AVERT Overview and Step-by-Step Instructions

U.S. Environmental Protection Agency
State Energy and Environment Program
Updated September 2020

United States Environmental Protection Agency

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

- AVERT (AVoided Emissions and geneRation Tool) translates the impacts of EE, RE, and other energy policies and programs into emission impacts ($PM_{2.5}$, NO_x, SO_2, and CO_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 first released in 2014 and is built to be:
  - user friendly
  - transparent
  - credible

For more information on EPA's EE/RE SIP Roadmap visit: https://www.epa.gov/energy-efficiency-and-renewable-energy-sips-and-tips/energy-efficiencyrenewable-energy-roadmap.

AVERT's Evolution

2014
- Initial release of AVERT with data for CO_2, NO_X, and SO_2

2015
- Published first paper at U.S. EPA's International Emissions Inventory Conference comparing emissions from AVERT regions and EE/RE resources

2016
- Extensive training and outreach, including video tutorials

2017
- Addressed net vs. gross considerations by accounting for parasitic load and transmission and distribution line loss
- Added $PM_{2.5}$
- Generated emission factors to support quick analyses and program calculations

2018
- Added compatibility with EPA's COBRA tool
- Launch of web-based AVERT

2019
- Updated AVERT to provide year-specific transmission and distribution loss factors from EIA generation and sales data

2020
- Revised AVERT regions to reflect the modern electric grid
- Added offshore wind and the ability to scale RE capacity factors
- Added statewide analysis function (web AVERT only)

Ongoing activities
- Annual data updates
- Enhancements
- Compatibility updates

Emission Quantification Methods
Basic to Sophisticated

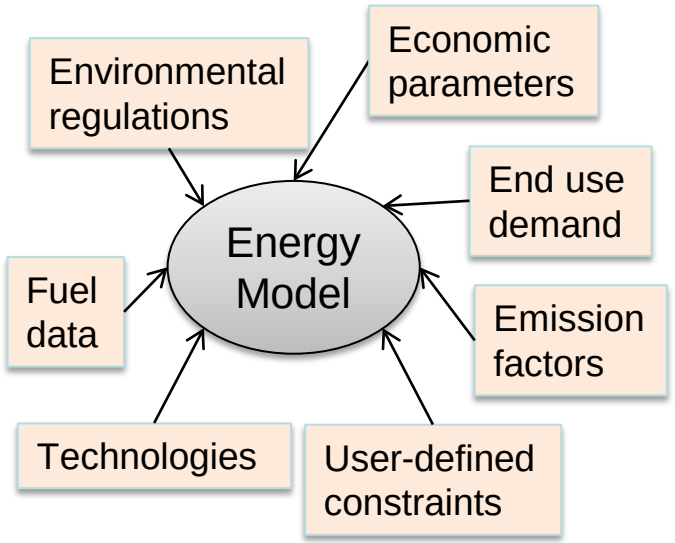
Basic Method
eGRID region non-baseload emission rates

Intermediate Method
Historical hourly emission rates

Sophisticated Method
Energy modeling
Dispatch or capacity expansion

eGRID

AVERT
AVoided Emissions and geneRation Tool
www.epa.gov/avert



Applications for AVERT-Calculated Emissions

- SIP credit in a state's National Ambient Air Quality Standard (NAAQS) Clean Air Act Plan
- Compare emission impacts of varying levels of energy programs, projects, and policies
- Calculate emission reductions in your state or county using AVERT's web-based edition
- Use AVERT-generated emission factors to estimate magnitude of emission reductions without running the tool
  - Six categories include offshore and onshore wind, rooftop- and utility-scale solar, portfolio EE, and uniform EE programs
- This is not a long-term projection tool
  - To conduct analysis more than five years from the baseline, users must use AVERT's statistical module and future year scenario template

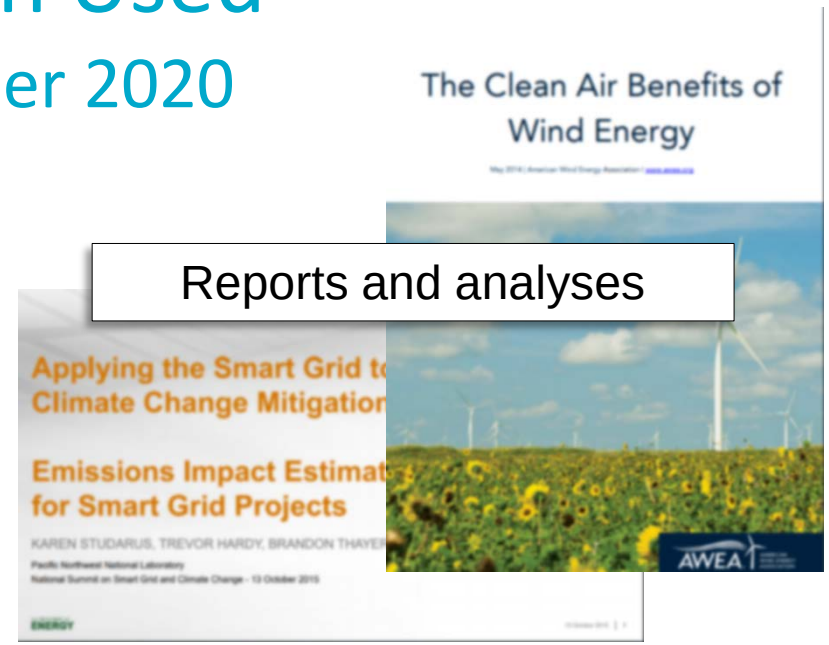
How AVERT Has Been Used

100+ citations as of summer 2020

Peer-reviewed papers

- Environmental Research Letters
- Environmental Science and Technology
- Nature Energy
- Journal of Industrial Ecology
- Energy Policy

…and more



Reports and analyses

Resource pages and factsheets

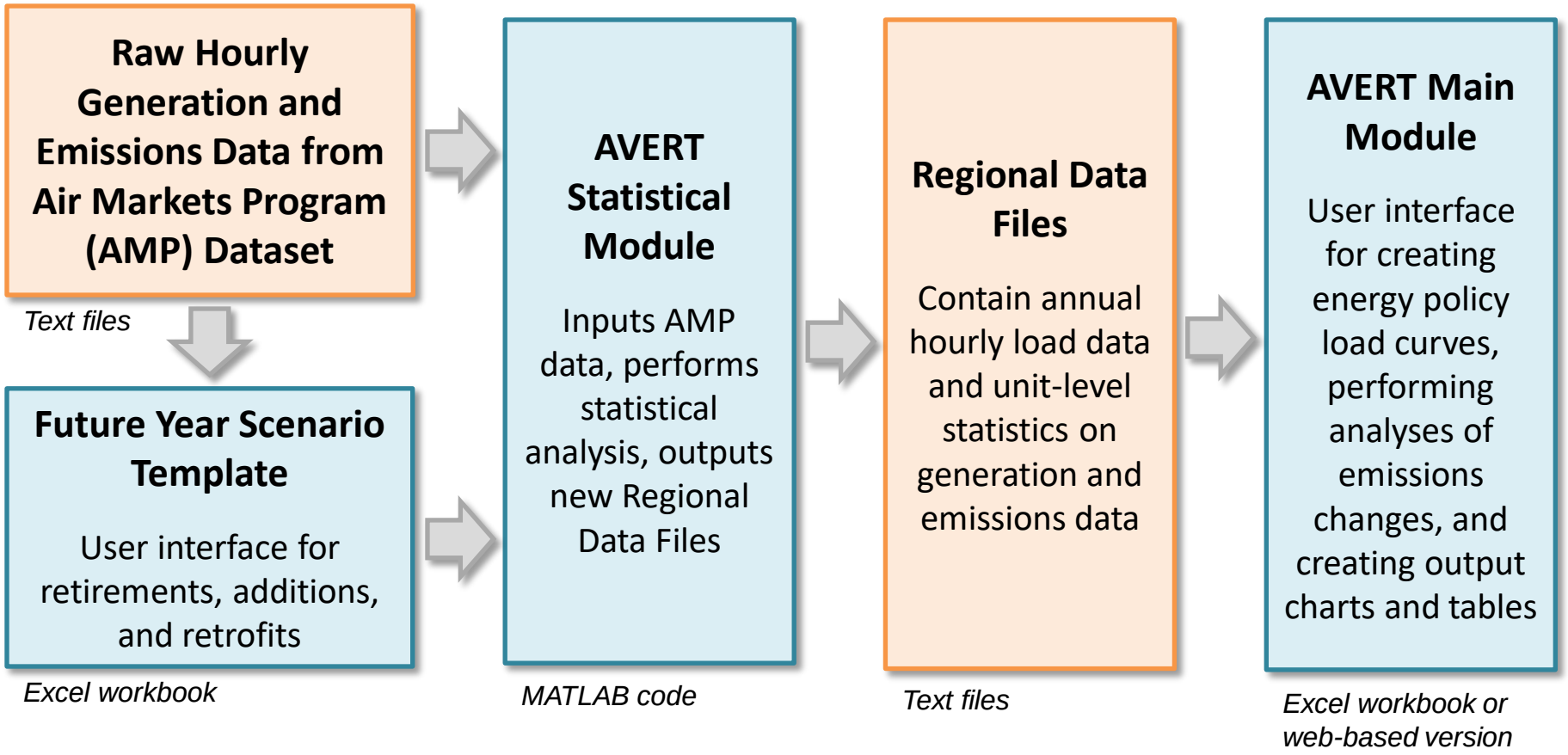
Examples Using AVERT

- Climate and Health Benefits of Increasing Renewable Energy Deployment in the United States (Buonocore et al., 2019)
- Potential Air Quality Benefits from Increased Solar Photovoltaic Electricity Generation in the Eastern United States (Abel et al., 2017)
- The Health and Environmental Benefits of Wind and Solar Energy in the United States, 2007-2015 (LBNL, January 2017)
- Electric Vehicles and Air Quality (North Carolina Department of Environmental Quality and the South Carolina Energy Office)
- Carbon Reductions and Health Co-benefits from U.S. Residential Energy Efficiency Measures (Levy et al., 2016)
- Renewable Portfolio Standard (RPS) Benefits Report (LBNL and NREL, January 2016)
- U.S. EPA's Ozone Advance Program - Clark County, NV's Paths Forward
- Assessing Emission Benefits of Renewable Energy and Energy Efficiency Programs (U.S. EPA, April 2015)
- Maine Distributed Solar Valuation Study (Maine PUC, March 2015)
- CarbonCount™ Green Bonds Scores (Alliance to Save Energy, March 2015)

How AVERT Works

- AVERT's Main Module simulates the hourly changes in generation and air emissions ($PM_{2.5}$, NO_x, SO_2, and CO_2) at EGUs resulting from EE, RE, and other energy policies and programs.
- User input: MWhs saved from energy programs, or wind and solar generation (MW)
  - Multiple options are built into the tool
  - Users can manually enter hourly impact data
- 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



Most users will only need to use the Regional Data Files and AVERT Main Module to calculate emissions. The web version of the Main Module provides similar functionality without the need to download any files or software.

