The Role of Fan Efficiency In Achieving Energy Reduction Goals

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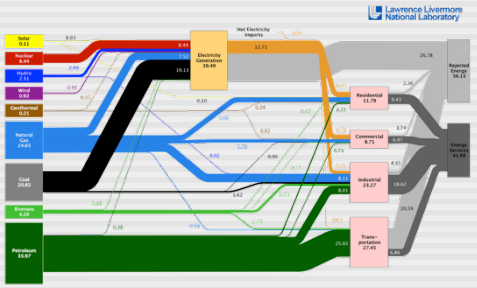
Outline

- Energy Consumption Overview
- Fan/System Energy
- Reducing Energy
  - ASHRAE 90.1 Power Limitation
  - FEG Fan Efficiency Grade
- ASHRAE 90.1 + FEG → Examples

Scale of Energy Usage

US Energy Consumption 2010* = 98 Quads (104 EJ)



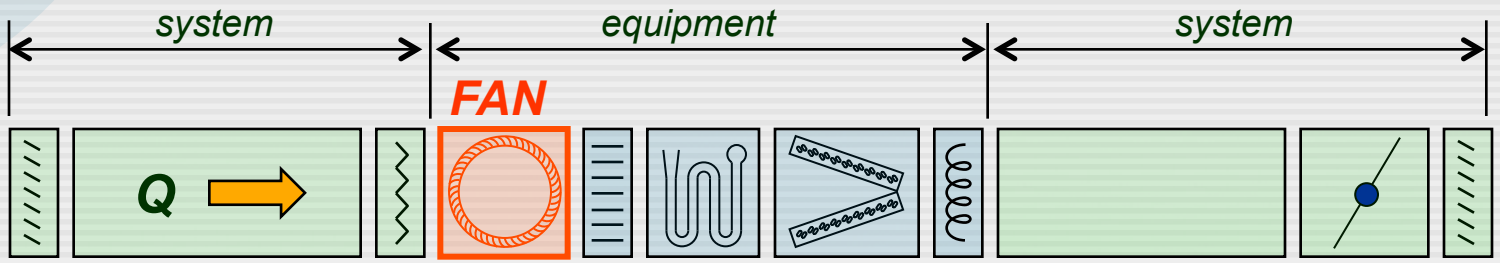
- Equivalent to **29 million million kWh**
- **37%** from petroleum → transportation
- **21%** from coal → electricity
- **25%** from natural gas → residential, commercial, industrial
- Over **half** of source energy **rejected** (heat)

