A Look at the Extended Product Motor Labelling Initiatives for Fans

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ABSTRACT

Motor-driven equipment consumes one-fourth of all electricity sold in the United States each year (DOE 1998). Customers in the commercial and industrial markets purchase motor-driven products that total approximately 10 million horsepower in connected load (R. Boteler, Consultant, NEMA, pers. comm., December 4, 2013). The horsepower generated are consumed predominantly by fans, pumps, and compressors. At a time when incentive programs for regulated motors, and for VFDs, are dwindling due to saturation or declines in cost effectiveness, these motor-driven products represent a significant new opportunity for efficiency program administrators. In response to a DOE rulemaking initiative on commercial and industrial fans, and through participating in the ACEEE/NEMA Extended Motor Product Label Initiative (EMPLI), fan manufacturers have been collaborating with efficiency organizations, DOE, and other stakeholders in developing new efficiency metrics and incentive programs. This paper explains the activities of the collaborations involving fans in the EMPLI program. It describes the new efficiency metric, Fan Efficiency Index, test standard, and labeling system. These efforts cover fans alone as well as extended-product combinations of fans sold with motors and fans sold with motors and drives. The metric, test standard, and label could be the basis for prescriptive rebate programs with deemed savings values. Such programs should accelerate the adoption of more efficient fan systems.

Background

On April 1, 2015, DOE issued a Notice of Intent to Establish the Fans and Blowers Working Group to negotiate a Notice of Proposed Rulemaking (NOPR.); similar to what was done with the pump industry the previous year. The purpose of the working group was to define key aspects of a proposed test procedure, and proposed energy conservation standard. The working group consisted of twenty five representatives of manufacturers, energy advocates, trade associations, government agency and others.

The working group met sixteen times in a five month period and successfully reached consensus on aspects related to scope, test procedures, metric, and aspects of the energy conservation standards related to certification. The working group negotiated an acceptable term sheet covering the important aspects of definitions, scope, industry test standards, performance metrics, standard levels, labeling and reporting. The final DOE fan rule is set to be published in the fourth quarter of 2016.

In parallel, the Extended Motor Product Label Initiative (EMPLI) was founded by ACEEE and NEMA at the 2013 ACEEE Summer Study on Energy Efficiency to develop three voluntary performance standards and associated marks for commercial and industrial fans, pumps and air compressors. This initiative would leverage the on-going and pending DOE rulemaking for the same three product categories. EMPLI is a collaborative effort among representatives from the fan, pump, and air compressor manufacturing sectors, the Air

Movement and Controls Association (AMCA) International, Hydraulic Institute (HI), Compressed Air and Gas Institute (CAGI), electric utilities, energy efficiency program administrators, and energy efficiency nongovernmental organizations. It has three working groups, one for each product category, and each working group is led by its respective trade organization. The Fan Working group is led by AMCA and has representatives from each of the other organization types. Fan manufacturers and AMCA have expertise in performance testing and responding to U.S. and European standards and regulations, as well as extensive market knowledge. Representatives from utilities have expertise in program design and implementation and knowledge of regulation and program evaluation. ACEEE has become the convening authority, and has provided the leadership and direction for the EMPLI program. The trade associations involved in the fan labelling initiative are the NEMA, and AMCA International. Efficiency programs that have participated to date include Pacific Gas and Electric (PG&E), Northeast Utilities, National Grid, the Energy Trust of Oregon (ETO), the Northwest Energy Efficiency Alliance (NEEA), the Bonneville Power Administration (BPA), the Northwest Power and Conservation Council, Southern California Edison (SCE), and Consolidated Edison (ConEd). The collaborative approach facilitates communication between program administrators and the manufacturers of motor-driven equipment.

Why the Need?

Motor-driven equipment consumes one-fourth of all electricity sold in the United States each year (DOE 1998). Twenty four percent of that equipment is a fan/motor combination (Table 1.) Each year, facilities in the commercial, industrial, and institutional sectors purchase motor-driven products that total approximately 10 million horsepower in connected load (R. Boteler, Consultant, NEMA, pers. comm., December 4, 2013. Electric utilities are constantly in search of new demand-side management program models that will help them reach their efficiency goals. U.S. customer-funded electric efficiency expenditures totaled nearly $7.3 billion in 2014, a thirteen percent increase from 2013 levels. (Cooper and Smith 2013). A label on the fan that included motor and drive losses could be applied on nearly one fourth of all motor applications, making it easier for utilities to design and implement utility rebate programs.

