GTI’s Energy Planning Analysis Tool (EPAT) – Version 1.1

The **Energy Planning Analysis Tool (EPAT)** is a screening tool to evaluate the potential benefits of direct gas use (fuel switching) in comparison to all-electric residential applications. The use of gas equipment, in place of traditional electric equipment, can provide energy, environmental, and economic benefits for space conditioning, water heating, cooking, and clothes dryers. Direct use of gas in these applications has demonstrated savings in source energy use and GHG emissions, as well as reductions in annual energy costs with favorable paybacks.

**Emission and Source Energy Factors**

Annual gas and electric energy use, total site and source energy, and corresponding emissions are based on GTI’s Source Energy and Emissions Analysis Tool (SEEAT) ([http://www.cmictools.com/](http://www.cmictools.com/)). SEEAT uses government published and publicly available data sources to estimate source energy and related air emissions for selected fossil fuels and electric energy consumed at a site. However, default values for nearly all parameters can be changed by the user. Users also have the option of using the eGRID2016 plant level database screened to verify and align fuel plant classification with primary input fuel. Default values for emission factors and source energy factors in the latest version of SEEAT using the following sources:

- **Greenhouse Gas and Criteria Pollutant Emission Factors**
  - Fossil fuels pre-combustion emissions are calculated using data from the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model version 1.8c released by Argonne National Laboratory in March 2009. GREET references current US EIA and EPA data sources as well as a database of information developed by Argonne National Laboratory during the past 15 years. The GREET program, sponsored by the U.S. DOE Office of Energy Efficiency and Renewable Energy (EERE), is being used by DOE for modeling emissions and energy use in transportation. ([http://www.transportation.anl.gov/modeling_simulation/GREET](http://www.transportation.anl.gov/modeling_simulation/GREET))
  - Fossil fuels on-site combustion emissions are calculated using GREET 1.8c data.
  - Fossil fuels combustion emissions for conversion to electricity are calculated using the EPA 2018 Emissions & Generation Resources Integrated Database (eGRID2016). EPA 2018 eGRID2016 provides detailed and aggregate data on electric power plant generation and emissions for the year 2016. Data is available for nearly all US power plants and aggregated at state, National Electric Reliability Council (NERC) sub-region, NERC region, and national levels. Relevant emissions data includes CO₂, NOx, SO₂, Hg, CH₄, and N₂O emissions. In addition, the database includes the percentage of power supplied by coal, oil, natural gas, hydro, nuclear, and other renewable sources. This generation mix data is useful to estimate source energy conversion factors at state, regional, and national levels. Heat rates for electricity generation using fossil fuels like coal, natural gas, and oil as well as electricity transmission and distribution (T&D) losses are also available from eGRID2016. ([http://www.epa.gov/cleanenergy/energy-resources/eGRID/](http://www.epa.gov/cleanenergy/energy-resources/eGRID/))
CO₂e emission factors are calculated using global warming potential (GWP) values for three of the greenhouse gas. Calculations are based on GWP values for pollutants 100 years lifetime as per 2013 Intergovernmental Panel on Climate Change (AR5 p714):
Carbon Dioxide (CO₂) GWP = 1; Methane (CH₄) GWP = 28; Nitrous Oxide (N₂O) GWP = 265.

- **Source Energy Factors**
  - Source energy factors for fossil fuels pre-combustion energy consumption are calculated using the National Renewable Energy Laboratory (NREL) U.S. Life-Cycle Inventory (LCI) database and GREET version 1 2012 rev. 2 data. The NREL LCI database provides data needed to calculate source energy conversion factors for the three major types of coal (bituminous, subbituminous, and lignite) used in US power plants. Related supplemental data are provided in NREL report TP-550-38617 “Source Energy and Emission Factors for Energy Use in Buildings”. ([www.nrel.gov/docs/fy07osti/38617.pdf](http://www.nrel.gov/docs/fy07osti/38617.pdf)) That report also provides data needed to calculate the percentage of coal fuel mix 2 March 19, 2010 (bituminous, subbituminous, and lignite) used in electric power generation at state, regional, and national levels. ([http://www.nrel.gov/lci/](http://www.nrel.gov/lci/))
  - Source energy factors for fossil fuels on-site combustion are assumed to be 100% (i.e., complete combustion).
  - Source energy factors for fossil fuels combustion at power plants for conversion to electricity are calculated using EPA eGRID2016 data.
    - Hydroelectric plant conversion efficiency is estimated at 90%. [1a]
    - Solar power generation conversion efficiency is estimated at 12%. [1b]
    - Wind power generation conversion efficiency is estimated at 26%. [1c]
    - Geothermal power generation conversion efficiency is estimated at 26%. [1d]
    - Nuclear power generation conversion efficiency is a national average value based on DOE EIA data. [2]
    - Biomass power generation conversion efficiency is based on eGRID2009 data.

