Fan Industry:
Facing Up to the Energy Challenges

AIR MOVEMENT AND CONTROL
ASSOCIATION INTERNATIONAL, INC.

Dr. Michael Brendel
Vice President, Engineering and Marketing
Lau Industries / Ruskin Company
Dayton, OH
USA

Franco Cincotti
Director,
Engineering
Comefri USA
Hopkinsville, KY
USA

Session Topics

- Part 1 - Overview of HVAC Energy Issues
  - ✓ HVAC System Energy Consumption
  - ✓ HVAC System Energy Metrics
  - ✓ Fan Efficiency Metrics - FEG and FMEG
- Part 2 - Draft Standard and Examples
  - ✓ Draft AMCA 205
  - ✓ Fan Selection Implications/Examples
- Questions/Discussion

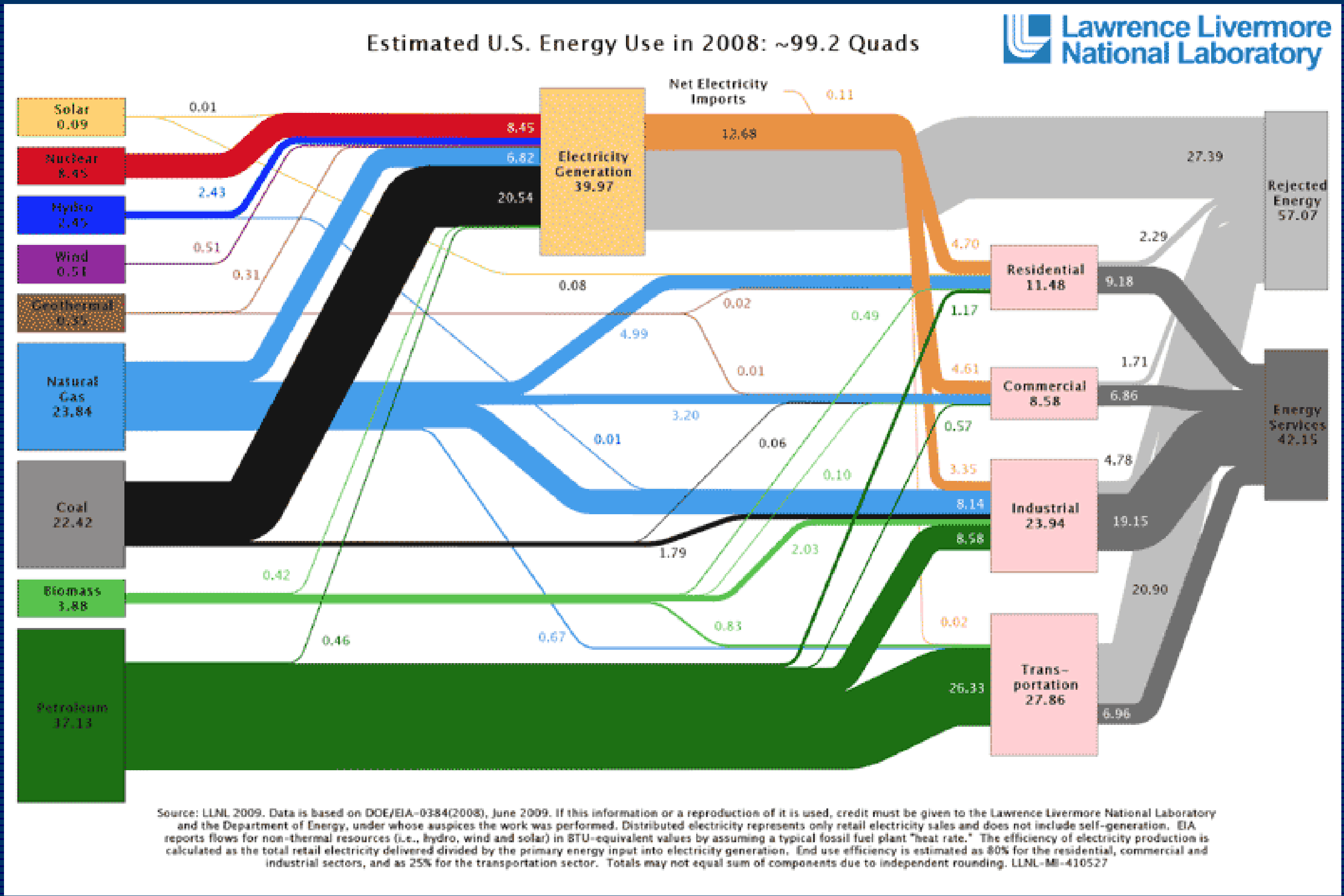
Energy Consumption

2008 Estimated US Energy Consumption[1]

99 Quads (I05 EJ)

[1]LLNL / DOE / EIA 2009

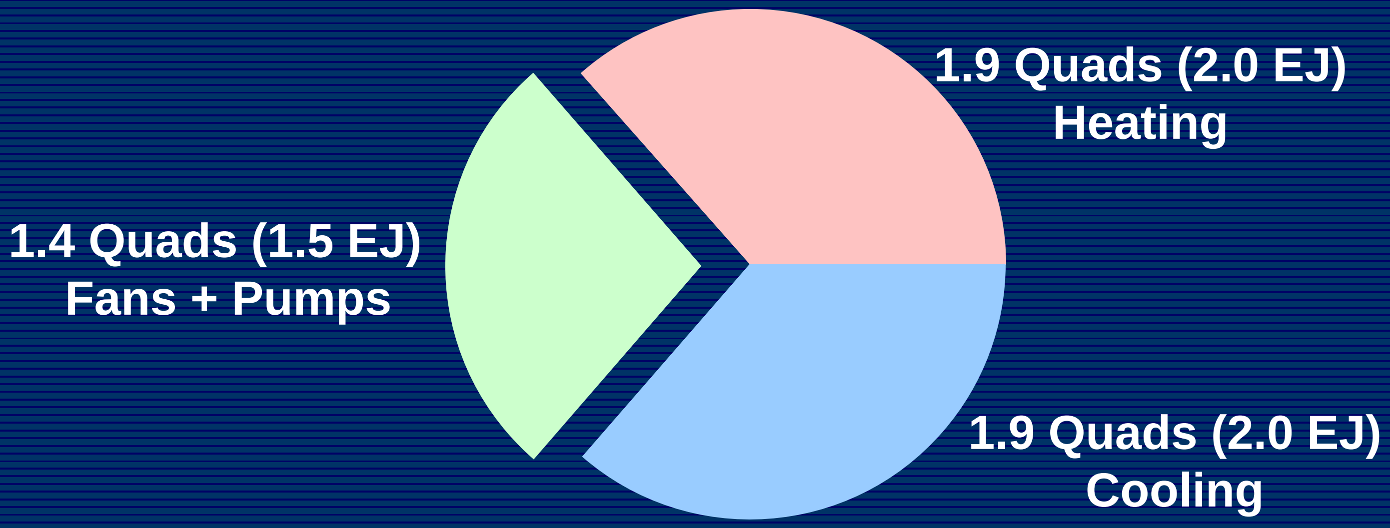
Energy Consumption



LLNL / DOE / EIA 2009

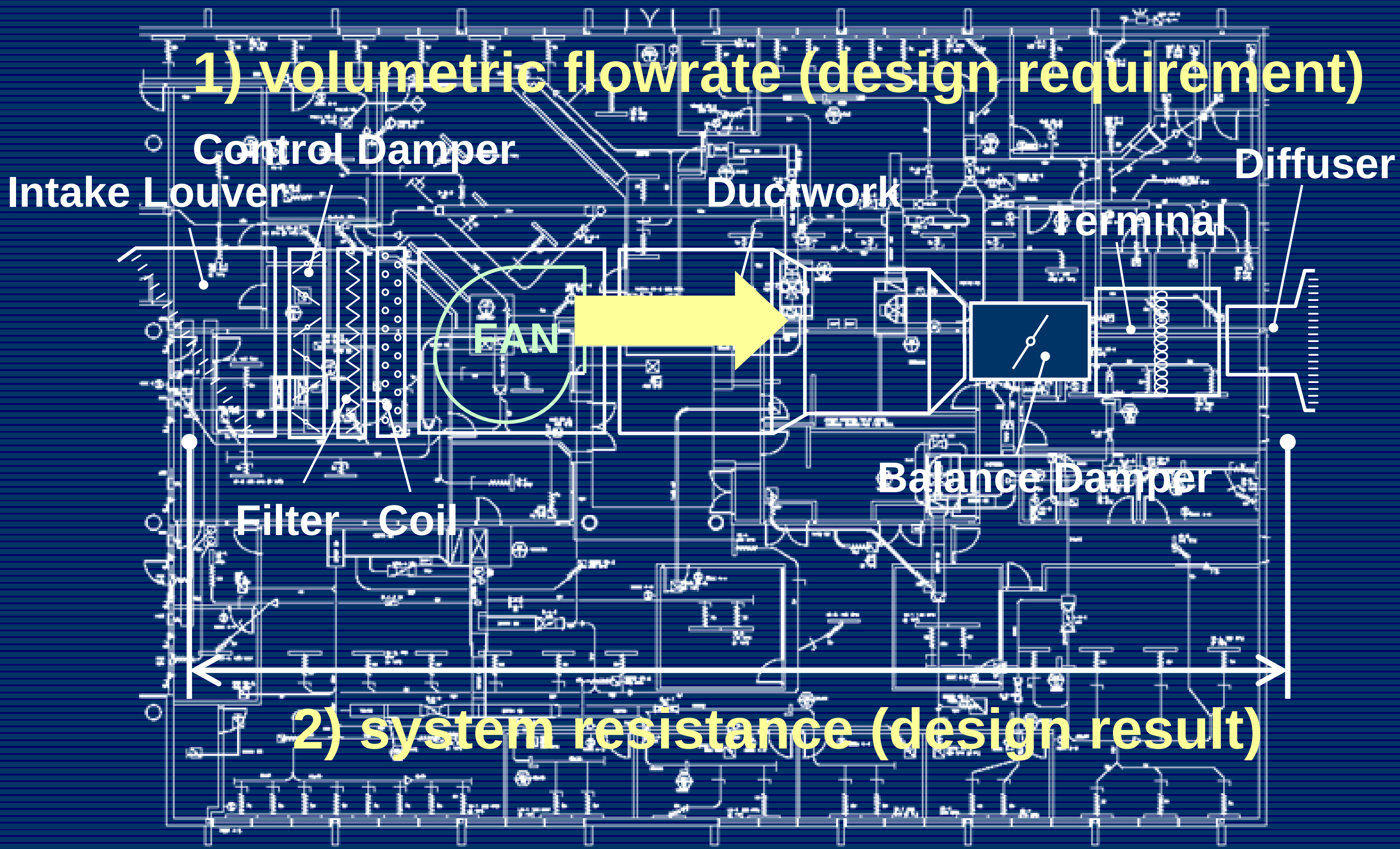
Energy Consumption - HVAC Systems

Estimated US HVAC Energy Consumption[2]



