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The Financial Impact of Refrigerant Leaks

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Ever Wondered What Impact Refrigerant Leaks Have on the Bottom Line?

Do you know the economic impact of refrigerant leaks and the significant effect they have on the bottom line?

Find out in this synthesis report, where we will look at the importance of containing refrigerant, adhering to refrigerant regulations, and following maintenance best practices, so that stakeholders can ensure peak HVAC/R equipment performance at minimum total cost of ownership.

It needs to be said: In our experience, the default option for most stakeholders is to wrongly invest maintenance costs in repairing refrigerant leaks, as opposed to preventing them. In other words, this is reactive maintenance, not proactive. But this kind of behavior towards HVAC/R assets just "kicks the can down the road" and the problems that later result can take many end-users by surprise.

Thus, using the Institute of Refrigeration's research paper **"Refrigerant Loss, System Efficiency and Reliability - A Global Perspective"** by David Bostock as the foundation of our argument, we seek to ultimately show the **great savings that end-users can achieve when maintenance truly shifts focus from repair to prevention.**

5 Key Areas Impacted By Refrigerant Leaks

Of course, energy consumption is a significant cost factor when evaluating the impact that result from leaks. But, it is not the only performance impact. In fact, leaks directly impact **5 key performance indicators:**

Material Needs

Maintenance Activities

Equipment Life Cycles

Energy Cost

Environment

So far, however, regulations from federal, state, and local jurisdictions have mostly driven the awareness on the impact of refrigerant leaks. Therefore, owners and operators have a legal responsibility to monitor and adhere to these varied, multi-level refrigerant regulations.

Moreover, since these refrigerant regulations are not harmonized with one another, they also drive confusion and challenge engagement, which further perpetuates the lack of awareness of the 5 key performance indicators. Therefore, it's little wonder why stakeholders forget about their financial responsibility to properly manage refrigerant leaks.

HVAC/R Accounts for Significant Building Energy Spend

HVAC/R systems occupy more than 30% of average commercial building's energy spend and that number varies based on property types and applications (U.S. EPA 2016). In fact, the top five building types with the highest energy use intensity (EUI) include (naturally, HVAC/R is higher for these groups):

1. **Data Centers**	**1,800 / Kw / Sq. Ft.**
2. **Convenience Stores**	**560 / Kw / Sq. Ft.**
3. **Grocery Stores**	**480 / Kw / Sq. Ft.**
4. **Colleges and Universities**	**262 / Kw / Sq. Ft.**
5. **Hospital**	**389 / Kw / Sq. Ft.**

A traditional office space has an EUI of 140, providing indication of the significance of the energy needed to operate these types of locations.

The fact is, energy prices are increasing, and, today, more than 30 building energy benchmarking reporting programs with varying levels of compliance requirements and thresholds have been created in markets from California to Alabama. Some of these markets have even instituted a cap on energy consumption at the building level and forced a dialogue between multi-level stakeholders, including building owners, managers, and tenants, in order to control consumption that impacts carbon emissions.

Finally, as previously introduced, HVAC/R systems have a significant impact on energy, and this synthesis, which uses Bostock 2013 as the foundation of our argument, seeks to show the financial impact that a refrigerant leak can cause to the bottom line.

Refrigerant Management—Terms Defined

Bostock 2013 provides numerous important definitions that pertain to refrigerant management. Let's look to a few of these to further our understanding of terminology that surrounds refrigerant leaks and management:

“Refrigerant containment is the prevention or minimization of a refrigerant fluid leaking to the atmosphere.”

Is Zero Leakage Possible? ‘A leak is defined as: **'A leak is a hole or porosity in an enclosure capable of passing a fluid from the higher pressure side to the lower pressure side.’** A leak may be the tail-end of a weld fracture, a speck of dirt on a gasket or microgroove between fittings. **All sealed systems leak**" (Bostock 2).

Consider the definition of *refrigerant containment* in this context: In 1994, the U.S. consumed an estimated 125 million pounds of refrigerant and had an installed base of roughly 500 million pounds. There has been a 400% growth in HVAC/R systems since the mid 1990s, and, with more than 2 billion pounds of HVAC/R systems installed in the United States, the present demand for refrigerants has skyrocketed to 540 million pounds yearly.

These statistics suggest that gross refrigerant leaks that exceed the legal leakage rate limit have continued in hundreds of thousands of HVAC/R equipment over the past two decades.