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Sources cited by U.S. EIA:
[1b] Solar Photovoltaic: Based on the average rated efficiency for a sample of commercially available modules. Rated efficiency is the conversion efficiency under standard test conditions, which represents a fixed, controlled operating point for the equipment; efficiency can vary with temperature and the strength of incident sunlight. Rated efficiencies are based on the direct current (DC) output of the module; since grid-tied applications require alternating current (AC) output, efficiencies are adjusted to account for a 20 percent reduction in output when converting from DC to AC.
[1c] Wind: Based on the average efficiency at rated wind speed for a sample of commercially available wind turbines. The rated wind speed is the minimum wind speed at which a turbine achieves its nameplate rated output under standard atmospheric conditions. Efficiency is calculated by dividing the nameplate rated power by the power available from the wind stream intercepted by the rotor disc at the rated wind speed.
[1d] Geothermal: Estimated by EIA on the basis of an informal survey of relevant plants.
Building Data
EPAT allows the user to evaluate the benefits of direct gas use at the state level for all-electric residences as identified by EIA 2009 Residential Energy Consumption Survey (RECS 2009).\(^3\)\(^,\)\(^4\) State populations and average floor space (square footage) were defined for the following five types of residential buildings: Mobile Home, Single-Family Detached, Single-Family Attached, Apartment Buildings with 2 - 4 Units, and Apartment Buildings with 5+ Units. The user has the option of evaluating each building type separately or grouping some or all building types to create custom target population.

For the state level comparison, checkboxes allow “user specified” data to be entered for number of units, average floor space, and average number of occupants. For the city level comparison\(^5\), the default number of all-electric buildings are estimated based on city populations as reported in the 2010 U.S. Census. “User specified” options allow users to change the population input for the city or state, residential fuel prices, and input building data to calculate the total energy, environmental and cost benefits.

Energy Prices
Regional electric, and gas residential prices are based on state-level EIA 2016 annual average prices (https://www.eia.gov/). Regional propane prices are based on PADD average annual 2016 EIA data. The U.S. average propane price is used as the default for states with unavailable data. EIA average energy prices are based on total costs, including fixed costs such as customer charge, divided by total energy consumption. Marginal energy prices are the incremental cost per energy use. In some cases, such as time of use rate structures, marginal prices may be higher than the average. EPAT defaults use marginal electricity prices developed and published by U.S. DOE, and marginal natural gas prices developed and published by AGA. The user has the option to modify any default energy prices.

Installed Equipment Costs
Installed equipment costs are based on NREL’s National Residential Efficiency Measures Database\(^6\) and the NREL/Building America installed cost database used in the Building Energy Optimization software (BEopt) (https://beopt.nrel.gov/). Cost data are supplemented by EIA published data or manufacturer information as necessary.

According to the website [6], the purpose of this database is to provide a national unified database of residential building retrofit measures and associated costs.

This database provides full cost estimates for many different retrofit measures. For each measure, the database provides a range of costs, as the cost data for a measure can vary widely across regions, houses, and contractors. Climate, construction, home features, local economy, and geographic location all affect the actual cost to perform any of these measures.

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\(^3\) Houses identified in RECS 2009 as electric heat pump heated were eliminated from population of likely targets for fuel switching

\(^4\) Data in RECS 2009 census region database including multiple states was disaggregated to states level using population density.

\(^5\) Available for cities included in NREL TMY2 weather database.

\(^6\) NREL’s National Residential Efficiency Measures Database http://www.nrel.gov/ap/retrofits/group_listing.cfm
Some measures have multiple costs that must be added together to obtain total cost for the measure. For example, air conditioner measures have a fixed cost ($) and a normalized cost ($/kBtuh) that must be combined to get the total cost for the measure.

