Total Cost of Ownership: Move to Just-in-Time Replacement

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Executive Summary

Effective equipment replacement and selection is more important now than ever to managing total cost of ownership (TCO). Stricter building codes and environmental regulations as well as new and improved high efficiency equipment offerings are adding complexity and increasing pressure to make informed decisions.

Most organizations that operate multiple facilities struggle with the decision of when to replace key equipment. The lack of all relevant data and the time to do a full analysis often lead to a decision to delay replacement as long as possible. **Most organizations are unaware this approach, sometimes referred to as "run-to-fail", increases the total cost of ownership for some equipment types by 10-20%, which may amount to $200,000 or more a year in lost value for an operator of 50 locations.**

Accurate measurement and analysis of the major components of Total Cost of Ownership (TCO) – equipment, installation, energy, and maintenance – provides the foundation to confidently identify and plan equipment replacement that delivers the best return on investment. New technologies enable organizations to capture the data and perform the analyses needed to perform effective replacement planning – and avoid the potentially substantial costs of a run to fail approach.

Introduction

Managing a large fleet of mission critical equipment, often spread across many states and dozens or hundreds of locations, is a challenging task. The need to support high uptime and superior customer experience is balanced against the "death by a thousand cuts" that can come from making financial decisions about repairs or replacement in an uncoordinated way. The end result is a frustrated Operations team, an exhausted Facilities team, and a Financial team who feels they have no effective way to understand and solve the problem. This is a "run to fail" asset management strategy in which all parties toss up their hands and decide that putting off equipment replacement as long as possible is the "least bad" option – if not actually the best one.

However, the run-to-fail model has been demonstrated to actually squander financial resources, as well as risk brand and customer loyalty. How can an organizations realistically do better? Consider Total Cost of Ownership; however, *this methodology has not been widely adopted*. Why is that? Factors include lack of data, lack of appreciation for just how significant operating costs are, and lack of tools to perform this type of analysis, particularly at scale.

An array of technologies is becoming available to address this situation – including mobile asset inspection tools, computerized maintenance management systems (CMMS), energy management systems that capture energy costs of specific equipment, and even connected equipment streaming performance data to the cloud, along with user friendly enterprise decision support tools.

These tools help facilities and operations executives make smart asset management decisions – including both when to replace equipment and with what – in the face of new regulatory standards and building codes that require the selection of more advanced and usually higher efficiency equipment.

For operators seeking to achieve industry leading performance, the financial and operational benefits of better asset management include reduced equipment operating costs, better employee productivity, and better customer experience. This whitepaper explores the way operators can move beyond the run-to-fail model, using new technologies to unlock this value.

A Brief History of TCO and Life Cycle Cost as Decision Tools

The concept of total cost of ownership was first used by information technology research firm the Gartner Group in the late 1980s to ensure all costs of buying and using enterprise software (as opposed to only the "sticker price" of the initial purchase) were captured in making purchase decisions. As far back as the 1960s, the related concept of Life Cycle Cost (LCC) had been established by the US Department of Defense. A fascinating paper from 1977 (here) provides context on the emergence of LCC.

Benefits of Life-Cycle Costing

The principle underlying life-cycle costing is a simple one: determine not only the acquisition costs but also the costs involved in operating and maintaining the system during its lifetime before deciding whether or not to acquire the system.