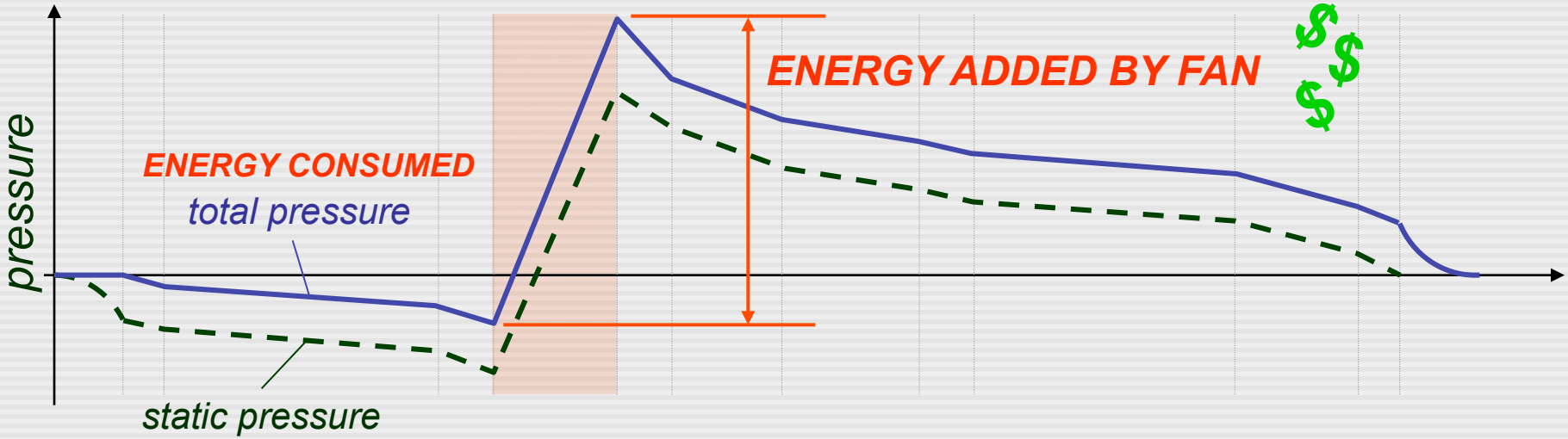
FOCUS ON AIR DISTRIBUTION

- **Estimated: 1.5% (435 billion kWh) for fans & pumps**
- **Estimated: ~20% commercial building energy budget**

*source LLNL

Airside Energy Consumption

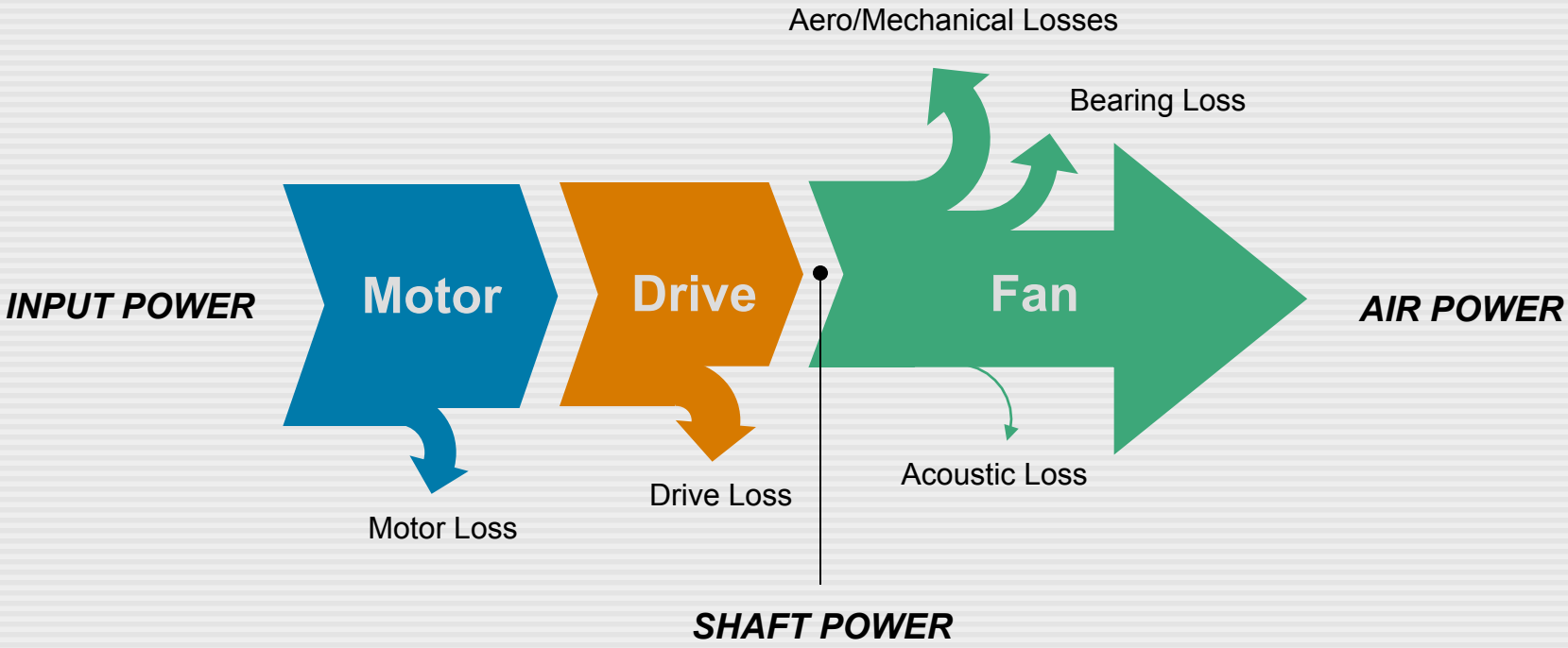




PRESSURE x FLOWRATE = $\frac{\text{FORCE}}{\text{AREA}} \times \frac{\text{VOLUME}}{\text{TIME}} = \frac{\text{ENERGY}}{\text{VOLUME}} \times \frac{\text{VOLUME}}{\text{TIME}}$ = **AIR POWER**

