Changing Installation Practices of A/C Installers: Three Years of Results

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ABSTRACT

As new federal air conditioning efficiency standards are implemented, the potential for achieving incremental savings by promoting higher efficiency equipment is becoming limited. Nonetheless, significant savings can be obtained by promoting better installation and sizing practices. This paper reports on one large utility's results in implementing a market transformation program to improve AC installation practices.

In 2003, TXU Electric Delivery began implementing an AC Installer and Information Market Transformation Program. This program was designed to encourage quality installation practices based upon the Consortium for Energy Efficiency Quality Installation Standards.

The impacts of this program were measured by comparing the installation practices of installers who had completed training efforts offered through the program against those of non-participating air conditioning technicians, both within the utility's service area and in adjacent utility service areas.

For the past three years, annual surveys of participants and non-participants have been conducted. The results of these surveys indicate that:

- Participating installers are more likely than non-participants to install complete HVAC systems (ARI-matched condensing unit and coil) in retrofit applications when only one of the components fails.
- Relative to non-participants, participating installers have a higher percentage of their installations in the 13-16 SEER range, and a lower percentage in the 10-11.9 SEER category.
- Installer program participants are more likely to install correctly-sized units in retrofit applications, and more likely to include duct leakage testing and sealing in new construction installations.
- Program participants are more likely to use longer-lasting materials to seal ductwork than non-participants.

Background

In Texas, air conditioning is responsible for a large portion of total residential electricity usage and peak demand, and energy efficiency programs focused on this end use provide an important energy efficiency opportunity. While TXU Electric Delivery and many other electric utilities have provided rebates or financial incentives to encourage the installation of more efficient equipment for many years, energy efficiency efforts related to this end use are now increasingly focused on market transformation. In Texas, PUCT Substantive Rule 25.181 defines market transformation programs as "strategic efforts, including, but not limited to, incentives and education designed to reduce market barriers for energy-efficient technologies and practices." The primary objective of this program is to provide cost-effective reduction in peak demand by helping to develop the market for proper HVAC installation practices. While new federal efficiency standards for air conditioning equipment in the U.S. will limit the additional gains that can be achieved through rebate programs that encourage the purchase or installation of more efficient equipment, immense opportunities remain for energy and demand savings through improved equipment installation and sizing practices (Neme, Proctor and Nadel, 1999).

TXU Electric Delivery's AC Installer Market Transformation Program was launched in 2003 to address several of the market barriers known to exist in the residential HVAC market in Texas which prevent or discourage the economically-optimum levels of energy efficiency in installed HVAC equipment. These barriers include :

- **Lack of information.** AC dealers often lack knowledge of proper installation, testing, and quality control techniques, including airflow measurement, duct leakage diagnosis and treatment, equipment sizing, and proper refrigerant charging techniques. Furthermore, they lack knowledge of the energy impacts of poor installation and maintenance practices. Sales data compiled by one Texas utility indicates that over 40% of the replacement condensing units sold by local distributors are not sold as part of a matched system. From the consumer perspective, the attributes of a proper installation are not readily known. As a result, consumers don't know what to ask for prior to the installation or what to look for after a unit has been installed.
- **Higher up-front costs.** As with other services, higher-quality installation services may be expected to cost more.
- **Split incentives.** Homeowners rely heavily on their AC dealers to recommend appropriate equipment. AC dealers may make recommendations based on a variety of factors, such as equipment availability, type of equipment already in place, ease of installation, and other factors, but not energy efficiency. In multifamily installations, the owner or property manager is generally more concerned with initial cost rather than annual operating cost, which are usually the responsibility of the tenant.
- **Performance uncertainties**. Homeowners may be wary of more complicated, high-SEER HVAC systems. AC dealers and installers may tend to oversize equipment to assure that there will be sufficient cooling under extreme conditions and to compensate for possible (in many cases, probable) air distribution system deficiencies. Homeowners may lack the confidence that a smaller-capacity unit will provide adequate comfort. Because of these uncertainties, homeowners incur extra cost up-front, from larger-than-necessary equipment, as well as higher operating costs over the life of the equipment. Short cycling can also lead to humidity problems and premature compressor failure.
- **Bounded rationality.** AC dealers typically replace an existing unit with a new unit of the same size, without performing Manual J® calculations or checking the condition of the duct systems. This practice saves the contractor planning time and effort, but may result in higher utility bills and reduced comfort.