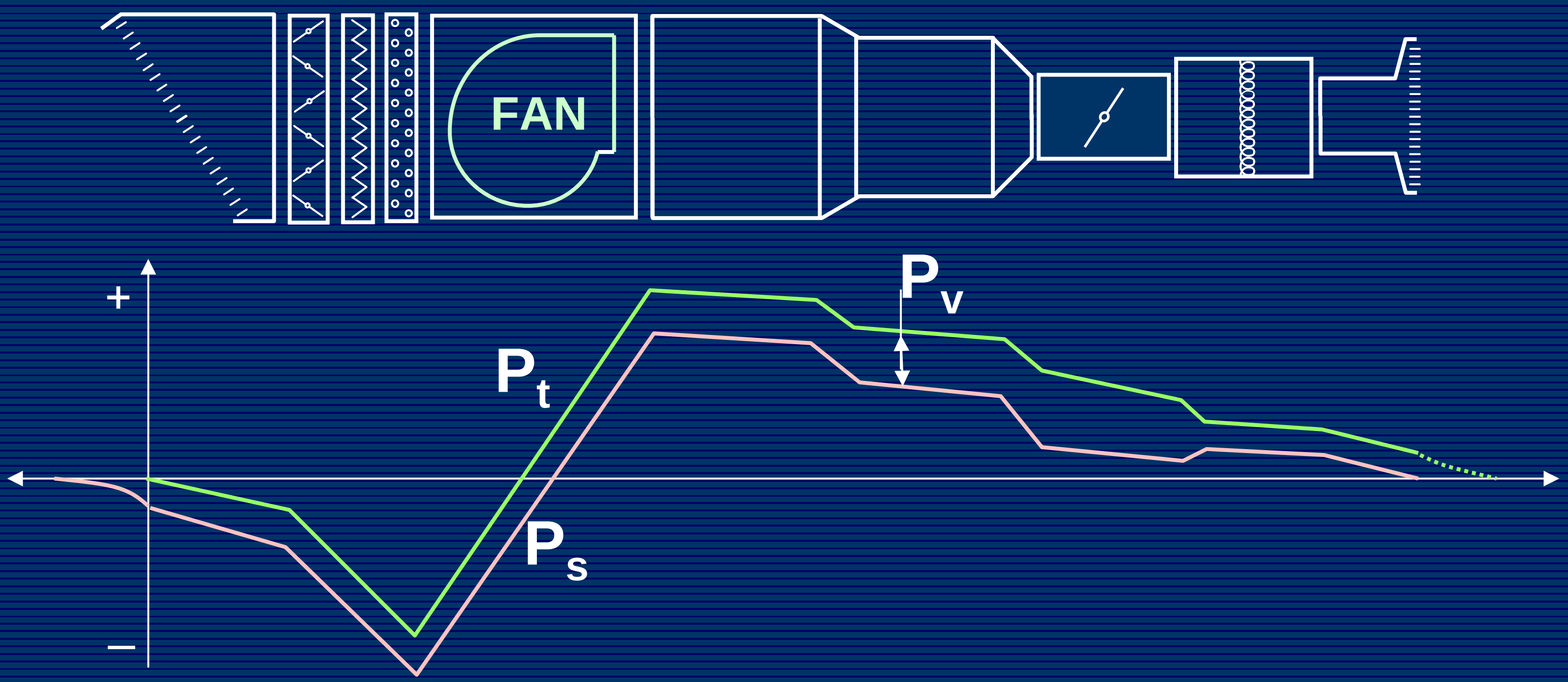
[2]DOE 1999 - source energy

HVAC System



1) volumetric flowrate (design requirement)
Control Damper
Intake Louver
Ductwork
Diffuser
Terminal
FAN
Balance Damper
Filter
Coil
2) system resistance (design result)

