Frequently Asked Questions

Introduction

Q How long has PaceControls' PACE+PACE Cloud smart grid suite been in operation?
A: PaceControls, an ENERGY STAR PARTNER and DOE and Ben Franklin Technology Partners funded company, commenced operations in 2005 to develop energy efficiency and smart grid HVACR (heating, ventilation, A/C and refrigeration) retrofit solutions to make existing heating, cooling, and selected refrigeration equipment more efficient. Over 19,000 units of our award-winning product suite have been deployed, and PaceControls is proud to be a DOE grant award winner and part of the DOE-funded Consortium for Building Energy Efficiency at the Philadelphia Navy Yard, a national center for building efficiency and smart grid innovation. PACE Cloud with Cloud API was launched in 2013.

Q: What kind of energy cost savings can the PACE+PACE Cloud smart grid HVACR retrofit suite deliver?
A: Substantial savings – the following are representative installed-cost payback estimates for mid-Atlantic region 2017 energy prices, which are lower than in many parts of the U.S.:

Air conditioning equipment, 3 or more units, average rated capacity 5-75 tons: 18-30 months
Refrigeration equipment, 3 or more tons rated capacity: 18-24 months
Gas- and oil-fired boilers, 500,000+ Btu/hour rating, "standard" efficiency: 12-18 months

Energy efficiency rebates, where available, and higher prices can considerably shorten even these quick paybacks. The PACE suite is rebate-eligible for electric and gas utility rebates generally anywhere such rebates are offered.

Q: How do these energy savings translate to my business?
A: The specific translation depends on your specific business. However, EPA and DOE have done a great deal of research, and they say the following – for more information, see the ENERGY STAR Website, www.energystar.gov :

Hospitals: Each dollar saved in energy costs is equivalent to generating new revenues of $20 for hospitals, or $10 for medical offices and nursing homes.

Hotels: A 10% reduction in energy costs is equivalent to increasing Average Daily Room rates by $.62 for limited service hotels and $1.35 for full service hotels.

Office Buildings: Saving 30% of energy costs in a commercial office building is equivalent to increasing the net operating income by 4%, which would support a 4% increase in asset value.

Supermarkets: For the average supermarket, reducing energy costs by 10% is equivalent to increasing sales per square foot by nearly $42.

Applications

Q: What kinds of HVACR equipment can use PACE+PACE Cloud retrofits?
A: Over 80 IPMVP-compliant metered trials, independent testing, and controlled lab testing 2005-17 have shown the patented and UL Listed PACE product suite to be suitable for a wide range of HVACR equipment. PACE+PACE Cloud was designed with significant input from the HVACR industry, to provide a highly flexible retrofit solution to a wide range of HVACR equipment. Primary applications are with positive-displacement (non-centrifugal – e.g. scroll, reciprocating, and screw compressor) air conditioning and refrigeration units from 3 up to about 100 tons, although in joint product development with a global OEM, PACE retrofits have shown good results even on residential-scale SEER 15+ equipment. In heating, non-condensing gas- and oil-fired boilers and furnaces with AFUE ratings less than 92 are generally excellent candidates. PACE retrofits also can be very effective with heat pumps, and another significant "sweet spot" application is rooftop gas/electric or electric/electric package units. A qualified HVACR technician or building engineer, in communication with PaceControls if necessary, can determine appropriate applications.

Q: What are the requirements for an installation?
A: PACE retrofits can be installed on a very wide range of HVACR appliances that are in good working order, by a qualified HVACR technician and in compliance with PaceControls technical documentation and support.

Q: Why must the installer be a qualified HVACR technician?
A: Installation is quick and relatively straightforward in most cases, but knowledge of HVACR control circuitry is important, and use of qualified HVACR technicians assures that the PACE retrofit is installed properly, in the right applications (and in reasonably functioning equipment), to assure both savings and full equipment operating performance.

Technical Operation

Q: How does the PACE retrofit make vapor compression cycle operation more energy efficient in air conditioning and refrigeration equipment?
A: Simply put, most machines that consume energy to address some work function are time-variant in their energy efficiency. For instance, an automobile will show variance in real-time m.p.g. consumption – dropping when the accelerator is depressed, and rising when the car is driven in "hypermiling" mode, where the car's momentum carries the car along, but with less gasoline consumed per mile on average. Similar to this analogy, the vapor compression cycle at the heart of most air conditioning and unitary refrigeration is time-variant in efficiency; cooling delivered does not depend per se on the amount of time the compressor is running, but rather on the amount of refrigerant flashing to vapor per unit of time.