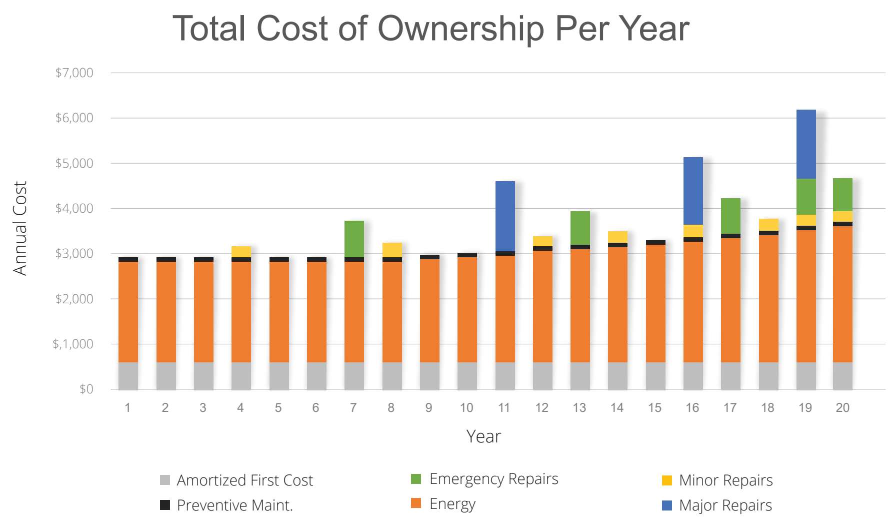
This being so, one might ask why this valuable decision-making tool was not employed to any great extent until fairly recently. The answer probably lies in the fact that in many cases, it is only when a detailed cost analysis is performed that one becomes aware of the magnitude of the nonacquisition costs relative to first costs, as well as the extent of the variability of these costs among the possible alternative systems. Thus, the importance of determining all costs is very often not evident until one performs the analysis, while at the same time there is no apparent reason to perform the analysis until the importance of the results is realized. It was not until this vicious circle was finally broken that the idea of life-cycle costing came into its own.

Insights from TCO: Rooftop HVAC Units

One of the most common types of equipment at small commercial facilities is the rooftop HVAC unit (RTU), and it is one of the most likely to be managed under the run-to-fail / reactive replacement approach. So, what is the total cost of ownership for this type of equipment? ASHRAE suggest the useful life of RTUs is 15 years (see here), although it is very common for assets to remain in service past the end of their useful life. A TCO calculation reveals how costly this might be.

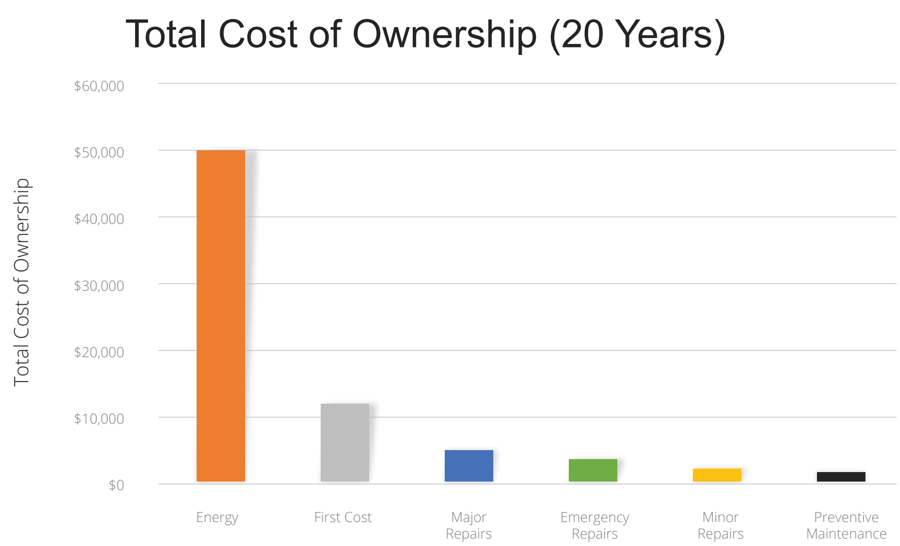
See Figure 1 for an illustration of how costs stack up over a 20 year period for a 10-ton electric cool/gas heat RTU that cools for 1,800 hours a year. Heating costs are assumed to be 25% of cooling costs due to the relative efficiency of creating heat with natural gas. This illustration is based on industry sources and data we have collected. Other assumptions include an electricity rate of $.10/kWh, annual preventive maintenance cost of $50, a minor repair cost of $250 per incident, major repair cost of $1,500 per incident, and emergency repair cost of $750 per incident. Energy costs and the frequency of repairs have been shown to escalate over time. Initial installed cost of the unit was assumed to be $1,200/ton of cooling capacity.