In order to address these barriers to energy efficiency, TXU Electric Delivery's AC Installer Program provides training and education to installers of HVAC equipment, along with financial incentives to encourage proper unit installation, duct sealing, and related measures. To address the bounded rationality and performance uncertainty barriers, the program requires proper unit sizing in the form of a Manual J or N load calculation. To address the information barrier, the program provides training sessions and/or materials for dealers and installers, as well as informational materials for end-users.

Installer Training

The AC Installer Program training is specifically designed to educate HVAC contractors and technicians on the practices that comprise a proper installation. The training is organized into the following classes:

- The Duct Rough-In class is taught on-site in English and Spanish. This hands-on training teaches the use of mastics and proper assembly and layout to minimize duct leakage in new construction.
- The New Construction Class focuses on sizing equipment correctly and duct selection and sealing. The class is divided between classroom and a lab to demonstrate the principles taught in the class.
- The Replacement Class teaches proper sizing and how to address the problems often faced in bringing an existing system up to standards. Using classroom instruction and a lab, the training objective is to teach methods for getting the most out of an HVAC system that was not installed to today's standards.
- The System Design class covers everything from proper sizing of equipment to sales. This class begins with the basics and goes through proper equipment and duct design. Air distribution, both supply and return, is taught as being critical to the delivery of the equipment's design output. Proper refrigerant charging methods and acceptable ranges are included.

All of the classes have a final exam, and participants must score 70 or above to receive credit for the course. The classes are recognized for CEU credits for NATE re-certification.

The Air Conditioning Contractors of America, North Texas Chapter (ACCA – NTX), administers the Installer Program for TXU Electric Delivery. The ACCA – NTX / TXU Electric Delivery Installer Program begins with a contract between ACCA – NTX and the dealer. After attending required training, dealers are allowed to submit system installations for incentives.

Validation of Installation Practices

Why validation and not inspection? Participating contractors were wary of other air conditioning contractors inspecting their work and communicating results to customers. The term "inspection" implies a critical review of the installation, whereas "validation" implies a confirmation. The participating contractor is also encouraged to be present when the on-site validation is being conducted, to alleviate some of these concerns.

Each installation receives a review of the commissioning data: system design, air distribution, air supply and return, refrigerant charge and duct leakage. These data are collected from the installing technician. This review is conducted by a licensed air conditioning contractor who is not participating in the Program. In addition, the Program uses two levels of on-site validations. Both the installation sites and the level of validation are determined by a random sampling protocol.

The first level of on-site validation is a visual inspection of the duct system and verification of the serial and model numbers of the installed system. The second level adds static pressure measurements, dry and wet-bulb temperature measurements, air leakage testing, and instantaneous kW readings taken with a power analyzer.

Once a system has passed the validation process, submission for an incentive payment is prompted by ACCA – NTX and a check is issued to the dealer by TXU Electric Delivery.

The AC Installer Program is actually one component of a suite of programs offered by TXU Electric Delivery to promote energy efficiency in air conditioning. The Air Conditioning Distributor Program provided up-stream incentives for the installation of high-efficiency air conditioning units less than 20 tons in size. (This program was discontinued at the end of 2005.) In addition, air conditioning equipment can receive an incentive through the utility's standard offer programs, and is an important factor in determining whether a new home qualifies for a financial incentive through the utility's Energy Star New Homes program.

Identifying the Impacts

Quantifying the impacts of market transformation programs that provide training and information is inherently difficult. Evaluating the success of this particular program presents some special challenges, since it is one program among a set of programs offered by the utility to promote air conditioning energy efficiency opportunities. For example, the Air Conditioning Distributor Program also provided considerable training and information that might (less directly) affect the installation and sizing practices of equipment installers.

In 2004, 2005, and 2006, installers that participated in the program (i.e., completed the training) in the previous year were surveyed, along with control groups of installers who had not completed the training. The groups surveyed included:

- Participants in TXU Electric Delivery's AC Distributor and AC Installer programs (all participants were included in the sample). In 2006, only the 2005 Installer program participants were surveyed.
- Non-participating dealers in or adjacent to TXU Electric Delivery's electric distribution service area.
- Dealers from areas outside TXU Electric Delivery's service area and adjacent counties.