In Bostock 2013, an **acceptable leakage rate** is described,

"A sealed system which operates for its useful life (say 20 years) without ever needing additional refrigerant to be added, in order to keep it running within normal operating parameters is considered to be leak tight'. That means that it has not leaked enough refrigerant to effect system performance (typically less than 10% of original charge, although some studies show that this may be as high as 20% before performance loss can be detected). Below this 10% lifetime benchmark the system leaks are not practically measurable - and it is deemed a "leak tight" system" (Bostock 2013).

The U.S. refrigerant management program, found at 40 CFR Part 82 Subpart F, sets the **allowable refrigerant leak rate by appliance type.**

Appliance Type	Allowable leak rate 2019 - Federal	Allowable leak rate California	Allowable leak rate, Washington
Industrial Refrigeration	30%	0%	24%
Refrigeration	20%	0%	16%
Comfort Cooling	10%	0%	8%

If a system surpasses the maximum allowable leak rate, one must follow the leak repair requirements (e.g., leak inspection, initial verification test, follow-up verification test, etc) according to 40 CFR Part 82 Subart F. Interestingly, California has a 0% allowable leak rate, or what Bostock 2013 calls a "zero tolerance of leaks" (Bostock 2).

Exposed: The Real Cost of Refrigerant Leaks

Now that the most important refrigerant management terms have been defined and the legal leak rate limits have been introduced, let's turn to true financial cost of refrigerant leaks.

Using Bostock 2013 as guide, Figure 1 shows the consequences of a refrigerant leak that stakeholders must consider. This report analyses four main areas: 1) Material Costs, 2) Energy, 3) Maintenance and 4) Equipment Life.

This study is a synthesis of results extracted from Kim 2010. In order to remain consistent, the data was used to extrapolate results and then test against the model to certify results. The Kim study used 6 systems identified in Figure 2 with varying charge types, air flow, capacity, and features.

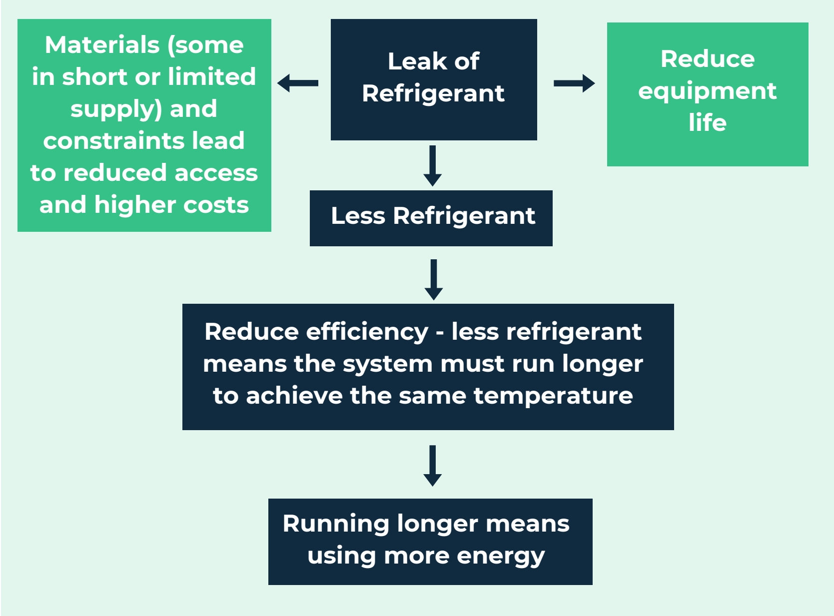
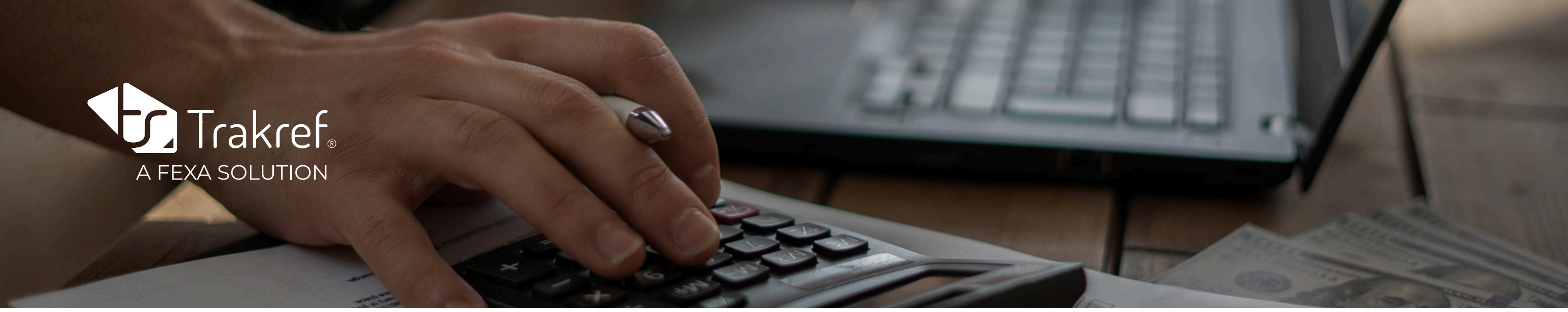


