Federal Energy Management Program

Quantitative Considerations for Building Electrification Projects

How do I decarbonize and electrify my building(s) cost-effectively?
This document breaks down key site-specific details useful for early prioritization and project development for electrification projects.

Why is electrification important?

In 2022, commercial buildings in the United States accounted for 797 million metric tons (MMt) of carbon dioxide (CO_2). This increase of over 11 MMt compared to 2021 was driven primarily by direct fuel use **(https://qrco.de/EIAFig9)**. Expanding carbon reduction goals at national, state, and community levels necessitates a shift toward low-carbon energy sources **(https://qrco.de/ExOrd)**. As the electric grid incorporates more renewables and reduces carbon emissions, building electrification becomes more important **(https://qrco.de/EISA)**. By replacing fossil fuel-powered equipment with electric-powered equipment, new and renovated buildings have significant opportunities to reduce emissions and realize even more savings as the grid evolves. Also, electrification can support future electric vehicle supply equipment (EVSE) initiatives as more buildings plan for and interact with EVSE at their sites. The question is not "do I electrify my buildings?" It is "which buildings should I electrify first?"

What do we mean when we say electrification?

Electrification in this context is assessing what equipment in your building currently uses fossil fuel energy, then swapping it out for new, fully electric-powered versions. This applies to base building functions such as space heating, domestic water heating, and cooking, but currently does not apply to mission critical industrial / manufacturing loads and backup generators. **(https://qrco.de/WELE)**

But how do you know which buildings to electrify first?

This document provides a framework with three quantitative key performance indicators (KPIs) for a preliminary look at whether a building is a good candidate for electrification. The three KPIs are:

- Pre- and post-retrofit energy rates
- Equipment efficiencies
- Emissions factors

Below is an overview of the steps involved in the process, including how they overlap with the KPIs. On page two, you will find additional information about each KPI. Page three provides a chart where you can insert your own values and ratios for some guided interpretation of results.

> NOTE: This fact sheet does not account for additional future emissions reductions from decarbonizing electric grids.

Pre Process Steps

Consider prioritizing buildings where:

- Equipment is aging and/or nearing planned replacement cycles
- There is planned change in function or modification (including performance contracts which may be able to be enhanced to include additional scope)
- Modification is necessary to meet organizational or portfolio goals

Overview of Process Steps

Gather information about the site that is available virtually:

See section 1.A on Energy Cost to use bill data to calculate delivered energy blended rates.
See section 1.C on Emission Factor to find the emission factors for your electric (eGrid) region, and your site burned fuel.

Consider options for new electric equipment:

See section 1.A on Energy Cost and **section 1.B** on Equipment Efficiency.
Can use rule of thumb, minimum code / Energy Star performance specifications or obtain vendor quote.

Gather on-site information, physically checking equipment:

See section 1.B on Equipment Efficiency to check equipment directly for an efficiency label or nameplate and review or prepare to examine existing electric service usage/capacity.

Ratio calculations:

Take the collected information and insert it into the table on page 3.
Compare cost and emission impacts with potential efficiency gains.

Analyze results with other factors to influence decision making:

Consider qualitative factors such as those presented in the Federal BPS.
Compare with other sites across portfolio.
(https://qrco.de/SusFed)

1.a Energy Cost Info

Compare site delivered energy cost (per unit delivered) for post-retrofit electricity to pre-retrofit fuel(s).

Get both electricity and fuel(s) blended rates into comparable units ($/MMBtu)

- Use total billed amounts as numerator.
- Convert all your total energy use into MMBtu to use as denominator. For example:
  - Your electricity bill may report delivered energy in units of kWh, which you can convert to MMBtu.
  - Your natural gas bill may report delivered energy in units of Therms, which you can convert to MMBtus.
- How to read a utility bill: Please refer to Section 3.6 Estimating Your Cost of Electricity. Calculate blended cost of your delivered commodity. **(https://qrco.de/BBSEngy)**

1 MMBtu = 1 KWh x 0.003412

1 MMBtu = 1 Therm x 10

1.c Emission Factor Info

Compare emissions factor from purchased electricity to that of stationary combustion of fuel(s).

For on-site fossil fuel consumption you can refer to the Stationary Combustion of Fuel emission factors at EIA (US Energy Information Administration) (**https://qrco.de/CO2Vol**). Make sure to normalize units to lbCO_2e/MMBtu.

For emissions from purchased electricity you can look up or contact your utility directly to see if they can provide you with a specific emission factor for the electricity you are using. If you can't find emission factors from your utility, then refer to regional averages from EPA's eGrid. Go to eGRID (**https://qrco.de/EGrid**) and insert the following choosing your specific subregion value.

Be sure that your output is in CO_2 equivalent, the analysis year is the most recent, and the source is set to "all fuels".

I want to explore Output emission rates (lb/MWh) for CO2 equivelant for all fuels at the eGRID subregion level for 2021.

lb CO_2e / MMBtu = lb CO_2e / MWh / 3.412

Additional future emissions reductions from decarbonizing electric grids are not accounted for.

