The Department of Energy (DOE) Better Plants (BP) program is a voluntary energy efficiency leadership initiative for U.S. manufacturers that encourages companies to reduce their energy intensity, typically by 25% within a ten-year period. BP partners are required to report their progress to the DOE annually by establishing an energy intensity baseline and tracking their energy consumption. BP partners receive access to a Technical Account Manager (TAM), DOE resources including software tools and trainings, and recognition when they achieve their goal.

This summary guide provides the basics of baselining and tracking your energy intensity. For a more information and special considerations, please see the *Energy Intensity Baselining and Tracking Guidance 2020* [1].

Energy Intensity Baselining & Tracking

Energy Intensity (EI) is the ratio of energy consumed to a unit of output. Reductions in EI represent more efficient use of energy by your facilities. Baselining and tracking EI is a critical first step for effective energy management because it will provide the measuring stick for your energy efficiency efforts and help you understand where/how you use energy.

For the BP program, only U.S.-based manufacturing operations are included in the program scope. EI baselines for each of your facilities must reflect energy and production over a 12-month period under normal operations without major disruptions or changes.

BP provides three main methods to calculate your EI improvement (Figure 1). DOE recommends that you work towards the regression approach for the most accurate results but will work with you to find the right method(s) for your facilities.

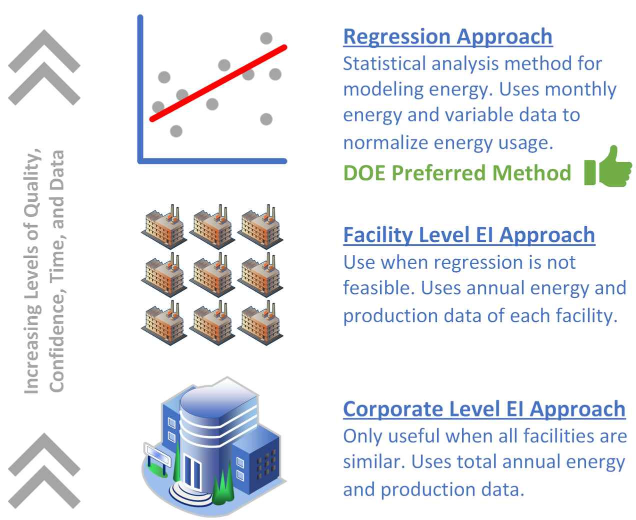

Figure 1: Better Plants energy baselining methods.

Baselining Steps

Basic steps to develop your EI baseline for tracking and BP reporting are outlined in Figure 2. Steps 1–3 are related to data collection and require decisions on which resources to track and when to set the baseline year. Most of the data collection for these steps can be done with a simple analysis of your utility bills. After selecting a baseline methodology (e.g., regression or energy intensity based), Step 4 is a decision on which variable(s) affect energy consumption. Steps 5–8 can be completed using DOE software tools. Your TAM can provide guidance as you navigate these steps.

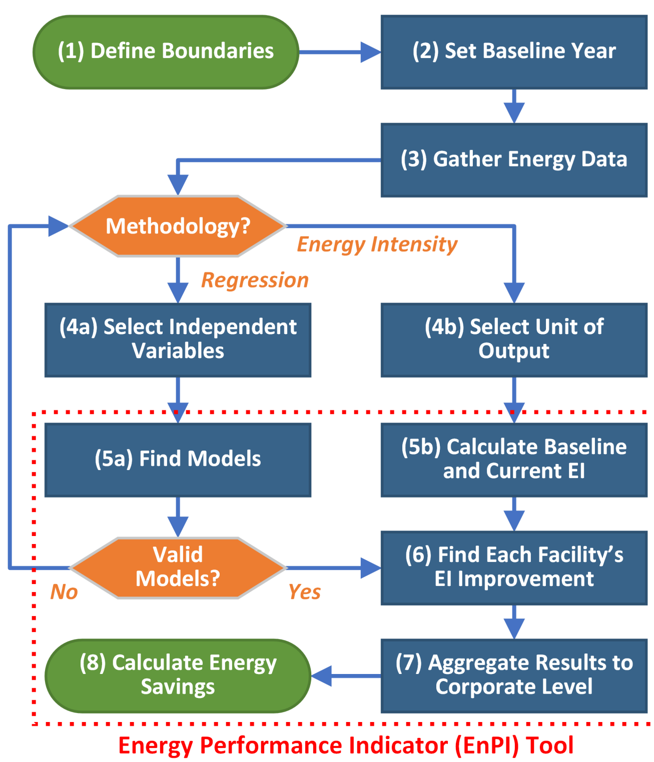

Figure 2: Process flow for developing an EI baseline.

