Strategies for Improving HVAC Efficiency with Quality Installation and Service

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Abstract
Residential and commercial air conditioning use the largest share of electricity demand in the United States with approximately 33% or 344 GW and 313 TWh. Space heating uses 5.08 quadrillion Btu per year or 57.3% of total residential and commercial gas consumption in the US. There are approximately 93 million air conditioners and 35 million furnaces in the US. Each year 6 million new air conditioners and 3.5 million new furnaces are installed. Research shows 50 to 70% of heating, ventilating, and air conditioning systems have improper refrigerant charge and airflow, leaky ducts, over-sized units, mismatched coils, or improper maintenance/operation causing them to be 10 to 40% less efficient than if they received quality installation or service (QIS). Significant energy and peak demand savings can be achieved with following measures: proper refrigerant charge/airflow, duct testing/sealing, cleaning condenser coils, proper-sized coils, matching coils, economizer maintenance, and cool roofs/attics. The historic market barriers to HVAC QIS measures include: organizational practices, high start-up costs, service availability, performance uncertainty, and lack of information. Innovative strategies are required to overcome these market barriers such as customer education, marketing, incentives, standards, labels, and verification service providers to train and equip HVAC technicians to deliver QIS measures. This paper provides an overview of energy savings, market barriers, and strategies in the US to improve HVAC efficiency with QIS and transform the market.

Introduction

Air conditioning uses the largest share of electricity demand in the United States with approximately 33% or 344 GW of total residential and commercial consumption [1]. Space heating uses the largest share of gas in the US with approximately 57.3% or 5.08 quadrillion British thermal units (Btu) per year of total residential and commercial gas consumption.[1] Annual air conditioning electricity consumption is approximately 161 TWh for residential and 152 TWh for commercial. Annual space heating consumption is approximately 3.32 quadrillion Btu for residential and 1.76 quadrillion Btu for commercial. There are approximately 93 million air conditioners and 35 million furnaces in the US. Each year 6 million new air conditioners and 3.5 million new furnaces are installed [2]. Energy efficiency programs have historically provided incentives to encourage customers to purchase high efficiency equipment to reduce heating, ventilating, and air conditioning (HVAC) energy use. This only captures a small portion of potential savings. Research shows 50 to 70% of HVAC systems have improper refrigerant charge and airflow, leaky ducts, over-sized units, mismatched coils, or improper maintenance/operation causing them to be 10 to 40% less efficient than if they received quality installation or service [3, 4, 5, 6].

Significant energy and peak demand savings can be achieved with following QIS measures: proper refrigerant charge/airflow, duct testing/sealing, cleaning condenser coils, proper-sized coils, matching coils, economizer maintenance, and cool roofs/attics. This paper provides a brief description of each measure along with field measurements and supporting information. The paper provides an overview of market barriers to HVAC QIS and how these market barriers are addressed by third-party verification service providers. The paper discusses program implementation strategies to improve HVAC efficiency with QIS including customer education, marketing, incentives, standards, labels, and verification service providers (VSPs) to train and equip HVAC technicians to deliver QIS measures. The paper also provides an overview of US efforts to address QIS and how these efforts should be improved to transform the market.

[1] The British Thermal Unit (Btu) is the energy required to raise one pound of water one degree Fahrenheit.

Energy Savings for HVAC Quality Installation and Service Measures

This section provides descriptions and energy savings associated with the following HVAC QIS measures: 1) proper refrigerant charge/airflow (RCA), 2) duct testing/sealing, 3) cleaning condenser coils, 4) proper sized coils, 5) matching indoor/outdoor coils, 6) economizer maintenance, and 7) cool roofs/attics.