(Table 1. Distribution of motors by application percentage for NEMA motors)

	Horsepower (HP)						
Application	**1-5**	**6-20**	**21-50**	**51-100**	**101-200**	**201-500**	**Total HP%**
Pumps	22.3	31.6	33.0	34.2	36.0	25.5	28.5
Fans	**22.5**	**24.9**	**26.6**	**25.7**	**18.9**	**21.7**	**24.0**
Material Handling	12.0	9.4	6.8	10.6	7.8	7.6	10.0
Air Compressors	1.8	1.3	2.2	5.6	5.4	8.3	2.2
Other	41.4	32.8	31.4	23.9	31.9	36.9	35.3

Source: DOE 2012, Table 7.2.3

AMCA and its fan manufacturers were interested in developing a label and a comparative metric to simplify their customers' efforts to identify more-efficient products. The utilities and program administrators were interested in new methods for identifying potential energy savings. AMCA and manufacturer representatives, who are more familiar with upcoming DOE test procedure and metric, will leverage the new fan regulation into the labelling initiative. The performance metric, meaning the mathematical formulae that determines compliance, is numerical (e.g., 1.0,1.1,1.2, and so on) while the label can also be comparative (e.g., “bronze,” “silver,” “gold” or “good”, “better” “best”). Data on the label would be certified by AMCA International to be accurate. The label and comparative hierarchy are still in early draft stage; however, it should be noted that we do not expect these labels to be present on fans. Instead, they would be present in manufacturer’s literature, program databases, and/or AMCA International’s certified ratings database. The performance label and associated label or mark can be used by organizations as a purchasing specification and it can be used by energy efficiency program administrators as a qualifying feature for program eligibility.

One of the primary goals of the EMPLI Fan Working Group is to create a mechanism that enables the fan industry to take a system approach versus a component approach with fans, motors and drives. A system approach will enable designers and end users to maximize energy savings and economy by considering the performance characteristics and costs of individual components working together. The preferred method is to take advantage of the “Prescriptive” or “Deemed” utility programs. Deemed utility programs are pre-determined, validated estimates of energy and peak demand savings attributable to the fan equipment. These programs are easy to manage and do not require field measurement and verification.

Another major goal is to provide program administrators a method for capturing system level savings in prescriptive programs. Savings are “deemed” per piece of equipment or by size of equipment, such as a variable frequency drive (VFD), or per horsepower of a high-efficiency motor. These programs reach the most products and applications with the least amount of administrative cost. Representatives from the efficiency program sector aid in the development of these new labels, the details of the labels and the documentation supporting them in order to structure a label that is compatible with the needs of such prescriptive programs. The efficiency programs also establish a method for validation and verification of the proposed savings by incorporating field testing in pilot programs.

A key motivation for utilities’ involvement in this initiative is that these new labels simplify the measurement and verification (M&V) for incentive programs by establishing straightforward eligibility requirements and the associated deemed energy savings. The EMPLI team expects the results of this project to be usable and potentially accepted by a large number of utilities not directly involved with the project. AMCA and fan manufacturers are in the process of identifying the criteria to be included in a label as well as the supporting data that will be needed to meet program evaluation criteria. The program representatives have shared their program development methodologies, which include an understanding of the variables that drive savings and the ability to predict the savings potential with acceptable accuracy. AMCA and the fan manufacturers are working to identify label content that can be used to place a product within a comparative category. For example, the comparative metric for a given industrial fan could be “silver” and a commercial fan could be “bronze.”

The Test Procedure

The fan test procedure will be based on the AMCA test standard - AMCA 210, for determining bare-shaft fan performance and performance of embedded fans. The test standard establishes a uniform test method for a laboratory test of a fan or other air moving device to determine its aerodynamic performance in terms of airflow rate, pressure developed, power consumption, air density, speed of rotation, and efficiency for rating or guarantee purposes

(AMCA 2007). The testable configuration for each equipment class of non-embedded fans will be defined in the test procedure and include, at a minimum and where appropriate, the following basic parts: an impeller, a shaft, bearings, and a structure or housing.