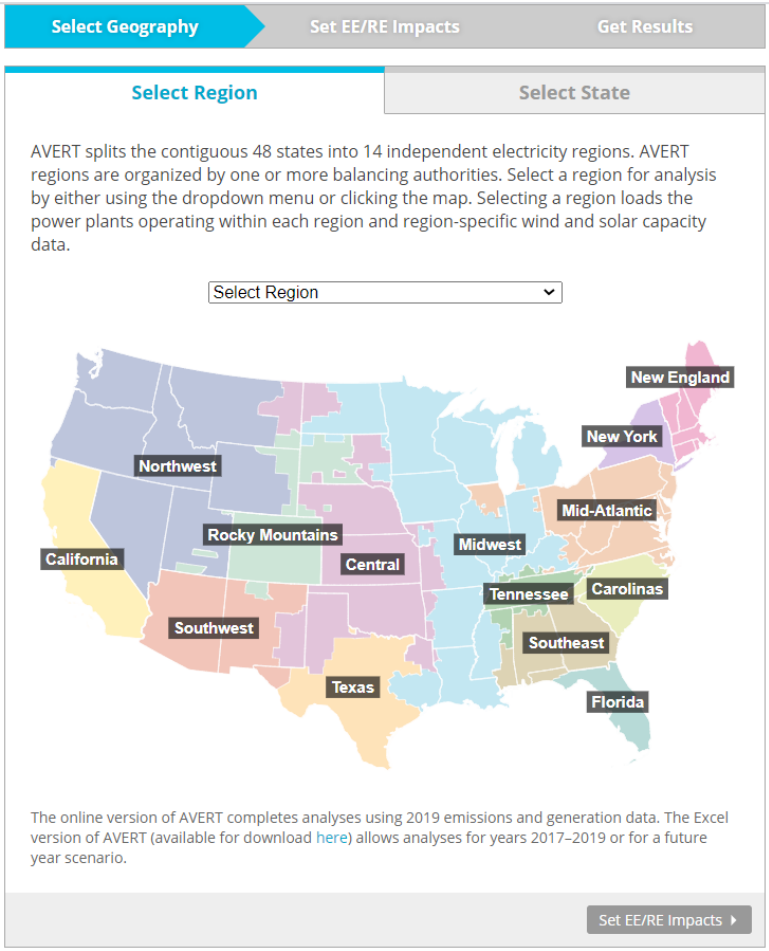
AVERT's Data Driven Analysis

- AVERT uses a data-driven analysis to distinguish which EGUs respond to marginal changes in load.
  - 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.
    - Supplemented with $PM_{2.5}$ data from EPA's 2014 National Emissions Inventory.
  - 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.

AVERT Main Module

AVERT's Web-Based Main Module

- Users can choose between AVERT's Excel-based version or the web edition
- In 2018, EPA released AVERT's web-based version
  - The online platform allows users to quickly estimate EE/RE program impacts using current year dataset
  - Users can enter standard EE/RE settings
  - Results are shown in graphical form and savable formats
- Allows statewide multi-region runs



www.epa.gov/avert/avert-web-edition

AVERT's Excel-Based Main Module Step-by-Step Overview

- Enabling Macros
- Using AVERT
- Step 1. Load Regional Data File
- Step 2. Set Energy Scenario
- Step 3. Run Scenario
- Step 4. Display Results

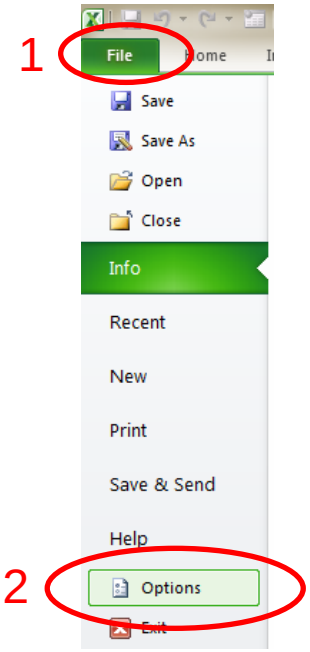
AVERT's Excel-Based Main Module Enabling Macros

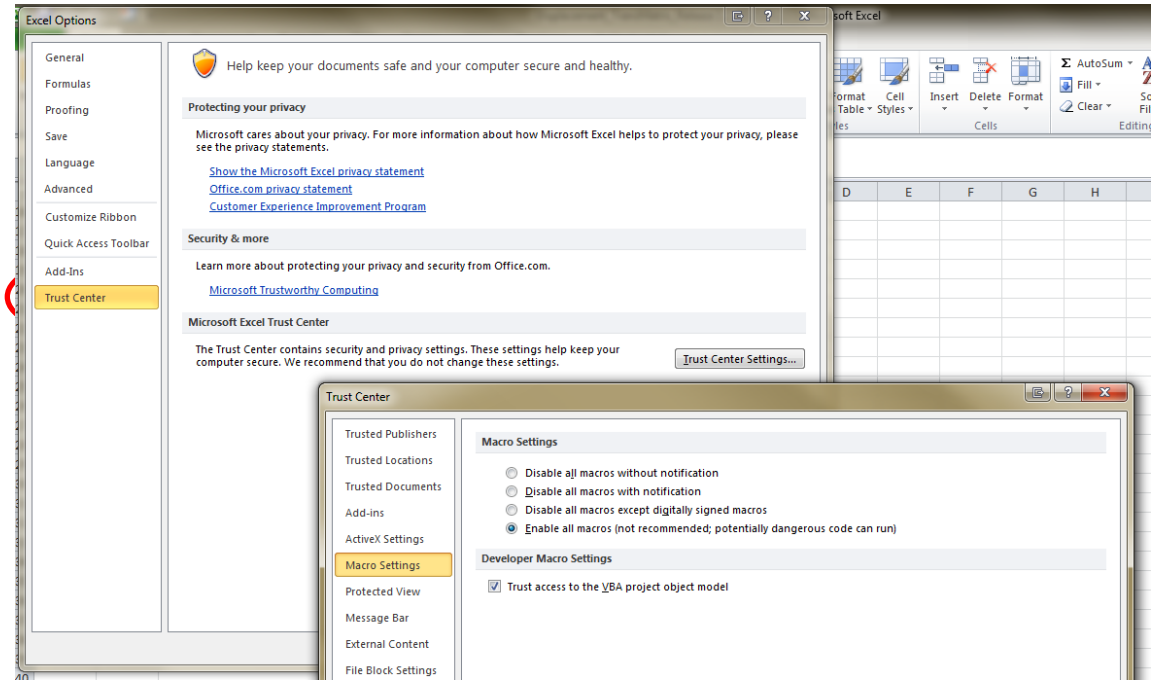
- In Windows, AVERT is compatible with Excel 2007 or newer versions.
- On a Mac, AVERT is compatible with Excel 2011 or newer versions.
  - Only the Main Module has been optimized for Mac. Other components (e.g., the Statistical Module) require Windows.
- You may want to revert to the default macro settings after using the model. Enabling macros in other Excel files may allow potentially dangerous code to run.

AVERT's Excel-Based Main Module Enabling Macros in Windows*

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

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



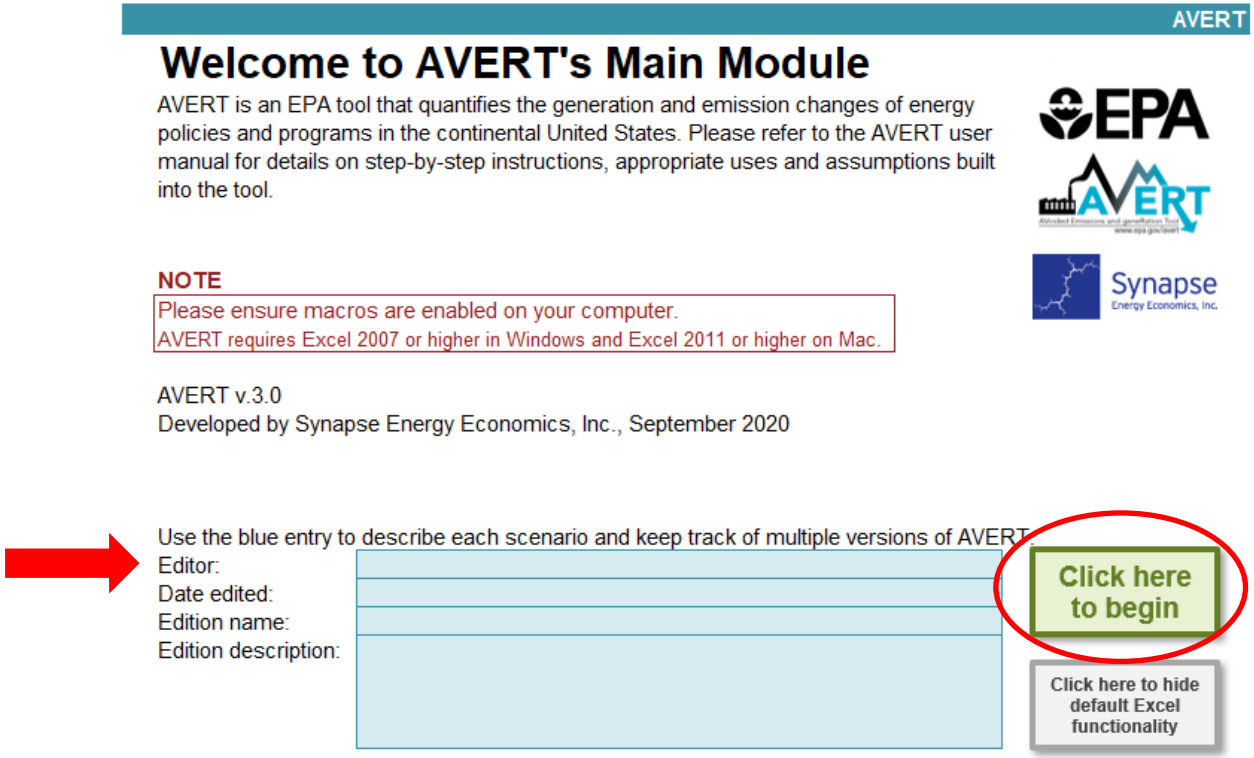


*If using Excel 2007, click the Microsoft Office Button: .