Refrigerant Charge and Airflow
Proper refrigerant charge and airflow improve the efficiency and longevity of split-system and packaged air conditioning systems. Average energy and peak demand savings for proper RCA are approximately 9 to 12 percent for kWh and kW based on field measurements and the 2004-2005 Database for Energy Efficiency Resources Update Study [7]. Several studies show approximately 40 to 67 percent of air conditioners suffer from improper RCA, and this reduces efficiency by roughly 10 to 20 percent [2, 8, 9]. A study of commercial units in California found 46% were improperly charged causing reduced cooling capacity and efficiency [10]. The study found 39% had very low airflow rates (< 300 cfm/ton).[2] The average airflow rate of all units tested was 325 cfm per ton or 20% less than the airflow generally used to rate efficiency. Improper charge and reduced airflow results in reduced efficiency and cooling capacity. The average energy impact is 9 to 12 % of annual cooling energy.

Most air conditioning technicians in the United States do not have proper training, equipment, and verification methods to diagnose and correct improper RCA. Consequently, many new and existing air conditioners have improper RCA causing reduced efficiency, noisy systems, and premature compressor failure. To address this problem, the California Energy Commission (CEC) adopted residential building standards in 2001 (CEC Standards) requiring either the Alternative Calculation Method (ACM), thermostatic expansion valve (TXV), or proper RCA [11]. Most air conditioners are installed using the ACM which is a computer method to show compliance with the annual energy budget requirements of the standards. The standards require inspections by Home Energy Rating System (HERS) raters to verify installation of TXV or proper RCA under the prescriptive approach or the ACM. The CEC allows a TXV to substitute for proper RCA based research findings from three laboratory studies showing improper RCA can be mitigated by a TXV [12, 13, and 14]. The studies found TXV systems only had an advantage over non-TXV systems when undercharged.

TXV-equipped systems have problems when incorrectly installed leading to a phenomenon known as “valve hunting.” This can occur when the evaporator coil experiences reduced heat loads caused by low airflow, dirty or icy coils, and low refrigerant charge [15]. Under these circumstances the TXV can lose control and successively overfeed and then underfeed refrigerant to the evaporator while attempting to stabilize control causing reduced capacity and efficiency. Overfeeding liquid to the evaporator can also damage the compressor. The tendency for hunting can be reduced by correcting RCA, by relocating the TXV sensing bulb to a better location inside the evaporator coil box, and by insulating the sensing bulb. Field and factory-installed TXV sensing bulbs are often installed without insulation, without adequate linear contact, and at incorrect orientations. This practice is not recommended by manufacturers [16]. Factory-installed TXVs with un-insulated sensing bulbs inside the evaporator coil box will be influenced by mixed supply-air temperatures which are typically 10-20°F higher than vapor line temperatures. Field-installed TXVs with un-insulated sensing bulbs located in attics or garages will be influenced by attic or garage temperatures which are 50 to 80°F higher than vapor line temperatures. The three laboratory studies measured TXV-equipped air conditioners with the evaporator coil box, TXV, and well-insulated sensing bulb located in conditioned space and this is not typical of field conditions.

Field measurements for a 4-ton TXV air conditioner are shown in **Figure 1** [2]. The TXV air conditioner used 5.8 kW when overcharged and 4.8 kW when properly charged for a savings of 1 kW. The energy efficiency ratio (EER) increased by 37 percent from 7.1 EER to 9.7 EER.[3]

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[2] The “cfm” is defined as cubic feet per minute of airflow. The “ton” is defined as 12,000 Btu per hour of cooling capacity equal to the rate of extraction of latent heat when one short ton of ice (i.e., 144 Btu per pound) is produced from water at the same temperature.

[3] The energy efficiency ratio or EER is the cooling capacity in thousand Btu per hour (MBtuh) divided by total air conditioner electric power (kW) including indoor fan, outdoor condensing fan, compressor, and controls. EER is typically measured under laboratory conditions at 95°F condenser entering air, 80°F drybulb, and 67°F wetbulb evaporator entering air.