TXU Electric Delivery program data was used to identify dealers who participated in the Distributor and Installer programs. The Texas Department of Licensing database was used to identify non-participating dealers, both inside and outside the utility's service territory. No attempt was made to include non-licensed contractors in the sample or characterize their installation practices. The two-page survey included questions on the following:

- Number of residential new construction and replacement installations performed during the most recent year
- Percentage of replacement installations that include a complete system changeout versus condenser-only changeouts
- Distribution of new and replacement installations by SEER ranges
- Average size (tons) for standard-efficiency versus higher efficiency units
- R-value of installed ductwork

- Charging techniques for TXV and capillary tube systems
- Use of a Duct Blaster™ or similar device in new and replacement installations
- Materials used to seal duct connections
- Percentage of replacement installations that were downsized
- Percentage of new and replacement installations that included measurements of air flow across the coil

Aside from a verification question asked at the beginning of the survey, participants and non-participants were asked the same questions. The survey for the 2004 program was modified to include a question on charging practices, and the questions about duct design and leakage were made more specific. Technical questions were also added about duct design. The purpose of these questions was to allow the researchers to distinguish between contractors who utilize industry-standard duct design procedures vs. "rule-of-thumb" techniques. For the 2005 program evaluation, the charging question on the survey was modified to yield more specific responses. A $20 gift card to Lowe's or Home Depot was offered to survey respondents as a thank-you for completing and returning the survey. Sample sizes, responses and response rates (in parentheses) are listed in Table 1.

Table 1. Sample Sizes and Responses

	2003 Program	2004 Program	2005 Program*
AC Distributor and Installer program participants	594	700	155
Non-participating dealers in or adjacent to TXU service territory	208	600	559
Non-participating dealers outside TXU service territory	548	998	593
Total surveys mailed	1,350	2,298	1,307
Participant responses	93 (15.7%)	170 (24.3%)	55 (35.5%)
Non-participants within TXU	44 (21.2%)	81 (13.5%)	75 (13.4%)
Non-participants outside TXU	59 (10.8%)	140 (14.0%)	69 (11.6%)
Total responses	196 (14.5%)	391 (17.0%)	199 (15.3%)

* for the 2005 Program, AC Distributor participants were not surveyed.

Survey Results

SEER Distributions

The distributions of installed units by SEER category were tabulated and weighted based on the number of residential new construction (RNC) and replacement tons installed in 2004 by each survey respondent. Table 2 provides the survey results for the years 2003-2005.

Table 2. Average Efficiencies of Equipment Installed

		2003 Program Year	2004 Program Year	2005 Program Year
SEER Values, Without Adjustment				
for Condenser-Only Retrofits				
TXU Installer and Distributor Participants				
	Rep. units weighted by # of installs and tons/unit	12.58	13.06	13.18
	New const. units, wtd. by # of installs and tons/unit	12.43	12.30	12.67
All non-participants				
	Rep. units weighted by # of installs and tons/unit	12.06	12.47	12.32
	New const. units, wtd. by # of installs and tons/unit	11.97	12.07	12.45
Difference in SEER between Parts. and Non-Parts.				
	Replacement unit SEER value difference (*p* value)	0.51 (<.0001)	0.59 (<.0001)	0.86 (<.0001)
	New const. unit SEER value difference (*p* value)	0.46 (0.0006)	0.22 (0.0907)	0.22 (0.1249)
SEER Values, Adjusted for the % of				
Condenser-Only Retrofits				
TXU Installer and Distributor Participants				
	Rep. units weighted by # of installs and tons/unit	12.54	13.02	13.14
	New const. units, wtd. by # of installs and tons/unit	12.43	12.30	12.67
All non-participants				
	Rep. units weighted by # of installs and tons/unit	11.97	12.36	12.18
	New const. units, wtd. by # of installs and tons/unit	11.97	12.07	12.45
TXU parts. minus all non-parts.				
	Replacement unit SEER value difference (*p* value)	0.57 (<.0001)	0.66 (<.0001)	0.95 (<.0001)
	New const. unit SEER value difference (*p* value)	0.46 (0.0006)	0.22 (0.0863)	0.22 (0.1249)
Impact of Condenser-Only Adjustment				
	Rep. units weighted by # of installs and tons/unit	10.6%	10.9%	10.8%
	New const. units, wtd. by # of installs and tons/unit	0.0%	0.0%	0.0%

P-values, provided in parentheses in the above table, indicate the probability of detecting a difference this large or larger between the sample means if the population means are in fact equal (the null hypothesis).

Tons Per Unit

To establish proper weighting by tons, the researchers utilized the average system size data collected from the surveys. One of the original hypotheses was that higher SEER (12 and above) units tend to be slightly larger than lower SEER units. This was thought to be due to the number of 10 SEER apartment-sized units in the 1.5 and 2-ton sizes, and due to the number of higher SEER units in large custom homes. Table 3 contains the data on tons per unit by SEER category.