*If using Excel on a Mac, select "Enable macros" in the dialog box that appears when opening the file.

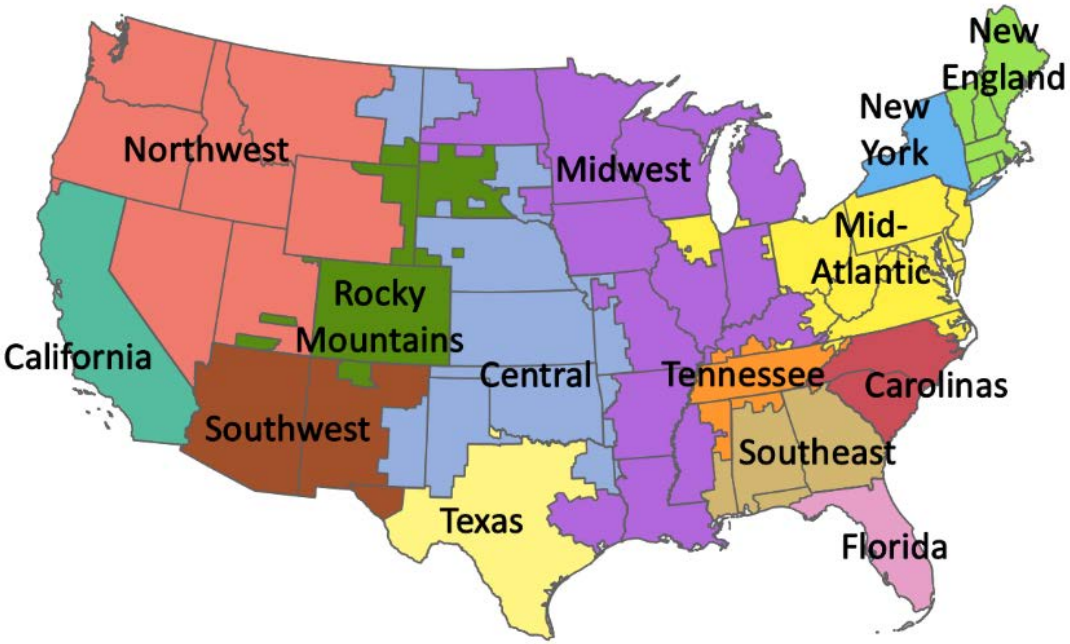
AVERT's Excel-Based Main Module Using AVERT

- Add details about the user, the date, and the energy program for which impacts are to be estimated.
- Click on the button labeled "Click here to begin."



AVERT's Excel-Based Main Module
Step 1. Load Regional Data File

Regions represent relatively autonomous electricity production zones and are aggregations of one or more balancing authority.

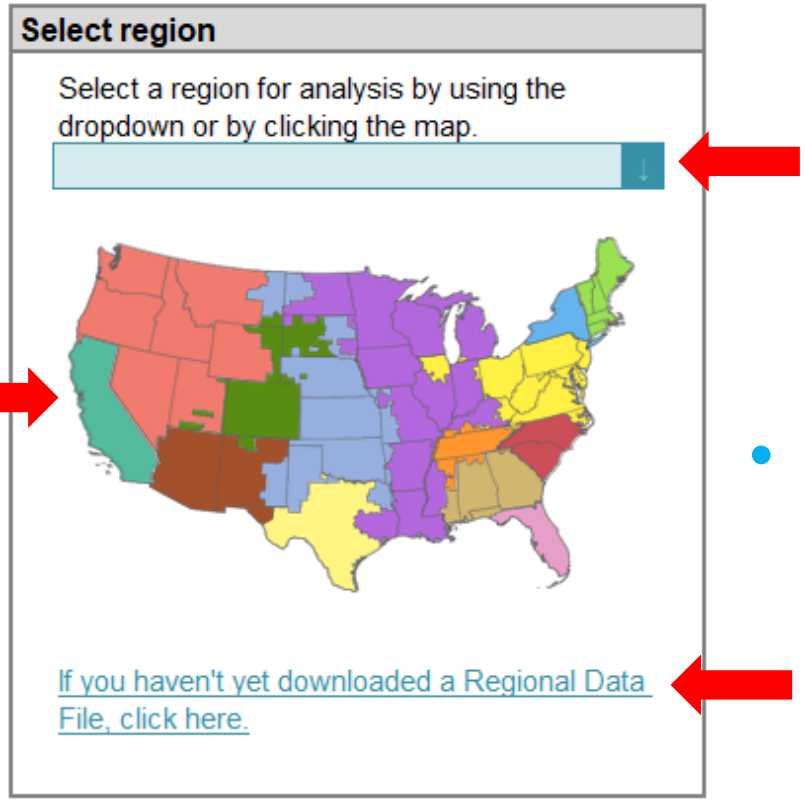


Regions include

- California
- Carolinas
- Central
- Florida
- Mid-Atlantic
- Midwest
- New England
- New York
- Northwest
- Rocky Mountains
- Southeast
- Southwest
- Tennessee
- Texas

AVERT's Excel-Based Main Module Step 1. Load Regional Data File

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

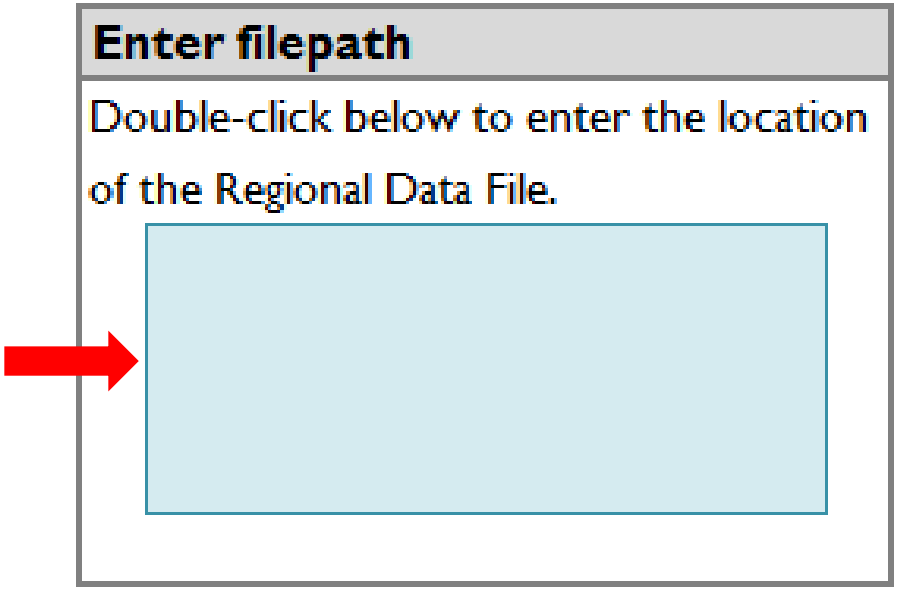


  - Selecting a region loads region-specific data for wind and solar capacity factors and dynamically creates a hyperlink to that region's data on EPA's website.

- After selecting a region, click the link under the map to download it from EPA's website.

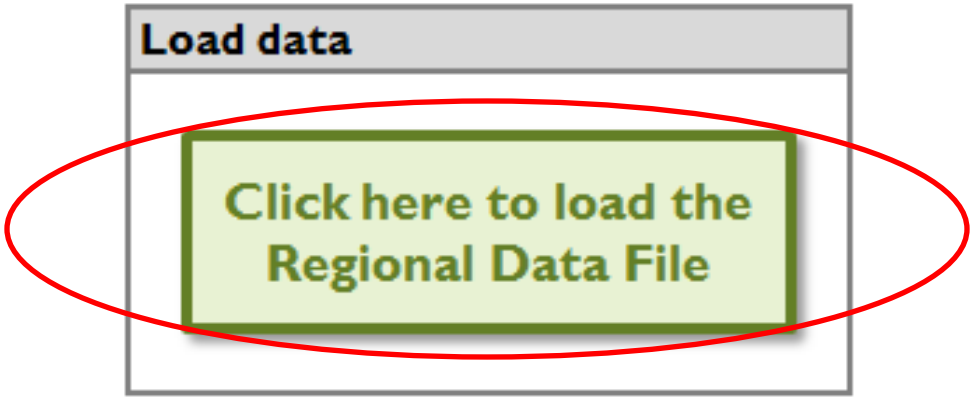
AVERT's Excel-Based Main Module Step 1. Load Regional Data File

- In the box labeled "Enter filepath," double-click the blue area to navigate to the location of the downloaded regional data file.



AVERT's Excel-Based Main Module Step 1. Load Regional Data File

- Click the button under "Load data" entitled:

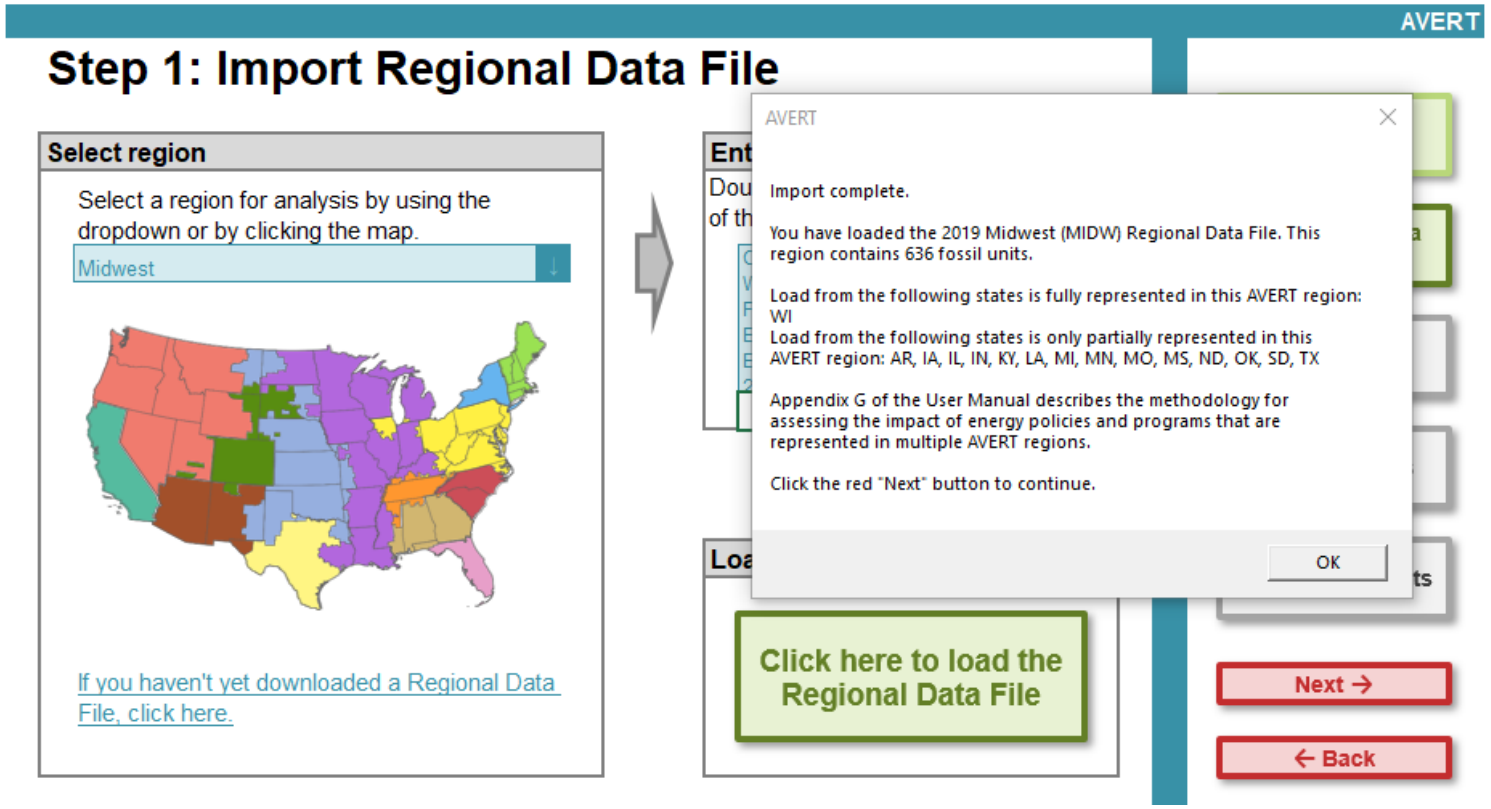


Clicking this button loads the following information from the regional data file:

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

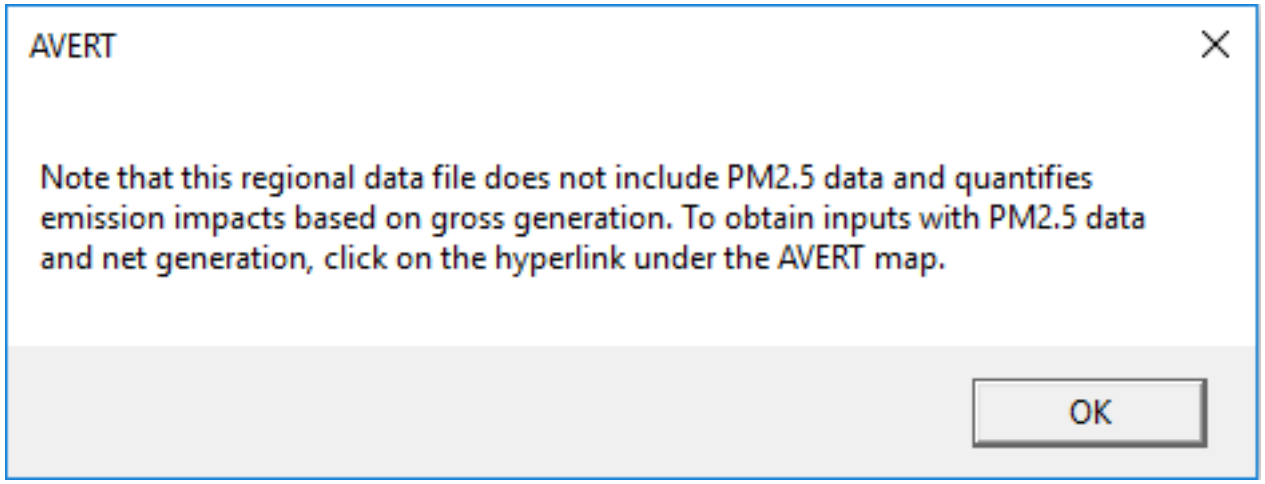
AVERT's Excel-Based Main Module Step 1. Load Regional Data File

- A popup will indicate when the file has finished loading and remind you how to handle states that are split across multiple AVERT regions.



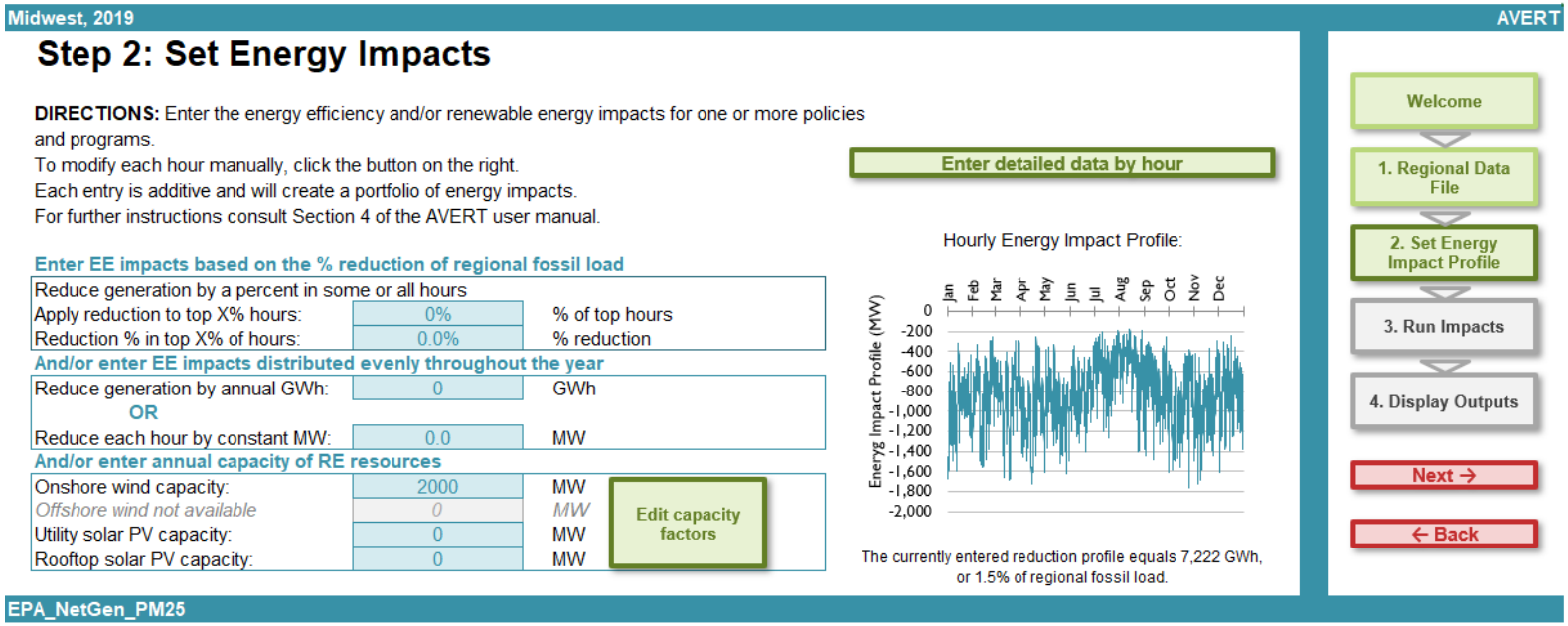
Step 1. Load Regional Data File
Regional Data File import pop-up

- Regional Data Files (RDFs) released before July 2017 do not have $PM_{2.5}$ emissions and they include net generation values to account for parasitic losses.
- If you are using an earlier RDF, another pop-up box will alert you and suggest that you download a newer RDF from EPA's website.



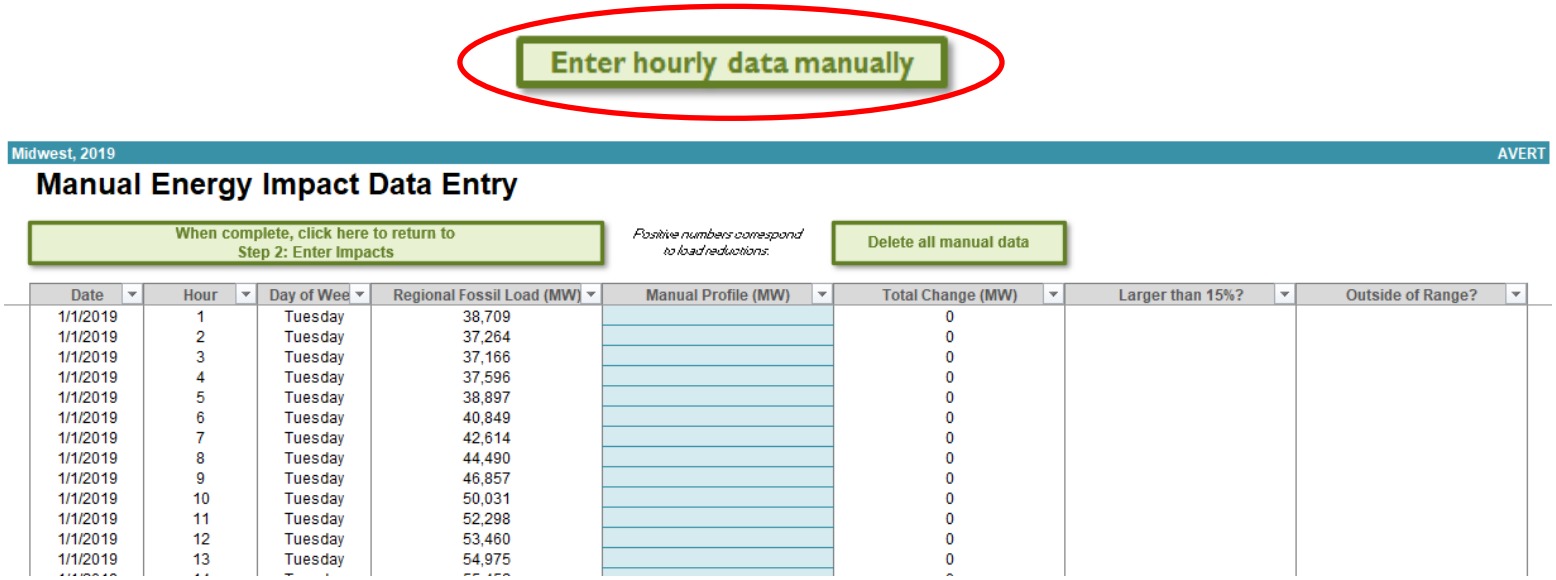
AVERT's Excel-Based Main Module Step 2. Set Energy Scenario

- This page leads you through the process of creating an energy impact profile depicting the impacts expected from an energy program.



