Low Rigor ISP Study Summary – Fan Coil Unit EC Motors

ISP Study Target Application: Fan Coil Unit Motors for Systems Designed from 2012 through 2014

ISP Report Finalization Date: 08/03/2017

1 RESEARCH SUMMARY

This ISP research report summarizes the methods, findings, and conclusions of a low rigor ISP study for electrically-commutated (EC) motors used in fan coil units (FCU) serving laboratory, hospital, large residential, office and school buildings designed in the 2012-2014 period. This ISP study was triggered by a need to establish baselines for projects included in the Comprehensive Design Approach (CDA) impact evaluation (P56). Table 1 summarizes the seven affected P56 sites (the P56 evaluation sample includes seven projects at six locations) with fan coil unit EC motors and the ex ante baselines applied by the PAs and recommended by this ISP research.

This ISP research included a combination of secondary research and eight interviews with credible and well-informed respondents, including mechanical system designers and energy consultants.

1.1 P56 Evaluation Baseline Recommendation

The P56 projects impacted by this research (see Table 1) all utilized EC motors in design case fan coil units and were evaluated against permanent split capacitor (PSC) motors in the baseline.

All respondents that were interviewed indicated that a significant amount (minimum 25%, maximum 75%) of PSC motors were still being specified for fan coil units over the past 3-5 years. Additionally, the respondents that primarily used EC motors in the past 3-5 years were generally more aware of utility incentive programs, citing energy savings and upfront costs as important considerations. Therefore, we recommend that PSC motors be considered "standard efficiency" technologies for designs utilizing fan coil units between 2012 and 2014. All of the sampled P56 projects were modeled by the Program Administrators' Technical Assistance (TA) providers as having baseline fan coil units with PSC motors. This baseline is consistent with the "standard efficiency" technology identified by interviewees.

The evaluation team observed that many of the sampled P56 project TA energy models included baseline FCUs operating continuously. The evaluators consulted with the P56 Baseline Advisory Group (BAG) and reviewed IECC and ASHRAE 90.1 to derive the baseline FCU motor control strategy. According to IECC 2009 Table 506.5.1(3)(note i) and ASHRAE 90.1-2007 Table 11.3.2A (note i), when modeling building energy savings for constant volume fan coil units, the baseline FCUs should be controlled in the same manner as the proposed design. The evaluators recommend that the ex post baseline FCU controls be updated to reflect the recommendations in Section 506 of IECC 2009 and Chapter 11 of ASHRAE 90.1 and that for constant volume FCUs, the baseline motor controls be similar to the as-built systems.

One exception to this baseline is systems where the proposed FCUs are variable air volume systems, which are not addressed in code, and per several interviewees, were not standard practice during the P56 timeframe. Based on the available information, the evaluators recommend that the ex post baseline for VAV FCUs be constant volume FCUs with PSC motors that cycle based on heating and cooling loads, unless continuous airflow is required for application specific purposes. In the case of Project E in Table 1, continuous baseline operation is considered allowable because continuous circulation air is required for the laboratory function.

Additional information regarding the evaluation baseline recommendations can be found in Section 4.1.