Regression Method

Regression is a statistical technique that can be used to model energy consumption taking into account multiple variables including production and weather. A properly developed regression can provide reliable estimates of your energy efficiency savings across multiple years. The following steps provide the basics of regression modeling, see the *Energy Intensity Baselining and Tracking Guidance 2020* for more details. [1].

Step 1: Define the Boundary

The first step of energy baselining is drawing fence line around a production facility (Figure 3). Energy resources entering this fence (e.g., electricity, gas, fuel) are tracked for BP reporting but can be excluded if they are less than 5% of total consumption. Feedstock energy is always excluded (e.g., fuels converted to product) and transportation energy can be tracked if desired. Energy resources leaving the fence (e.g., surplus electricity, steam) count as a credit towards reporting.

A fence should be drawn for all of your U.S.-based manufacturing facilities. Non-manufacturing spaces (warehouses, offices, etc.) may be included in your BP pledge if desired. Only include your direct operations; distributor and supplier activities should be excluded.

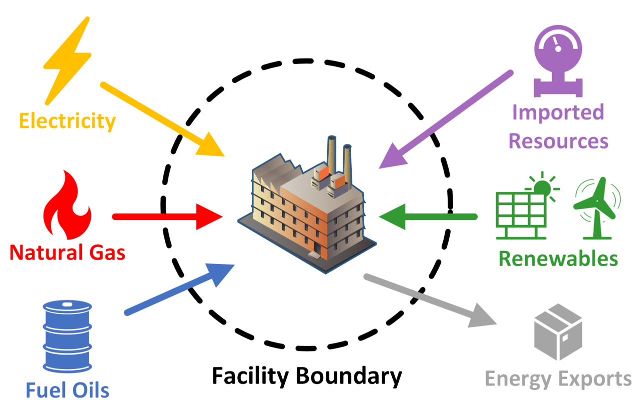

Figure 3: Establishing your facility boundary enables accurate accounting of energy streams.

Step 2: Set the Baseline Year

Selecting the baseline year creates your benchmark for measuring Better Plants progress (Figure 4). The baseline year is usually the most recent calendar/fiscal year since joining the program although it can be up to three years prior to joining if there are recent energy savings you would like to capture in your pledge. A good baseline year represents typical facility operations without major changes to equipment or production. Your pledge will be to reach your energy intensity reduction goal within ten years of your selected baseline year.

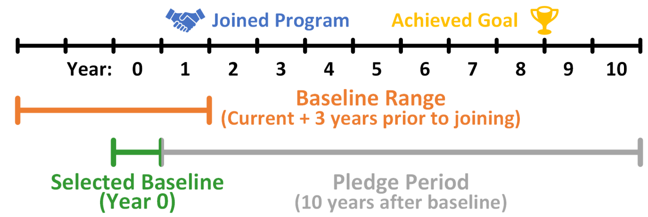

Figure 4: Example for setting baseline and BP pledge period.

Step 3: Gather Energy Data

For each energy resource identified in Step 1, you must collect data for the baseline and reporting years. Common resources for data collection are shown in Figure 5. Each resource must to be converted to a common unit (usually MMBtu) using an appropriate conversion factor. Multipliers for non-energy resources (purchased compressed air, steam, chilled water, etc.) can be found in the full Energy Baselining Guidance [1]. The DOE's Energy Footprint (EF) tool can help organize your site energy data during this step.

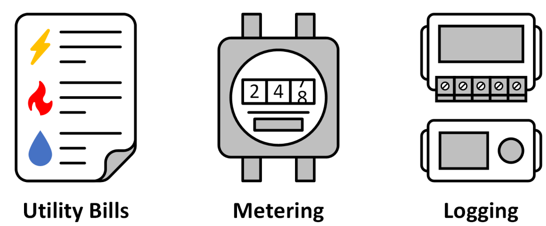

Figure 5: Common sources for collecting energy data.

All site energy streams must be converted to primary energy for BP reporting. Using primary energy captures the full benefits of efficiency improvements and on-site generation technologies (solar, wind, combined heat and power, etc.) by including inherent losses in power generation and distribution (Figure 6). Electricity requires 3 kWh of generation for 1 kWh of site consumption. Renewables and fuels such as natural gas have a 1.0 multiplier. See [1] for multipliers for non-energy resources such as compressed air and steam.