AVERT's Excel-Based Main Module Step 2. Set Energy Scenario

- If the hourly load impacts expected from an energy policy, program, or measure are known, a manual stream of load impact values can be entered for every hour of the year by clicking the "Enter hourly data manually" button. Displacements (load reductions) should be entered as positive values.

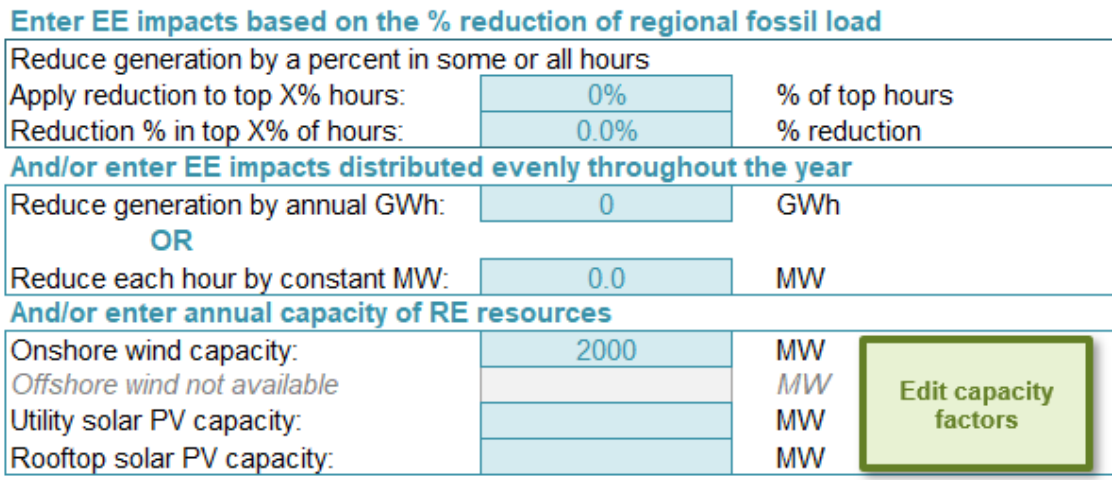


Date	Hour	Day of Wee	Regional Fossil Load (MW)	Manual Profile (MW)	Total Change (MW)	Larger than 15%?	Outside of Range?
1/1/2019	1	Tuesday	38,709		0		
1/1/2019	2	Tuesday	37,264		0		
1/1/2019	3	Tuesday	37,166		0		
1/1/2019	4	Tuesday	37,596		0		
1/1/2019	5	Tuesday	38,897		0		
1/1/2019	6	Tuesday	40,849		0		
1/1/2019	7	Tuesday	42,614		0		
1/1/2019	8	Tuesday	44,490		0		
1/1/2019	9	Tuesday	46,857		0		
1/1/2019	10	Tuesday	50,031		0		
1/1/2019	11	Tuesday	52,298		0		
1/1/2019	12	Tuesday	53,460		0		
1/1/2019	13	Tuesday	54,975		0		

AVERT's Excel-Based Main Module Step 2. Set Energy Scenario

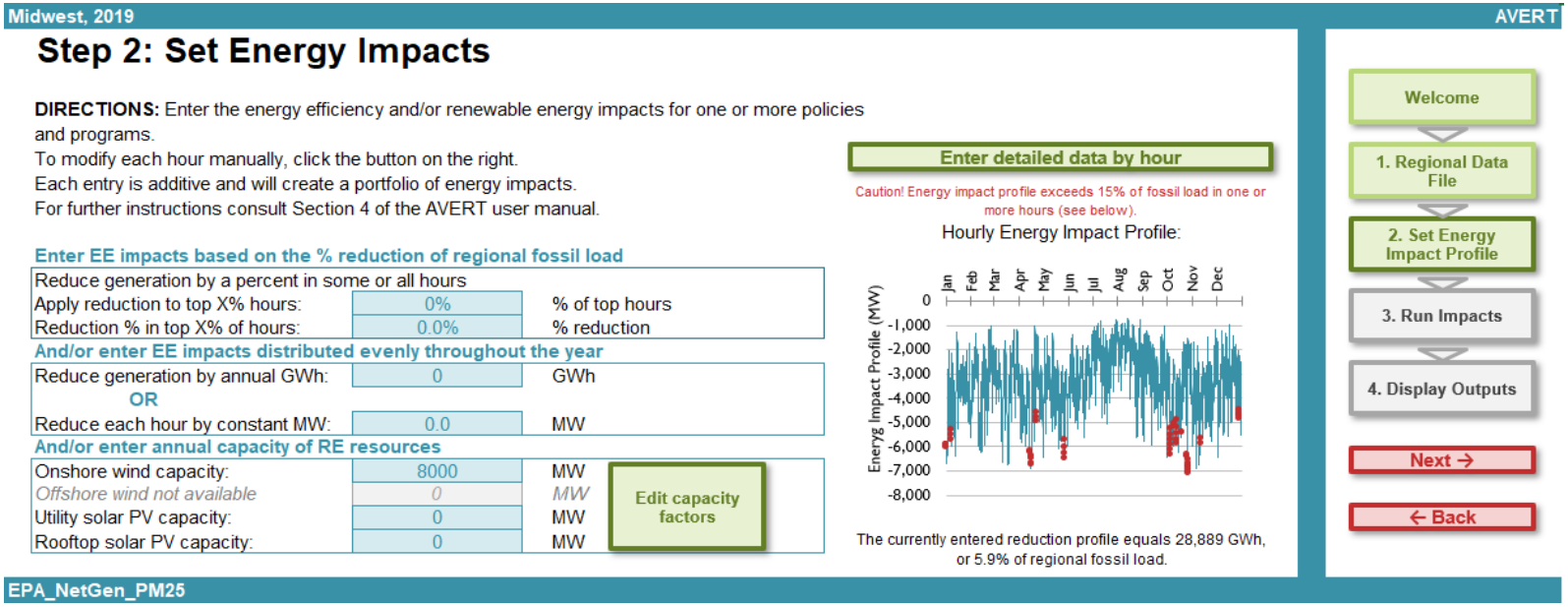
This page also allows you to estimate an energy impact from basic characteristics:

- 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, with the ability to scale hourly capacity factors
- Combination of EE/RE programs including combining pre-set options with manual hourly energy profile entry



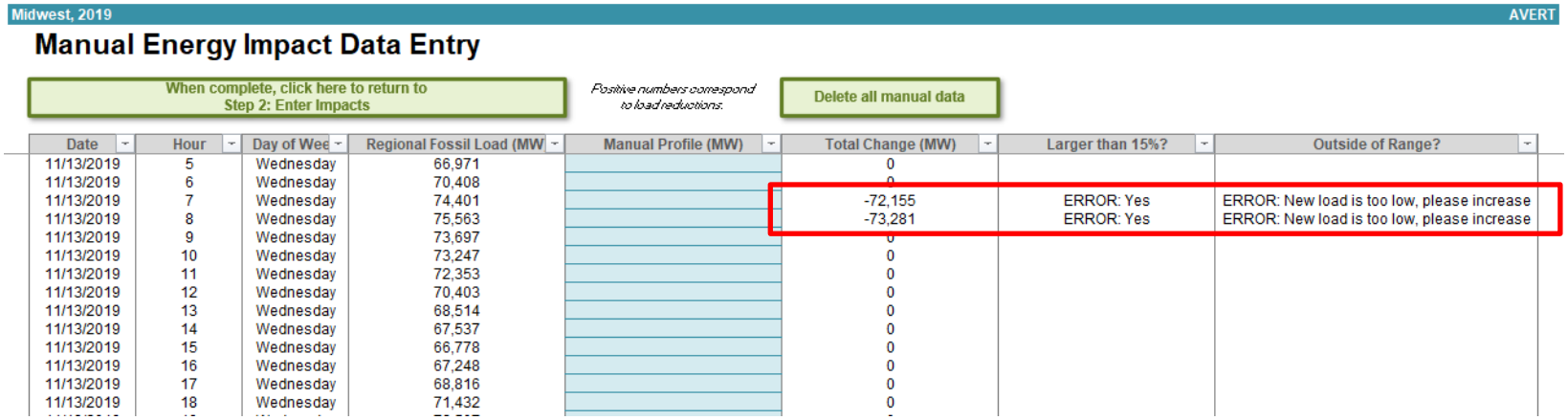
AVERT's Excel-Based Main Module Step 2. Set Energy Scenario

- If you enter a scenario that exceeds 15% of regional fossil load in any given hour, you will be shown an alert highlighting the hours of exceedance, but you can still proceed with the calculations.



AVERT's Excel-Based Main Module Step 2. Set Energy Scenario

- If you enter a scenario that exceeds the calculable range in any given hour, you will be directed to change load impact in the hours identified in the "Outside of Range?" column of the Manual Energy Profile Entry page. These cells must be corrected before you may proceed.