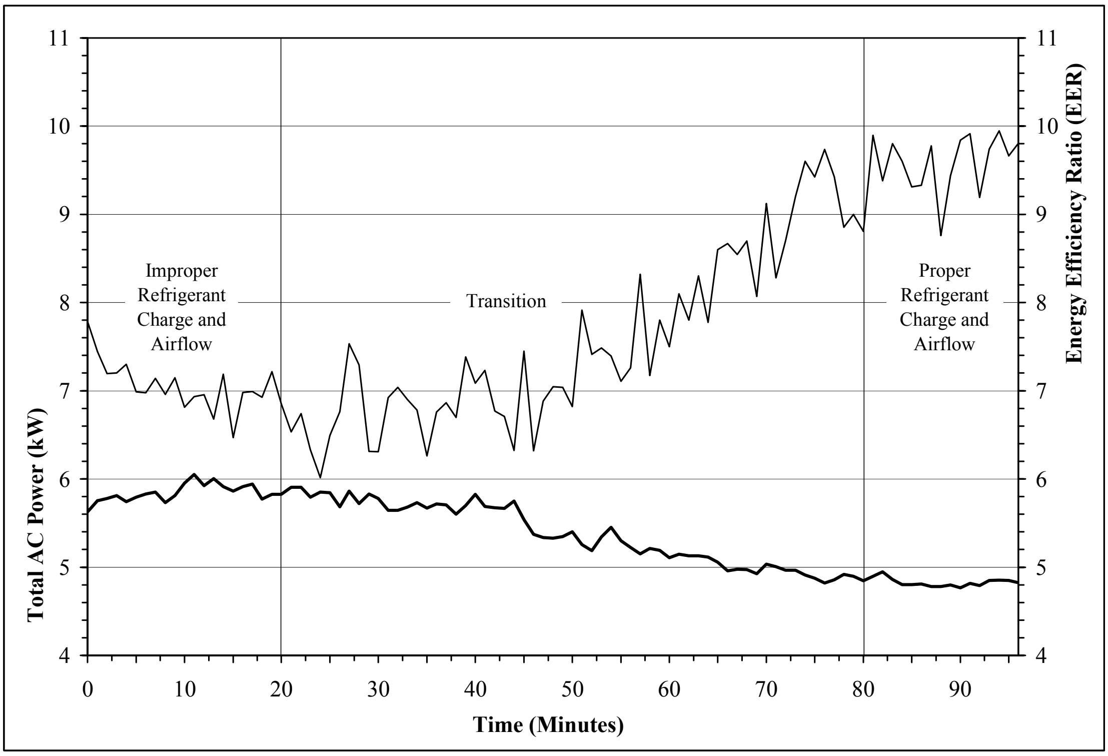

Figure 1. Measurements of a 4-ton TXV Unit with and without Proper RCA Source: [2]

Measurements of a 10-ton packaged rooftop air conditioner with and without proper RCA are shown in **Figure 2**. The 10-ton unit had a dirty/icy evaporator coil and dirty air filters and was overcharged by 14.2 ounces or 7.1 percent of the factory charge. With improper RCA the average efficiency was 5.7 EER, and average power usage was 13 kW. With proper RCA the efficiency improved to 10.3 EER, and the average power was reduced to 9.5 kW. This is consistent with the ARI rating of 10.3 EER.