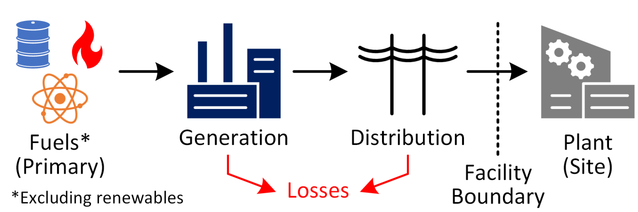

Figure 6: Site energy does not capture production and transmission losses from delivery of energy.

Step 4a: Choose Relevant Variables

Normalizing energy consumption for the variables that are most relevant to your facilities ensures a fair comparison of energy performance between years. You will need to identify and collect data on potential variables that affect facility energy consumption for each year prior to starting the regression analysis.

The most common variables that affect energy consumption at manufacturing facilities are production and weather (Figure 7). Production is usually measured by units/parts produced although hours worked can be used if your product mix or energy intensity between products is too varied. If you choose revenue as a production metric, make sure to adjust for inflation using an economic indicator. Common metrics for weather conditions include degree days, humidity, and average temperature all of which are available from several online sources. Consultation with your plant managers and your BP TAM can help you identify these and other factors that may affect your energy consumption.

Figure 7: Common variables that affect energy consumption.

Step 5a: Find Regression Models

While regression analysis is often complex, the DOE's Energy Performance Indicator (EnPI) tool automates the process. Data from Steps 3–4 stored in the EF tool can be easily exported in an EnPI compatible format.

Energy Performance Indicator (EnPI) Tools

EnPI is a free DOE software tool designed to help BP partners with energy intensity baselining and tracking. Two versions of the tool are available:

Feature	EnPI Lite	EnPI
Platform	Online	Excel
Ease of Use	Easy	Moderate
Energy Intensity Approach	✗	✓
Regression Based Approach (# of Modeling Methods)	✓ (2)	✓ (3)
Corporate Roll-Up	✗	✓

To start your regression analysis, download and install the EnPI tool. Open Excel and select "*EnPI Step-by-Step Wizard*" from the EnPI tab. The wizard will guide you through creating an Excel table from your data, labeling reporting periods, and unit/primary energy conversions. Lastly, select your energy sources, independent variables, baseline year, and reporting year.

Three regression methods are shown in Figure 8 and choosing between these methods is based on your selection of a model year in the EnPI menu. Forecasting predicts future energy usage using baseline year data as a model, backcasting simulates past energy usage using reporting year data as a model, and chaining is a combination of both methods using an interim model year. Savings occur when future energy consumption is less than modeled energy consumption and/or past consumption is greater than modeled consumption. Note EnPI Lite does not support the chaining method.

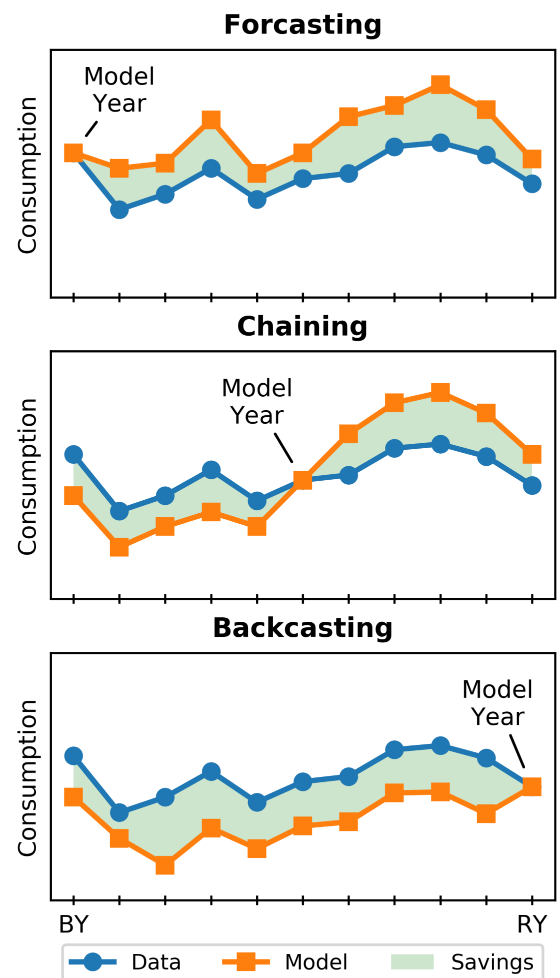

Figure 8: The three types of regression modeling used by EnPI for EI analysis. Start your regression with forecasting but try backcasting and chaining if no valid model exists.