HVAC System



P_t always decreases in absence of energy input

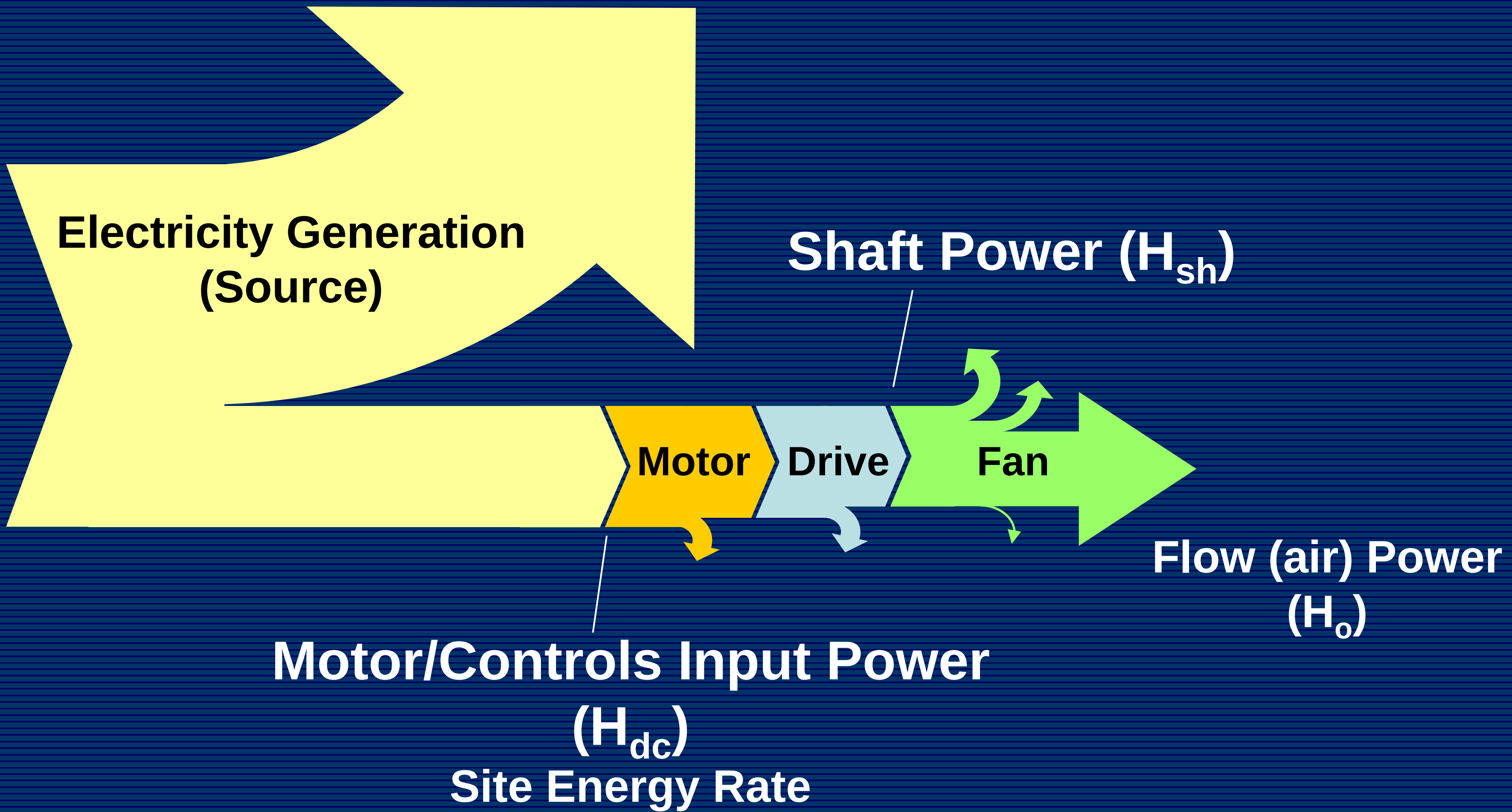
System Energy Metrics

Total Energy = Kinetic Energy + Potential Energy