Midwest, 2019 AVERT

Manual Energy Impact Data Entry

When complete, click here to return to Step 2: Enter Impacts

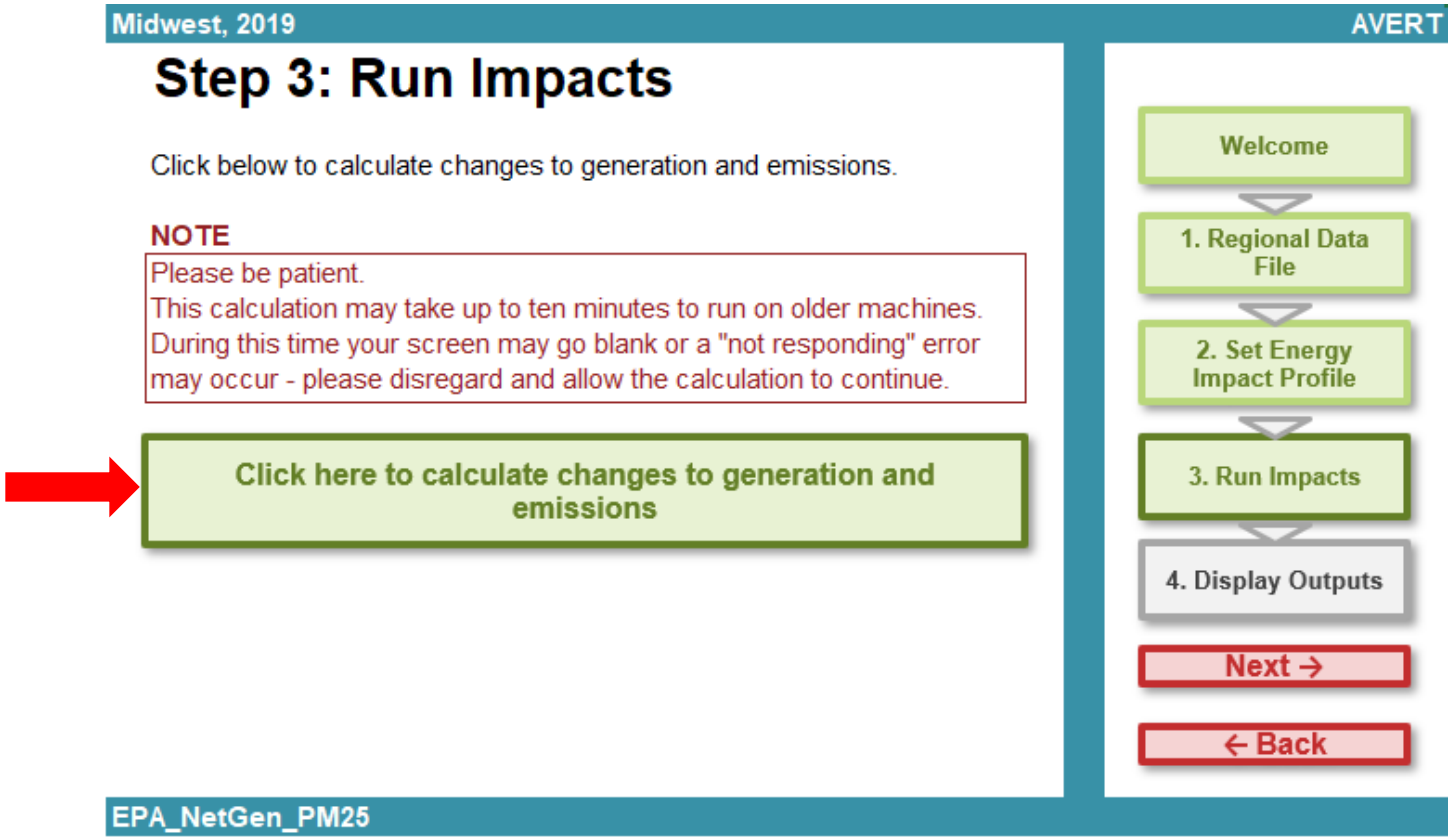
Positive numbers correspond to load reductions.

Delete all manual data

Date	Hour	Day of Wee	Regional Fossil Load (MW	Manual Profile (MW)	Total Change (MW)	Larger than 15%?	Outside of Range?
11/13/2019	5	Wednesday	66,971		0		
11/13/2019	6	Wednesday	70,408		0		
11/13/2019	7	Wednesday	74,401		-72,155	ERROR: Yes	ERROR: New load is too low, please increase
11/13/2019	8	Wednesday	75,563		-73,281	ERROR: Yes	ERROR: New load is too low, please increase
11/13/2019	9	Wednesday	73,697		0		
11/13/2019	10	Wednesday	73,247		0		
11/13/2019	11	Wednesday	72,353		0		
11/13/2019	12	Wednesday	70,403		0		
11/13/2019	13	Wednesday	68,514		0		
11/13/2019	14	Wednesday	67,537		0		
11/13/2019	15	Wednesday	66,778		0		
11/13/2019	16	Wednesday	67,248		0		
11/13/2019	17	Wednesday	68,816		0		
11/13/2019	18	Wednesday	71,432		0		

AVERT's Excel-Based Main Module Step 3. Run Scenario

- Run the scenario by selecting the button entitled "Click here to calculate changes to generation and emissions."

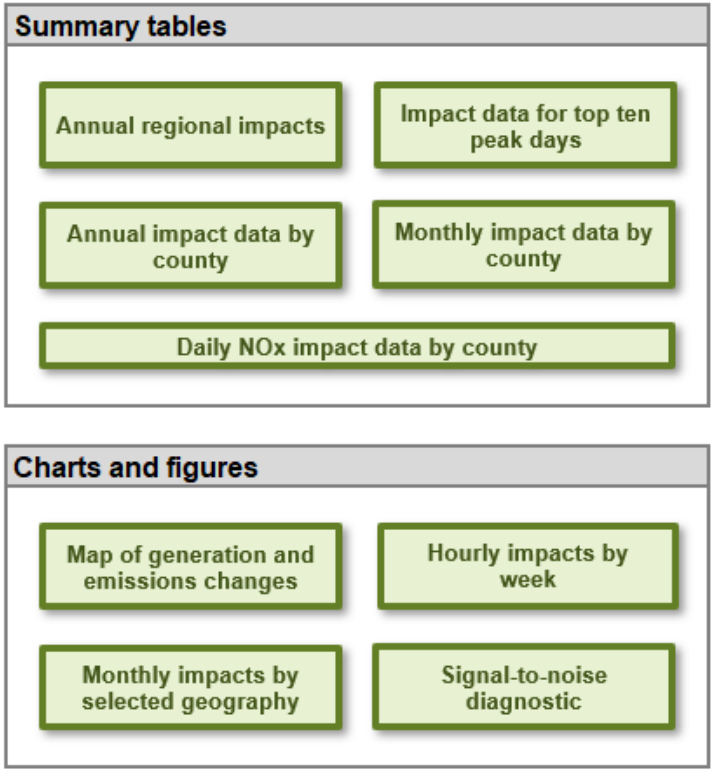


AVERT's Excel-Based Main Module
Step 3. Run Scenario

- This step calculates hourly change in generation and emissions ($PM_{2.5}$, SO_2, NO_X, CO_2) 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 10 minutes.

AVERT's Excel-Based Main Module Step 4. Display Results

- The results generated in Step 3 are aggregated in two groups of charts and tables in Step 4.



AVERT's Excel-Based Main Module Step 4. Display Results

Annual regional impacts

- 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 modeled energy impact ("Post Impact").

Midwest, 2019 AVERT

Output: Annual Regional Impacts

Click here to return to Step 4: Display Outputs

	Original	Post Impact	Impacts
Generation (MWh)	492,254,600	470,633,650	-21,620,950
Total Emissions from Fossil Generation Fleet			
SO_2 (lbs)	705,939,950	672,226,070	-33,713,880
NO_x (lbs)	518,286,020	492,875,500	-25,410,520
CO_2 (tons)	423,535,880	404,950,360	-18,585,530
$PM_{2.5}$ (lbs)	82,292,060	78,922,090	-3,369,960
Fossil Generation Fleet Emission Rates			
SO_2 (lbs/MWh)	1.434	1.428	
NO_x (lbs/MWh)	1.053	1.047	
CO_2 (tons/MWh)	0.860	0.860	
$PM_{2.5}$ (lbs/MWh)	0.167	0.168	

Negative numbers indicate displaced generation and emissions.

All results are rounded to the nearest ten. A dash ("—") indicates a result greater than zero, but lower than the level of reportable significance.

AVERT's Excel-Based Main Module
Step 4. Display Results

Annual impact data by county

- This table presents a summary of the changes in 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.

Midwest, 2019

Output: Annual Impact Data by County

Click here to return to Step 4: Display Outputs

State	County	Peak Gross Generation, Post-Impact (MW)	Annual Gross Generation, Post-Impact (MWh)	Annual Change in Generation (MWh	Annual Change in SO2 (lbs)	Annual C NOx
AR	Craighead County	79	21,770	-4,930	-60	-7,
AR	Hot Spring County	1,235	4,533,950	-276,470	-1,010	-96,
AR	Independence County	1,392	5,151,660	-463,980	-2,522,200	-634
AR	Jefferson County	1,715	8,063,330	-581,510	-2,871,550	-784
AR	Mississippi County	1,147	6,916,010	-264,030	-274,700	-157
AR	Pulaski County	402	303,070	-60,070	-90	-77,
AR	Union County	1,793	10,673,540	-422,730	-1,400	-138
IA	Allamakee County	212	406,970	-54,340	-28,140	-23,
IA	Audubon County	82	96,310	-15,200	-1,250	-15,
IA	Black Hawk County	9	3,820	-850	-10	-4,
IA	Cerro Gordo County	468	2,362,450	-184,830	-670	-7,
IA	Des Moines County	193	1,103,240	-34,750	-201,490	-59,
IA	Louisa County	676	2,948,820	-355,970	-1,135,600	-609
IA	Marshall County	712	3,550,760	-229,010	-750	-21,
IA	Muscatine County	150	909,640	-38,440	-51,400	-108
IA	Polk County	312	252,960	-43,290	-290	-6,
IA	Pottawattamie County	1,350	7,429,940	-508,250	-1,040,620	-806
IA	Scott County	37	4,220	-1,340	–	-2,
IA	Story County	26	126,920	-7,990	-780	-11,
IA	Union County	32	4,700	-1,460	-20	-15,

For each county, annual output statistics are given for:

- Peak Gross Generation Post-Impact
- Annual Gross Generation Post-Impact
- Annual Change in Generation
- Annual Change in Heat Input/$PM_{2.5}$/SO_2/NO_X/CO_2
- Ozone Season Change in SO_2/NO_X/$PM_{2.5}$
- Ozone Season, 10 Peak Days Change in SO_2/NO_X/$PM_{2.5}$

AVERT's Excel-Based Main Module
Step 4. Display Results

Impact 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.

