WHITE PAPER

THE IMPACT OF ELECTRIFICATION ON BUILT ASSETS

New laws, regulations and codes are encouraging the use of mechanical systems that reduce Greenhouse Gases. RSP's *Brandon Burrows* assesses the benefits and practicalities of switching to all-electric boilers.

With new laws and building codes comes a move to re-think conventional practices, especially when carbon emissions are involved. Over the last five years, many cities and state legislatures across the country have implemented regulations to encourage clean energy programs hoping to hit specific targets by a certain date. Additionally, the recently enacted Inflation Reduction Act includes rebates and tax credits for energy-efficient systems that help reduce Greenhouse Gases (GHGs).

In December 2023, the Massachusetts Department of Public Utilities (DPU) passed a ruling aimed at encouraging the use of electricity for heating and other purposes, including a pilot program in up to ten communities to implement fossil fuel-free requirements. In Maryland, the state's General Assembly passed the Climate Solutions Now Act that sets the admirable goals of cutting greenhouse gas emissions 60% from 2006 levels by 2031, achieving 100% clean energy by 2035 and reaching net zero emissions by 2045. While these are just two examples, many other states are considering—if not on track to—implementing these kinds of changes to their building codes.

While this is good news for the environment, the transition from natural gas to an all-electric solution is much more complex than simple equipment replacements. Even recently installed mechanical and electrical systems typically need major modifications or total replacement to support these new systems, and those initial capital outlays can be prohibitive. In addition to higher installation costs, there are utility costs to be considered, which are driven by volatile market forces.

Still, all-electric systems provide many benefits: These systems have higher efficiencies than conventional natural gas systems. The rebates and tax credits help to mitigate those high initial costs. And, of course, the long-term benefits of reducing Greenhouse Gases.

ABOUT RSP

Founded in Minneapolis in 1978, RSP Architects has emerged as one of the country's most trusted, diverse and agile architecture practices.

The firm's clients are a dynamic cross-section of Fortune 100 global brands and retailers, innovative start-ups, thoughtful non-profits, government agencies, and more.

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CASE STUDY

To better understand the impacts of full electrification, we analyzed an existing 516,000-SF, 68-acre campus located just outside Baltimore, Maryland. A 29-year-old natural gas boiler plant provides hot water, low-temp domestic hot water, and high-temp kitchen domestic hot water to the entire campus.

Our study examines the impacts of retrofitting four existing natural gas boilers with four new electric boilers. We used Carrier's Hourly Analysis Program (HAP) and ASHRAE weather data for the Baltimore region to model energy usage of the campus. The study was performed over the entire useful life of the boiler—25 years. While boilers can last beyond 25 years, they begin to lose efficiency and tend to require more repairs.

DESIGN IMPACTS

We began the study with an assessment of the campus' electrical infrastructure. Depending on the power requirements of the new equipment, an upgrade to the electrical service may be required to support the load. If the campus has the electrical capacity, new circuit breakers, disconnects, and conduit (at a minimum) would need to be installed for the equipment. Additionally, to support an all-electric system, the existing mechanical infrastructure would likely need modification to suit the new equipment requirements.

The type of electric boiler should also be investigated. For any electric boiler over 250 kW, an industrial boiler would be best suited over a commercial boiler. For new construction projects, these costs would be "baked into" the math of the project or, at least, offset as the building could be designed around these changes.

From the campus evaluation, it was determined that all the existing natural gas piping would need to be removed from the system. Vent piping would become unnecessary and need to be removed as the electric boilers do not need to be vented. In addition, boiler controls may need to be updated to support the equipment.

Another difference in the design of an electric boiler versus a natural gas boiler is the need for carbon monoxide detectors and emergency fuel shutoffs. Because an electric boiler does not require any fuel for operation, there are no risks of a carbon monoxide leak. There is also no need for an emergency shutoff for the boilers as there are no gas lines to be shut off.

A key benefit of electric boilers is their higher efficiencies when compared to natural gas boilers. Electric boilers tend to have a Coefficient of Performance (COP) of 0.99, higher than that of a natural gas boiler, which tends to have a COP of around 0.83. Electric boilers can also help with the lowering of a buildings energy usage intensity (EUI). This reduction in EUI can help with acquiring LEED certification in new construction or Energy Star certification in a retrofit project.