EnPI will indicate valid regression models and automatically select the one with the best statistical fit. Make sure to carefully evaluate each valid model before making a final choice, the default option may contain variables or coefficients that are illogical (Figure 9). For example, a model with a negative coefficient for production would predict decreased energy consumption with increased production. Similarly, if natural gas is used for heating avoid models that use cooling demand as a variable. Finding the right model for your facilities may require experimentation with different variables or model years until a valid realistic model can be found. If no valid models are found, revisit Steps 1-4a for other factors that may explain energy trends or switch to the Energy Intensity Method.

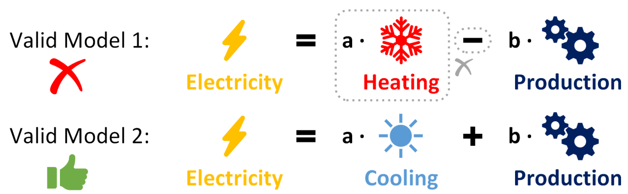

Figure 9: Consider two valid electricity models for a typical manufacturing plant. Select Model 2 because electricity will not be used for heating and should increase with production.

Step 6-8: Calculate Improvement Metrics

EnPI will use the models you developed in Step 5a to estimate normalized energy consumption for a facility and automatically calculate improvement in energy intensity. Repeat Steps 1-5a for each of your company's U.S.-based manufacturing facilities (Step 6). Facility savings are aggregated to the corporate level by opening a new spreadsheet and selecting the "*Corporate Roll Up*" option in EnPI ribbon. Use the "*Import Data from Other Files*" option to include each facility's energy savings results. EnPI will calculate a combined corporate-level EI improvement (Step 7) and your total estimated energy savings since the baseline year (Step 8).

Annual Reporting with Regression

Corporate-level data from Steps 7-8 are used for Better Plants annual reporting. New data is added each year to EnPI and the regression process is rerun with the same baseline and model year. Facility operations that undergo significant changes from the baseline year may cause model validity checks to fail over time which will require establishing new regression models. Guidelines for when and how to find new models can be found in the full Energy Intensity Baselining Guidance [1] including common scenarios and examples.

Classic Energy Intensity Approach

While regression analysis will provide the most accurate results, data collection requirements may not be feasible for all partners. Energy Intensity (EI) analysis is the next best option and requires only annual total energy consumption and production levels to complete. Only Steps 4b and 5b are significantly different for the EI approach from the regression steps outlined before.

Step 4b: Select Unit of Output

Energy Intensity (EI) is the ratio of total annual energy consumed to a unit of production. You will need to select a single unit of output for each facility that has the greatest impact on total energy consumption with common choices given in Figure 10. If submetering is available in your facilities, consider tracking EI improvement for each product, especially when EI varies significantly between products. If product mix is too varied to track separately, you should develop a "standard unit of output" that reflects the range of EI for all products (see [1] for more information). For example, because product 'A' takes twice as much energy to produce than product 'B', the common unit of output could equal 2 $\times$ Product A + Product B.

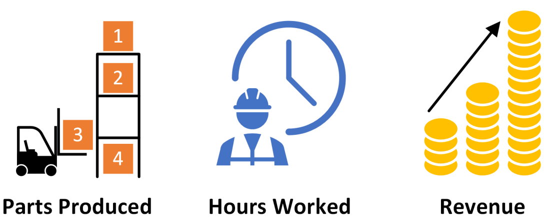

Figure 10: Common units of output for EI analysis.

Step 5b: Calculate Baseline and Current EI

To analyze data in EnPI with the EI approach, follow the instructions in the "*EnPI Step-by-Step Wizard*" as before with the regression approach. Make sure to select "*Use Actual Data*" as the calculation method for the EI approach. Choose your energy resources, unit of output, and baseline year to start the analysis.

Steps 6-8: Calculate Improvement Metrics

Repeat Steps 1-5b for each of your company's U.S.-based manufacturing facilities (Step 6). As with the regression approach, your facility level savings can be "rolled up" into your corporate EI improvement metric (Step 7) and total energy savings (Step 8) results. Note that EnPI will allow you to combines results from plants using regression analysis and EI analysis into the same corporate level results.