Figure 1



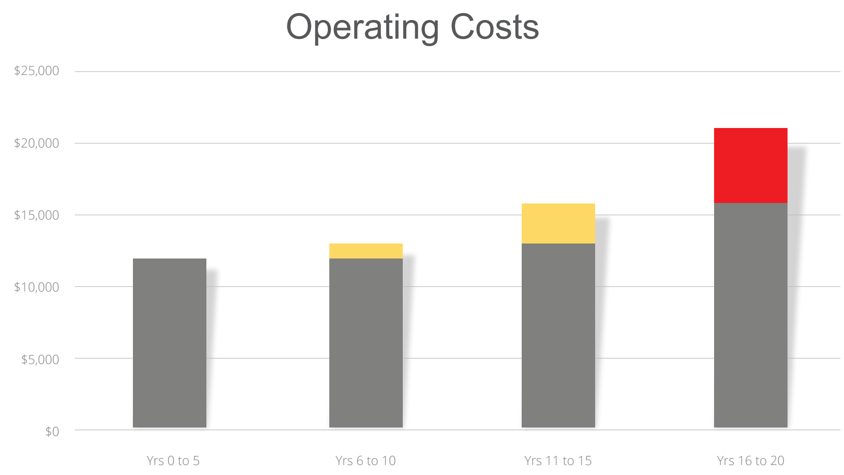
Compiling the total cost of ownership is revealing. For facility managers or finance staff who have ignored the impact of equipment energy usage on costs – which is the majority of them - Figure 2 should be eye opening. For starters, **over a 20 year period energy comprises about 70% of the total cost of ownership.** The amortized first cost represents roughly 15% and the remaining 15% is repair and maintenance.

Fig 2



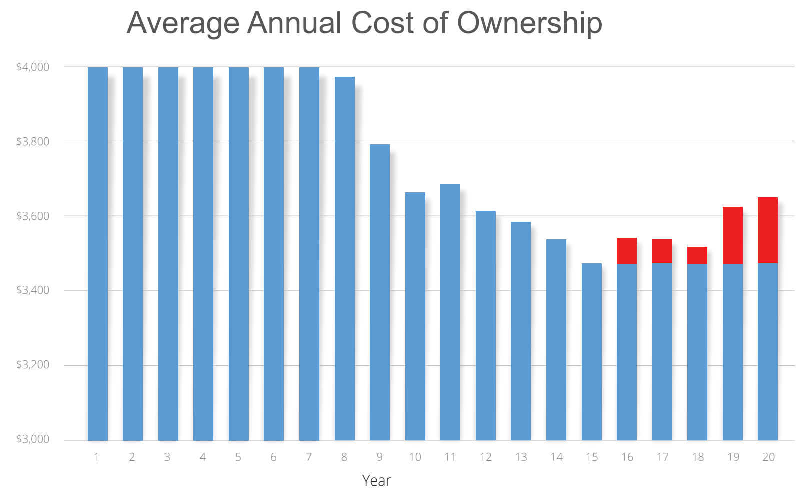
Another insight from this example is the distribution of costs across the years. In particular, the cost of ownership in the five years after the end of the expected useful life rises dramatically, as shown in Figure 3. Extending past the useful life (years 16-20) means owning and operating the asset during the most expensive period of the life cycle, estimated here $5,000 in additional costs for the 5 year period.

Fig 3



Another way to look at TCO is to consider the optimal number of years of ownership. See Figure 4 for the average annual TCO for different durations of ownership. For example, if this equipment were replaced after 9 years, the average total cost of ownership would have been $3,800 per year, or $34,200 in total. This cost is calculated as all operating costs for 9 years plus the initial hardware and installation costs divided by 9 years. Since this calculation includes the amortization of the initial equipment and installation cost, the cost per year may be expected to decrease as the period of ownership gets longer. However, this **cost starts to rise again as the cost of extending the useful life of the equipment grows.** In this illustration the optimal period of ownership is shown to be 15 years; this results in the smallest average annual cost of ownership.