$$P_tQ = P_vQ + P_sQ = \text{flow (air) power } (H_o)$$

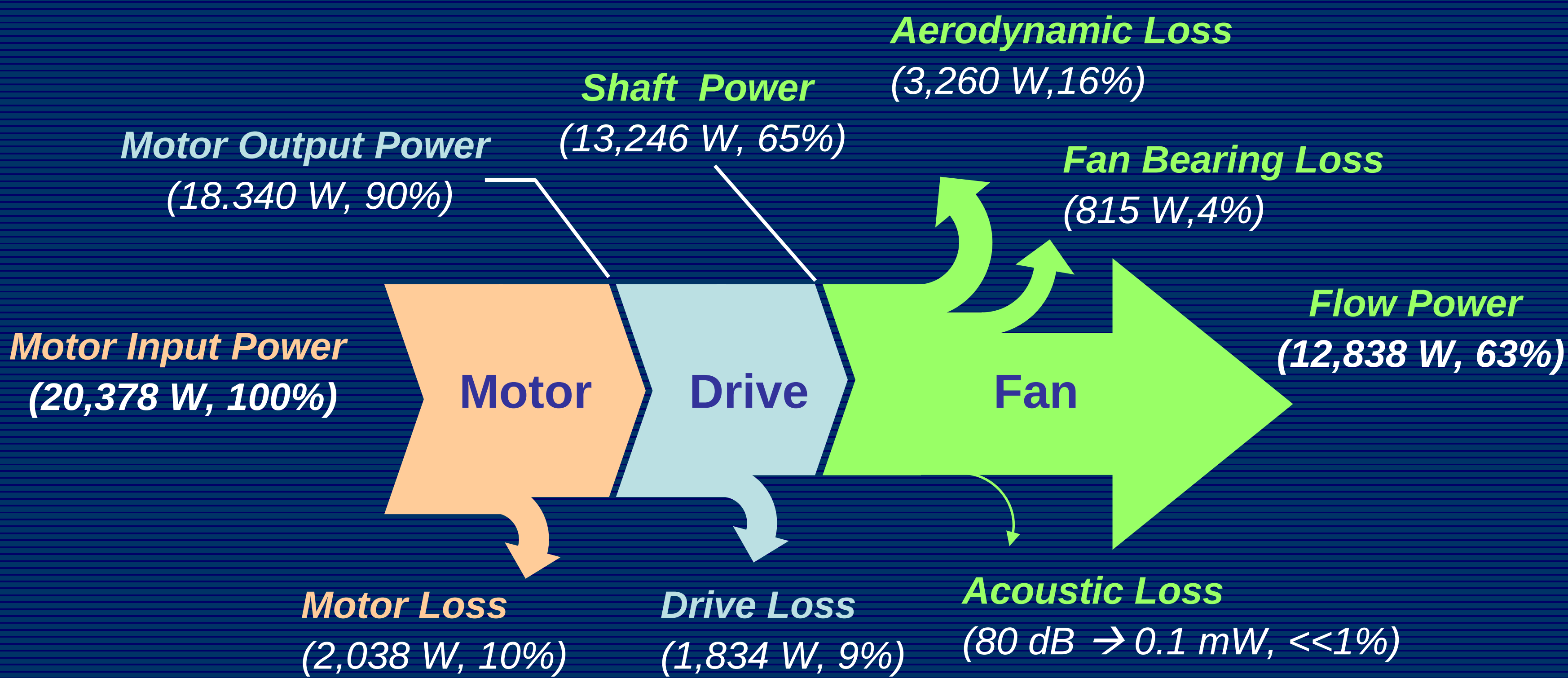
- ✓ **Energy rate to maintain air motion**
- ✓ **Energy rate to overcome resistance**