Table 1. P56 CDA Impact Evaluation – Fan Coil Unit Motor Measure Details

CDA Project	Bldg Type and Location	Design Year & Applicable Code	Measure Description	Ex Ante Baseline	Evaluation Ex Post Baseline
Fan Coil Units A BR+A 487,000/753,000 kWh	Mixed-use office/residential building in Boston, MA	2009 IECC and ASHRAE 90.1-2007 w/ amendment 1	FCU ECMs (131 total fan coils ranging in size from 290-1,350 CFM installed with EC motors as one measure, and cycling controls as a second measure)	FCUs with constant speed PSC fan motors run continuously to supply outdoor air for ventilation.	The evaluators recommend that the baseline FCUs be modeled as having controls similar to the as-built units, but with PSC motors rather than EC motors. See site report for CS9571 for additional details.
Fan Coil Units B A&L 66,000/4,500,000 kWh	Hospital in Worcester, MA	IECC 2009 and ASHRAE 90.1-2007 w/ amendment 1	47 FCUs with EC motors serving IT, mechanical and electrical equipment rooms	Constant speed PSC fan motors run continuously	FCUs with PSC motors that cycle to maintain temperature setpoints during operating hours, similar to the installed EC motors
Fan Coil Units C Atelier ten UK/218,000 kWh 1/9 measures	Academic Dormitory Hall in Cambridge, MA	IECC 2009 and ASHRAE 90.1-2007 w/ amendment 1	Fan coil units are installed with EC motors, fan controls are such that baseboard takes precedence over FCU to conserve fan energy	Fans are installed with PSC motors and run continuously at 100% speed.	FCUs with PSC motors that cycle to maintain temperature setpoints during operating hours, similar to the installed EC motors
Fan Coil Units D DMI 53,000/780,000 kWh	High School in Leominster, MA	IECC 2009	9 FCUs are installed with EC motors. Unit sizes range from 750 to 1,250 CFM	FCUs installed with PSC motors and run continuously during occupied hours	FCUs with PSC motors that cycle to maintain temperature setpoints during operating hours, similar to the installed EC motors
Fan Coil Units E B2Q 48,000/850,000 kWh	Chemical Engineering Lab in Cambridge, MA	IECC 2009 and ASHRAE 90.1-2007 w/ amendment 1	142 FCUs are installed with EC motors and fan speed modulation to maintain space temperature setpoints when the heating/cooling valves are fully open	FCUs installed with PSC motors that run continuously at 100% speed	Same as ex ante - FCUs with PSC motors that run continuously, similar to the installed EC motors
Fan Coil Units F&G (App. No.'s 976238 and 3549519)	Pharmaceutical Research Lab in Boston, MA	IECC 2009 and ASHRAE 90.1-2007 w/	200-250 EC motors for the whole building.	PSC motors running @75% speed for 5,000	FCUs with PSC motors that cycle to maintain temperature

A&L 23,000/1,600,000 kWh		amendment 1		hrs/yr	setpoints during operating hours, similar to the installed EC motors

1.2 Additional ISP Findings

In addition to asking ISP interviewees about fan coil unit motors used during the CDA-applicable period (2012-2014), the ISP researchers asked interviewees about more recent (2016/2017) system design practices.

For projects designed more recently, the ISP interviewees were consistent in stating that EC motors are becoming more common practice, which is consistent with recent updates to the MA Energy Code. IECC 2015, which went into effect in MA in 2017, requires fractional horsepower motors to be EC motors with efficiencies >70%. Interviewees added that certain applications, specifically those with high pressure drops, may still require the use of PSC motors; however, this is not addressed by code. This use of PSC motors was not observed in P56.

Details regarding the findings of this ISP research, including more additional observations regarding ISP for EC motors in FCUs outside of the P56 project scope, are included in Section 4 and Appendix A of this report.

2 Background Information

Fan coil units typically utilize factional horsepower motors to power its fans. Older motor technologies for fractional horsepower sized motors are known to operate at relatively poor motor efficiencies. The commonly used fan coil unit motor types include:

- Permanent Split Capacitor (PSC)
- Electrically Commutated (EC)

IECC 2009

There is no mention of electrically-commutated motors in IECC 2009.

Fan Power limitation Table 503.2.10.1(1) and Fan Power Limitation Pressure Drop Adjustment Table 503.1.10.1(2) apply to fans above 5 hp not found in fan coil units

During the period of interest (2012-2014), the Massachusetts building code referred to IECC 2009 and the 2009 IMC to define the minimum mechanical system requirements for new buildings. Neither IECC 2009 nor 2009 IMC includes any mention of fan power limitations or specific control requirements for sizes under 5 hp as found in fan coil units. Additionally, ASHRAE 90.1 2007 does not have fan power requirements or fan coil unit control requirements for systems of this size. The footnotes in Section 506 of IECC 2009 and Chapter 11 of ASHRAE 90.1-2007 include recommendations for fan coil unit controls, but not motor efficiency or type. This ISP study seeks to determine the standard practice for fan coil unit motors for new construction laboratory, hospital, large residential, commercial, and school buildings designed between 2012-2014.

3 METHOD

The measure baseline is the equipment that was commonly designed in the sectors and time period identified in Section 1, absent program intervention.