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Another thing to consider is the sound output and footprint of these systems. Gas boilers tend to have a larger footprint and produce more sound when compared to electric. This can limit where the system can be located on site. With electric boilers tending to smaller and quieter, there is more flexibility in where they can be located.

TABLE 1
Comparison of Electric and Natural Gas Utility Costs

Unit	$ / Unit	Conv to MMBtu	$ / MMBtu
Therm	$0.93	10	$9.30
kWh	$0.0749	293	$21.95

Figures based on 2024 BG&E gas and electric rates.

COST IMPACTS

When assessing costs, it is important to understand the difference between initial or upfront cost versus life-cycle costs, which cover expenses over a period of time. For our case study, it was determined that electric boilers tend to be the more cost-effective choice being around 30% cheaper. As of this writing, there is also a higher utility cost associated with these installations; electric brings a higher cost per unit of energy than natural gas. As seen in *Table 1* above, and based on the current 2024 Baltimore utility rates, the cost per MMBtu of electric is around 2.4x more expensive than natural gas.

As seen in *Table 2*, the utility costs for an all-electric plant are nearly double that of the natural gas plant. There are methods in which to reduce some of these additional costs to lessen the financial burden of implementing an all-electric system.

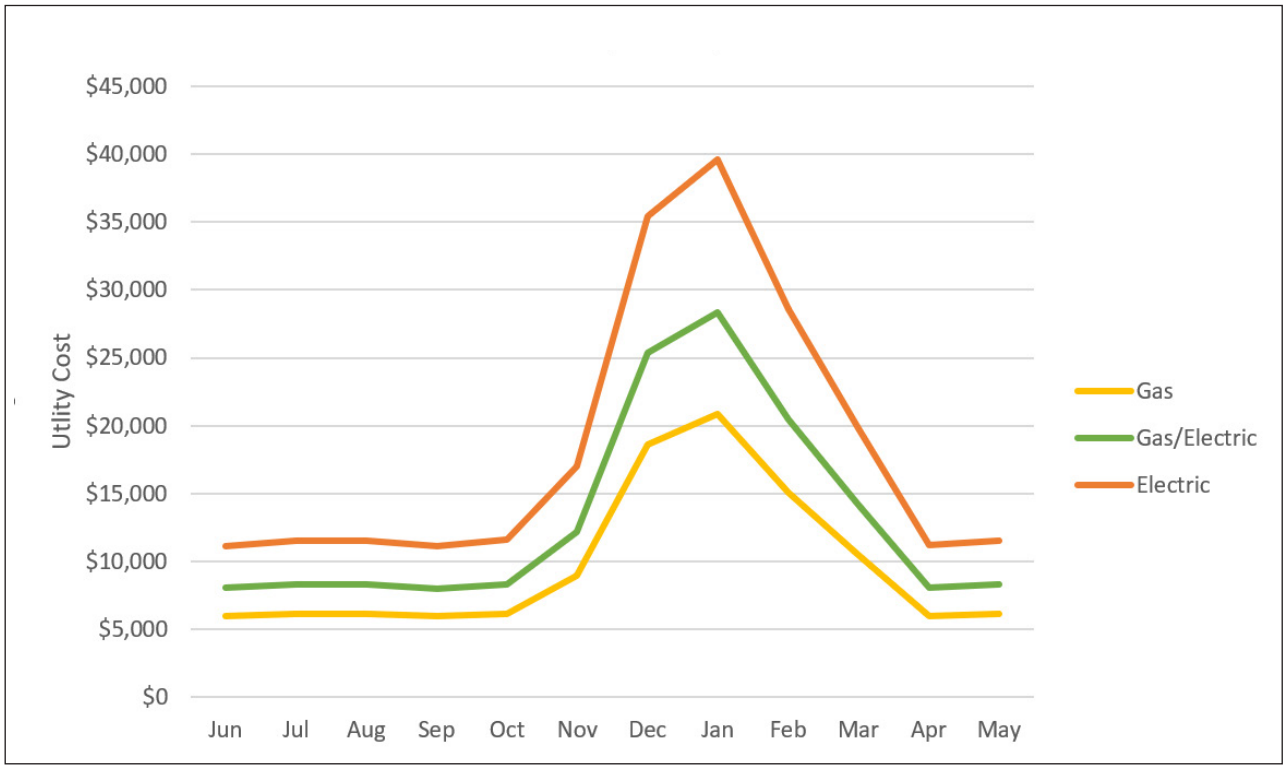
While the electric boiler is a more cost-effective design, over the lifetime of the boiler they tend to be more expensive. Over 25 years, the total cost of the electric boiler design is around 12% higher than the gas boiler design. Unlike a few other states, Maryland offers no rebates for these kinds of installations. While this is the case in the Baltimore area, in other areas in the United States the total cost can be less. If the cost of natural gas was to rise above $1.14/Therm, the cost of an electric boiler design would be the cheaper alternative. Even if the cost of electricity was lowered to $0.065 kWh, the all-electric design was also cheaper.