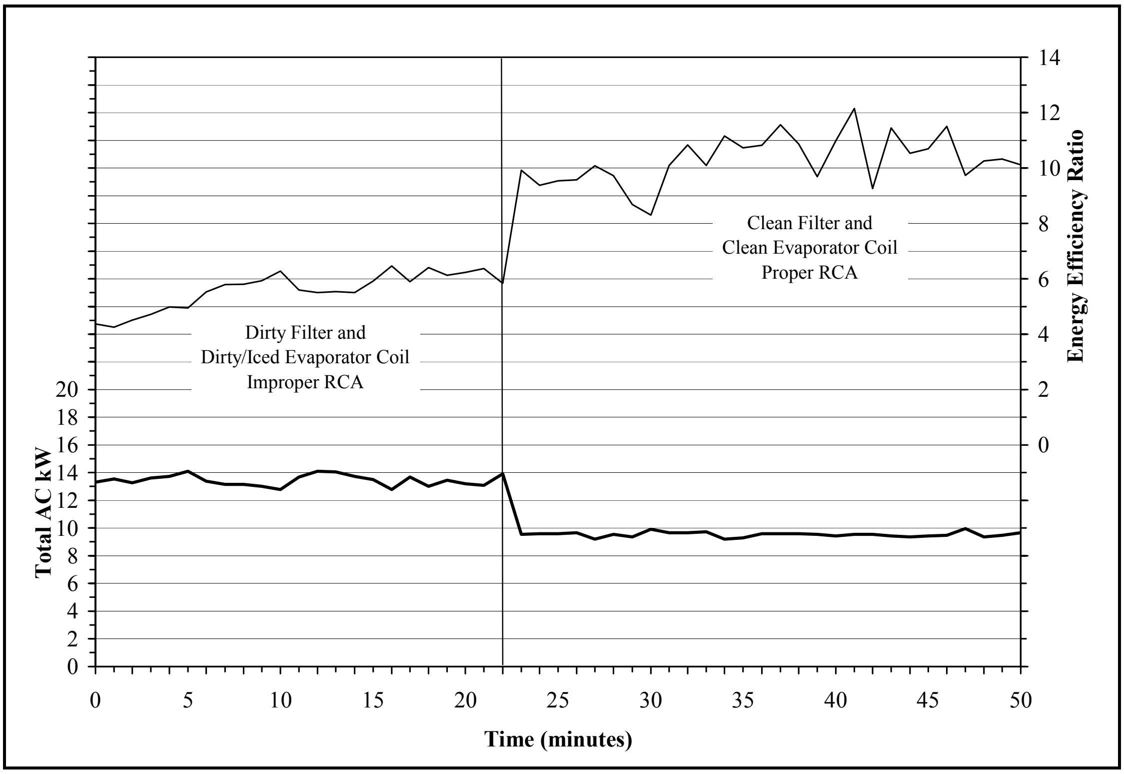

Figure 2. Measurements of 10-ton Packaged Unit with and without Proper RCA Source: [2]

Duct Testing and Sealing
Duct testing and sealing reduces duct leakage and run time and improves efficiency of heating, ventilating, and air conditioning systems. Average energy and peak demand savings for residential duct testing and sealing are 5.8 to 8.8% for kWh and 8.4 to 27.6% for therms based on the 2004-2005 DEER Study Update [7]. Research indicates that duct leakage in commercial buildings may be comparable to residential buildings [18, 19, 20]. Ducts in commercial buildings with simple rooftop package units are often located in ceiling plenum spaces that are similar to residential attics.

Duct leakage is typically described three ways: 1) Fraction of flow through the HVAC equipment that is lost, 2) Equivalent hole size, or 3) Leakage flow at a reference pressure. The latter two are often normalized by either the surface area of the ductwork or the conditioned floor area. The ductwork in small commercial buildings is leaky by all three metrics. Using the first metric, the work at LBNL indicates the average supply duct leakage for 25 Constant-Air-Volume (CAV) systems was 26% of the flow through the HVAC equipment, as compared to average supply-side leakage of 17% in residential systems [18]. Using the second metric for the 25 systems, LBNL research showed an average normalized commercial duct leakage area of 3.7 cm^2 per m^2 of floor area for supply and return ducts. The comparable residential attic duct-leakage is 1.3 cm^2 per m^2 of floor area. These results suggest that duct leakage of some light commercial duct systems can be greater than residential systems.

Cleaning Condenser Coils
Clean condenser coils provide optimal heat transfer from the condensing coil to deliver rated capacity and efficiency for split-system and packaged air conditioners. Average energy and peak demand savings for condenser coil cleaning are 8 to 12% based on the 2004-2005 DEER Study [7]. Trane found an efficiency loss of 27 percent due to conditions of accelerated fouling for multi-row coils equivalent to 8 years of typical operating conditions or annual fouling of 6.8% for commercial multi row coils [22]. Trane provided data from a study of two air conditioners operated continuously with condensers exposed to a dirty factory environment for 18 months, and this was reported as equivalent to roughly 4 to 8 years of typical operating hours. Performance measurements indicated the air conditioner with a standard plate fin coil lost 17% of its capacity and 27% of its efficiency.