Fig 4



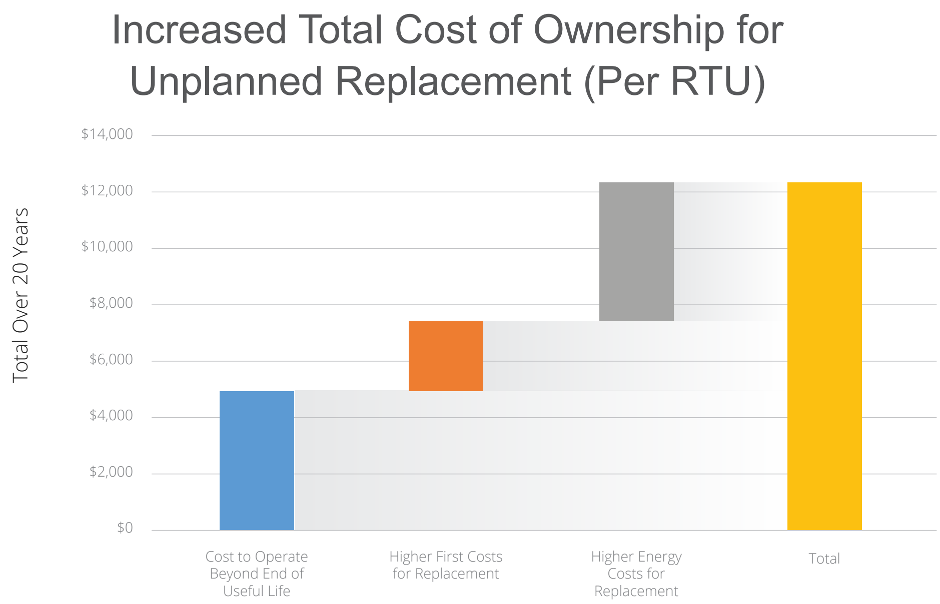
The decision to delay equipment replacement has other costs. Reactive replacement usually happens during the peak heating or cooling season. If the equipment has failed, it often needs to be replaced as fast as possible, whatever the cost. The total costs of replacement fall into two buckets:

1. **Replacement Costs.** With planned replacement, equipment can be replaced during low demand periods. This allows time to get multiple bids, both for the equipment itself and the installation – which is often less expensive during non-peak months. Planned replacement may also allow for volume discounts. Assuming the added cost is 20%, another $2,500 has been added to the TCO for the new equipment. There may also not be time to research and procure utility or other incentives for efficient equipment, potentially pushing meaningful savings off the table.

2. **Operating Costs.** Selecting the best replacement equipment is impossible when the situation is perceived as an emergency and there is pressure to minimize the length of the time before a replacement is installed. This yields no time to analyze whether the system at each location has the correct capacity. More importantly, the most energy efficient equipment may not be in stock. The optimal equipment for a given location may require many weeks of lead time to manufacture / procure. Said another way, if you need a new 10 ton RTU in 48 hours, you are unlikely to get the unit that is best suited to your needs. As a result, if we've reduced the energy efficiency of the replacement unit such that the energy used over the lifetime of that new equipment is 10% higher, we've added another $5,000 to the TCO of the replacement equipment.

Figure 5 on the next page pulls all these costs together and demonstrates the major source of value that a just-in-time replacement program can provide. **For an operator with 50 locations with mature equipment with a TCO of $300,000 and an expected life of 15 years, the annual value of planned replacement could be $200,000.**

Fig 5



Why Isn't Total Cost of Ownership Used as a Standard Practice?

General awareness of and knowledge about TCO and its benefits has been on the rise for many years. For example, TCO has been promoted by lighting technology vendors and utilities offering rebates. For lighting, a higher first cost is more than compensated by lower annual operating costs, making the TCO for advanced lighting technologies attractive.

The same type of analysis appears to be much less common for other types of equipment, in particular HVAC/R. Why is that the case? As shown in the previous section, ignoring equipment operating costs – in particular energy costs – ensures any decision process will not be based on an accurate assessment of TCO. But, few companies capture maintenance costs at the equipment level – and even fewer have equipment level energy cost data.

Even if equipment level data were available, TCO analysis remains complex and time consuming and beyond the current abilities of many organizations.