Adding solar infrastructure helps to offset some of the higher electrical load associated with these systems and utilizing any rebates offered for the implementation of these systems can help with some of the upfront costs.

Additionally, because all-electric systems have a simpler design, the average costs of annual maintenance will go down. The U.S. Energy Information Administration (EIA) estimates that the average annual maintenance cost of a natural

Table 2

Monthly Heating Utility Costs of a Boiler Plant



Calculation based on $0.0749 / kWh and $0.93 / Therm

gas boiler is about 16.2 times higher than electric boilers.

ENVIRONMENTAL IMPACTS

The main driving factor for total electrification is to reduce carbon emissions from natural gas systems.

According to the DOE, a boiler plant accounting for an average of 28% of a facility's energy usage, converting the boilers to all electric provides significant emission savings. These products produce GHG emissions such as carbon dioxide (CO_2) and methane (CH_4). In addition to GHG, gas boilers also emit nitrogen oxides (NOx), carbon monoxide (CO), and nitrous oxide (N2O).

In *Table 3* on the following page, we have broken down the types of emissions and measured them over the life of the boiler. Methane in particular is an extremely volatile emission. Over a 20-year period, methane is about 80 times more potent than carbon dioxide. Carbon monoxide not only is a hazard to the environment but also has negative impacts on health. Carbon monoxide can lead to headaches, nausea, and, in the case of constant exposure, death.

In our case study, switching to an all-electric system would save around 708 tons of CO_2 equivalent emissions, which is comparable to the carbon output of 153 cars over the course of one year.

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Over the lifetime of the boiler, this equates to 17,700 tons of CO_2 equivalent emissions, which is comparable to the amount of carbon sequestered by 18,747 acres of U.S. forests over the course of one year.

Table 3

Carbon emissions over boiler lifetime

Emission	Tons/Lifetime
Carbon Monoxide	12.25
Carbon Dioxide	17,561.50
Methane	0.25
Nitrous Dioxide	0.25
Ammonia	0.50
Nitrogen Oxides	14.50
Particulate Matter	1.00
PM10	1.00
PM2.5	1.00
Sulfur Dioxide	0.10
Volatile Organic Matter	0.75

These savings are beneficial to the environment and, when done on a mass scale, can help protect the environment for years to come.

CONCLUSION

There are many factors to consider when switching to an all-electric system, including the higher upfront and long-term costs of the system. While there are ways to mitigate these costs, such as rebate programs, tax credits and/or adding solar infrastructure to offset the increase in electrical consumption, many property owners are reluctant to make the switch. Over the long term, though, the benefits—lower carbon emissions and alignment with new legislation—may outweigh the challenges.

As dated systems approach the end of their practical life-cycles, and for new construction or major renovations, switching to all-electric solutions may not just be an environmentally sound path to take, it may be the only path to take.

ABOUT THE AUTHOR

Brandon Burrows *is a mechanical designer at RSP Architects and a recent graduate of the University of Delaware with a B.S. in mechanical engineering. He has designed the mechanical systems on a variety of project types, focusing on complex data centers and investment-grade energy audits. With an eye for detail, Brandon analyzes HVAC system performance to provide solutions that consider both cost to ownership and operational efficiencies.*