Field measurements of a packaged air conditioning unit with a leaky Schrader valve and dirty condenser coil are provided in **Table 1** [23]. The AC unit was found to be inoperable due to lack of refrigerant from a leaky Schrader valve. The leaky valve was repaired and 55 ounces of R-22 was weighed in with a digital scale to achieve proper superheat within ±5°F.[4] Technicians then combed and cleaned the condensing coil. The cooling capacity and electric power usage were measured before and after adding refrigerant charge and combing/cleaning the condensing coil. Savings from combing and cleaning the condenser coil are estimated to be 15% based on the measured EER improvement (9.0 EER with dirty coil and 10.4 EER with clean coil).

Table 1. Field Measurements of Air Conditioner Efficiency from Cleaning Condensing Coil

Description	Rated EER 95 ODT	Rated Capacity Btuh	Rated kW	Measured EER 80 ODT	Measured Capacity Btuh	Measured kW
Leaky Schrader valve no refrigerant charge	8.5	18,000	2.1	0.2	174	1.1
Repaired leaky Schrader valve and added 55 ounces of R-22 refrigerant				9.0	19,000	2.1
Post-retrofit cleaned condenser coil				10.4	21,900	2.1

Source: [23]

Proper Sized Coils (ACCA Manual J)
Proper sized coils (per ACCA Manual J) improve the capacity and efficiency of split-system air conditioners. Energy and peak demand savings for proper sized evaporator/condenser coils per ACCA Manual J are 10 to 18 percent based on field studies showing most units are significantly oversized, resulting in inefficient operation, reduced reliability due to frequent cycling of compressors, and poor humidity control [24]. Oversized systems waste capital invested in both the HVAC unit and

[4] The factory charge is 55 ounces of R-22 refrigerant, for the 1.5 ton Carrier rooftop AC unit Model 585GJ018040.

distribution system. System over-sizing also affects the ability of the system to provide simultaneous economizer and compressor operation, and exacerbates problems with distribution system fan power, since larger units are supplied with larger fans. Each time an air conditioner starts, the input energy is approximately constant, while it takes several minutes to reach full cooling capacity. Oversized units operate for a shorter cycle, and the startup time is a greater fraction of the total runtime. The startup losses are also a greater fraction of the total cooling output, reducing overall efficiency. Systems that are properly sized will run longer during each cycle, and the startup losses are small relative to total cooling output. In a study of 250 rooftop units conducted for Pacific Gas and Electric Company, the typical runtime under hot conditions was 6 minutes, with an off-time of 16 minutes [25]. This represents a 27% runtime fraction with a reduction in unit efficiency of 18%. The system efficiency is reduced as the runtime decreases. When the unit runs continuously (CLF = 1), the part-load factor is 1.0, indicating no degradation due to cycling. When the unit runs 60% of the time, the CLF is 0.6 and the unit efficiency is reduced by about 10%. If the unit runs only 30% of the time, the efficiency is reduced by about 15% [26].

ARI Matching Coils on Split System Air Conditioners
ARI matching coils provide the rated capacity and efficiency for split-system air conditioners. Energy and peak demand savings for ARI matching coils on split system air conditioners are 5 to 15 percent based on field measurements of systems with improper matching coils. Even with correct refrigerant charge many split-system air conditioners do not perform at their rated efficiency due to improperly matching evaporator and condenser coils. Condensing coil manufacturers cannot guarantee rated efficiency per Air-Conditioning and Refrigeration Institute (ARI) SEER/EER ratings with evaporator coils manufactured by independent coil manufacturers that are not listed in the ARI directory as a proper match for the condensing coil [27]. Field measurements of two new split-system air conditioners are provided in **Table 2** [28]. Pre-EER values were measured with improper RCA, and post-EER values were measured with proper RCA. The post-EER is 6.5 or 35 percent less than the 10 EER rating due to improper matching coils. This is a common problem with split system units.