This ISP research included interviews with eight engineering firms that are familiar with the design of fan coil units in HVAC applications. In addition, secondary research was performed to identify the codes and existing standard practice research for these systems. The results of this research have been triangulated across multiple primary data sources and supplemented with the secondary data, and they are summarized in this report. The method generally follows the low rigor protocol described in the Baseline Framework.[1]

The primary data collection included questions regarding the following:

- Design practice at the time of the CDA project design (2012-2014) and in the future (2015 and beyond)
- Factors (e.g., building type) influencing the system design
- The influence of Energy Efficiency Service providers on system design

A preponderance of evidence standard was applied in the final recommendation of baseline.[2]

4 FINDINGS AND RECOMMENDATIONS

The findings and recommendations for this research are presented in the following two sections. The first section describes the baselines recommended for the seven P56 sites described in Table 1, while the second section includes general ISP recommendations for fan coil unit motor selections. Appendix A provides detailed primary and secondary research findings.

4.1 Rationale for P56 Project ISP Recommendations

The P56 projects impacted by this research (see Table 1) all used EC motors in fan coil unit designs. For all buildings types, both the secondary research and primary data collection indicated that between 2012 and 2014 use of PSC motors in fan coil units was common. All of the projects included in the P56 evaluation sample were modeled by the TAs to have baseline fan coil unit systems with PSC motors (see Table 1). This baseline is consistent with the "standard efficiency" technologies identified in our ISP interviews and described in secondary research (see Appendix A). Based on the available information, the evaluators recommend that the ex post baseline for the seven P56 evaluation projects be PSC motors, similar to the ex ante baseline. The evaluators also recommend that the baseline PSC motor efficiency/power demand be determined based on the following references (listed in order of priority):

[1] See Section 6.2 of *MA Commercial/Industrial Baseline Framework*, Final Report, DNV GL and ERS, February 2, 2017, for discussion on high and low rigor approaches for non-site-specific ISP methods.
[2] As per the 2017 Massachusetts Commercial/Industrial Baseline Framework: "Preponderance of evidence" means that "the greater weight of evidence" favors one condition or the other. The quality of evidence is more important than the volume of it." For further discussion on this methodology, see *Early Retirement Using Preponderance of Evidence*, v1.0, July 16, 2014. Prepared for the California Public Utilities Commission.

1. Review of project files to determine if a specific alternative FCU model or motor was included in the original building design and document by the Energy Efficiency Service providers and/or TAs.
2. Review manufacturer's literature for the installed FCUs to determine if a PSC-equipped alternative was offered; include baseline motors with power draw/efficiency equivalent to the manufacturer's specified alternative.
3. Use industry standard efficiencies, which have been shown to be in the range of 35%-50% efficiency for PSC motors and 70%+ for EC motors[3].

The evaluation team observed that many of the sampled P56 project TA energy models included baseline FCUs operating continuously. The mandatory provisions of IECC 2009 and ASHRAE 90.1-2007, which were the code references applicable to the sampled P56 projects, do not include FCU motor control requirements, making the baseline control strategy for these systems ambiguous. In the absence of mandatory code requirements for motor controls, the evaluators consulted with the P56 Baseline Advisory Group (BAG) and reviewed the alternative compliance paths of the IECC and ASHRAE 90.1 to derive the baseline FCU motor control strategy. According to IECC 2009 Table 506.5.1(3)(note i) and ASHRAE 90.1-2007 Table 11.3.2A (note i), when modeling building energy savings for constant volume fan coil units, the baseline FCUs should be controlled in the same manner as the proposed design. The evaluators recommend that the ex post baseline FCU controls be updated to reflect the recommendation in Section 506 of IECC 2009 and Chapter 11 of ASHRAE 90.1 and that for constant volume FCUs, the baseline motor controls be similar to the as-built systems. One exception to this baseline is systems where the proposed FCUs are variable air volume systems, which are not addressed in code, and per several interviewees, were not standard practice during the P56 timeframe. Based on the available information, the evaluators recommend that the ex post baseline for VAV FCUs be constant volume FCUs with PSC motors that cycle based on heating and cooling loads.

4.2 Additional Findings

While the catalyst for this ISP research was to characterize the baselines for the P56 evaluation projects, it also presented an opportunity to gather insights beyond the P56 project scope to inform future ISP for fan coil unit motors.