Table 3. Tons Per Unit By SEER Category

		Average tons	
		SEER 10-11.9	SEER >11.9
2003	Participants	3.61	3.92
	Non-Participants	3.02	3.45
	Difference (*p* value)	0.59 (<.0001)	0.47 (<.0001)
2004	Participants	3.34	3.63
	Non-Participants	3.23	3.52
	Difference (*p* value)	0.11 (0.0261)	0.11 (0.0258)
2005	Participants	3.48	3.71
	Non-Participants	3.18	3.66
	Difference (*p* value)	0.30 (<.0001)	0.05 (0.4578)

P-values, provided in parentheses in the above table, indicate the probability of detecting a difference this large or larger between the sample means if the population means are in fact equal (the null hypothesis).

Condenser-Only Replacements and Their Estimated Impact on System SEER

For each of the three years, program participants and non-participants were asked to provide the percentage of replacement installations that involved complete system replacements (new condensing unit and indoor coil), versus a "condenser-only" change-outs. Table 4 provides weighted averages of condenser-only changeouts.

Table 4. Condenser-Only Replacements

		Condenser-Only Changeouts in Replacement Applications
2003	Participants	35.6%
	Non-Participants	33.9%
	Difference (*p* value)	-1.7% (0.5548)
2004	Participants	35.1%
	Non-Participants	41.2%
	Difference (*p* value)	6.1% (0.0081)
2005	Participants	28.1%
	Non-Participants	40.8%
	Difference (*p* value)	12.7% (0.0003)

To adjust SEER values for the effect of condenser-only retrofits, the assumptions reported in Table 5 were utilized.

Table 5. Condenser-Only Retrofit Assumptions

	Participants
% of these in 10 SEER category	90%[1]
% of these in 10.1-11.99 SEER	10%
% of these in 12-12.99 SEER	0%
% of these in 13-13.99 SEER	0%
% of these in 14+ SEER	0%
Impact on 10 SEER Systems	10%
Impact on 10+ SEER Systems	10%

[1] Most condenser-only changeouts are assumed to be at or near 10 SEER

The two assumptions are that nearly all of the condenser-only replacements are in the lowest SEER ranges, and that the effect of a mismatched indoor coil is 10% reduction in SEER. The assumption that the SEER value of a split system air conditioner or heat pump will only be degraded by 10% would appear conservative, based on the potential ramifications of mismatched indoor coils, which include the following:

- Reduced heat absorption capability
- Improper pressure drop through the expansion device, distribution tubes and circuiting
- Improper charging due to the unknown volume of the existing coil
- Reduced air flow due to the degradation of the existing coil over time

However, a literature and web search did not identify any published data on the quantitative impacts of mismatched coils on system efficiency, so a conservative estimate of 10% impact on SEER was utilized. As is indicated in Table 2, the impact of the adjustments to SEER values to account for condenser-only changeouts in replacement installations is an increase of 10.6%-10.9% in the difference between the SEER values of program participant replacements versus non-participant replacements.

Downsizing in Replacement Applications

Beginning with the 2004 program, a question was added on downsizing in replacement applications. Table 6 provides weighted average responses on downsizing in replacement installations.

Table 6. Downsizing in Replacement Installations

		percentage of time do you install a system with a lower capacity than the existing system?
2004	Participants	15.6%
	Non-Participants	6.1%
	Difference (*p* value)	9.5% (0.0004)
2005	Participants	10.4%
	Non-Participants	4.7%
	Difference (*p* value)	5.7% (0.0060)

Based on the tons per unit and SEER values reported in the surveys, each downsized unit reduces peak demand by 0.54 kW. This assumes that all units are downsized by 0.5 tons. Multiplying this value by the incremental number of downsized installations each year gives downsizing impacts for 2004 and 2005 of 1.12 and 0.74 MW, respectively.

Duct Leakage Testing and Repair

Beginning with the 2004 program, several questions were added to the survey to gather more information duct leakage testing and sealing practices in new construction and replacement installations. Table 7 lists the responses to the duct testing and sealing questions.

Table 7. Duct Leakage Testing and Repair Practices

Question	Do you use a Duct Blaster or similar device?	If yes, what percentage of replacement installations include duct leakage and repair services?	What percentage of new construction installations include duct leakage measurements?
2004 Participants	52.0%	11.5%	32.1%
2004 Non-Participants	10.5%	7.5%	0.2%
Difference (*p* value)	41.5% (<.0001)	4.0% (0.1598)	31.9% (<.0001)
2005 Participants	39.1%	15.6%	19.4%
2005 Non-Participants	10.7%	4.9%	12.6%
Difference (*p* value)	28.4% (<.0001)	10.7% (0.0004)	6.8% (0.1954)

Of interest to the researchers is the significant increase in the percentage of non-participants performing duct leakage measurements in new construction. In 2004, this percentage was lower than that for replacement installation, but in 2005 it was considerably higher. Subsequent surveys will allow the researchers to determine if this was an anomaly or a trend.