In air conditioning and refrigeration systems, PACE's patented software optimizes compressor operation to move more refrigerant per unit of energy-consuming compressor run time. The effect is improved heat transfer within the vapor compression cycle, and thus the ability to deliver the same cooling with reduced but more efficient vapor compression cycle operation, and with cooling continuing via continued movement of air over still-cold coils, even during periods when the compressor is idled (for no less than the OEM-specified anti-short-cycling intervals – during which time, the thermostatic call will often satisfy under the continued cooling).

Q: How do PACE retrofits make natural gas- or oil-fired heating more efficient?
A: The PACE heating solution effectively converts an older, less-efficient unit into a more modern modulated-firing system using existing control architecture, and at a fraction of the cost of replacing the burner, if the latter is possible at all. Instead of overlong burn cycles, with much of the heat wasted in regular setpoint overshoots due to the "flywheel effect" of chained time delays in heating control loops, PACE optimizes burner operation in response to the thermostatic. Enhanced heat transfer results in more fuel energy effectively transferred to the air or water heating medium, and reduced overshoots translate directly to fuel savings.

Q: How is PACE technology different from a duty-cycling controller? Or different from a VFD (variable-frequency drive)?
A: The PACE retrofit line is designed and manufactured under several broad patents and patents pending, that incorporate algorithms to establish optimized run times based upon enhancing the thermodynamics of energy transfer within the HVACR unit's heating and cooling cycle. In short, PACE retrofits address the fact (also discussed above) that in vapor compression cooling cycles – essentially the same thermodynamic cycle pioneered by Willis Carrier some 100 years ago – compressor operation (which typically accounts for 60%-80% of the unit's nameplate kW rating) is time-variant in the cooling it can deliver for every turn of the compressor. In heating units, PACE retrofits trim the overshoot (complementary with any existing thermostatic controls) that wastes gas or oil on any burn cycle. PACE retrofits do not just establish an on and off cycle, but an optimal operating sequence that uses energy more efficiently, while maintaining end use performance. A VFD (variable-frequency drive) is an electronic duty cycling control device that acts to vary the speed of a motor in proportion to the load sensed on it -- that's the energy-saving mechanism. Good classic VFD applications are pumps and fans (including HVACR fans and blowers) where the volume of air or liquid needed to be moved is time-variant. This is a perfectly good energy-saving aftermarket retrofit for variable-load electric motors. However, most HVACR compressors are designed to be either off, or running at near or at rated capacity, and their components are not built for VFD applications. In compressor-driven cooling and refrigeration cycles, PACE retrofits (via an entirely different mechanism than a VFD's) save energy by taking the optimal slice of compressor runtime, maximizing the compressor's volumetric efficiency; the compressor ends up running less (that's the energy-saving mechanism), and running at higher efficiency when it does, thus delivering the same cooling capacity but more efficiently.

Q: How is what PACE+PACE Cloud retrofits do, different than a building-wide monitoring and control system?
A: PaceControls retrofits are compatible with all building-wide management systems (BMS), and most current PACE installations are in buildings that have some form of BMS. Most BMS systems are designed to allow such benefits as remote thermostatic control with setbacks, equipment run time normalization, monitoring and reporting, online diagnostics, prevention of harm from poor electricity quality, and similar features. These, of course, are all valuable.

In contrast, PACE technology is focused at the "foundation" of building energy consumption, by improving the energy efficiency of the compressor cycle (in the case of cooling or refrigeration systems) and/or thermal energy source (in the case of heating systems). Thus, it operates "below" the BMS level, but quite compatibly and visibly with it, and with easy interconnection.

Q: Can PACE+PACE be used with or in place of a remote monitoring system?
A: As noted above, the PACE suite is purpose-built via Cloud API, 3-way wireless capability and BACnet addressability to be fully compatible with all building management systems (BMS), wired or wireless, and can also be networked with the BMS if desired. And PACE+PACE Cloud

provides not only IPMVP-compliant remote monitoring and fault detection, but can also perform as an edge router to convey or aggregate date for other BMS. Our technical professionals can provide guidance on operation within specific monitoring and reporting systems.