The AMCA 210 test procedure provides purchasers, specifiers and utility program managers with reliable and accurate information for the selection, and efficient use of the listed products. Product performance is vital to the operation and continued success of the labelling program. Requiring the AMCA 210 test procedure gives specifiers, contractors, and building owners assurance that manufacturers' performance ratings are correct, and their product lines have been tested and rated in conformance with DOE test standards and requirements.

The Label (DRAFT)

The label must contain several mandatory fields per the new DOE rule: model number, serial number, design flow and design pressure, date of manufacture, and the Fan Electrical Index (FEI). The intent of the label is to describe the fan in a manner that can be readily understood in the respective markets using the DOE metric. The numerical component is the Fan Electrical Power (FEP) and the FEI. The comparative metric can be seen with the bronze, silver, and gold designations. The label is still in development and may be portrayed as Figure 1.

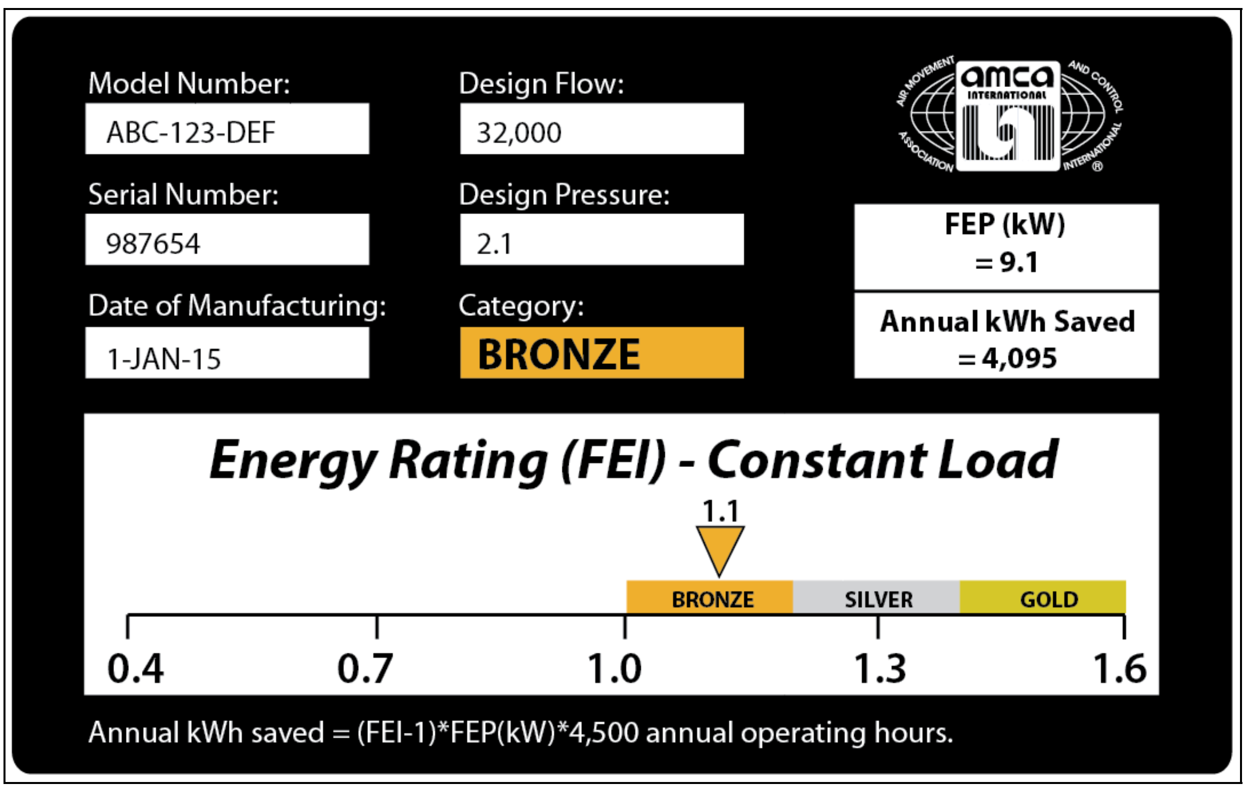

Figure 1. Draft label for fans. *Source*: Twin City Fan Companies

Understanding the Metric

The primary focus of the metric will be to represent the fan electrical input power (FEP). In the new metric, the measured FEP for a given fan will be compared to the maximum FEP allowable under the new DOE rule (FEPstd). The measured FEP will be compared to the FEP_{std}. (DOE 2015). The FEP shall be determined either through direct measurement of the fan electrical input power, and/or measurement of the fan's shaft input power and the combination of default values that will be incorporated in the FEP for bare-shaft fans, fans sold with regulated motors, fans sold with air over motors, and fans sold with regulated motors and dynamic continuous controls. All formulas are per the DOE term sheet.

