Emerging Technologies: What will be the cost of the next level of efficiency?

Elizabeth Titus, Northeast Energy Efficiency Partnerships
Brian McCowan, ERS Consulting
Valerie Eacret, ERS Consulting
David Jacobson, Jacobson Energy Research
Denise Rouleau, TetraTech

ABSTRACT

As many mainstay measures of residential and commercial energy efficiency programs are becoming standard practice, emerging technologies will play an increasingly important role. Whether initially introduced as pilot offerings or part of efficiency programs, quantifying cost-effectiveness is required. Emerging technologies by definition have less cost information to rely upon; product developers and advance marketers often provide estimates that are wide ranging, overly optimistic, or both. And, market conditions can change rapidly.

Research was conducted utilizing systematic, proven, approaches for predicting the incremental costs for a group of emerging technologies that offer promising savings for homes and businesses. The technologies were selected in consultation with a stakeholder committee of efficiency program administrators who wish to include emerging technologies in their program offerings as soon as they are properly vetted. The study, to be complete in May 2016, will present baseline, full, and incremental costs for at least the following emerging technologies:

- Ultra-high performance residential and commercial HVAC systems, including variable refrigerant flow systems of various configurations
- LED fixtures with integrated multi-function controls
- Controllable "smart" devices, including multi-function hubs, plug load controls, lighting, HVAC and communication capable appliances
- Advanced thermostats offering integrated control of heat pumps and additional heating systems to maximize net efficiency
- Advanced performance heat pump water heaters, including gas fired units
- Communication enabled compressed air control and maintenance systems
- Advanced motor technologies beyond EC motors

This paper summarizes the research and presents high level characterization of the technologies, the cost findings, trends and "shelf life" of the data and it suggests the approach is applicable to other emerging technologies for future study.

Introduction

Nearly all efficiency programs wish to include emerging technologies in their portfolio of offerings. Yet these same programs are bound by cost-effectiveness rules that although varying in their specifics, require savings and incremental costs to be predicted and later evaluated. Emerging technologies present many unique challenges in assessing them for inclusion in energy

efficiency programs. Not only are the potential savings difficult to predict, but the total and incremental costs compared with appropriate baselines are unknowns that are difficult to estimate.

The Northeast Energy Efficiency Partnerships' Evaluation, Measurement, and Verification Forum (NEEP EM&V Forum) has completed several incremental cost studies in recent years, covering most measures that are typically included in residential and commercial efficiency programs. These studies relied, and rightly so, on actual project invoice data in assessing total and incremental costs. When planning the emerging technology study, the decision was made to focus on technologies that were relatively new or truly emerging and had not yet achieved success in the marketplace. This decision led to approaches designed to estimate future costs, rather than reporting on recent costs. The project staff developed a multi-pronged approach to estimating future costs which varied based on the market position of the technology category addressed.

Selecting Technology Categories for Study

NEEP assembled a project advisory board with representatives from the sponsoring electric and gas efficiency programs which serve the majority of territories throughout the Northeast and Mid-Atlantic regions. The advisory board, NEEP staff, and the project contractor (ERS) collaborated to select technology categories that were identified as having not reached full market acceptance and also fitting in one or more of the following categories:

- Technologies approved for pilot programs
- Technologies considered for custom incentives
- Emerging replacement technologies for measures transitioning to standard practice
- Technologies that promise wide market appeal
- Measures that may assist in reaching underserved markets

The selected technologies were then prioritized into two groups of five to facilitate a reassessment of the effort and associated budget before researching technologies deemed to represent lower priority. The final collection of selected technologies is presented in Table 1.

Table 1 – Researched Technology Categories with Summary Incremental Cost Information