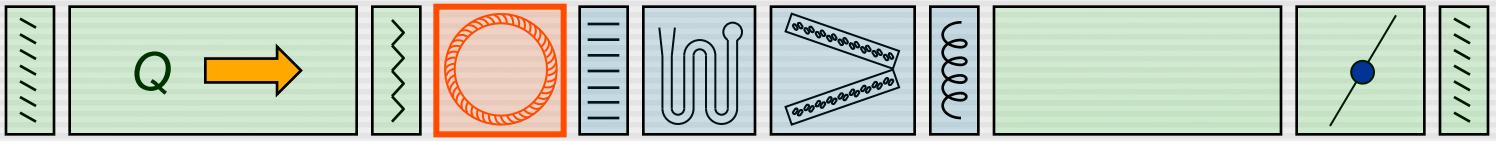
$$P_t \times Q = \text{Air Power}$$

Fan Energy Consumption



$$\textit{FAN EFFICIENCY} = \frac{\textit{AIR POWER}}{\textit{SHAFT POWER}}$$

Airside Energy Consumption

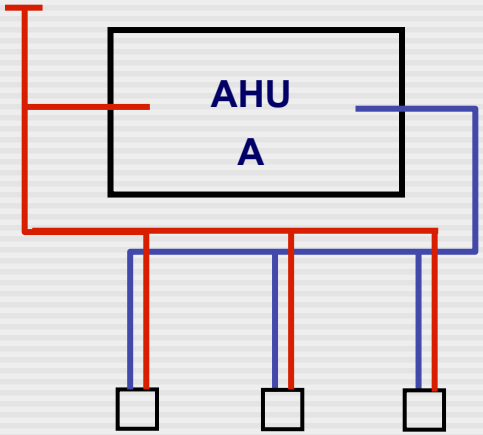


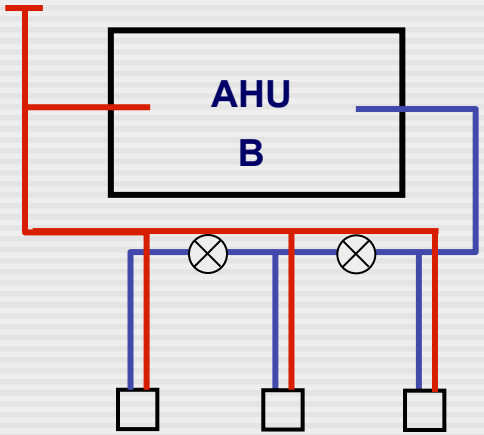
Fan Energy Reduction Opportunities

- **REDUCE SYSTEM FLOW - PRESSURE** → HVAC System Designer
- **REDUCE INTERNAL RESISTANCE** → Equipment Manufacturer
- **INCREASE MOTOR EFFICIENCY** → Motor Manufacturer
- **INCREASE DRIVE EFFICIENCY** → Drive/Equipment Manufacturer
- **INCREASE FAN EFFICIENCY** → Fan Manufacturer

Fan Energy Consumption

Energy reduction based entirely on fan efficiency?





Supply Flow: 20,000 cfm (9.4 m^3/s)
ISP: 2 in-wg (500 Pa)

System A
ESP: 3.5 in-wg (870 Pa)
TSP: 5.5 in-wg (1,370 Pa)
SE: 65%

BHP: 26.6 hp (19.8 kW)