A document recently produced by the US Department of Energy (DOE) does an excellent job of laying out the details of a TCO analysis that makes the business case for early replacement of RTUs. The chart includes many data elements used to fully characterize the business case for the project. To calculate TCO, the following data is used:

1. Age and condition of the RTU
2. Estimate of remaining useful life
3. Estimate for time to failure
4. Annual energy costs (electricity, gas)
5. Expectation for how operating costs how will these change year to year
6. Annual repair and maintenance costs
7. Expectation for how R&M costs will change year to year

Figure 6

Superstore Example: Early Retirement of 5 RTUs
Weight the Costs and Benefits

Up-Front Costs

Capital

+ Design and analysis	
+ Cost of RTUs	$8,000/unit
+ Installation & Building Upgrade Costs	$20,000
- Utility Incentives	-$1,640/unit
- Financing Options	
- Scrap Value	-$200/unit
Total Cost for 5 Units	$50,800

Variable Ongoing

- O&M ($500 x 5 Units) = $2500/yr x 5 yrs	-$12,500
+Tax Depreciation ($70 x 5 Units) = $350/yr x 5 yrs	$1,750

Benefits

Energy Savings

+ $7,688 x 5 years =	$38,439

Additional Cost Savings

+ Right-Sized Equipment	(incl. in price)
+ Avoided Emergency Replacement	$26,250
+ Bulk Purchase	(incl. in price)
+ Multiple-Measure RTU Packages	(incl. in price)
+ Avoided R-22 Costs	(included in O&M)

Qualitative Benefits

+ Air Quality and Comfort	$2,000
+ Sustainability Values	

Financial Metrics

ROI Energy and Other Costs	52%	NPV	$5,030
Payback Period	3.3 Years	IRR Energy and Other Costs	16%

http://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/ARC_Business_Case.pdf

To summarize, TCO is not widely used because TCO analysis is both time and data-intensive, and critical data, such as equipment level energy usage and repair and maintenance costs, have historically been unavailable. The next section of this paper explores how new technologies can be used to address these barriers.

Technologies for Gathering the Data

As noted in the prior section, perhaps the primary reason TCO analysis is not standard is the lack of the required data. New technologies can be used to provide that missing information.

1 **Equipment energy use.** There are now numerous ways to cost – effectively "sub-meter" energy usage for a given piece of equipment. Techniques include both short-term data loggers and ongoing measurement through an advanced asset and energy management system. Collecting data on an ongoing basis delivers value not only for supporting TCO analysis but, even more importantly, for delivering equipment performance diagnostics.

2 **Equipment repair/condition history.** Tracking repair costs at the individual equipment level is now possible with more advanced Computerized Maintenance Management Systems (CMMS). These systems often provide a barcode or other unique identifier for each piece of equipment so repairs can easily be linked directly to each unit.

3 **Mobile data collection tools.** Some critical information for TCO analysis, such as the condition of the unit, does not lend itself to automatic collection but instead requires human interaction. The advent of easy to use mobile apps enable the accurate and cost-effective collection of the data. With some mobile apps, bar codes can be scanned, conditions captured via standardized evaluation scales and pictures added to confirm conditions. This helps build an understanding of asset condition to support prediction of likely future repair costs and remaining useful life. Of equal importance, these apps can be used to capture the key characteristics of the equipment – including make, model, and capacity – which may not have been previously available.

4 **Performance History.** The rise of equipment that is itself directly connected to the Internet (think Internet of Things) or connected via an onsite energy/asset management system means more than just energy and maintenance cost data is available at the equipment level. Data is increasingly streaming 24/7 - often minute-by-minute - and can include onboard diagnostics or runtime counters that can help assess overall asset condition, remaining useful life, and possibly the likelihood of major future repairs.

There is a much longer history of remote data analysis with higher value equipment. For example, General Electric was an early pioneer in remote diagnostics for its locomotives, aircraft engines, and other technologies. See an example from 16 years ago here and a more recent example from UPS here. As the cost of the technology has dropped dramatically, all types of consumer and business equipment are now becoming "smart" in this manner.