	Technology	Sector		Category Range	Application*		Approximate Incremental Cost	Notes
		RES	C&I		NC	R		
1a	VRF heat pump – A/C	x	x	Multi-split and VRF systems – Single-family residential, multifamily, and small commercial units ≤ 16 ton	x		Variable from approximately $1,500 to $6,000 per ton - plus an additional 17% for cold climate performance	Single zone mini-split systems are covered in earlier NEEP incremental cost studies
1b	Multiple-zone variable capacity HP – modulating compressors	x	x		x			
2	Advanced LED lighting controls		x	Fixtures with integral controls and control systems designed for LED	x	x	Highly variable	Typically priced on a building area basis
3a	Home energy management products	x		"Smart" hubs and dedicated energy-impacting devices; appliances with communication capability for energy savings; power strips with logic beyond master/controlled	x	x	Highly variable cost, from $6-$200+	Often referred to as "smart" products, the home energy management products category focuses on products with energy saving or load-shifting capabilities.
3b	Tier 2 power strips	x			x	x		
4	Advanced/ultra-high efficiency rooftop packaged A/C (SEER >18)		x	CEE size categories ≤ 65,000 Btu/hr and 65,000 to 135,000 Btu/hr include current packaged high efficiency units (15–18 SEER)	x		$360–$560/ton capacity	Limited reseach as deemed not cost-effective in the study region
5	Integrated heat pump multi-system thermostatic controls	x	x	Controls that are capable of controlling hp and additional heating system(s) typically via an interface with "smart" thermostats	x	x	$365–$660 per control	Ductless mini-splits are now controlled seperately from other heating systems, preventing automatic sequencing.
6	Advanced compressors for commercial refrigeration		x	Supermarket refrigeration systems for new construction of reconfiguration of existing systems	x		Highly variable from 0-55	Current retrofit market dominated by compressor rebuilding and the retrofit of controls
7	Automatic compressed air system diagnostic monitoring		x	Focus on systems communicating with dashboard	x	x	Fullly installed cost; typical systems average $7,500–$17,500	Industrial measure – large savings potential
8	Improved HP water heaters	x		Residential systems offering higher-than-typical COPs at ambient temperatures below 68°F	x	x	$1,000–$2,100 compared with electric storage water heaters	Many heat pump water heaters as currently configured do not perform well in cool basements
9	Natural gas heat pump water heaters		x	Large-capacity commercial industrial systems	x	x	$176.50/MBtu/hr and $276.50/MBtu/hr	Limited market activity; commercial, municipal, and multifamily, large DHW loads
10	Q-Sync motors for evaporator fans (proprietary QM Power product)	x	x	Limited sizes and applications, further products under development; current market focus is small refrigeration fan motors	x		Estimated at $120–$230 for typical installed project cost	One supplier to date; UL approved for some sizes

* Application:

NC = New construction and end-of-life replacement

R = Retrofit applications

Study Approaches

The very nature of emerging technologies makes traditional methods of calculating incremental costs of limited value. For this study the strategies for developing estimates of future incremental costs for emerging technologies included:

- Program Data – Where available costs from the limited projects was obtained from program administrators.
- Web research – Some products such as residential smart hubs and lamps have readily researchable pricing obtainable on the web. We identified actual selling pricing rather than simply manufacturers' suggested retail pricing. Advisory websites such as Green Building Advisor also provided valuable cost insights.
- Cost service research – Services such as RS Means maintain databases of equipment and installation costs. ERS subscribes to relevant informational data, and used the service to provide baseline and incremental costs to the extent practicable.
- Vendor and customer interviews – Vendor and customer interviews were utilized to identify real-world installed costs, especially for products requiring professional installation.
- Overseas market investigation – For products emerging first overseas, investigation of markets outside the U.S. provided valuable data. Historical pricing correlations for previously emerged technologies helped guide this result.
- Application of product pricing strategies – Most firms utilize strategic pricing guides or services to help establish pricing for market introduction. Sequoia Cap and 360pi are two well-known guides that were used to enhance gathered data.
- Product cost-effectiveness strategies – Historically, emerging technologies in the efficiency and renewable energy fields are introduced at pricing that is somewhat above a cost-effective basis. At that stage they are attractive to early adopters, and as the incremental cost is reduced, they become more widely accepted. Applying typical historical factors from recently emerged products to emerging products proved to be a successful strategy. For example, heat pump water heaters were initially introduced at higher price points. As product competition grew, along with efficiency program interest in supporting the technology, pricing was reduced to levels consistent with program cost-effectiveness requirements.

Table 2 presents the approaches used for estimating incremental costs for each technology category.