System B
ESP: 5.0 in-wg (1,250 Pa)
TSP: 7.0 in-wg (1,750 Pa)
SE: 70%

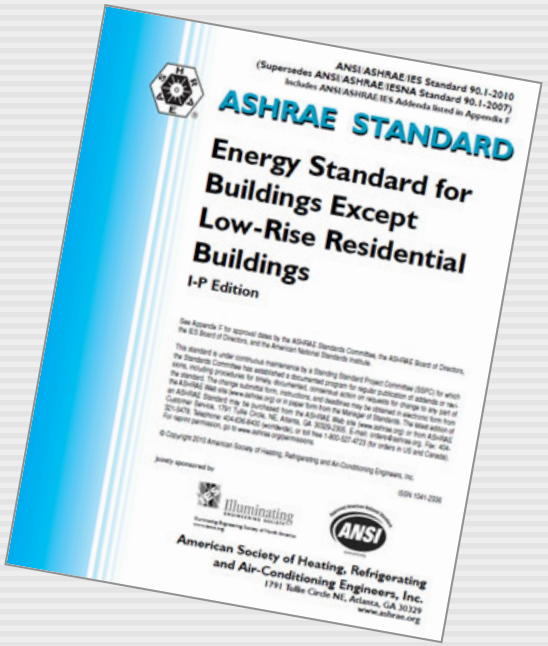
BHP: 31.4 hp (23.4 kW)

Fan in System B consumes 18% more energy than Fan in System A

Fan Energy Consumption

ASHRAE 90.1 – 2010: Fan Power Limitation

- Two Options → motor nameplate hp & bhp
- Two Systems → CV & VAV



$$H \leq \alpha Q_S + A$$

α = coefficient, e.g. 0.0013 for VAV systems
A = pressure drop adjustment
Q_S = max design supply air (cfm)
H = bhp

Fan Energy Consumption

ASHRAE 90.1 – 2010: Fan Power Limitation

Based on **Specific Fan Power** (SFP) approach

$$SFP = \frac{shaft\ \ power}{flowrate} = \frac{H}{Q} = \frac{P}{\eta}$$

$$\frac{H}{Q_S} \leq \alpha + B$$

α = limit, e.g. 0.0013 for VAV systems
$B = A/Q_S$
Q_S = max design supply air (cfm)
H = bhp

Encourages low pressure drop or high fan efficiency

Fan Energy Consumption

ASHRAE 90.1 – 2010: Fan Power Limitation

Special case – Single fan, no pressure adjustments

$$\frac{H}{Q} = \frac{P}{\eta} \leq \alpha$$

Implications

- Upper limit on ΔP since $\eta < 100\%$
- High $\Delta P \rightarrow$ high η
- Low $\Delta P \rightarrow$ low η

Example:

VAV limit , α = 1.3 Hp/kcfm

max ΔP = 8.2 in-wg @ 100% η
max ΔP = 6.2 in-wg @ 75% η

max ΔP = 4.2 in-wg @ 50% η

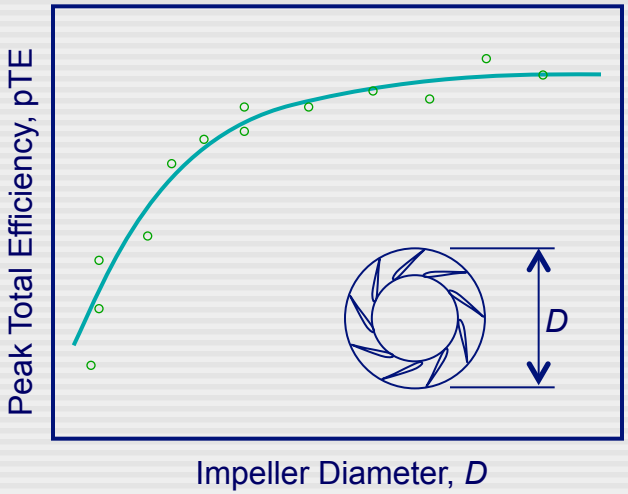
Implicit (Variable) Fan Efficiency Requirement