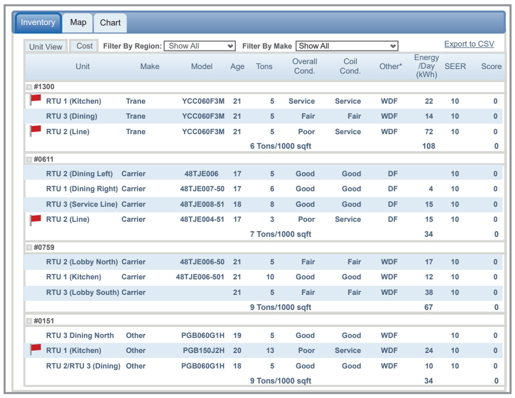
Technologies for Performing TCO Analysis

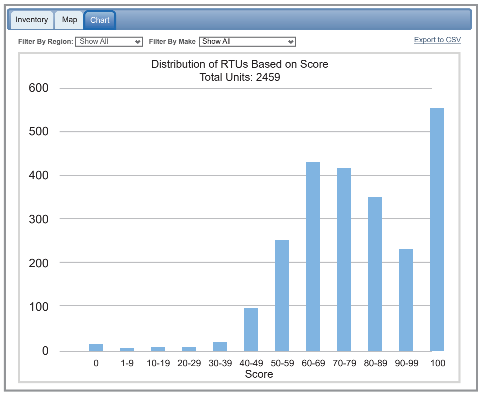
With the data needed for TCO available, there is a need for tools to aggregate, analyze, and present the data across the enterprise to enable effective capital planning.

1 **Integration of Data Types.** The aggregation and combination of different data types is a necessary precursor of TCO. Until recently, both tasks were time intensive and often nearly impossible. Today, with major data sets in the cloud, the task becomes gathering them together and performing analysis to generate useful conclusions. The proliferation of cloud application programming interfaces (APIs) enables this type of integration. Data sets, until recently stuck in their own silos, often across departments, can now be joined for the purpose of measuring and calculating TCO. External data sets can also be added to further enhance decision making. One example is the Database of State Incentives for Renewables and Efficiency (DSIRE), which identifies where utility or other rebates and incentives may be available to help offset some of the costs of new, more efficient equipment.

2 **Enterprise decision support tools.** Now that the data can be assembled, an additional tool is needed to make TCO decision making easy, intuitive, and fast. Software for this type of task continues to evolve. Key attributes include; customizable reporting, data presentation formats useful for varied audiences (executive, operations manager, procurement, finance), data visualization/ graphics, and in some cases easy access on a mobile device. Examples are shown below.