Q: How does PACE technology differ from other HVACR efficiency solutions?
A: The industry-leading PACE suite is best-in-class for ROI in saving 10%-20%+ on cooling and heating energy bills for 90%+ of the world's HVAC, without sacrificing end-use performance. And since PACE is able to deliver optimization of either cooling or heating units, this is a tremendous cost and logistical benefit in large-scale deployments, since the just 1 PACE Node on a standard gas/electric package unit 2-100 tons can optimize both the A/C and heating stages. Seemingly competitive products may be redundant with thermostatic controls, and/or may require expensive networks and peripherals – with poorer savings, performance, and payback, and without PACE's extraordinary credentialing of strong, dependable results over thousands of units. PACE retrofits deliver the most efficient equipment operation sequence that also can reduce electric demand at the meter (see below), for a quick payback at a low installed cost. They can also optionally accept a variety of temperature and other sensor inputs (see below), and deliver Demand Controlled Ventilation and breakthrough proprietary OpenADR demand response, along with fault detection and diagnostics, in 1 easy-to-install node system.

Q: What additional control levels are available?
A: A key strength of the PACE suite is the wide variety of external optional temperature, humidity, pressure, and other environmental system inputs that can be accepted. To add demand controlled ventilation, for example, it may be useful to add a wireless CO2 or occupancy sensor. And for heating equipment, e.g., for gas- or oil-fired hydronic hot water heating systems, it may be similarly useful to install a hot-leg water sensor. A wide variety of off-the-shelf peripherals by major controls OEMs can be used as PACE Node inputs.

Q: How is the PACE product suite powered?
A: UL Listed PACE retrofits have very low power requirements, a key feature. The PACE Nodes are installed in the control lines of the controlled HVACR unit, and take what power is used from the control lines, just like a thermostat – also, a key installation advantage. Depending upon what wireless option is chosen, or if optional sensor peripherals are chosen, these may require 24VAC or 110VAC power, but also at low power requirements.

Financial

Q: How do PACE retrofits save money? Are incentives available?
A: In all applications, PACE retrofits reduce energy consumption (kWh and therms), and save the operating cost of the saved energy. In cooling and heat pump applications, PACE retrofits can also reduce time-average demand (kW) substantially, as a PDR (permanent demand reduction) EEM, providing additional savings from reduced demand charges. PACE is eligible for both electric (both kWh and kW) and gas energy incentives, generally anywhere such incentives are offered.

Q: What approximate level of efficiency savings can I expect?
A: Most appropriate applications have experienced whole-HVACR-unit cooling-component bill savings of 15%-25+%, and almost always at least 18%, and heating-component bill savings of 15%-20%+, with many IPMVP-compliant studies showing 25%+ whole-HVACR-unit savings. Consumers with billing and metering that enable substantial demand charge reductions have experienced bill reductions as high as 40%, in facilities with a large portion of electric load from

HVACR. Also see the discussion below for the factors involved in energy baseline consumption and energy savings off that baseline consumption.

Q: What factors determine HVACR energy consumption and dollar savings achieved?
A: As usual with energy projects, the primary factors that affect baseline energy consumption, and thus energy savings off that baseline are (in typical order of effect): (1) the size of the controlled HVACR equipment, (2) the all-in $ energy cost per kWh or therm for the equipment, (3) the hours of annual run time for the appliance, and (4) the baseline energy efficiency of the HVACR unit. Clearly, larger, longer-running HVACR units in higher-cost areas will have the highest operating costs, and thus have the best paybacks for PACE installation. However, the percentage savings noted above will generally be achieved, thus dollar savings will be higher for those larger and longer-running HVACR units in higher-cost areas.

Q: How are demand charges reduced? How can demand charge savings be maximized?
A: A utility's demand charge for a customer, as it appears in monthly billing, reflects how much electric power in kilowatts (kW) it assumes must be made available to serve the customer's load. Many commercial customers pay a demand charge to reflect the highest metered load, for a period that may be as short as 15 minutes during the course of a year. PACE retrofits can often optimize compressor run time by 20% and more, and thus reducing load comparably. All customers with a demand charge have lower demand, but savings depend on the exact tariff, metering arrangements, and load details. (Also see the handout "Electric Demand Charges".)