Table 2 – Research approaches utilized for each technology category

	Technology Category	Program Project Data	Web Based Research	Cost Service Research	Market Actor Interviews	Overseas Market Research	Market Pricing Strategies	Cost-Effectiveness Model
1a	VRF heat pump – A/C	√	√	√	√			
1b	Multiple-zone variable capacity HP – modulating compressors	√	√	√	√			
2	Advanced LED lighting controls	√	√		√			
3a	Home energy management products		√		√			
3b	Tier 2 power strips	√	√		√			
4	Advanced/ultra-high efficiency rooftop packaged A/C (SEER >18)	√	√	√	√			
5	Integrated heat pump multi-system thermostatic controls		√		√		√	
6	Advanced compressors for commercial refrigeration	√	√		√		√	
7	Automatic compressed air system diagnostic monitoring		√		√	√		
8	Improved HP water heaters	√	√		√	√		
9	Natural gas heat pump water heaters	√	√		√	√		
10	Q-Sync motors for evaporator fans (proprietary QM Power product)		√		√		√	√

Researched Technology Descriptions and Research Approaches

Technology Categories 1a and 1b – Residential and Commercial Variable Capacity and Variable Refrigerant Flow Air Source Heat Pumps and A/C

Inverter-driven air source heat pumps and air conditioning (A/C) systems utilize a variable frequency drive (VFD) to modulate the compressor output to match changing demand.

Variable refrigerant flow (VRF) systems also utilize an inverter-driven compressor, but additionally have the capability to modulate the flow of refrigerant to each individual fan coil within the building. Some VRF systems also have the ability to provide simultaneous heating and cooling across zones through heat recovery at a central distribution point. This study covers inverter-driven multiple-zone systems for residential and small commercial applications, as well as VRF systems that have the capability of simultaneous heating and cooling. Single-zone "mini-split" heat pumps were included in earlier NEEP studies.

Research focused primarily on market actor interviews and the estimation of baseline and emerging technology project costs for several prototypical installations. As market actors reported that this category is the fastest growing and evolving segment of the HVAC market, we were not able to rely heavily on previously installed project data.

Technology Category 2 – Advanced LED Lighting Controls

Advanced LED lighting controls have the capability of responding to multiple signals in order to turn lighting off, and/or to dim lighting. Although there is no established industry definition, this study defines an "advanced" LED control system to be one that allows the use of a minimum of three of the following control strategies: occupancy sensing, daylight harvesting, task tuning, networking, and individual addressability (the ability to control single lights independently of the other lights in the zones).

Concurrent research conducted under NEEP's Commercial Advanced Lighting Controls (CALC) project provided significant insight for these systems. In addition, we conducted multiple market actor interviews and recorded costs from recently installed or currently proposed projects that were assigned to ERS for technical review by efficiency program implementers.

Technology Category 3a & 3b – Home Energy Management Products and Smart Thermostats

Home energy management products, such as hubs that control lighting and other devices, plug load controls, communication capable appliances, and smart thermostats, were combined into one category as they share many features. Furthermore, smart thermostats are beginning to be marketed as devices with the ability to control more than HVAC systems. In addition to thermostats and lighting products, tier-2 advanced power strips for plug load control and remote-controllable major household appliances are included.

This is the only category where we were able to obtain pricing from multiple online and brick & mortar retailers. In addition, we conducted several market actor interviews regarding smart thermostats, large appliances, and Tier-2 advanced power strips.

Technology Category 4 – Advanced Rooftop Air Conditioning Units with SEER Ratings of 18 and Above

Rooftop air conditioning units (RTUs) are the most common systems for the conditioning of commercial buildings. Improved compressor, fan motor, evaporative coils, and control strategies have allowed the efficiency of these units to improve significantly over the last several years. Major manufacturers are now developing/introducing RTUs that represent the next step up in efficiency.

Research was limited by design for this category, as the study sponsors communicated that cost-effectiveness was a barrier in the Northeast climate zones. We collected data from the

"working papers" and database maintained by the California Public Utilities Commission. In addition, we conducted limited market actor interviews to estimate the near-term expectations for installed costs.

Technology Category 5 – Integrated Residential Multi-System Heat Pump Controls

This category includes controls that can be utilized to thermostatically control two heating systems – a heat pump and a furnace, boiler, or electric resistance – in order to maximize overall performance. Although heat pump manufacturers have been working on thermostats with this capability, their focus has now shifted to interfaces that allow existing "smart" thermostats such as Nest and Ecobee to control multiple heating sources.

Extensive market actor interviews led us to an understanding of the heat pump industry's approach for integrating the control of heat pumps with additional heating systems. The approach most often reported was a collaborative effort with the manufactures of adaptive "smart" thermostats. As a result, interviews with both heat pump and thermostat manufactures informed pricing for the interfaces capable of controlling multiple systems.