Figure 7



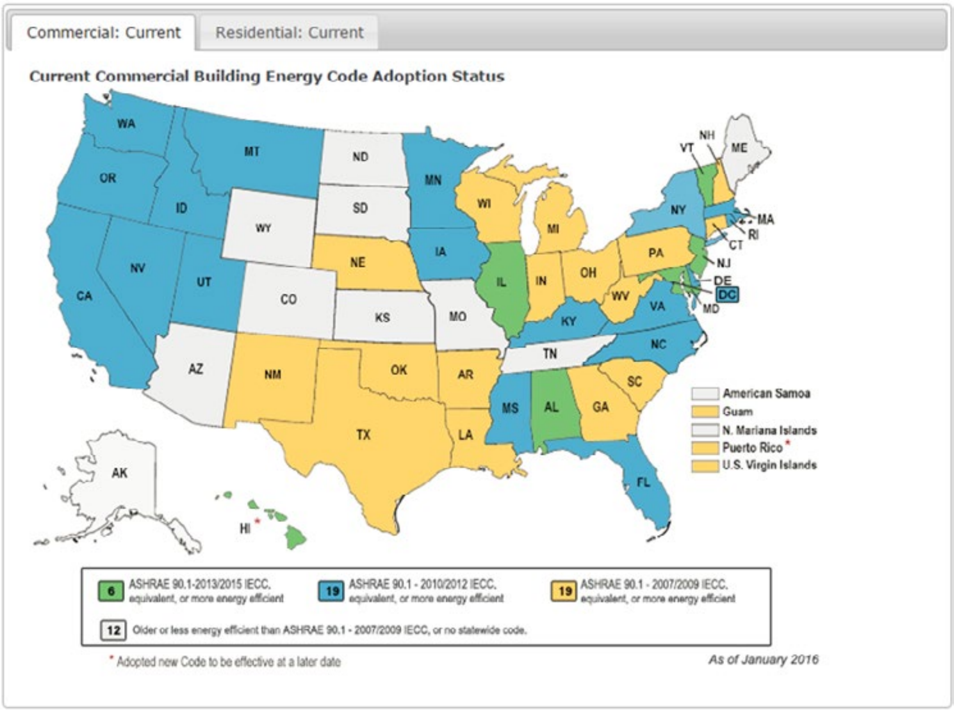


TCO Needed More Than Ever - Drivers of Change for HVAC/R Equipment Selection

New regulatory standards from various Federal agencies, state initiatives, as well as municipal laws and building codes, are all adding requirements that impact the decision process for HVAC/R equipment replacement. In particular, organizations that are building large numbers of new facilities will face decisions that TCO is well suited to address. A sampling of these regulatory requirements is listed below.

- RTU Energy Efficiency (Dept. of Energy). These regulations require manufacturers to produce more efficient equipment. The first deadline is 1/1/2018. These requirements will drive the availability of more efficient equipment. More details on the regulations are here.
- Technology innovation. Equipment manufactures continue to innovate in order to win customers in the market. This note from research firm Frost and Sullivan highlights energy efficiency as a key point of product differentiation for heating and cooling equipment.
- Refrigerant Global Warming Potential (EPA). The impact of refrigerants on climate change / global warming is increasingly being regulated. One of the most common refrigerants, R22, is slated for a production phase out by 2020. The selection of refrigeration equipment with a life expectancy of 10 years or more is impacted by these regulations. The movement towards natural refrigerants is accelerating. More details here and here.
- More Stringent Building/Energy Codes. Over the last decade there has been a renewed interest in building codes as policy tools to support energy efficiency. The chart on the following page, found here, provides a good way to explore building codes across the country. California has been the most aggressive through their Title 24 regulations. The 2016 edition of the Title 24 code takes effect 1/1/2017 and includes many provisions for HVAC/R equipment as well as lighting.

Figure 9



https://ashrae.iwrapper.com/ViewOnline/Standard_90.1-2013_I-P

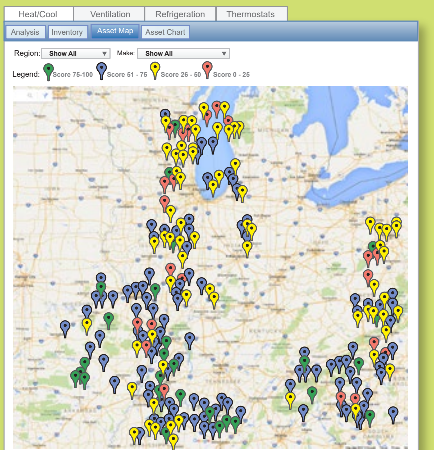
- Federal and State Incentives. There are also "carrots" amongst the regulatory "sticks". These incentives include tax breaks, cash rebates, and subsidized financing that may be available through government and utility programs. These incentives are designed to have a material impact on the equipment selection decision making process, up to ~25% of the cost of the equipment. Information on tax incentives is here and state incentives are here. The EnergyStar program is also a good source for finding more efficient products (see here) as well as rebates (see here for the latter).

How to Transition To Just-in-Time Replacement

The first priority should be to identify equipment beyond its useful life that could fail any day. This is the equipment that is destroying value. Ideally, you should perform an inventory of the equipment at each location. Based on what we have seen, the majority of multi-site commercial operations do not have a complete handle on what equipment assets they have at each site.