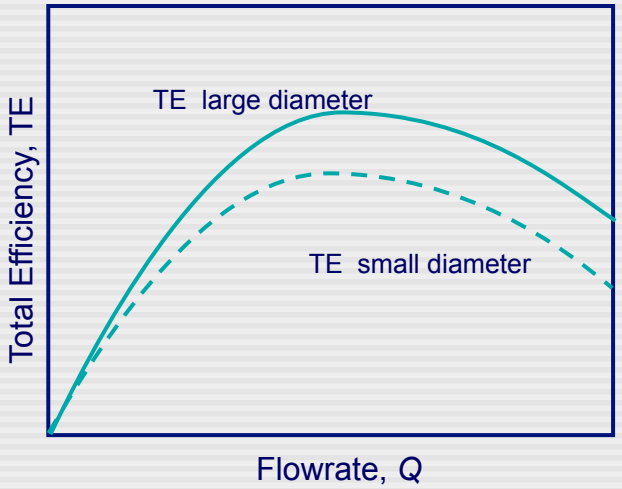
Fan Energy Consumption

Fan Efficiency

Practical Considerations

- *Peak efficiency varies with…*
  - Fan type (FC, AF, BC, etc)
  - Impeller speed
  - Impeller size
  - Flowrate
- *Due to…*
  - Reynolds number
  - Manufacturing tolerances
  - Bearings don't follow the fan laws…





Fan Energy Consumption

New Grading Standards

ISO I2759 Fans - Efficiency Classification for Fans

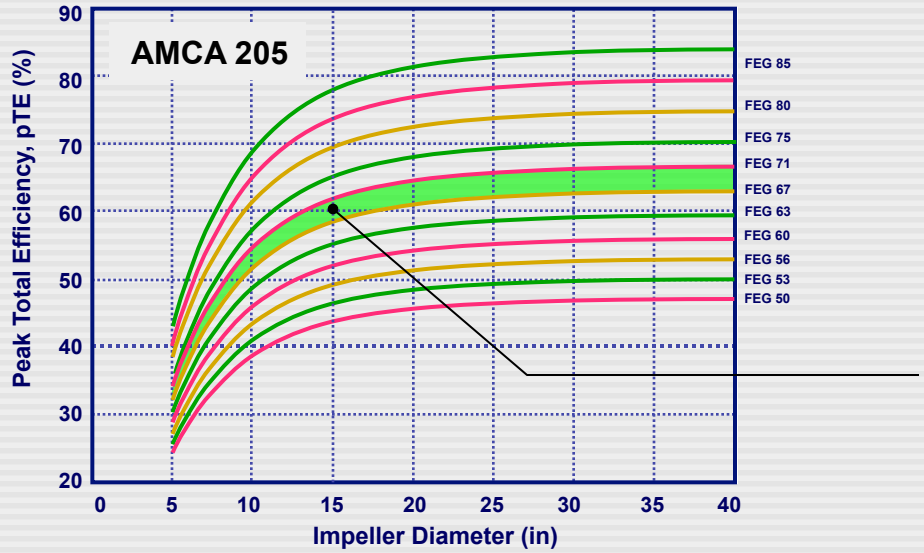
AMCA 205 Energy Efficiency Classification for Fans

Fan Energy Consumption

FEG = Fan Efficiency Grade

Indicator of aerodynamic quality

- Based on peak **AIR POWER** conversion efficiency = total efficiency
- Recognizes effect of **impeller diameter** on peak efficiency
- Fans from a single product likely to have same **FEG**
- For use in standards/codes: ***"FEG shall be X or greater…"***
- Offers path for **progressive improvement**, FEG67 → FEG71



15" fan with peak total efficiency of 60% would be rated **FEG67**

Fan Energy Consumption

ASHRAE 90.1 – 2010: Fan Power Limitation

*Proposed addition of fan efficiency requirement – FEG67**

Example (Single fan, VAV, Option 2 = 1.3 hp/kcfm, *A*=0):

Flow: 20,000 cfm (9.4 m^3/s)
Pressure: 6 in-wg (1.5 kPa)
Selection Efficiency: 78%
FEG: 85

BHP: 24.2 hp (18.1 kW)

☑ **SFP: 1.2 hp/kcfm**

☑ **FEG: 85**

PASS

***with certain exclusions**

Fan Energy Consumption

ASHRAE 90.1 – 2010: Fan Power Limitation

Proposed addition of fan efficiency requirement – FEG67

Example (Single fan, VAV, Option 2 = 1.3 hp/kcfm, *A*=0):

Flow: 20,000 cfm (9.4 m^3/s)
Pressure: 4 in-wg (1.0 kPa)
Selection Efficiency: 58%
FEG: 63

