• Output file can be used directly in Main Module
AVERT Statistical Module
Obtain Correct Version

- AVERT Statistical Module requires is sensitive to PC specifications.
- 32-bit and 64-bit operating system versions available.
- Obtain correct version of AVERT Statistical Module.
- Obtain correct version of MCR from Mathworks.
- Determine if your Windows system operates in a 32-bit or 64-bit environment.
  - Find this information in “properties” of “My Computer” in Windows XP, or “Computer” in Windows Vista, Windows 7, or Windows 8.
AVERT Statistical Module Unpacking and Startup

• Download the AVERT Statistical Module package.

• Run the executable to decompress the package to three files and three subfolders.

To obtain historic base years, visit [http://epa.gov/statelocalclimate/resources/avert-download.html](http://epa.gov/statelocalclimate/resources/avert-download.html) and obtain both the CAMD input file and the Future Year Scenario Template for that same year.
AVERT Statistical Module File Structure

- **AVERT Future Year Scenarios**
  - Excel-based input files for altering EGU

- **AVERT Output**
  - Statistical Module output files
  - These become Main Module input files

- **CAMD Input Files**
  - Processed CAMD data files
  - New versions expected 2nd quarter annually

- **AVERT_StatMod_2012_v1_64bit**
  - Executable
Obtaining Other Base Years

To obtain additional historic base year data, visit: http://epa.gov/statelocalclimate/resources/avert-download.html.

• Download AVERT Future Year Scenario for the same historic base year.
  – Place the file in “AVERT Future Year Scenarios”

• Download the CAMD input file for the historic base year.
  – Place the file in “CAMD Input Files”

Note: Historic base years must match-up with the Future Year Scenario Template.
AVERT Statistical Module

Input Parameters

• Higher number of Monte Carlo (MC) runs reduces noise.
  – For test runs, use a low number of MC runs (10) and generation-only MC runs (5).
  – For final runs, use a high number of MC runs (1,000) and generation-only MC runs (500).

• Select “Y” to write output and save runs.

Use letters and numbers only. No special characters and no spaces.
AVERT Statistical Module
Choose Data File

• Choose base year for analysis.
  – Data from 2007 through 2015 are available.
  – New data will be ready by the second quarter of the next year.

• Requires data to be vetted by EPA and post-processed.
AVERT Statistical Module

Choose Future Year Scenario

• Select either
  – Saved future year scenario (see slide 41)
  – Present year analysis

Present year analysis makes no modifications to the AVERT dataset.
  – Uses EGU that exist in data year
  – No changes in emissions rates
AVERT Statistical Module

Choose Region(s) of Interest

- Choose region (or multiple regions) of interest.
- Same regions as in AVERT Main Module
- Once you hit “OK”, the program will run uninterrupted until completion.
  - Program returns updated run status on a regular basis.
  - Output graphic and file indicate successful completion.
Part III
AVERT Future Year Scenario Template
AVERT Future Year Scenario Overview

• Purpose
  – AVERT is not forward-looking: cannot predict EGU retirements, new additions, or emissions modifications.
  – Future Year Scenarios allow users to
    • Remove EGU from analysis.
    • Include additional proxy EGU.
    • Modify emissions characteristics.

• Advanced use of AVERT
  – Excel spreadsheet
  – Read into AVERT Statistical Module

• Each spreadsheet becomes a scenario.
  – Spreadsheet becomes input file for AVERT Statistical Module.
  – Each future year scenario template is specifically designed to match the same historic base year.
Use AVERT Future Year Scenario in Statistical Module

- Obtain Future Year Scenario Template (slides 33-36).
- Modify Future Year Scenario Template (slides 44-46).
- Save Future Year Scenario Template with a meaningful name.
- Run Statistical Module (slides 37-40).
  - Provide a unique name for the statistical module run (slide 37).
  - Choose saved future year scenario (slide 39).
AVERT Future Year Scenario Retires and Modifications

- Find EGU of interest, or filter by state or region.
- To retire, select “Yes” in the “Retire?” column.
- To change emissions rate, select “Yes” in the “Revise Emissions Rates?” column and enter new rate(s) in columns I, J, or K.
### AVERT Future Year Scenario Additions

#### In order
1. Select region
2. Select fuel type
3. Select generator type
4. Select specific EGU (unit)

Description will appear about EGU type automatically.
AVERT Future Year Scenario Additions

- Choose proxy unit capacity (will scale all other factors)
- Choose state (within region)
- Choose county (within region)
- Save file
Use AVERT Future Year Scenario in Statistical Module

- Run Statistical Module (slides 37-40).
- Provide a unique name for the statistical module run (slide 37).
- Choose saved future year scenario (slide 39).
For More Information

• Visit the AVERT website at www.epa.gov/avert.
• Contact EPA’s State and Local Climate and Energy Program at avert@epa.gov.