Midwest, 2019 AVERT

Output: Impact Data for Top Ten Peak Days

Click here to return to Step 4: Display Outputs

Day Rank	Date	Total Fossil Generation (MWh)	Expected Change in Generation (MWh)	Change in Generation (MWh)	Change in NO_x (lbs)	Change in SO_2 (lbs)	Change in CO_2 (tons)	Change in $PM_{2.5}$ (lbs)
1	Jul 19	1,902,830	-51,560	-51,290	-67,740	-60,930	-41,340	-8,060
2	Jan 30	1,868,580	-71,950	-71,560	-57,720	-84,490	-51,030	-10,970
3	Jul 02	1,835,170	-28,530	-28,870	-40,140	-33,990	-23,220	-4,450
4	Jan 31	1,833,870	-88,140	-87,310	-72,690	-98,070	-60,620	-14,470
5	Jul 17	1,833,710	-46,270	-46,430	-63,550	-55,220	-39,680	-7,440
6	Jul 18	1,825,060	-40,470	-40,120	-49,940	-47,280	-33,710	-6,560
7	Aug 06	1,818,660	-30,790	-30,720	-40,540	-37,510	-25,340	-5,180
8	Aug 12	1,808,150	-23,450	-23,300	-31,790	-26,880	-19,960	-3,940
9	Aug 07	1,781,340	-25,550	-25,120	-35,030	-29,680	-22,010	-4,160
10	Aug 19	1,780,230	-28,520	-28,420	-38,730	-33,420	-23,770	-3,960

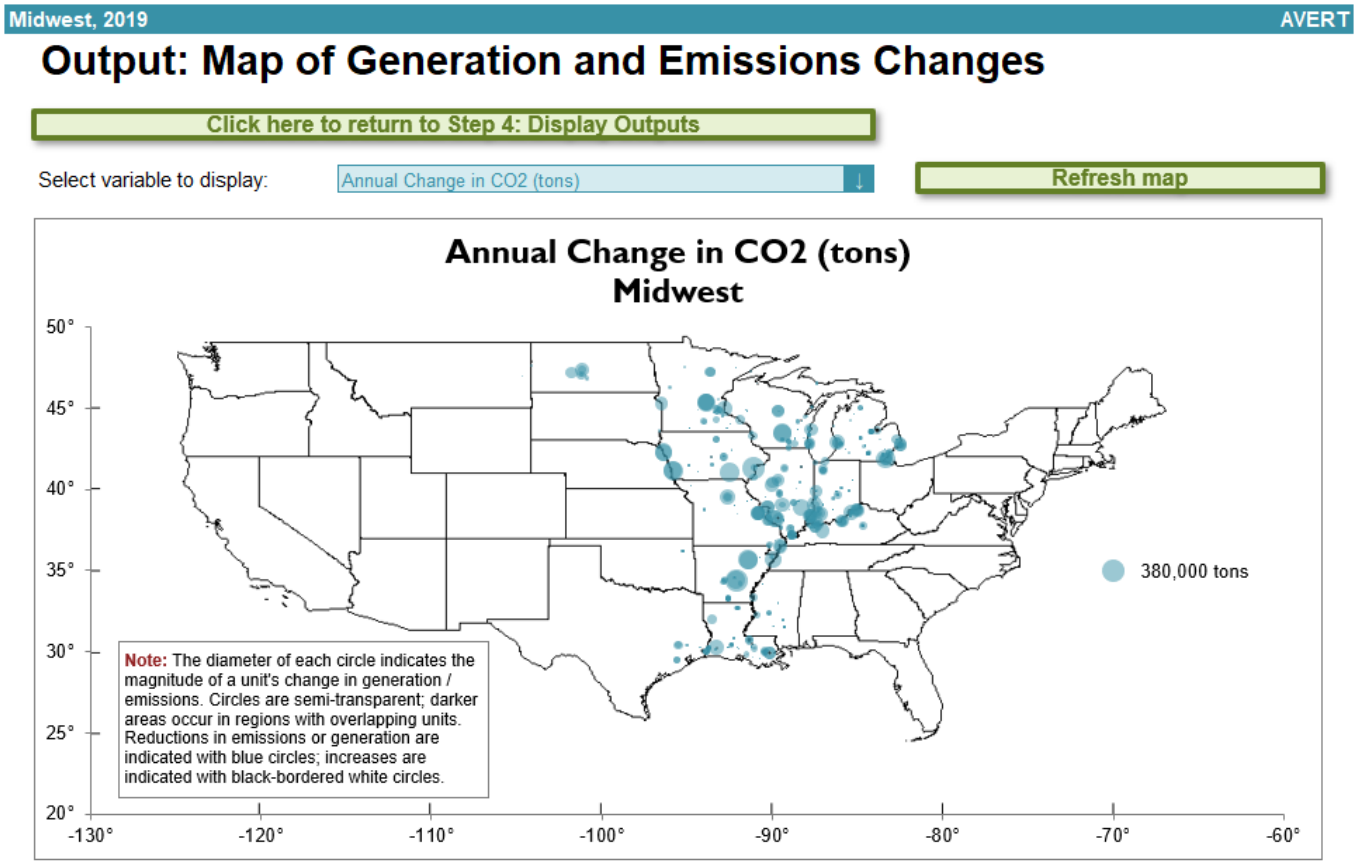
Negative numbers indicate displaced generation and emissions.

All results are rounded to the nearest ten. A dash ("—") indicates a result greater than zero, but lower than the level of reportable significance.

AVERT's Excel-Based Main Module Step 4. Display Results

Map of generation and emissions changes

- This dynamic map allows the user to view where emissions change within the selected region. Users can view changes in generation, heat input, $PM_{2.5}$, SO_2, NO_X, and CO_2.

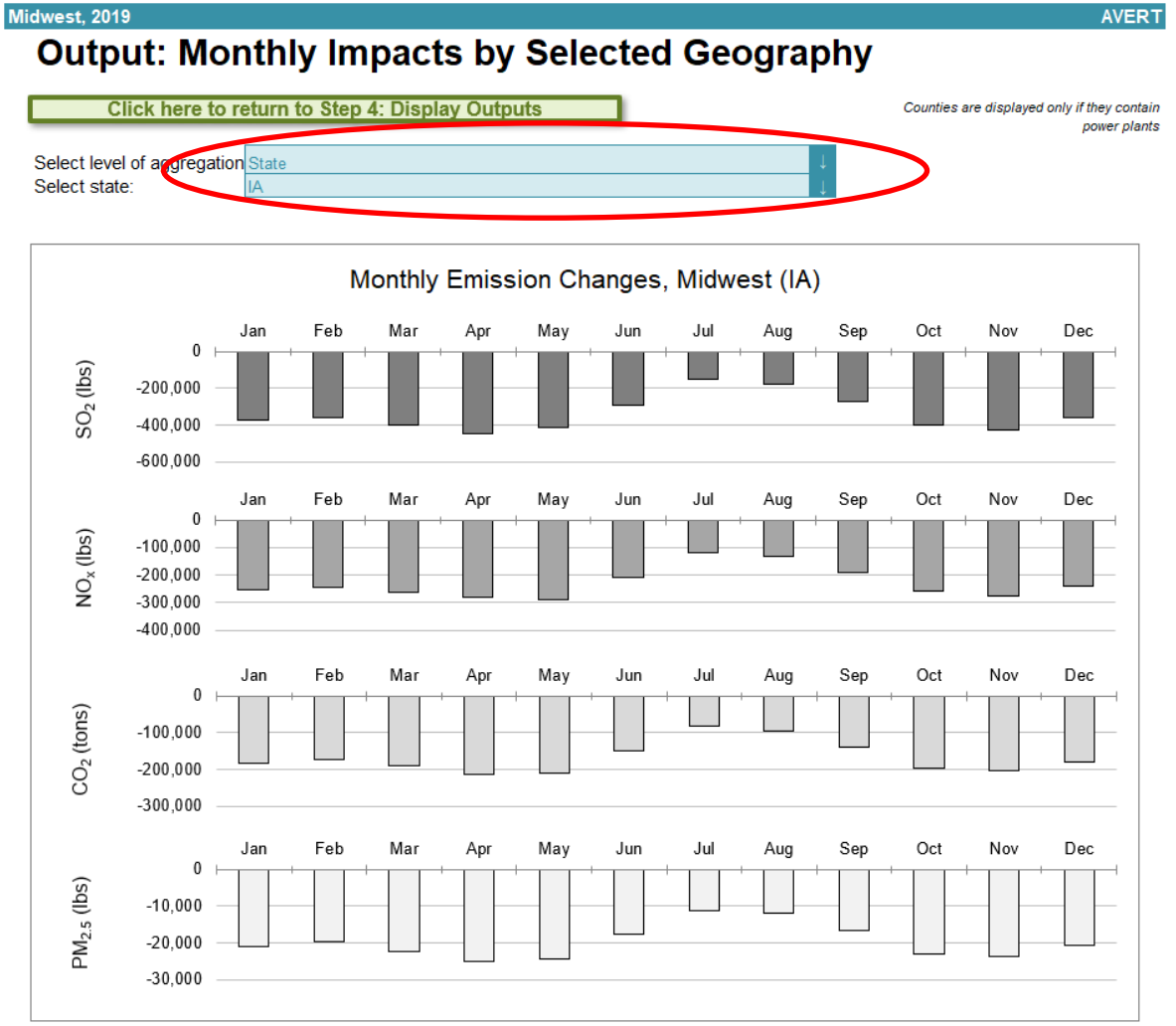


AVERT's Excel-Based Main Module Step 4. Display Results

Impact data by month

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

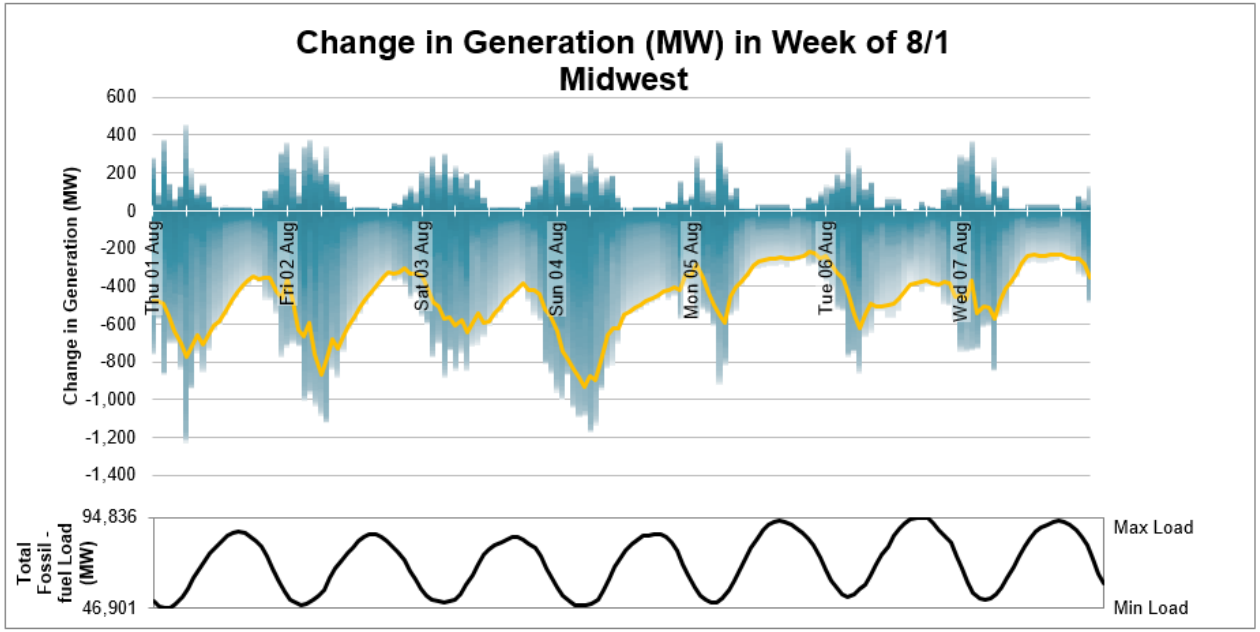
- First select region, state, or county in the top dropdown menu.
- If selecting a state, choose the state in the next dropdown menu.
- If selecting a county, choose both the state and the county in the next two dropdown menus.