Figure 1. Consequences of a refrigerant leak

System Size	Size	Refrigerant Type	Expansion Device	Accumulator	Assembly Type	Air Flow	Charge Level
System 1	4 ton	R-22	EEV	50 ounces	split	Nominal	80-100%
System 2	4 ton	R-22	FXO	no	split	Nominal	60-110%
System 3	4 ton	R-22	FXO	no	split	Nominal	60-100%
System 4	4 ton	R-22	FXO	33 ounces	split	Nominal	80-100%
System 5	3 ton	R-22	TXV	yes	split	800 CFM	70-130%
System 6	3 ton	R-410	TXV/FXO	yes	split	1000 CFM	40-130%

Figure 2. Kim 2010.



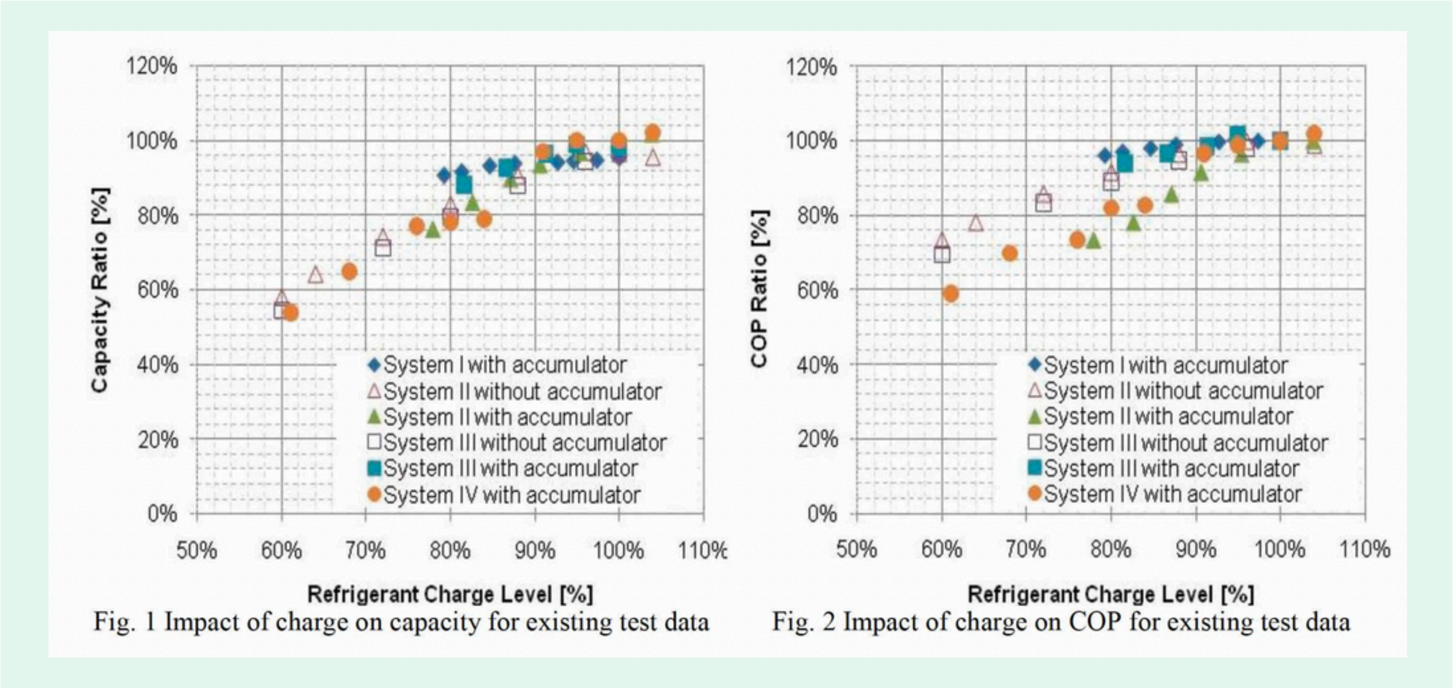


Figure 3. Impact to Efficiency (Kim 2010).