Most customers have many energy-consuming devices on a single meter measuring demand, so the whole-building kW demand will be the superimposed kW demands of all those loads. According to EIA, HVAC cooling loads contribute approximately 20%-40%+ to total facility electric demand, depending upon building type, climate zone, and other factors. Reduction in HVAC demand charges can be maximized by retrofitting all HVAC units on the same meter. It is also be possible to use PACE to establish "asynchronous" starting of air conditioner loads off the same thermostat, for instance, which has the additional potential to reduce peak load seen at the meter. Additionally, PACE+PACE Cloud can deliver enhanced Demand Response and voluntary curtailment features, allowing participation in utility Demand Response programs for even greater savings.

End-Use Performance

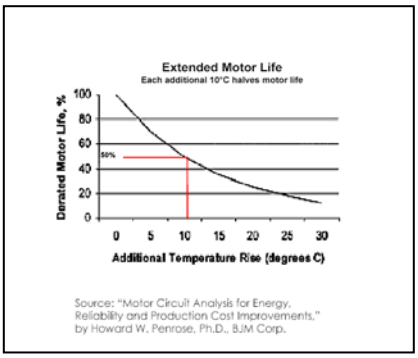
Q: Do PACE retrofits affect end-use performance?
A: PACE retrofits can always maintain desired end-use performance. If desired end-use performance is not initially achieved, programming can be adjusted or an optional sensor added, and the equipment should also be checked for other possible sources of reduced performance. In some cases with programmable thermostats (which PaceControls recommends be used wherever possible), it may be necessary to move the morning warmup/cooldown time back perhaps ½ hour – e.g., from 7 a.m. to 6:30 a.m. – to allow for a slightly slower ramp on warmup/cooldown. Since the vast bulk of opportunity for energy savings occurs during the rest of the day and night, this has little or no effect on total energy savings.

Q: Can PACE retrofits improve comfort?
A: In many heating and air conditioning applications, PACE can improve user comfort. Time and again, PACE retrofits have been shown to minimize overshooting or undershooting of the temperature called for by the thermostat, with heated or cooled air provided more constantly at a more moderate temperature, closer to the desired level. In particular, PACE in heating

systems has been noted to reduce uncomfortable temperature overshoots in morning warmup periods, e.g., in box retail stores. Also see the comment from Carrier Corp. (p. 6, below) on PACE benefits in humidity control for oversized systems.

Operations

Q: How can PACE+PACE Cloud improve compressor performance and life?
A: All data and customer testimonials we have indicates that PACE Node retrofits contribute to both improved compressor performance and extended life, in the following 5 ways:



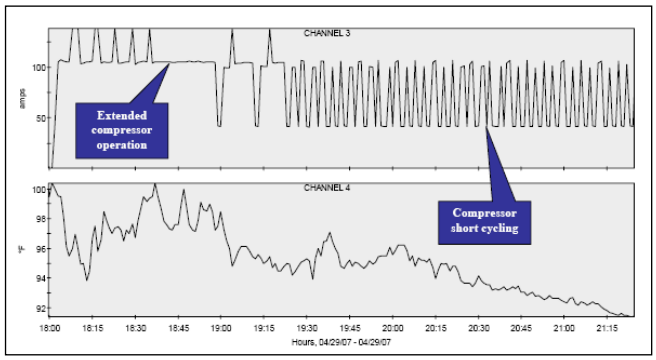
- *reduced total compressor runtime, which also provides much of the savings.*
- *higher lubrication efficiency during compressor operation.*
- *lower motor stator winding temperatures on average, due to the shorter runtime -- studies by General Electric and others have shown that a 10°C increase in average stator temperatures can result in a 50% reduction in effective compressor life, due to accelerated degradation of the windings (see the diagram at right).*
- *reduced coil freezeover, which means that the compressor does not have to work as hard to effect heat transfer through frozen-over coils, and reducing or completely avoiding slugging.*
- *Elimination of short-cycling (also see the question below).*

Earlier versions of our current PACE+PACE Cloud product suite have been installed since the late 1990's, and several major customers and current testimonials (including McDonald's, Anheuser-Busch distributors, and the U.S. Postal Service) have had them installed for over 10 years. If units were causing equipment issues, they would certainly be letting us know, but there have been no such reports – in fact, anecdotal reports are that compressors are lasting longer, which would be expected from the combined benefits listed above.