Technology Category 6 – Advanced Compressors for Commercial Refrigeration

This category addresses improvements and alternatives to the centralized direct expansion (DX) systems that are used to provide cooling for nearly all grocery stores, supermarkets, and other commercial refrigeration applications in the United States. DX systems use a refrigerant vapor expansion/compression (RVEC) cycle to directly cool the supply air to the space. It is the same basic technology as that used for standard air conditioning systems. Advanced refrigeration compressor solutions are now available that offer efficiency improvements, reduced refrigerant leakage, and alternative refrigerants with lower greenhouse gas (GHG) impacts compared with standard practice equipment.

ERS reviewed data from efficiency custom incentive programs implemented by National Grid, Efficiency Maine, and Pacific Gas and Electric (PG&E) in order to understand the baseline systems and costs for current standard practice systems. Interviews with market actors were used to identify multiple alternative systems that are now, or will soon be, entering the marketplace. Incremental costs will vary significantly as all systems are custom installations, but we were able to estimate cost ranges.

Technology Category 7 – Advanced Compressed Air Diagnostic Monitoring

Advanced compressed air system diagnostic monitoring is an industrial measure with large savings potential. While there are multiple compressed air diagnostic monitoring solutions available, the emerging technology option that this study focused on includes systems that communicate with a dashboard visible by either the company providing the service, the client, or both. These systems can automatically determine and adjust the number of compressors and storage tanks (receivers) in a plant that are operating, detect leaks, and improve pressure control through increasing the accuracy of the system pressure.

Market research focused on extensive interviews with two market actors who actively promote these systems in the Northeast. The system costs vary widely based on compressor plant configurations and monitoring system features selected. Actual installed system invoice data as well as market actor estimates were used to calculate system costs.

Technology Category 8 – Improved Efficiency Electric Heat Pump Water Heaters

This technology category is focused on residential and small commercial electric heat pump water heaters (HPWHs) that offer improved performance in installation environments that experience ambient temperatures below the standard testing/rating ambient temperature. The manufacturer published efficiency ratings for HPWHs are calculated at an industry standard ambient temperature of 68°F. Below that temperature, the performance deteriorates rapidly for most HPWHs. In the Northeast, most residential water heaters are installed in unheated or semi-heated basements with average temperatures below 68°F.

A study conducted by the Northwest Energy Efficiency Alliance (NEEA) focused on the cold climate performance of HPWHs provided excellent guidance for this category. That study is now being updated, and interviews with the authors helped to identify current market activity and pricing. Efficiency program cost data, home center published pricing, and interviews with plumbing contractors also contributed to the cost estimates.

Technology Category 9 – Commercial Natural Gas Engine Powered Heat Pump Water Heaters

Natural gas engine powered heat pump water heaters (GHPWH) are heat pump water heaters that utilize an integral engine to power the system and typically recover heat from engine exhaust to increase operating efficiency. There are a number of different types of systems, including air to air, air to water, water to water, and variable refrigerant flow (VRF) type systems. This study focuses on systems designed to heat large quantities of water for large commercial, industrial, or institutional applications.

National Grid was able to provide us with cost estimates for two proposed projects. In addition, the sole active marketer of these systems in the Northeast also provided us with installed cost estimates. As these systems are more common in Europe and Asia, we also researched foreign markets to obtain cost estimates.

Technology Category 10 – Q-Sync Motors

Q-Sync motors are proprietary synchronous motors manufactured by QM Power. They are permanent magnet synchronous motors that directly utilize utility-supplied ac current. By contrast, standard electronically commutated (EC) motors require that the ac current be rectified to dc before it is applied to the motor windings, and rectifying electrical current produces some parasitic losses.

As a patent protected, proprietary technology not yet active in the marketplace, obtaining accurate estimated costs was difficult. However, the manufacturer has adopted a marketing approach of matching the approximate cost of currently available EC motors in the same output power ranges, and we were able to use that intent to estimate costs. In addition we were able to locate one supermarket facility manager who was currently investigating a pilot project and shared cost estimates. With this limited information, we also performed a calculation based on the pricing needed to meet typical cost-effectiveness requirements for efficiency programs, as QM Power reported recognition of the importance of such programs to the success of the project.