Figure 4 is an aggregate of the impact from a refrigerant leak and provides a scope for the discussion presented in the sections below. Keep in mind that the intention of the report is to assist in the process of converting various reports and measurements into a financial formula that users can rely in order to predict costs and identify opportunities for savings.

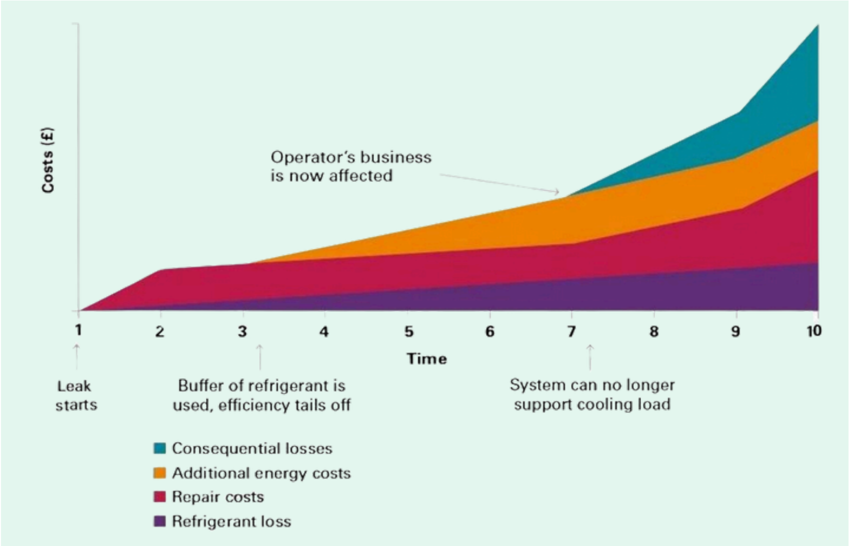


Figure 4. Carbon Trust.

Increased Energy Spend

Bostock 2013 describes the increased energy costs during the period of a leak. He explains, "This factor is very difficult to assess as there are a large number of variables to consider. If the system has a receiver installed (buffer of refrigerant charge), then of course the system could leak up to 30% (or more) of its initial charge before there is any measurable impact onsystem cooling capacity or efficiency. The relationship between the loss of performance (capacity and efficiency) is very difficult to predict but, in results derived from experimental measurements taken by [Kim 2010], [it shows] that when the effective refrigerant charge is reduced to 85% of the correct amount, then annual running costs are increased by 10%. This annual running cost penalty increases in a non-linear manner so that at 60% correct charge, the running cost penalty is 45% .

Take the case that a typical system costs £60,00 [$80,000] 0 per year in electricity costs to run, then if the system charge is reduced to 80% (20% annual leakage rates still being typical in some applications), the operator incur a 15% annual running cost penalty" (Bostock 2013).

See Figure 5 (right) - Relationship between annual running costs and refrigerant leakage for small air-conditioning and commercial system

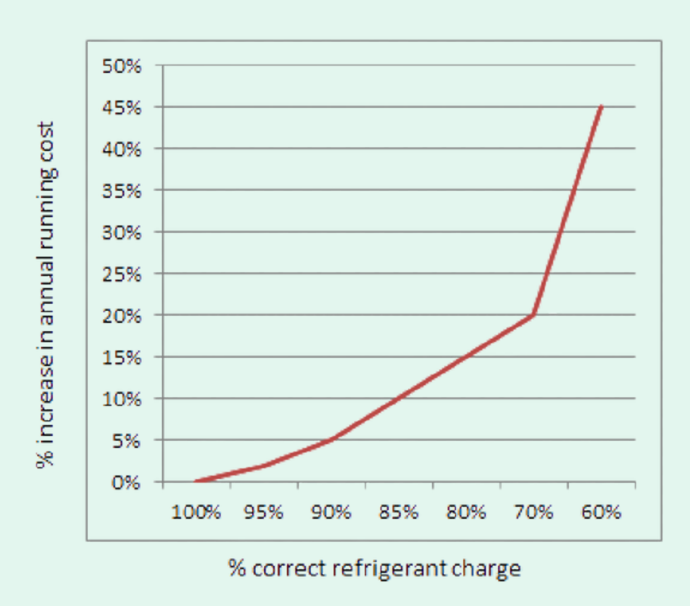


Figure 5. Bostock 2013.