System Energy Metrics



System Energy Metrics - Example

25” Belt Drive Airfoil DWDI Blower
Motor - 90% efficient, Drive - 90% efficient
Operating point: 16,800 cfm @ 6.5 in-wg (total)

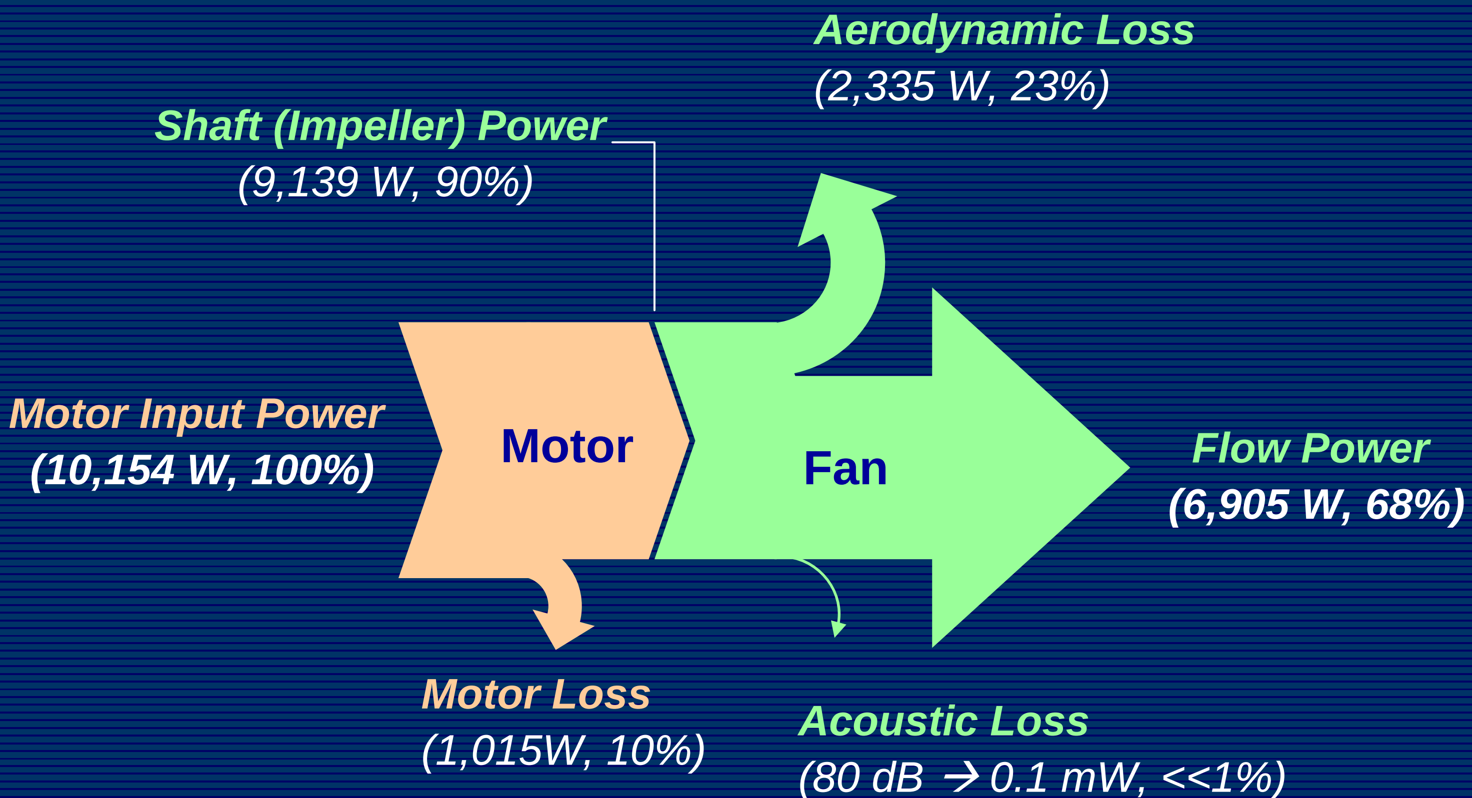


System Energy Metrics - Example

25” Direct Drive Plenum Fan

Motor - 90% efficient, No Drive

Operating point: 9250 cfm @ 6.35 in-wg (total)