Corporate vs. Facility Level Analysis

There are two ways to use the EI approach to capture EI savings at the corporate level. Calculating EI improvements for each facility and then "rolling up" to find the corporate improvement metric is called the *Facility Level EI Approach* (Figure 11). If energy and production for all facilities are combined before calculating EI, the method is called the *Corporate Level EI Approach*. This approach requires that all facilities use the same production metric or that only the final assembled part count is used.

If you choose to use the EI method instead of regression analysis, the DOE recommends that you use the Facility Level EI approach. Although the Corporate Level EI approach requires the least amount of data and is easier to implement, it has the major disadvantage of hiding your good and bad performers. By calculating savings at the facility level you will be able to identify your best practices, provide recognition for your high-performing facilities, and allocate resources to the facilities that need them the most.

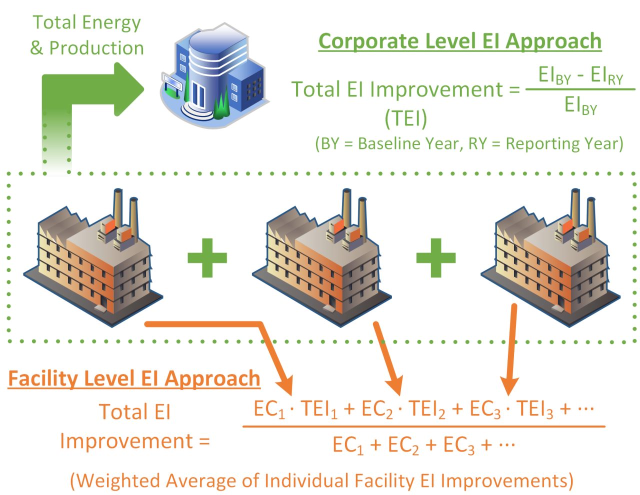

Figure 11: Facility-level analysis weights facility EI improvements by baseline energy consumption (EC) to find corporate improvement. Corporate-level analysis combines energy and production for all facilities before calculating metrics.

Annual Reporting with EI

As with regression, operations at partner facilities will change over the pledge period. Adjustments to baseline energy consumption can accommodate for internal changes at a facility (e.g., new product lines, expansions, consolidations), opening or closing of facilities, unexpected events, etc. The full *Energy Intensity Baselining and Tracking Guidance* [1] contains information on dealing with these and other situations.

Baselining and Tracking Example

The following example aims to demonstrate the process of developing your corporate energy baseline and how to track improvement in energy intensity. Files for each example plant are available on the Better Plants Solution Center website [2].

Fine Factories Company (FFC) has 7 total facilities in the US (Figure 12): 4 manufacturing, 2 distribution centers, and 1 headquarters. Only the four manufacturing plants must be part of the BP pledge. Each plant uses electricity and natural gas provided by local utilities as part of their manufacturing process. FFC joined the BP program in 2019 and therefore reviews energy data from 2016-2019 for their baseline year. FFC's selection of 2017 as their baseline year means that their pledge is to reduce their energy intensity 25% by 2027.

Figure 12: US based facilities of Fine Factories Company.

FFC's Knoxville manufacturing facility is working towards regression as their baselining technique. Data on energy consumption for the years 2017-2019 was collected from utility bills while production numbers were obtained from internal monthly reports. Although the plant has an on-site wind turbine, it was determined that it provides less than 5% of the facility's total energy and is therefore excluded. Cooling/heating degree days (both with balance temperature of 60°F) are also selected as relevant variables to track for regression using data from the local airport weather station.

Electricity from the baseline (2017) thru the reporting (2019) year are converted from site to primary energy with a 3.0 multiplier and from kWh to MMBtu (0.00341 MMBtu/kWh) using the EnPI Tool. Natural gas is also converted from hundred cubic feet (CCF) to MMBtu by EnPI using the higher heating value (HHV) for standard U.S. natural gas (0.1027 MMBtu/CCF).