Life Cycle Costing

Approximately $400 / unit or $2400, assuming a 10 year system (10% reduction in life expectancy for the unit or for any part), with an expected lifetime of 20 years and a present market value of $8000 each.

Bostock 2013 explains that, when taking into the life cycle cost of refrigerant leaks, "We need to focus on the long-term issues - the Total Cost of Ownership (TCO), rather than the short-term capital costs." He also provides a figure of the life cycle costs (i.e., Figure 6 in this synthesis report).

Bostock 2013 describes this figure, in which he says it " shows a typical split between the 3 major elements of TCO ... In most applications the cost of the energy to run the refrigeration system can be up to 90% of the TCO. It is clear long-term benefit to invest upfront in more efficient, higher quality (leak tight), easy to maintain systems, with planned preventative maintenance programs in order to reduce TCO and the Lifetime CO2 emissions of the system."

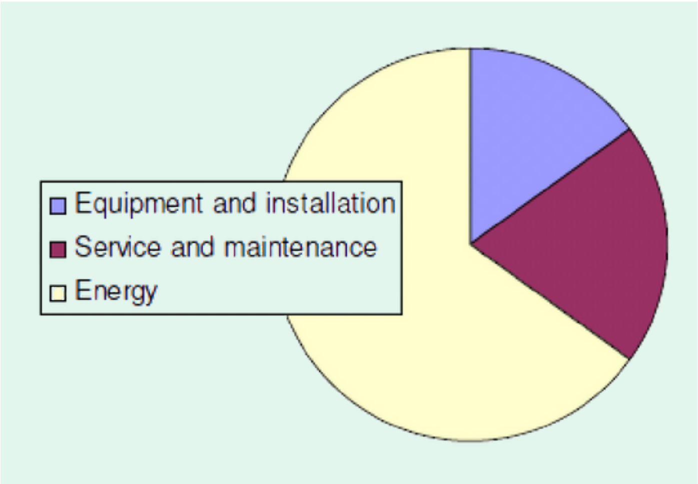


Figure 6. Bostock 2013.

Reduced Life of Equipment

Furthermore, if the charge of the system reduces to less than 80% of capacity, then the unit will cycle more frequently because there is not enough refrigerant to pull across the compressor. When this happens, the unit will cycle on and off, and it is these on/off cycles that will degrade the life cycle faster than either heat from reduced cooling or ambient temperature changes.

The charge decreases by an amount equal to the annual slow leak rate based on the nominal charge for every year. If charge is 20 lbs and leakage rate is 5%, then, after the first year the charge is 19, and, after the second year, it is 18, and so on and so forth, until service is performed (at that point charge is restored to 20 lbs). This is repeated over the lifetime of the system. 10% extra cycle time will directly correlated to a reduction in life of a system by 10%.

Interestingly. Bostock 2013 goes on to explore "the impact of leakage on the overall lifetime of C02 emissions" and provides a figure on it (see below, as we have included his figure):