1.b Equipment Efficiency Info

Pre- and post-retrofit heating equipment efficiencies can be used to make a unitless impact ratio to compare with the impact ratios from Energy Cost and Emission Factor data. In order to do so, both efficiency ratings must be based upon a measure that compares the total heat transferred to the total energy utilized. Typically, the best ratings to use for this are AFUE or thermal efficiency (E_t) for gas fired equipment **(https://qrco.de/TBoiler)** and COP for heat pumps.

Existing fossil fuel equipment

Find efficiency by:

- Referencing the equipment nameplate or online in a manual
- Look up on AHRI **(https://qrco.de/AHRIDir)**
- If unable to get site specific information:
  - Can use FEDS to help estimate a baseline performance level based on age and building **(https://qrco.de/FedPNNL)**
  - Rule of thumb would be to use 80% for most gas fired equipment, for oil can use 78%

Electric equipment

Get a vendor quote for the equipment if possible!

If you don't have a specific piece of equipment in mind you can consider options by referencing:

- Minimum efficiency level for different equipment types from:
  - Energy Star **(https://qrco.de/EnerStar)**
  - FEMP designated equipment list **(https://qrco.de/ESProc)**
- Minimum performance specifications as defined in ASHRAE 90.1 -2019 Table 6.8

If you are considering a heat pump, their performance (efficiency) is dependent upon climate specific conditions (https://qrco.de/ColdHP).

To improve accuracy:

- Request climate specific performance information directly from vendor
- Use an Energy Model (FEDS) **(https://qrco.de/FedPNNL)**
- Default to rule of thumb DOE calculated federal portfolio weighted averages for COP:
  - RTU Furnace = COP 1.76
  - Residential Heat Pump = COP 2.4

When verifying onsite equipment, one should also check the existing electrical capacity of the site for the capacity to add additional electric loads. One can check directly in drawings, documentation, or within physical equipment; or begin conversations with an electrician/engineer or the utility provider to verify existing energy utilized and capacity. This is more important for larger sites and larger electrification project scopes.

KPI Calculations and Analyze Results

The table below highlights how to use the KPIs when considering electrification of building equipment. Each section has two examples highlighting potential differences in data based on location and project details. Following the examples is a row for users to input data. Users can insert their project specific data into the appropriate cells and the results will be calculated and returned in the final cell of that row for reference.

	Old Fossil Fuel Equipment	New Electric Equipment	Impact Ratio / Indicator
Cost of Energy, Based on Region ($)	$/Therm converted to $/MMBtu	$/kWh converted to $/MMBtu	New / Old = Result
Ex: National average (EIA Annual Energy Outlook 2023, Commercial)	Natural gas = $10.99/MMBtu	Electricity = $36.67/MMBtu	36.67 / 10.99 = 3.34
Real life ex: Federal site in PA	*Natural gas = $9.15/MMBtu*	*Electricity = $18.1712/MMBtu*	*18.1712 / 9.15 = 1.99*
USER Value Inputs	1.00	1.00	**1.00**
Efficiency Rating of Equipment	Convert % eff rating to decimal equivalent	Input heating COP values directly or convert % eff rating to decimal equivalent	New / Old = Result
Ex: Forced draft natural gas furnace converted to electric resistance	84% Combustion efficiency *(84% = input 0.84)*	99% Thermal efficiency *(80% = input 0.8)*	0.99 / 0.84 = 1.18
Used for ex: Minimum performance residential furnace converted to heat pump	*80% Et gas furnace (99% = input 0.99)*	*COP 2.4 Heat pump furnace*	*2.4 / 0.8 = 3.0*
USER Value Inputs	1.00	1.00	**1.00**
Emission Factor for Fuel, based on Region	Find national average from EIA	Use local factor or lookup eGrid electricity emission factors:	New / Old = Result
Ex: Stationary combustion of natural gas emission factor (EIA):	Natural gas = 117 lb CO_2e/MMBtu	National average = 251.2 lb CO_2e /MMBtu	251.2 / 117 = 2.15
Real life ex: Stationary combustion of natural gas emission factor (EIA):	*Natural gas = 117 lb CO_2e/MMBtu*	*Federal site in PA area, RFCE: 198.1 lb CO_2e /MMBtu*	*198.1 / 117 = 1.69*
USER Value Inputs	1.00	1.00	**1.00**

Hide Numbers

How to interpret the ratios and additional information

Efficiency improvements can lead to decreases in both operational cost and emissions. For instance, at the example Federal site in PA above, the furnace to heat pump efficiency impact ratio **(3.0) is greater than the cost impact ratio (1.99)** so the project would be likely to have operational cost savings. Similarly, at the example Federal site in PA above, when the impact ratio from efficiency **(3.0) is greater than the emission factor impact ratio—which for natural gas conversion would be 1.69**, resulting from 198.1 lb CO_2e (from purchased electricity)/117 lb CO_2e (from natural gas)—it is likely that CO_2e savings will be achieved.

Note: *Future electric grid decarbonization is not accounted for in this simplified indicator calculation but is expected and would improve emissions impacts over the lifetime of the equipment.*

With this information and along with other factors, YOU can decide which buildings are the most appropriate to prioritize for electrification.

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For more information, visit:
energy.gov/femp

PNNL-SA-193398 · FEBRUARY 2024