System Energy Metrics

How do we reduced HVAC (airside) energy consumption?

Flow resistance (system design)
- ✓ Minimum duct resistance
- ✓ Low pressure drop components (coils, filter, dampers)

$$\min \{P_t Q\}$$

Flowrate (application requirement)
- ✓ Minimum Q to achieve HVAC goal
- ✓ Minimize system leakage

System Energy Metrics

One approach…

Specific Fan Power (SFP)

$$SFP \equiv \frac{\text{Fan Input Power}}{\text{Flowrate}} \equiv \frac{H_{dc}}{Q}$$

System Energy Metrics

Specific Fan Power (SFP)

$$SFP = \frac{H_{dc}}{Q} = \frac{P_t}{\eta_{dc}}$$

Input Power (H_{dc})

Required Flowrate (Q)

System Total Pressure (P_t)

Input Power → Air Power Efficiency (η_{dc})

System Energy Metrics

Efficiency - including motor, drives, fan:

Air Power

$$\eta_{dc} = \frac{H_o}{H_{dc}} = \frac{P_t Q}{H_{dc}}$$

Input electrical energy

System Energy Metrics

η_{dc} - combination of component efficiencies:

System resistance

$$SFP = \frac{P_t}{\eta_c \, \eta_m \, \eta_d \, \eta_t}$$

controls

motor

drive

fan

System Energy Metrics

Placing upper limit on SFP:

Example:

If SFP < 700 W/kcfm (0.94 HP/kcfm)

- **Places upper limit on P_t = 6 in-wg (1,500 Pa)**
- **Pt < 6 in-wg for η_{dc} < 100%**

Effective means to assure efficient system design

System Energy Metrics

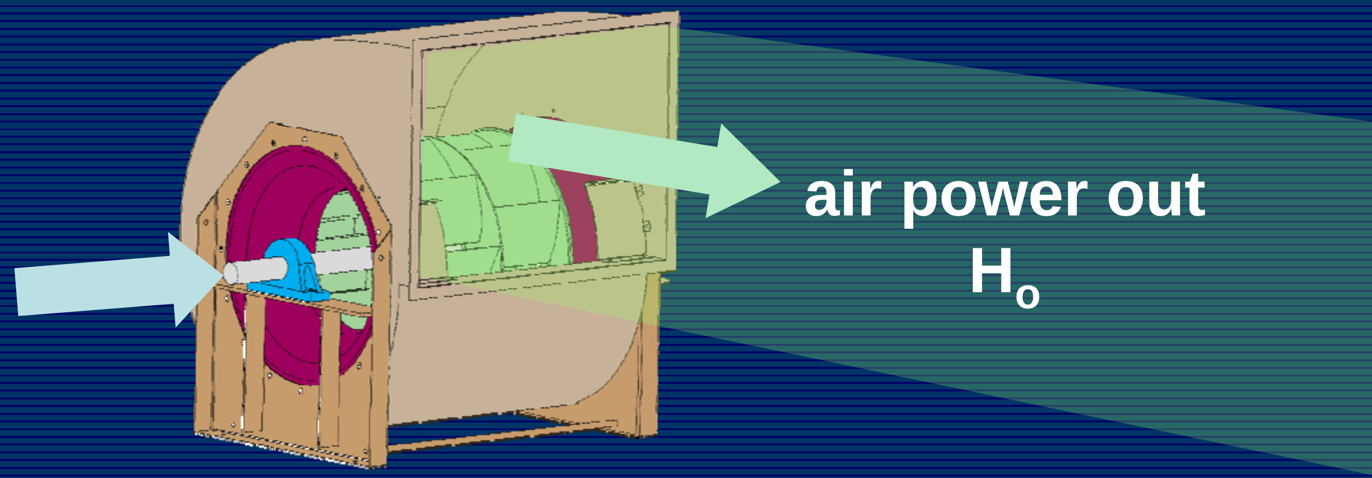
Reducing Energy Consumption

- Minimize P_t for given flow requirement (SFP)
  - ✓ Duct/System designer responsibility
- Maximize motor/control/drive efficiency (η_m, η_c, η_d)
  - ✓ Motor/Control/drive supplier responsibility
- Maximize fan efficiency (η_t)
  - ✓ Fan manufacturer responsibility