The maximum allowable fan electrical input power (FEP_{STD}) at each declared operating point i (Q_i, P_i) shall include: the fan shaft input power corresponding to a fan with a fan efficiency equal to $H\eta_{STD,i}$; belt losses as calculated using the default belt efficiency curve (L_{Belt}); and default motor losses (L_M) at that operating point.

$$FEP_{STD} = H_{\eta_{STD,i}} + L_{Belt} + L_m$$

Where:

$FEP_{STD,i}$ = maximum allowable fan electrical input power kW

L_m =Part Load Loss at full load efficiency

$H_{\eta_{STD,i}}$= Fan Shaft Power at operating point i

L_{Belt}= Belt Loss

The maximum fan shaft power at operating point i will be determined by using the following formula:

$$H_{\eta_{STD,i}} = \frac{Q_i \times P_i}{6343 * \eta_{STD,i}}$$

Where:

Q_i = flow (cfm) at operating point i

P_i = total pressure for ducted fans / static pressure for unducted fans (in.wg) at operating point i

$\eta_{STD,i}$ = minimum fan total efficiency for ducted fans/ minimum fan static efficiency for unducted fans

The fan working group determined the minimum fan total efficiency for ducted fans, and the minimum fan static efficiency for unducted fans at operating point i shall be calculated in accordance the following equation that gives a credit for low flow and low pressure applications. The flow constants (Q_0) and the pressure constant (P_0) account for the intrinsic inefficiencies of lower flow and lower pressure designed systems.

$$\eta_{STD,i} = \eta_{target} \frac{Q_i \times P_i}{(Q_i + Q_0)(P_i + P_0)}$$

Where:

$\eta_{STD,i}$ = minimum fan total efficiency for ducted fans / minimum fan static efficiency for unducted fans (percent) at operating point i ;

Q_i= flow (cfm) at operating point i

P_i = total pressure for ducted fans, static pressure for unducted fans (in.wg) at operating point i

Q_0 = flow constant =250

P_0 = pressure constant =.4

η_{target}= .62 for unducted fans, and .68 for ducted fans

Note: all pressures refer to standard air density.

The $FEP_{STD,i}$ assumes that all fans are belt driven. Direct driven fans will not have belt losses when the FEP is calculated and will realize a credit in the drive train efficiencies of a direct driven fan. To determine the belt loss (L_{Belt}) of a fan, two formulas are used. Since the transmission efficiency is dynamic when a load is placed on the belt system, two formulae are applied. These formulae are determined using the AMCA 203 belt loss curve for fan applications.

$$L_{Belt} = \frac{H_{\eta STD\,i}}{\eta_T} - H_{\eta STD\,i}$$

Where:

L_{Belt}= Belt Loss

$H_{\eta STD\,i}$= Fan Shaft Power at η_{std}

η_T = Transmission efficiency

and

$$\eta_T = 0.96\left(1 - EXP(-(27B * H_{\eta STD\,i})^{0.49})\right)$$

Where:

$H_{\eta STD\,i}$= Fan Shaft Power at η_{std}

η_T = Transmission efficiency

Finally, the motor loss is quantified and is added to the belt losses and the fan input power. In this rulemaking, the full load efficiency of the default motor used in the FEP_{STDi} calculation for a fan sold with a regulated motor will be based on the motor full load nominal efficiency from table 5 of 10 CFR 431.25 for the motor horsepower and pole configuration identical to that of the fan's motor. For air over motors [11], the full load efficiency of the default motor used in the FEP calculation will be based on the motor full load nominal efficiency from table 5 of 10 CFR 431.25, and by using the full load efficiency corresponding to the following number of NEMA bands below the values in table 5 of 10 CFR 431.25.

Standard level efficiency

The target efficiency levels that determine the FEP_{std} will differ if the fans are ducted or if they are unducted. By categorizing the fan types into two categories (ducted or unducted), encouragement is given to the most efficient design by allowing product substitution across design categories. AMCA members and efficiency advocates negotiated that DOE minimum efficiency levels should be set such that 25% of the fans in the marketplace would become noncompliant. In other words, the 25% least efficient fans would not be available after DOE fan efficiency regulations take effect.