AVERT's Excel-Based Main Module Step 4. Display Results

Hourly impacts by week

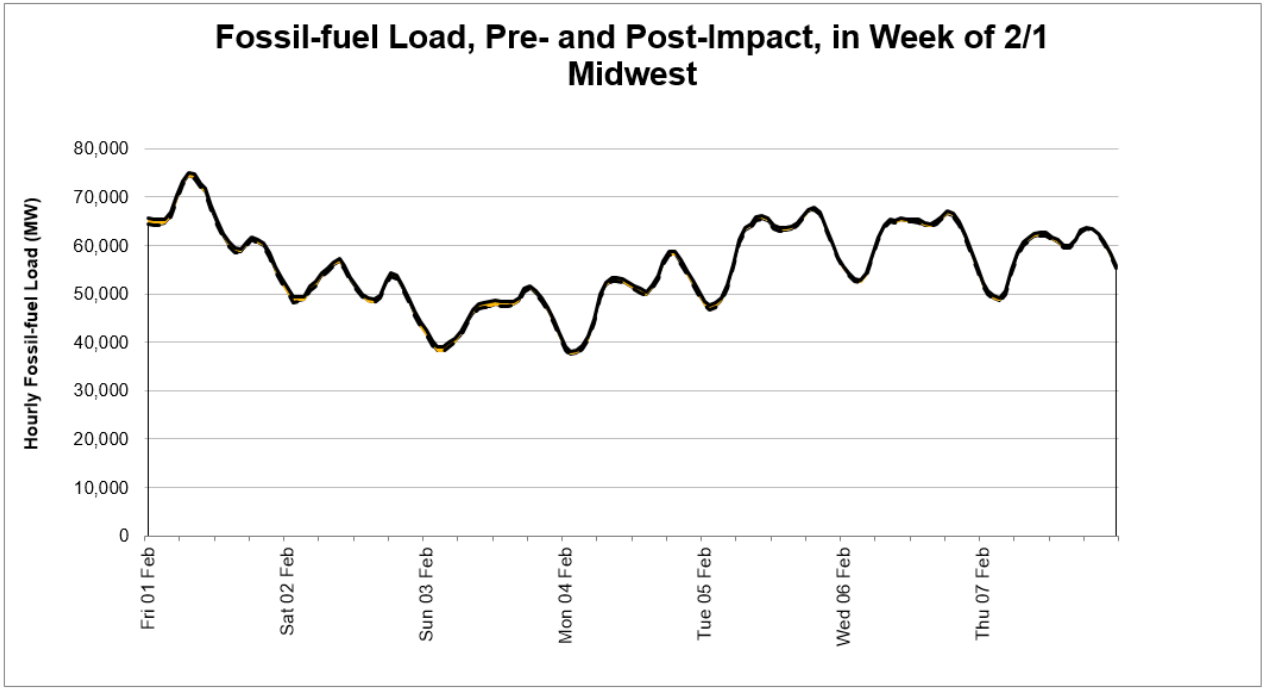
- This graph displays a dynamic representation of hourly impacts to each EGU in a region. Individual plants are stacked as gradated bar plots.



AVERT's Excel-Based Main Module Step 4. Display Results

Hourly impacts by week

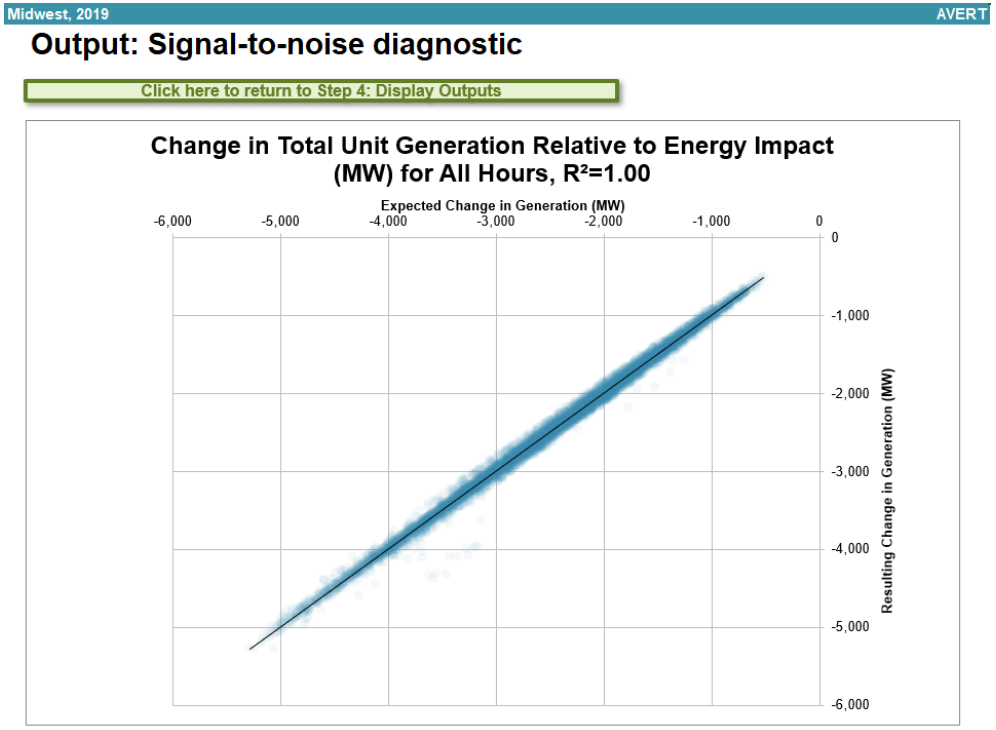
- The second figure shows the same week-long energy impact profile, but presents the change in generation in reference to the total fossil-fuel load to illustrate the degree of change represented by the energy program relative to the baseline.



AVERT's Excel-Based Main Module Step 4. Display Results

Signal-to-noise diagnostic

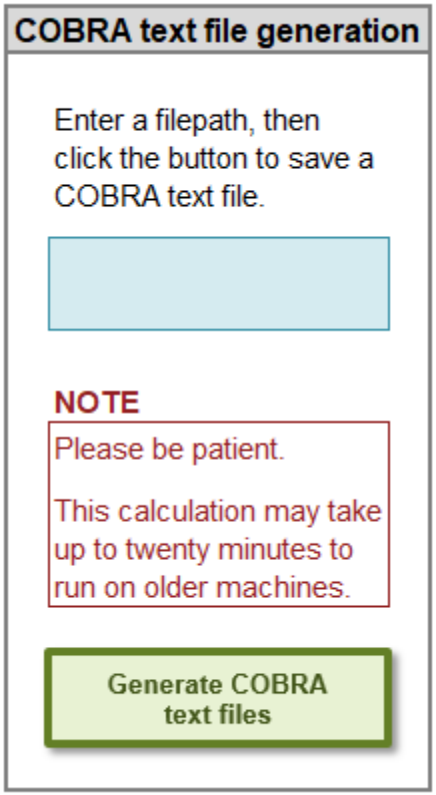
- This chart is a scatterplot of every hour of the year, showing calculated total change in generation in each hour (y-axis) against the user-input change in generation in each hour (x-axis).
- Ideally, AVERT perfectly matches change in unit generation to the amount of energy impacts requested by the user.
- This graphic shows where that assumption holds, where it does not hold, and to what extent.



AVERT's Excel-Based Main Module
Step 4. Display Results

COBRA Output

- AVERT outputs may be used as inputs to EPA's CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool to assess public health implications of the modeled scenario
- To download a COBRA-formatted file, double-click the blue box to enter a filepath and hit the green button to save a CSV file (example below)
- The file will contain county-level emission impacts for $PM_{2.5}$, SO_2, and NO_X, and will be ready for upload into COBRA

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FIPS,STATE,COUNTY,TIER1NAME,NOx_REDUCTIONS_TONS,SO2_REDUCTIONS_TONS,PM25_REDUCTIONS_TONS
01001,Alabama,Autauga County,FUEL COMB. ELEC. UTIL.,-1.13,-0.05,-0.765
01015,Alabama,Calhoun County,FUEL COMB. ELEC. UTIL.,-0.315,-0.005,-0.06
01033,Alabama,Colbert County,FUEL COMB. ELEC. UTIL.,-3.23,-11.365,-0.13
01039,Alabama,Covington County,FUEL COMB. ELEC. UTIL.,-0.5,-0.005,-0.09
01047,Alabama,Dallas County,FUEL COMB. ELEC. UTIL.,-0.11,0,-0.01
01063,Alabama,Greene County,FUEL COMB. ELEC. UTIL.,-3.32,-12.685,-0.735
01073,Alabama,Jefferson County,FUEL COMB. ELEC. UTIL.,-5.835,-8.575,-0.07
01081,Alabama,Lee County,FUEL COMB. ELEC. UTIL.,-0.455,-0.01,-0.225
01085,Alabama,Lowndes County,FUEL COMB. ELEC. UTIL.,-0.05,0,-0.025
01097,Alabama,Mobile County,FUEL COMB. ELEC. UTIL.,-5.89,-9.695,-0.265
01103,Alabama,Morgan County,FUEL COMB. ELEC. UTIL.,-0.395,-0.025,-0.15
01113,Alabama,Russell County,FUEL COMB. ELEC. UTIL.,-3.465,0,-0.195
01117,Alabama,Shelby County,FUEL COMB. ELEC. UTIL.,-3.57,-15.625,-0.22
01121,Alabama,Talladega County,FUEL COMB. ELEC. UTIL.,-0.13,0,-0.01
01123,Alabama,Tallapoosa County,FUEL COMB. ELEC. UTIL.,-0.12,-0.01,-0.08
01127,Alabama,Walker County,FUEL COMB. ELEC. UTIL.,-17.395,-15.505,-0.11
01129,Alabama,Washington County,FUEL COMB. ELEC. UTIL.,-7.16,-1.605,-0.415
05031,Arkansas,Craighead County,FUEL COMB. ELEC. UTIL.,-0.105,0,-0.005
05059,Arkansas,Hot Spring County,FUEL COMB. ELEC. UTIL.,-2.365,-0.015,-0.28
05063,Arkansas,Independence County,FUEL COMB. ELEC. UTIL.,-15.845,-39.095,-0.46
05069,Arkansas,Jefferson County,FUEL COMB. ELEC. UTIL.,-19.94,-42.335,-0.415
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For More Information

- Visit the AVERT website at www.epa.gov/avert.
- Contact EPA at avert@epa.gov.