New construction projects in Massachusetts are required to comply with the Massachusetts Building Energy Code ("the Code") to define baseline. Until mid-2014, the applicable version of the MA Energy Code referenced IECC 2009 (and the 2009 IMC) as well as ASHRAE 90.1-2007 to define project baselines. This was the version of code that was applicable for all of the projects in the P56 evaluation sample. On July 1st, 2014, the Code was updated to reference IECC 2012 (and the 2012 IMC) as well as ASHRAE 90.1-2010. This code was in effect through December 31, 2016. The Code was again updated on January 1, 2017 and now references IECC 2015 (and IMC

[3] See 2013 U.S. Department of Energy study, Page 16: *Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment* - https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf

2015) as well as ASHRAE 90.1-2013. With recent changes in code, the minimum requirements for fractional horsepower motors has become more stringent:

- IECC 2009/IMC 2009 and ASHRAE 90.1-2007 does not mention EC motors or requirements for fractional horsepower motors. Fan coils are listed in the standard HVAC design table has having constant speed, cycling fan controls.
- IECC 2012/IMC 2015 had similar fractional motor requirements to IECC 2009/IMC 2009
- Starting with ASHRAE 90.1-2013 and IECC 2015, which became applicable in Massachusetts on 1/12017, the code required that fractional horsepower motors must be electronically commutated with a minimum efficiency of 70% as rated in accordance with DOE 10 CFR 431.

The majority of interview responses indicated an increase in EC motor usage since 2012, with a significant portion of the FCU motor market now (as of early 2017) being made up of EC motors. In addition, the use of EC motors in applications with fractional horsepower motors has recently become a requirement in multiple code documents (e.g. IECC 2015, ASHRAE 90.1 2013). This information offers a preponderance of evidence that projects designed in 2017 and beyond are included EC motors as the baseline for FCUs. However, the baseline for projects designed between 2014 and 2017 is less clear as the most recent code requirements were not yet in effect and interview respondents indicated that the market was still transitioning in this period.

While respondents were consistent in stating that EC motors were standard in 2017, two respondents mentioned that using the variable-speed capability of EC motors was still not standard practice, indicating a potential opportunity for energy efficiency measures through improved FCU motor controls.

APPENDIX A – DETAILED RESULTS OF PRIMARY AND SECONDARY RESEARCH

Summary of Primary Research

A summary of the interview questions and answers are included in Table A-1, and key observations from this research are highlighted below.

- Respondents generally agreed that PSC motors were commonly used for fan coil units installed between 2012 and 2014:
  - Five respondents stated that at least 50% of fan motors were PSC 3-5 years ago.
  - Three respondents stated that they switched to EC motors 3-5 years ago but also added that PSC motors were commonly used at that point.
  - All MEP firms stated that EC motors are primarily used today, some of which also cited the new code requirement. Two of those firms cited the need to still use PSC motors in applications with high pressure drop requirements.
  - Most of the interviewees were MEP design engineers with experience in system design and limited knowledge of whether utility incentives were received for their designs. Feedback regarding the influence of energy efficiency programs was split with half the respondents indicating that incentives were typically not pursued for EC motors. Of the respondents stating that incentives were not influencing their decisions, the majority indicated that upfront material costs was an important factor.
- Respondents were also consistent regarding the design of systems installed today (2016/2017):
  - All eight respondents stated that EC motors account for the vast majority of projects installed today.
  - One respondent mentioned that PSC motors are still used in high pressure applications. This respondent did not mention specific code exceptions that allow this practice.
  - Two respondents discussed utilizing the variable speed capability of EC motors as a potential energy efficiency practice.

Table A-1. Primary Data Sources

Company	# of systems designed/installed/analyzed over the last 5 years	Type of system installed 2012-2014	Influence of energy efficiency programs on design	Type of systems installed today
MEP Firm A	Respondent indicated they had experience with system installation over the last five years; did not provide a number.	Approximately 25% PSC, 75% EC, with EC becoming increasingly more common in the past 3-5 years.	Yes.	EC motors are much more commonly installed today.
MEP Firm B	50+	Primarily EC motors but still many PSC motors.	Cost and energy savings are considerations and EE programs do influence design.	Primarily EC motors since it is now code required. PSC still used for high pressure applications.
MEP Firm C	Respondent indicated they had experience with system installation over the last five years; did not provide a number.	Switched to EC motors about 3-5 years ago.	None.	EC motors.
MEP Firm D	20-25	80% PSC, 20% EC. Considered 'premium' design.	Did not know but installation/operating cost is a factor.	90% EC, 10% PSC. Nearly all FCUs have EC motors.
MEP Firm E	12	80% PSC, 20% EC. EC motors were just transitioning 3-5 years ago.	Incentives not a major factor but a consideration. Energy savings are important.	90% EC, 10% PSC. Still some PSC motors for specific applications.
MEP Firm F	Respondent indicated they had experience with system installation over the last five years; did not provide a number.	Mostly PSC motors 3-5 years ago. EC more common in labs/universities that need finer variable speed controls.	Generally no, across all states in the northeastern US.	Moving towards EC motors but PSC motors still used in some applications, esp when no need for variable speed control.
MEP Firm G	Respondent indicated they had experience with system installation over the last five years; did not provide a number.	50% PSC, 50% EC. EC motors used as much as possible.	Only 10-15% of projects w/ EC motors; however, energy savings and upfront cost are considerations.	More EC motors are being used today.
Modeling Firm A	15	50% PSC, 50% EC. Often dropped in value engineering.	Yes, influenced by incentives.	Variable speed capability of EC motors being utilized more often.