A joint recommendation defined one target static efficiency (between 62% and 66% at the fan shaft) for non-ducted fans, and another target total efficiency (between 66% and 70% at the fan shaft) for fan categories that are generally applied with a duct at the fan outlet. A data base of 1.3 million fan selections, representing 46% of the American market in the regulated range, was analyzed in order to advocate for these levels. This data base enabled the DOE to use data that is a statistically significant representation of the market to analyze non-compliance rates at different target efficiency levels.

The non-compliance rate of 25% equals a target static efficiency of 62% for non-ducted fans, and a target total efficiency of 68% for ducted fans (Table 2).

(Table 2- Fan Types and Proposed Efficiency Levels)

Fan type	Category	Static/Total	Target efficiency
Axial housed	Ducted	Total	68%
Panel	Non-ducted	Static	62%
Centrifugal –housed	Ducted	Total	68%
Centrifugal -unhoused	Non-ducted	Static	62%
Inline/mixed flow	Ducted	Total	68%
Radial -housed	Ducted	Total	68%
Power roof ventilators	Non-ducted	Static	62%

Source: Appliance Standards and Rulemaking Federal Advisory Committee**,** Commercial and Industrial Fans and Blowers Working Group Term Sheet - September 3, 2015 (edited September 24, 2015)

Fan efficiency Index (FEI)

The Fan Efficiency Index (FEI) will be calculated using the FEP of a fan that exactly meets the standard (FEP_{STD}.) The FEI approach determines the maximum power input for any combination of flow and pressure. If the FEI rating is 1.1, it means that the fan will use 10% less energy than the maximum allowed by the DOE regulation. Ten percent savings on the fan with the 1.1 rating applies to that particular fan.

$$FEI = \frac{FEP_{STD}}{FEP}$$

Where:
FEP = Fan Electrical Input Power
FEI = Fan Energy Index

It is not an average savings of a population of similar fans, or an estimate, or a projection. It is *the* savings on that fan operating under the design conditions specified on the label.

AMCA members and efficiency advocates gained confidence that FEI based savings projections would be credible, predictable, and real.

DOE Rule & Label Interface

The label reflects the impact of the DOE Fan rule as seen by the fan curve in Diagram 1. A fan that has a higher FEI will migrate to the peak efficiency of the fan. The metric and label also reflect that slower fans are also relatively more efficient than higher speed fans. Fans that have an FEI equal to or greater than 1.0 are compliant. It is the goal of the EMPLI team that fans first shift towards compliance and then to higher FEI levels over time. The implementation of labelling and rebate programs should help the market shift towards this endeavor.