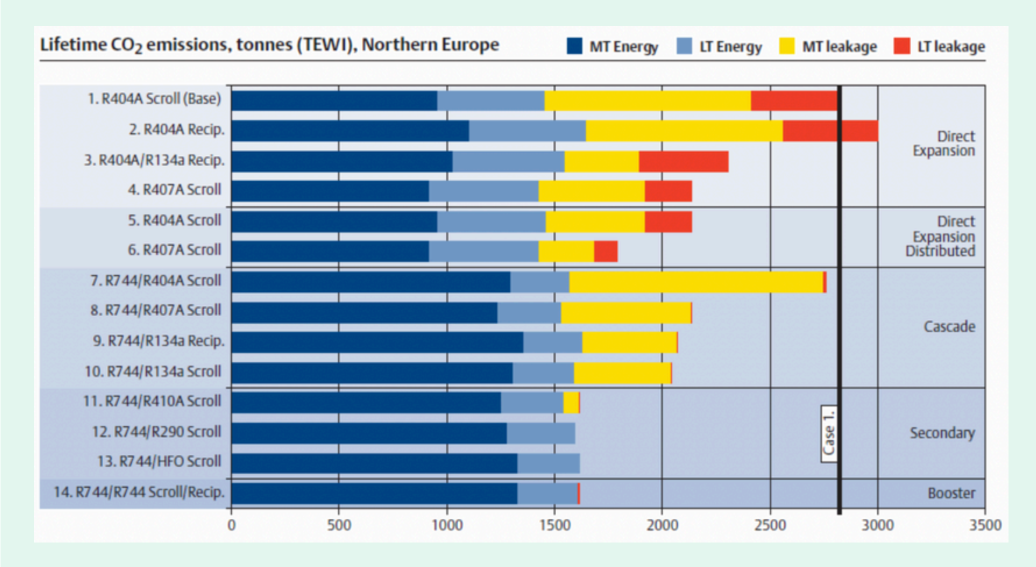


Figure 7. Bostock 2013.

Bostock states that the figure assumes “an annual leakage rate of 10-15% dependent on the system type.”

Increased Maintenance Cost

Additionally, there is the cost of the repair. The Carbon Trust uses a typical cost for the labor time to repair a leak as $910, and Bostock 2013 elaborates further upon this cost.

He explains, "Using the Carbon Trust typical repair cost of [$910, the operator could better invest this cost to preventative leak detection (and repair on the same day); and could then visit twice per year (cost [$1820], 2 total) and limit the annual leakage rate to 5%, and therefore save [$4,420]" (Bostock 2013). (Euros were converted to dollars.) The savings could be used for refrigerant tracking hardware and software to monitor service that would expose the leak(s) and allow management to guide staff to make the repair.

Keep in mind that the most cost effective means to monitor refrigerant leaks is to use a system of software that will both project the leak and notify stakeholders about the use of the refrigerant and the needed follow-up service. And while the data that exposes a refrigerant leak and its impact is likely documented on the invoice and/or on the panel of the AC or the refrigeration unit, this data is not accessible to proper decision makers or staff. Additional maintenance would be eliminated since the leak will have been resolved before the service event can be closed.

Furthermore, stakeholders must consider the impact of a refrigerant leak on equipment life cycle.

Refrigerant Management:
A Multi-Faceted Responsibility

In sum, HVAC/R systems play a significant role in keeping people comfortable, upholding food safety, and producing a variety of vital products. The world has seen a massive amount of growth since the initiation of the Montreal Protocol. In fact, more than 500% growth in the U.S. alone, and global growth is much larger. But science has exposed the risk that leaking refrigerant has on the environment, and this has thereby brought attention to the impact these chemicals can have on our environment and our quality of life.

However, as shown, **the most significant impact that refrigerant leaks have is on our financial health.** That's why, in this document, we have synthesized data from refrigeration experts around the world to record the cost impacts that result from a combination of poor maintenance and a lack of awareness of multi-servicer work activities.

System Size	Size	Refrigerant Type	20% Lost Refrigerant	Price per ton
System 1	4 ton	R-22	$240.00	$60.00
System 2	4 ton	R-22	$240.00	$60.00
System 3	4 ton	R-22	$240.00	$60.00
System 4	4 ton	R-22	$240.00	$60.00
System 5	3 ton	R-22	$180.00	$60.00
System 6	3 ton	R-410	$81.00	$27.00

Ultimately, refrigerant leaks impact 5 key performance indicators: **1) Material Needs; 2) Maintenance Activities; 3) Equipment Life Cycles; 4) Energy Costs; and 5) Environment.**

As awareness grows, so do regulations that limit flexibility in the handling of these gases. Of course, regulators typically focus singularly on the environmental impact (e.g., to curb carbon emissions, reduce the need for power, and/or slow the impact to the environment, etc). However, in this document, the concern, again, is with the financial impacts and exposing it in order to convert kw, labor, materials, and equipment life into ($) dollars and cents.

Cost Center	Cost related to leaking systems
Energy	$6,200.00
Maintenance	$910.00
Life Cycle	$2,400.00
Materials	$1,220.00
Total	$10,730.00

The Bottom Line: Total Cost to a 20% leak from 6 small systems

To close, consider this: The leaks from 6 small systems can impact an operation in a significant way, exposing system owners to more risk and, if not well understood, a decreased ability to control costs. As you can see, it is of the utmost importance to take these results in this paper, see how it relates to your own operations, and then make sure to apply HVAC/R best practices to reduce refrigerant leaks. Once this is accomplished, one can shift maintenance budgets from reactive to proactive, so that less time is spent on repairs and more on prevention.

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