Technology Trends Suggested for Further Study

Discussions with market actors and related research allowed us to identify several trends that should be tracked carefully by efficiency program administrators in order to effectively incorporate emerging technologies into their programs, and/or support pilot programs. Notable trends include:

- Advanced thermostat capabilities – Recent developments are incorporating new features into thermostats. In addition to controlling HVAC systems, thermostats are promising additional home energy management capabilities similar to those offered by "smart" hubs.
- Smaller VRF systems – To date, VRF systems have been designed for commercial HVAC. Market actors have expressed plans to introduce "mini-VRF" systems for installation in single family homes.
- Large residential communication capable appliances – This study found this market to be very immature, with multiple product introductions and retractions. But, the success of the Internet of Things (IOT) is widely predicted and the potential for achieving demand reduction/response capability is promising.
- Compressed air strategies – With the exception of variable frequency drives, and leak repair, industrial compressed air is largely overlooked by program administrators. The options for advanced monitoring and control are expanding, and the potential savings are large.
- Commercial refrigeration – New restrictions on refrigerants are driving research and development into alternative systems. Many of these systems will offer efficiency opportunities for supermarkets and refrigerated storage.
- Advanced integrated lighting and controls – The new systems researched for this study appear to only be the beginning of a trend toward solid-state lighting systems with integrated controls. In addition, low-voltage systems are increasingly promoted as allowing higher efficiency at reduced installation costs.

Summary

Estimating full and incremental costs for emerging technologies is complex. No single method will generate accurate data, as the market readiness, activity, and chains vary greatly. For products mass-marketed to homeowners the process is relatively simple, although the product variety can be large, as with HEM products. Given the abundance of online pricing information for these products, it is not a complicated process to stay current on pricing trends. However, beyond these mass-market categories, the study team found it extremely useful to rely on a variety of data sources and approaches. Although market actors are often reluctant to provide project pricing due to competitive considerations, interviews with such actors proved to be the most valuable path for most of the technologies researched. Baseline costs can sometimes be readily obtained from efficiency program administrators, but restrictions on data sharing sometimes limit this source. When the above approaches did not result in sufficient reliable data, the study team incorporated alternative approaches such as researching foreign markets, calculating pricing needed to meet efficiency program cost-effectiveness tests, and market based price competitiveness strategies.

Efficiency programs need to progressively adopt emerging technologies in order to keep step with evolving market activities, and to harvest real savings as many of the efficiency measures supported for years are becoming standard practice due to advancing codes, standards, and technology progress. Although some program rules allow emerging technologies to be piloted outside the barriers of cost-effectiveness tests, for new technologies to be supported for full program delivery, incremental costs must be known and cost-effectiveness demonstrated. This study and subsequent updates will allow program administrators to assess cost-effectiveness during early program planning allowing program staff to better focus their efforts. As this study demonstrates, a research strategy employing multiple sources and methods and combining

limited data sources with other market intelligence can deliver timely information which helps program administrators seize emerging energy efficiency opportunities.

References

CEE (Consortium for Energy Efficiency). 2015. *Commercial HVAC.* http://library.cee1.org/sites/default/files/library/5347/CEE_CommHVAC_HECAC__InitDescip.pdf

CPUC (California Public Utility Commission). 2015. *California Statewide Work Paper SCE13HC036: VRF Systems.* www.caltf.org/s/Statewide-Workpaper-List_Cal-TF_150430_PUBLIC.xlsx

CPUC. 2015. *DEER Resources-costs pkg HVAC systems.* http://www.deeresources.com/files/DEER2016/download/DEER2016-Costs_PkgHVAC-Boilers_8-31-2015-DRAFT.xls

CPUC. 2012. *Ex Ante Measure Cost Study Final Report.* http://www.calmac.org/publications/2010-2012_WO017_Ex_Ante_Measure_Cost_Study_-_Final_Report.pdf

Fricke, B and Becker, B. 2015. *Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits.* Oak Ridge National Laboratory. http://info.ornl.gov/sites/publications/Files/Pub58600.pdf

Mitsubishi. 2015. *Thermostat interface product information.* http://www.mitsubishicomfort.com/sites/default/files/thermostat_interface_pr.pdf

NEEP. 2014-15. *Incremental cost studies phases 1, 2, 3 and 4* . *http://www.neep.org/incremental-cost-study-phase-1 http://www.neep.org/incremental-cost-study-phase-2 http://www.neep.org/incremental-cost-study-phase-3 http://www.neep.org/incremental-cost-study-phase-4*

NEEA (Northwest Energy Efficiency Alliance). 2015. *Northern Climate Heat Pump Water Heater Specification.* http://neea.org/northernclimatespec

Omar, T. 2015. *Does the VRF market in the United States deserve the buz? IHS Technology.* https://technology.ihs.com/527236/does-the-vrf-market-in-the-united-states-deserve-the-buzz