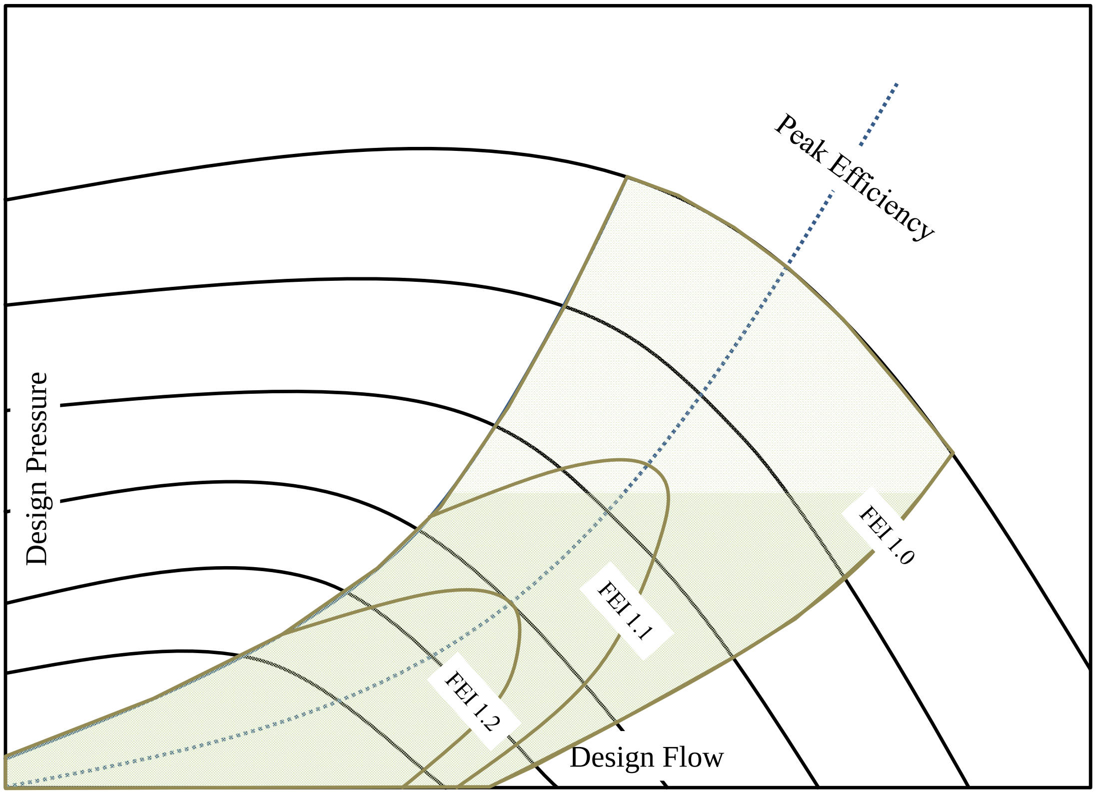

Figure 2. Graphical representation of FEI boundaries and fan curves. *Source*: Twin City Fan

The EMPLI Process

The EMPLI process as shown in Diagram 2 denotes the interaction between the AMCA fan manufacturers and the Efficiency Program managers. There is a significant overlap in label development, verification and implementation efforts between the two entities.

After the metric and test standard have been adopted, pilot programs and field testing can confirm energy savings. The iterative process can take lessons learned from the initial labelling efforts and adjust accordingly.

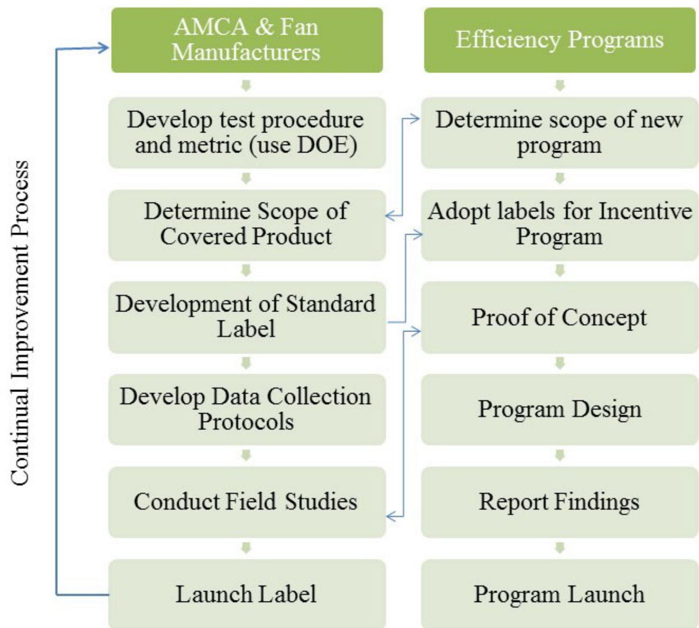

Figure 3. EMPLI process for label creation. *Source:* Ethan Rogers, ACEEE, 2014.

CONCLUSIONS

The collaboration of fan manufacturers, AMCA, NEMA, and the energy efficiency community will soon yield a new performance label for fans and fans packaged with motors and drives for commercial and industrial applications. The current label (draft) satisfies both comparative and quantitative aspects. As efficiency programs seek new program models to cost-effectively acquire energy efficiency resources from the commercial and industrial fan markets, the fan manufacturers can satisfy their needs simultaneously due to the collaborative nature of the EMPLI program.

The task of developing the DOE performance metric for extended products has proven both complex and challenging. As a result, the fan manufacturers and the participating efficiency programs have indicated a desire to pilot the program before the end of 2016. If the collaborative is successful, as it appears it will be, within the next few years several efficiency programs around the country will deploy new prescriptive rebate programs with deemed savings for common industrial and commercial fans. These programs will accelerate the adoption rate of more efficient integrated products ahead of the expected federal requirements and bring about savings in the quadrillions of BTU's over the next ten years. The logical extension of this will be to encourage and promote more energy efficient products in the market and allow the customers and utilities visibility of comparative performance.

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