Table 2. Field Measurements for Two New Split-System Air Conditioners

Site	Rated EER	Rated Capacity MBtuh	Measured Cooling Capacity Post MBtuh	Average Outdoor, Indoor Dry/Wet Bulb °F	Airflow cfm	Duct Leak cfm @ 25 Pa	Infil. cfm @ 50 Pa	EER Pre	EER Post	Service Adjust Oz.	Percent Charge Adjust per Factory Charge
#1	10	51	38.5	105/81/65	1631	19%	1830	3.9	6.5	+98.2	+49.4%
#2	10	51	41.6	105/80/64	1734	12%	1537	5.5	6.5	+12.5	+6.3%

Note: Rated EER values are based on manufacturers' data. Source: [28]

Economizer Set-up and Maintenance
Economizer set-up and maintenance reduce unnecessary air conditioning when outdoor temperatures are cool enough to provide free cooling (i.e., reduce compressor use). Average energy and peak demand savings for commercial economizer set-up and maintenance are 9 to 21% based on the 2004-2005 DEER Study [7]. A study of commercial packaged units in California with economizers generally found 64% not operating properly [24]. Failure modes included dampers that were stuck or inoperable (38%), sensor or control failure (46%), or poor operation (16%). The average energy impact of inoperable economizers is about 37% of the annual cooling energy. The 2005 DEER Study found annual savings of 21.3%.

Selection of the changeover setpoint has a major influence on the energy savings potential of an economizer. If the changeover setpoint is set too low, then mechanical cooling will operate exclusively even when the economizer is capable of meeting the cooling load [24]. Single point changeover setpoints are selected on the economizer controller according to an A, B, C or D setting. The selection of the changeover setpoint depends on the climate; humid climates require a lower setpoint than dry climates. According to the Title 24 Energy Standards, the "A" setpoint is appropriate for all climates in California. However, observations of single point changeover setpoint selection in the PIER study behind this Design Guide showed that the "A" setting was rarely used. Manufacturers may not ship their products with the "A" setting as the default, requiring a field adjustment of the controller setting. The distribution of economizer control setpoints observed in the field for single point enthalpy economizers shows only 28% of the systems in the "A" position as required by Title 24. Most systems were set in the "D" position, which results in the fewest hours of economizer operation.

Many of the economizer problems observed in the field can be avoided through careful selection and specification of rooftop unit economizer features. The following measures will improve economizer efficiency and reliability [24].

1. **Specify factory-installed and run-tested economizers**. The majority of economizers are installed by the distributor or in the field. Specifying a factory-installed and fully run-tested economizer can improve reliability.
2. **Specify direct drive actuators.** Economizers with direct drive actuators and gear driven dampers can reduce problems with damper linkages that can loosen or fail over time.
3. **Specify differential (dual) changeover logic.** Differential temperature or enthalpy changeover logic instead of single point changeover systems eliminates problems with improper setpoint and maximizes economizer operation.
4. **Specify low leakage dampers for outside and return air.** Low leakage dampers with blade and jamb seals will improve economizer effectiveness by limiting return air leakage during economizer operation and outdoor air infiltration when the unit is switched off.