The cost data represents the total cost to implement the retrofit measure. For example, a new air conditioning unit that just meets code may cost $5,000. In addition to a measure that just meets code, the database may also include a measure to install a more energy-efficient air conditioner that costs $5,700. In this case, the cost listed in the database represents the full cost of the air conditioner ($5,700), and not the incremental cost ($700) to improve the unit from code.

This database is not intended to provide specific cost estimates for a specific project. The cost estimates do not include any rebates or tax incentives that may be available for the measures. Rather, it is meant to help determine which measures may be more cost-effective. NREL makes every effort to ensure accuracy of the data; however, NREL does not assume any legal liability or responsibility for the accuracy or completeness of the information.

More detailed information on assumptions for each measure can be found at: http://www.nrel.gov/ap/retrofits/pdfs/development_document.pdf

Energy Consumption

Annual site consumption is calculated based on user-selected inputs for fuel type, equipment specifications, location, building square footage and occupancy.

- **Air-Source Heat Pumps (ASHP)**

  ASHP performance is very dependent on ambient temperatures. In cooling mode, ASHP moves heat from inside the home to the outdoor condensing unit. In heating mode, ASHP extracts heat from the outdoor air, transferring that heat to an indoor fan coil. ASHP heating efficiency and capacity is reduced at lower ambient temperatures when less heat can be extracted from the surrounding air. To maintain performance at low ambient temperatures, ASHPs typically switch to electric resistance heating mode.

  Heating Seasonal Performance Factor (HSPF), used to describe ASHP heating efficiency, is defined by the annual space heating required in Btu, divided by the total electrical energy consumed in watt-hours. The Energy Planning Analysis Tool uses an adjusted HSPF for the selected location based on a formula developed by Fairey et al.\(^7\) that estimates seasonal field HSPF as a function of winter outdoor design temperature. This formula includes use of backup electric resistance heat during cold periods when the heat pump cannot provide enough heat. This analysis also assumes ducted ASHP.\(^8\)

  ASHP cooling seasonal efficiency is indicated by its SEER rating, which is also used for central air conditioning systems. SEER is defined by the average cooling delivered in Btu, relative to every watt-

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hour of electricity consumed over a cooling season. The Energy Planning Analysis Tool calculates ASHP cooling energy use based on climate-adjusted SEER factors using DOE2 algorithms.

Output
EPAT output reports the following calculations for each baseline and alternative options:

- Annual site and source energy consumption
- Annual CO2, SOx, NOx, CH4, N2O, and GHG full fuel cycle emissions
- Annual energy costs
- Estimated installed equipment costs
- Potential cost savings and simple payback for alternative technology options

Frequently Asked Questions (FAQ)

1. **How is state-level annual energy use determined?**

   A. Annual energy use is calculated based on city-level weather data and then rolled up to state-level using a population weighted average.

      - Space conditioning energy use is estimated based on location and the home square footage.

      - Water heating energy use is based on number of occupants, and also includes hot water use for dishwashers and clothes washers. Annual energy use for heat pump water heaters is also dependent on location.

      If options for dishwasher or clothes washer are selected and set to zero, the resulting increased water use is reflected in increased energy use for water heating.

      - Estimated energy use for water heating and other appliances is based on number of occupants.

2. **Why is 2009 RECS data used instead of the more current 2015 RECS?**

   A. EPAT continues to use 2009 RECS database because no state level estimates were available for the 2015 RECS due to a smaller sample size. (See below)

Reference:
**Residential Energy Consumption Survey (RECS) 2015 Technical Documentation Summary:**
A return to the traditional number of respondents after an increase in the previous RECS. The total number of responding households is 5,686 in the 2015 RECS compared to 12,083 in the 2009 RECS. Due to the smaller sample size, no state level estimates are available for the 2015 RECS.

3. **Why is the EPAT total state energy consumption lower than total residential consumption reported elsewhere?**
A. Default housing data is from the RECS database which only includes homes that are a primary residence. This does not include secondary homes, any vacant units, military barracks or common areas. (See below)

Reference:
Residential Energy Consumption Survey (RECS) 2015 Technical Documentation Summary:
The scope and purpose of RECS differ slightly from similar EIA products that report residential energy data. RECS samples homes occupied as a primary residence, which excludes secondary homes, vacant units, military barracks, and common areas in apartment buildings. As a result, RECS estimates do not represent sector-level estimates, but they are best suited for comparison across different characteristics of homes within the residential sector.