Q: Why isn't what the PACE does harmful short-cycling?
A: Very short run times that do not permit lubricant to circulate fully is "short-cycling" that can be harmful to a compressor. All A/C and refrigeration compressors go on and off, usually on an irregular cycle established by a thermostat. PACE programming is always for a run time longer than the minimum established by manufacturers to avoid harmful short-cycling – thus, PACE actually enforces these ASC limits where that (ASC) circuitry may not exist in the native control architecture, particularly for older and smaller HVACR units. Carrier, for instance, in its instructions on use of the PACE, stipulates pacing of "…a minimum of 4 minutes on and 2 minutes off for packaged equipment. For split systems the minimum off time must be increased to 4 minutes to allow proper return of oil." (The Carrier instructions also contain the statement that "Carrier Corporation supports the claim that the [PACE]… will help reduce peak kW distribution and production/ transmission loads especially for oversized equipment. It may also help stabilize system humidity control on systems that are oversized and are short cycling due to the oversized equipment, but the proper solution for these types of problems would be proper sizing of the equipment." [Emphasis added.])

Thus as a significant collateral benefit, the PACE software machine protections outright prevent short-cycling and as excessive cycling, as defined (for instance) by Carrier, wherein "a compressor or furnace is restarted immediately after it has been turned off", since the PACE control sequence always begins with an "OFF" interval. (Also see the "Example HVACR

Manufacturer" tearsheet, and the question above.) Many facilities managers are not aware of short-cycling as a life-shortening element in their HVAC equipment, and it can occur in even large and sophisticated pieces of equipment. The figure below shows datalogging of a large (50 ton) package air conditioning unit, built within the last 10 years, on a large distribution facility. The top graph shows current draw (1 phase) from the unit, while the lower graph shows rooftop temperature. The datalogging clearly shows both extended compressor run times, at declining marginal energy efficiency, and substantial short-cycling as temperatures cooled toward evening. If this truck-sized unit is doing that, what are <u>your</u> units doing?



Q: Does PACE+PACE Cloud affect appliance maintenance or operations?
A: As noted above, PACE software protections can actually <u>benefit</u> compressor life. They can also improve system performance, most frequently by reducing or eliminating compressor-coil freeze-over. In most applications, PACE retrofits can be expected to have no impact on appliance maintenance or operations. There may be <u>slightly</u> increased wear of contactors, but A/C contactors (1) are rated for tens to hundreds of thousands of operations – see any equipment catalog, (2) are an inexpensive maintenance item (typically $19-$30 at most), and (3) always checked in the course of annual maintenance in any case. There are simply <u>no</u> reported instances of PACE retrofits damaging a compressor or other HVACR appliance. (An occasional question will come up about “inrush current” – this is where AC induction motors [which is to say, nearly all HVACR compressors)] experience momentary heightened current flow during motor startup, as the motor’s magnetic fields are established. Even many facilities professionals don’t realize how momentary – and designed-for – this effect is. A reasonable description of inrush current can be found online at www.Wikipedia.com – as the article notes, the inrush current is only for a few cycles, and so, since electric power is 60 cycles per second in North America, perhaps <u>[2-5]/60th of a second</u>. PACE retrofits <u>always maintain the equipment cycle limitations recommended by the OEM</u>, <u>resulting in the equipment running less but more efficiently</u>, and in addition, <u>actually enforce the anti-short-cycling limits recommended by OEMs, but not always enforced</u> by the native control architecture).

Q: How reliable are PACE retrofits?
A: The UL Listed PACE suite is built and tested to global industrial component performance standards, with an EUL of 15 years, in environmental conditions from -40F to 160F, is extremely reliable, and is also relatively simple to install by any qualified HVAC technician, thus reducing the chance for installation-related error. The PACE product suite comes with a standard 12-year limited warranty, and has had an outstanding field record with over 19,000 units installed.

Q: What technical support is available for PACE+PACE Cloud installation?
A: PaceControls maintains a technical services staff and toll-free support (877-PACE-HVAC) for all technical questions, and by calling the same toll-free number we can provide additional documentation and specification services. We also have relationships with a national network of HVACR companies and ESCOs; these can provide either contracted installation, or a “teamed installation” with your own technicians, after which your technicians will be able to do future installations in a time- and cost-effective approach. PaceControls also provides installation training by experienced staff HVACR technicians, at a reasonable cost; training can either in the form of on-site briefing, Webinar, 1-on-1 “tele-training”, or teamed installation.