Cool Roofs and Cool Attics

Cool roofs and cool attics reduce cooling loads and improve cooling capacity and reduce run time for split-system air conditioners in residential buildings. Average energy and peak demand savings are 10 to 30% based on studies by Lawrence Berkeley National Laboratory and the Florida Solar Energy Center [29, 30]. Cool attics provide similar savings using radiant barriers or attic ventilation fans. Solar-powered or conventional attic ventilation fans with thermostat control will reduce solar heat load transferred to conditioned space and attic temperatures where air conditioner evaporators and ducts are located. Cool roofs stay cooler in the sun than conventional roofs. Roofs that have high solar reflectance (high ability to reflect sunlight) and high thermal emittance (high ability to radiate heat) tend to stay cool in the sun. The same is true of low-emittance roofs with exceptionally high solar reflectance. Low roof temperatures lessen heat flow from the roof into the building, reducing space cooling electricity use in conditioned buildings. Since building heat gain through the roof peaks in late afternoon, when summer electricity use is highest, cool roofs also reduce peak electricity demand. Prior research indicates savings are greatest for buildings located in climates with long cooling seasons and short heating seasons, particularly buildings that have distribution ducts in the plenum, cool-coatable distribution ducts on the roof, and/or low rates of plenum ventilation [30]. Prior studies measured air-conditioning energy and peak demand savings from cool roofs on nonresidential buildings in California, Florida, and Texas. Cool roofs typically have measured summertime air-conditioning energy and peak demand savings of 10–30%, although savings have been as low as 2%.

Cool roofs transfer less heat to the outdoor environment than do conventional roofs. The resulting lower outside air temperatures can slow urban smog formation and increase human health and outdoor comfort. Reduced thermal stress may also increase the lifetime of cool roofs, lessening maintenance and waste. The potential of cool roofs to save cooling electricity has not gone unnoticed. In its revised standards for commercial and residential buildings, the American Society for Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) included provisions to offer credits in building energy-use budgets for cool roofs [31]. In January 2001, the state of California followed ASHRAE by adopting standards to offer Title 24 compliance credit to new commercial buildings with cool roofs [11]. Georgia, Florida, and Chicago also have building codes to encourage cool roofs.

Market Barriers

There are many market barriers to HVAC quality installation and service (market barrier definitions are from 32). Performance uncertainty is an important barrier since consumers have difficulty evaluating claims about future benefits associated with unverified energy guide performance labels. Truth in advertising is important to consumers who assume new units will be installed properly. Unfortunately, many new air conditioners do not perform as advertised due to improper installation or service, and this undermines the credibility of the US energy guide labels [33]. At a minimum, the labels should include a caveat regarding SEER ratings only being valid for air conditioners installed with quality installation and service according to manufacturers' specifications. Other important market barriers include lack of information or knowledge about the importance of quality installation and service in terms of delivering rated efficiency, reducing noise, and maintaining longer life of air conditioners. Organizational practices and rules of thumb discourage quality installation such as "add or remove refrigerant until the suction line is six-pack cold" or "shows 70 psig on the suction side and less than 250 psig on the liquid line." Service availability for new air conditioners is an important barrier for manufacturers, distributors, and dealers who are generally not verifying quality installation and service due to lack of awareness and availability of cost effective and easy-to-use verification services.

These market barriers are addressed by third-party verification service providers such as: Verified™, Enalasys™, Honeywell Service Assistant™, and CheckMe™ [34, 35, 36, 37]. VSPs offer cost-effective methods to verify proper RCA, TXVs, duct testing/sealing, and other measures. Verification software is provided on several platforms: 1) Personal Digital Assistant (PDA), 2) cell-phone telephony, 3) web-enabled PDA, 4) cell phones, 5) notebook computers, or 6) telephone call-in systems. VSP programs can be deployed in any language, and since the systems are automated, the cost per verified unit is low. Verification information is collected and archived on databases where technician-supplied data is checked for accuracy and can be viewed over the internet by consumers, inspectors, dealers, and program managers. The VSP randomly inspects jobs to ensure quality results. One third-party VSP provides clearly identifiable Verified™ labels and locking, double-sealing, laser-etched Schrader caps, with tamper-proof keys for technicians. Locking caps are designed to maintain proper RCA for the life of the air conditioner. This is important since air conditioning systems are made of welded copper pipe and Schrader valves are the weakest link. Air conditioners vibrate and this causes Schrader valve cores to loosen over time and leak refrigerant. Most air conditioners have easily removable Schrader caps without integral "O-ring" seals. Safety is another reason why locking Schrader caps are important as evidenced by the deaths of two teenagers in Southern California due to inhalation of refrigerant as an intoxicant [38].