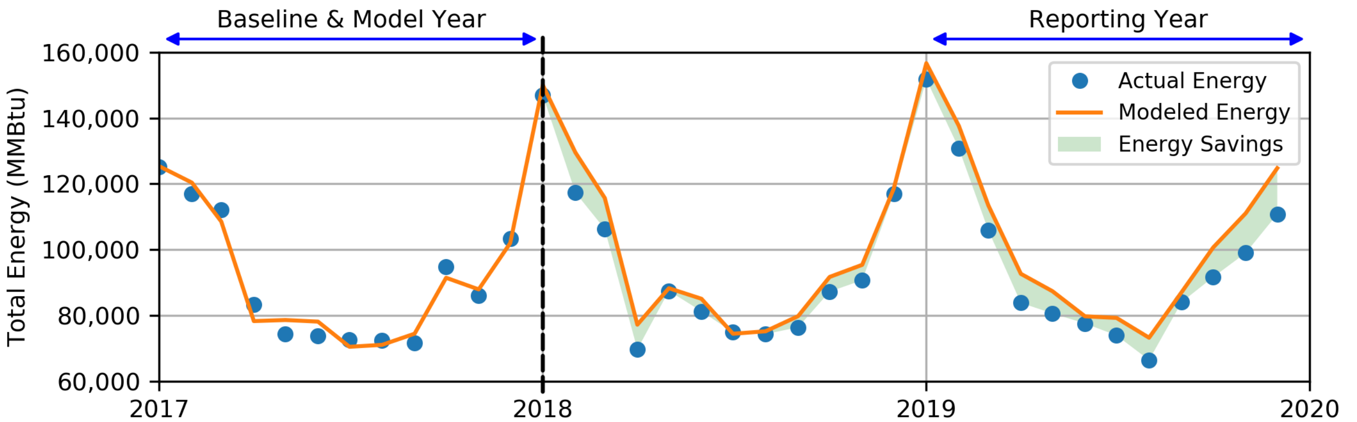

Figure 13: EnPI Results showing savings calculated from modeled and actual energy consumption for FFC's Knoxville Facility.

The Knoxville facility selects 2017 as their regression model year which gives only one valid forecast model for electricity (Equation 1). Note that the coefficients are all positive which follows expected relationships between production and cooling demand with electricity. The natural gas forecasting model was selected from multiple valid models because gas is used in the manufacturing process and for heating. Normal production levels prevent the negative constant in the gas equation from making the modeled gas consumption less than zero. If no valid and/or reasonable forecast models had been found, 2018 or 2019 could be explored for chaining or backcasting analysis.

$$\begin{aligned} \text{ELEC} &= 0.11 \cdot \text{Production} + 33 \cdot \text{CDD} + 30{,}670 \\ \text{NG} &= 0.19 \cdot \text{Production} + 12.8 \cdot \text{HDD} - 10{,}440 \end{aligned} \quad (1)$$

EnPI uses the collected energy and relevant variable data with the models to calculate expected total energy (Figure 13). Results show a 7.0% total improvement in energy intensity since the baseline year for the Knoxville plant with an annual improvement of 2.68% for 2019.

FFC's Lexington, KY plant also attempted to use regression analysis but was unable to find valid models for both electricity and natural gas in the same model year. Therefore facility personnel chose to use an energy intensity based analysis. The "*Use Actual Data*" option in EnPI was used to calculate energy intensity improvement by selecting monthly electricity, natural gas, and production data. Results show a 3.1% total improvement in energy intensity for the Lexington plant with an annual improvement of 4.7%.

Table 1 summarizes results from each of FFC's manufacturing facilities as well their percentage of total corporate baseline energy. These numbers are combined using the "*Corporate Rollup*" feature in EnPI to calculate the total energy savings and improvement in energy intensity for Fine Factories Company. The rollup shows that despite the Columbus facility's negative improvement, at the corporate level FFC has a total energy intensity improvement of **+2.5%** since the baseline year.

Table 1: Fine Factories Company EnPI Results

Location	% of Baseline Total Energy	Total EI Improvement
Columbus, OH	28.6%	**-4.5%**
Cincinnati, OH	9.3%	**+2.0%**
Lexington, KY	43.2%	**+3.1%**
Knoxville, TN	18.9%	**+7.0%**
Roll-up	–	**+2.5%**

Please see the *Energy Intensity Baselining and Tracking Guidance 2020* [1] for more examples and additional information about energy baselining and tracking.

Authors & Acknowledgements

This guide was developed for the U.S. DOE's Office of Energy Efficiency and Renewable Energy as part of the Better Buildings, Better Plants program by Dr. Christopher Price, Dr. Sachin Nimbalkar, and Thomas Wenning of the Energy and Transportation Sciences Division at Oak Ridge National Laboratory, Oak Ridge, TN, USA under Contract No. DE-AC05-00OR22725.

References

[1] Oak Ridge National Laboratory (ORNL), *Energy Intensity Baselining and Tracking Guidance*. US Department of Energy, 2020.

[2] US Department of Energy, "Better Plants Solution Center." https://betterbuildingssolutioncenter.energy.gov/better-plants/better-plants-solutions.