Summary of Secondary Research

A summary of the secondary research resources are included in Table A-2. The secondary research provided information on the requirements in other jurisdictions and recent developments in the IECC, ASHRAE 90.1, IMC, and MA Energy Code.

The secondary sources indicated that EC motors did not become standard practice until codes were updated to reflect ASHRAE 90.1-2013 or IECC 2015. There are no EC motor requirements prior to these documents.

IECC 2015 and ASHRAE 90.1 2013 require the use of EC motors with a minimum efficiency of 70% for fractional horsepower motors. Exceptions to this requirement include fan motors used for heating-only applications and fans/motors that comply with additional efficiency specifications (IECC 2015 Tables C-403.2.3 or C403.2.12, see Table A-2).

Table A-2. List of secondary sources

Document	Publishing Organization	Major Findings of Document Review	Relevant Time Period	Web Link
IECC 2009	International Code Council	Does not mention EC motors, fan coils are listed in the standard HVAC design table as having constant speed, cycling fan controls. This is the relevant code for 2012/2013 projects.	2010 - July, 2014	http://codes.iccsafe.org/app/book/toc/2009/I-Codes/2009%20IECC%20HTML/index.html
IECC 2012	International Code Council	Includes same details as above. There is also a balancing requirement stating that fans >1 HP need ability to reduce speed.	July 2014 - 2016	http://codes.iccsafe.org/app/book/toc/2012/I-Codes/2012%20IECC%20HTML/index.html
IECC 2015	International Code Council	Section **C403.4.4.4** requires that fractional HP motors must be electronically commutated with a minimum efficiency of 70%, rated in accordance with DOE 10 CFR 431. The motors must have the means to adjust motor speeds for either balancing or remote control. **Exceptions include:** *1*-motors in the airstream of heating only fan coils and terminal units *2*-motors in space conditioning equipment that comply with tables C403.2.3 (HVAC minimum efficiency requirement tables) or C403.2.12 (fan power limitation section) *3*-motors that comply with section C405.8 (minimum average full load efficiency tables for electric motors)	2017	http://codes.iccsafe.org/app/book/toc/2015/I-Codes/2015%20IECC%20HTML/index.html
ASHRAE 90.1 2013	ASHRAE	**6.5.3.5 Fractional Horsepower Fan Motors.** Motors for fans that are 1/12 hp or greater and less than 1 hp shall be electronically-commutated motors or shall have a minimum motor efficient of 70% when rated in accordance with FOR 10 CFR 431. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed Exceptions: 1-motors in the airstream of heating only fan coils and terminal units 2-motors in space conditioning equipment that comply with tables C403.2.3 (HVAC minimum efficiency requirement tables) or C403.2.12 (fan power limitation section) 3-motors that comply with section C405.8 (minimum average full load efficiency tables for electric motors)	2017	N/A
2013 CA Building Energy Efficiency Standards - Fractional Motors	CA Utilities Statewide Codes and Standards Team	Study comparing performance of PSC motors to EC motors for fractional HP motors. Recommends amending standards document to almost exactly the same language as IECC 2015 section C403.4.4.4 without the exception for heating only terminal units.	Published August 2011, Adopted in 2014	http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-08-17_workshop/documents/8_Fractional_Motors.pdf
IMC 2009	International Code Council	No requirements for Fan coils or fractional HP fan motors.	2010 - July, 2014	http://codes.iccsafe.org/app/book/toc/2009/I-Codes/2009%20IMC%20HTML/index.html
IMC 2015	International Code Council	No requirements for Fan coils or fractional HP fan motors	2017	http://codes.iccsafe.org/app/book/toc/2015/2015%20San%20Antonio/2015%20IMC%20HTML/