Strategies

A number of intervention strategies are required to improve HVAC efficiency with quality installation and service such as third-party verification service providers, customer education, marketing, training, incentives, standards, and labels. Third-party verification service providers are required to train and equip HVAC technicians to deliver and verify quality installation and service. Customer education, standards, and labels are important to create demand for QIS. Incentives will help motivate interest, but are insufficient by themselves to deliver HVAC QIS and transform the market. Consumers generally assume their air conditioners are properly installed. Current efficiency standards do not mention the importance of QIS, and California building standards allow a TXV to substitute for proper RCA to receive the same compliance credit. Therefore, most consumers and builders do not understand the value of proper RCA. Research studies show HVAC dealers lack interest, training, equipment, and methods to perform proper installation and service measures such as RCA and duct testing/sealing measures. To develop a robust set of supply-side market actors, Verification Service Providers (VSPs) must recruit, train, and equip local HVAC dealers to deliver HVAC QIS measures.

Several utility programs in the United States offer verification service provider incentive programs. Most programs do not include the new construction market and most programs are implemented through only one VSP. This is a problem for HVAC dealers who are trained and equipped to perform HVAC QIS with a different VSP. Switching to a different VSP to participate in a program creates unnecessary barriers and can cost thousands of dollars per technician. Having a different program in each utility service area creates problems for larger HVAC contractors who have an established VSP relationship. Classroom training on quality installation will not be effective without VSP involvement to increase participation and help transform the market for third-party verification. With greater participation, there will be more demand and competition for QIS. Competition will expand the market and drive down the incremental measure cost to the point where QIS is "standard practice" and incentives can eventually be withdrawn (i.e., exit strategy).

Utilities and government agencies should consider implementing comprehensive and consistent HVAC programs targeting new and existing residential and commercial market segments. The following measures should be considered: 1) proper refrigerant charge/airflow, 2) duct testing/sealing, 3) cleaning condenser coils, 4) proper sized coils, 5) matching indoor/outdoor coils, 6) economizer maintenance, and 7) cool roofs/attics. VSPs and Home Energy Rating System providers should work together to recruit, train, and equip HVAC contractors to help transform the market for third-party verification of quality installation and service for both new and existing construction. Programs should consider internet or database registration and permanent labels for identification and facilitation of evaluation, measurement, and verification inspections. Locking Schrader caps should be promoted for RCA measures to help maintain efficiency, promote public health and safety, encourage proper refrigerant management practices, and prevent further stratospheric ozone depletion [39]. Programs should work with manufacturers to incorporate HVAC quality installation and service standards within warranty requirements, ASHRAE, and the International Standards Organization Technical Committee 86 (ISO, refrigeration and air conditioning, www.iso.org).

Conclusions

Energy efficiency programs have historically provided incentives to encourage customers to purchase high efficiency equipment to reduce HVAC energy use, but this only captured a small portion of potential savings. Research shows 50 to 70% of HVAC systems have improper refrigerant charge and airflow, leaky ducts, over-sized units, mismatched coils, or improper maintenance/operation causing them to be 10 to 50% less efficient than if they received quality installation or service. With approximately 93 million air conditioners and 35 million furnaces in the US and 6 million new air conditioners and 3.5 million new furnaces installed each year, the estimated potential energy savings from HVAC QIS are significant. These savings can be achieved through a number of intervention strategies aimed at downstream, midstream, and upstream market actors including: education, marketing, training, incentives, standards, and labels. One of the most important strategies for success is developing and supporting a robust supply-side verification service provider network to train and equip HVAC technicians to deliver and verify quality installation and service. Utilities and government agencies should encourage manufacturers, distributors, and HVAC dealers to work with VSPs to improve HVAC efficiency with QIS. Utilities and government agencies should also motivate consumers to demand HVAC QIS through education, marketing, incentives, standards, and labels.

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