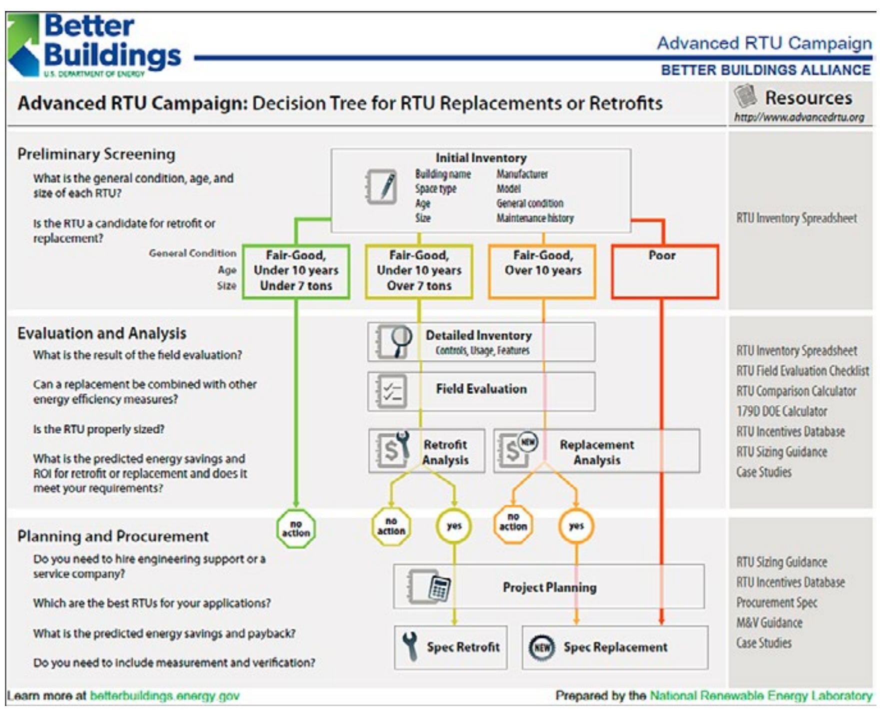
An inventory should cover the basics, such as make, model, and age; but should also cover such issues as refrigerant and condition, including cabinet condition, coil condition, whether there is standing water, and other observations. And, while you are at it, a picture is worth a thousand words, as the picture at left may attest. These factors all play a role in the repair/replace decision. As noted earlier, there are asset data capture apps available that make it relatively easy for a technician to capture this information.

The next step is to plan for the replacement of the oldest, least efficient equipment during a time when installation and equipment sourcing costs can be well managed.



Either after or in parallel with this initial wave of planned replacements the next step is to develop the systems and infrastructure to begin to measure TCO in real-time. The goal is to adopt a process similar to Figure 10 below, which is a US Department of Energy concept from the Advanced RTU Campaign. Building out this infrastructure may take a few years, but the more information you can easily access, the better your decisions will become.

Figure 10



Along this journey, our suggestions include:

- **Track energy costs at the equipment level.**
- **Make sure you capture the cost of maintaining individual HVAC units, rather than lumping together HVAC as a single category**, or as many companies do, just tracking maintenance in total.
- **Research utility rebate programs** in your operating territories to see if there are applicable rebates. A good source of information is the DSIRE (Database of State Incentives for Renewables and Efficiency) operated by North Carolina State University.
- **Develop a methodology for prioritizing equipment replacement.** Factors include; age, condition, frequency of required maintenance, growth in maintenance costs, and energy cost (the remaining lease term at each location may play a role as well). Some energy and asset management software packages have algorithms that integrate data into equipment scoring metrics.
- **Develop an internal budgeting and planning process** to determine how much can be spent annually on proactive replacement (recognizing there will still be inevitable reactive replacement), when it should happen, and what the overall process should be in terms of timing, getting vendor bids, etc.

Conclusion

The Total Cost of Ownership methodology reveals that organizations who delay equipment replacement as long as possible (a.k.a. "run-to-fail") are missing an opportunity to create substantial value.

Planned replacement avoids owning and operating equipment during the most expensive part of the lifecycle, allows for the most cost efficient replacement process, and avoids locking in unnecessarily high energy costs for the life of the replacement equipment.

Today, technology allows for the accurate collection of equipment-specific energy and repair cost data, and enterprise software tools can translate that data into Total Cost of Ownership (TCO) to support "just-in-time" equipment replacement. These make it possible for organizations to transition to this superior equipment replacement process.

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