To evaluate the impact of performing duct diagnostics on new construction installations, field measurements were conducted on samples of Energy Star homes during 2004. In these homes, air flow and duct system leakage rates were measured for qualifying and non-qualifying homes.

To estimate kW and kWh demand savings from duct leakage reduction, the deemed savings approved by the Public Utility Commission of Texas for duct efficiency measures were applied. These deemed savings values are 0.000486 kW per square foot for demand reduction and 0.718 kWh per sq. ft. for energy savings (North Texas Weather Zone, Electric AC / Gas Heat). These values were adjusted, based on the difference in leakage reduction assumed by the deemed savings calculations, and the leakage reduction measured in the sample of new homes. Table 10 presents a calculation of the impacts from duct sealing:

Table 10. Calculation of Impacts from Duct Sealing

2004 New Construction	2005 New Construction	2005 Replacements	
32.1%	19.4%	15.6%	Pct. of participants' new construction installations that include duct leakage test
0.2%	12.6%	4.9%	Pct. of non-participants' new construction installations that include duct leakage test
126	160	160	Number of dealers participating in 2003-2004 installer programs
392	330	152	Average number of RNC installations per installer program participant
49,437	52,781	24,291	Number of installer program participants' RNC installations
15,736	3,595	2,596	Incremental number of duct leakage tests
3.33	3.65	3.49	Average system size
399	399	399	CFM per ton (from field test data on 2004 homes)
1,328	1,458	1,393	CFM per system
1,895	1,895	1,895	Ave. sq. ft. per system (from field test data on program year 2004 Energy Star homes)
16.48%	16.48%		Baseline leakage rate (from field test data on non-qualifying 2004 homes)
5.27%	5.27%		Program leakage rate (from field test data on 2004 Energy Star homes)
		20%	Baseline leakage rate for 2005 existing homes (lower end of ranges from several studies)
		90	Post installation leakage rate for 2005 existing homes, CFM (from survey responses)
11.2%	11.2%	13.5%	Incremental leakage rate reduction from Installer program
0.000486	0.000486	0.000486	Deemed demand savings for duct leakage, KW/SF
0.718	0.718	0.718	Deemed energy savings for duct leakage, KWH/SF (TX Weather zone 2, gas heat)
0.561	0.561	0.676	Savings adj. (deemed savings is based on reduction from 30% leakage to 10%)
8.12	1.86	1.62	Deemed demand savings, MW
12,001	2,741	2,387	Deemed energy savings, MWH

Summary of Survey Results

For the differences in installation practices that can be readily quantified, the impacts for the 2004 and 2005 AC Installer Programs are summarized in Table 11.

Table 11. Summary of 2004-2005 Installer Program Impacts

2004 Installer Program Impacts		
Component	MW	MWH
Higher SEER	6.47	8,420
Downsizing	1.12	
Duct sealing in new construction	8.12	12,001
Program Totals	15.71	20,421

2005 Installer Program Impacts		
Component	MW	MWH
Higher SEER	9.27	11,574
Downsizing	0.74	
Duct sealing in new construction	1.86	2,741
Duct sealing in replacement installations	1.62	2,387
Program Totals	13.49	16,703

Conclusions

Initiatives to address air conditioning efficiency are being refocused to promote better installation and sizing practices.

TXU Electric Delivery's AC Installer Program appears to have achieved success in encouraging installers to install more efficient equipment, install complete HVAC systems in replacement installations, utilize better procedures for measuring duct leakage and sealing duct systems with longer-lasting materials, and adopt proper equipment sizing methods.

Additional survey activities should be conducted to provide better data on the attribution of program impacts. Surveys and other activities that provide data on changes in dealer and installer practices that occur as a direct result of program participation may provide the additional data required to better evaluate the impact of specific program elements on installation practices.

It should be noted that this savings estimate does not take into account the impact of other differences in installation practices that may be attributable to the Installer Program. These factors include refrigerant charging, air flow optimization, duct outlet and supply sizing, and other system start-up practices. For example, 65% of participants reported that they use the subcooling method to charge systems with a TXV, versus 42% of non-participants. Also, 38% of non-participants reported using duct tape, versus 3% of participants. In these and other instances, significant differences between the installation practices of participants and non-participants have been identified, but the quantification of the peak demand and annual energy consumption impacts of these differences is difficult. As more research into measuring the impacts of proper installation practices is reported, more comprehensive estimates of the impacts of this and similar market transformation programs may be obtained.

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