BHP: 21.7 hp (16.1 kW)

☑ **SFP: 1.1 hp/kcfm**

☒ **FEG: 63**

FAIL

Fan Energy Consumption

ASHRAE 90.1 – 2010: Fan Power Limitation

Proposed addition of fan efficiency requirement – FEG67

Example (Single fan, VAV, Option 2 = 1.3 hp/kcfm, *A*=0):

Flow: 20,000 cfm (9.4 m^3/s)
Pressure: 6 in-wg (1.5 kPa)
Selection Efficiency: 70%
FEG: 85

BHP: 27.0 hp (20.1 kW)

☒ **SFP: 1.35 hp/kcfm**

☑ **FEG: 85**

FAIL

Fan Energy Consumption

ASHRAE 90.1 – 2010: Fan Power Limitation

Proposed addition of fan efficiency requirement – FEG67

Example (Single fan, VAV, Option 2 = 1.3 hp/kcfm, *A*=0):

Flow: 20,000 cfm (9.4 m^3/s)
Pressure: 8 in-wg (2.0 kPa)
Selection Efficiency: 82%
FEG: 85

BHP: 30.7 hp (22.9 kW)

☒ **SFP: 1.53 hp/kcfm**

☑ **FEG: 85**

FAIL

Fan Energy Consumption

ASHRAE 90.1 – 2010: Fan Power Limitation

Proposed addition of fan efficiency requirement – FEG67

Example (Single fan, VAV, Option 2 = 1.3 hp/kcfm, *A*=0):

Flow: 20,000 cfm (9.4 m^3/s)
Pressure: 4 in-wg (1.0 kPa)
Selection Efficiency: **48%**
FEG: 67

BHP: 26.2 hp (19.5 kW)

☒ **SFP: 1.31 hp/kcfm**

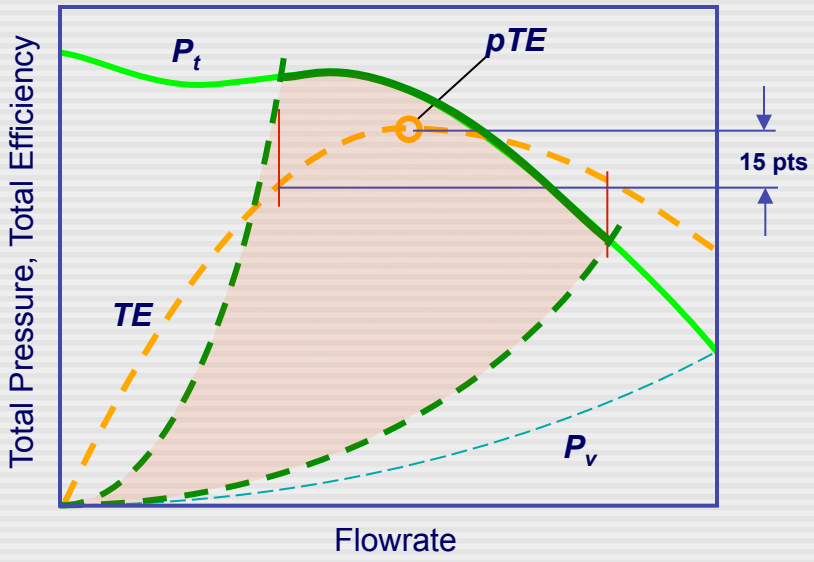
☑ **FEG: 67**

FAIL

Fan Energy Consumption

ASHRAE 90.1 – 2010: Fan Power Limitation

Proposed addition of fan efficiency requirement – FEG67
*… **and** requirement that fan be selected within 15 pts pTE*



- 15 pts is **generous**
- Covers most fan's ***recommended range***
- **Fan Power Limitation** similar function

Wrap-up

- Fan Energy Consumption – growing concern → regulation
- Fan Efficiency alone does not drive energy savings
- ASHRAE 90.1 Fan Power Limitation – system and fan responsibility
- ASHRAE 90.1 Fan Power Limitation – implicit efficiency
- FEG – valuable metric to compliment energy standards
- ASHRAE 90.1 + FEG – impacts low pressure systems

Thank You!

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