Next: Focus on fan efficiency

Fan Energy Metrics

$$\text{Fan Efficiency} = \frac{\text{air energy rate out}}{\text{shaft energy rate in}} \qquad \frac{\text{air power out}}{\text{shaft power in}}$$



Fan Energy Metrics

Efficiency - fan (without drives):

$$\eta_t \equiv \frac{H_o}{H_{sh}} = \frac{P_t Q}{H_{sh}}$$

Fan input power

Fan Efficiency

Proposed Fan Energy Grading Metric

Goals

- Simple to implement
- Grading system applies to fan model range
- Provide simple means to compare fan designs
- Based on total fan energy (total pressure)
- Provide tool for regulative bodies

Fan Efficiency

Two Proposed Metrics:

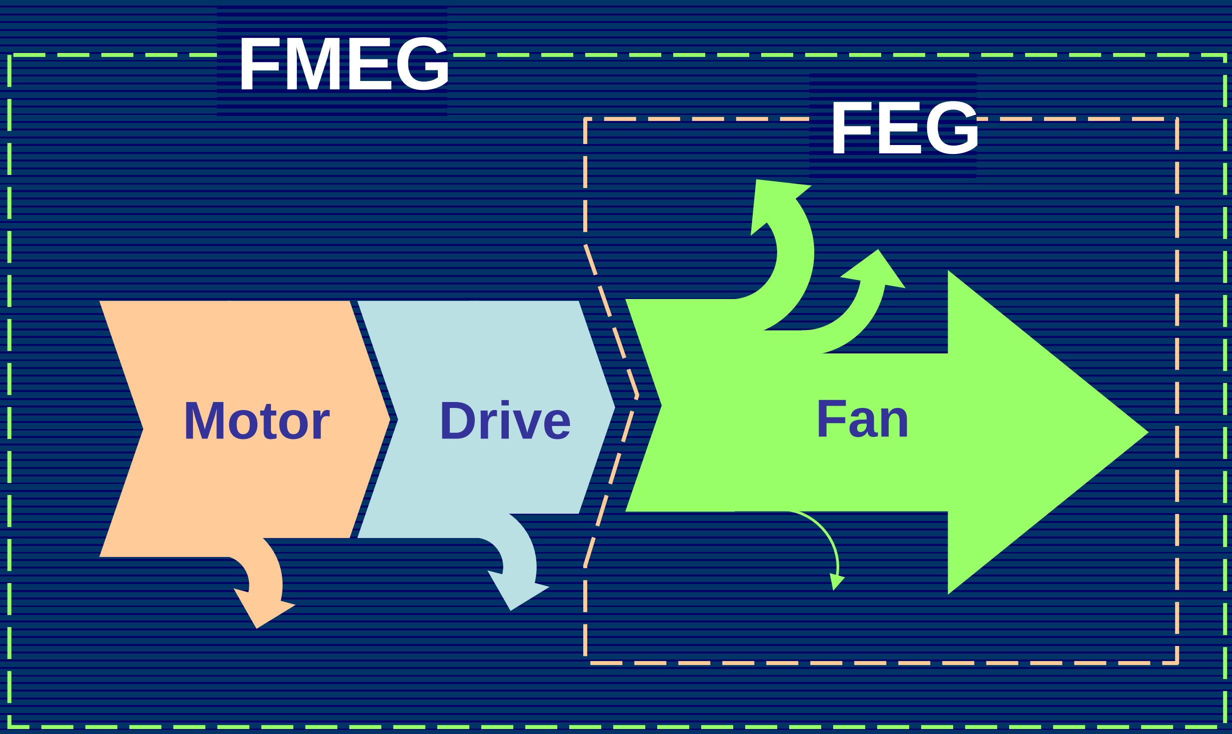
Fan Motor Efficiency Grade (FMEG)

- Input at motor/control electrical mains
- Suitable for fans sold with integral motorized impeller
- Based on overall fan efficiency
- Function of motor/control input power

Fan Efficiency Grade (FEG)

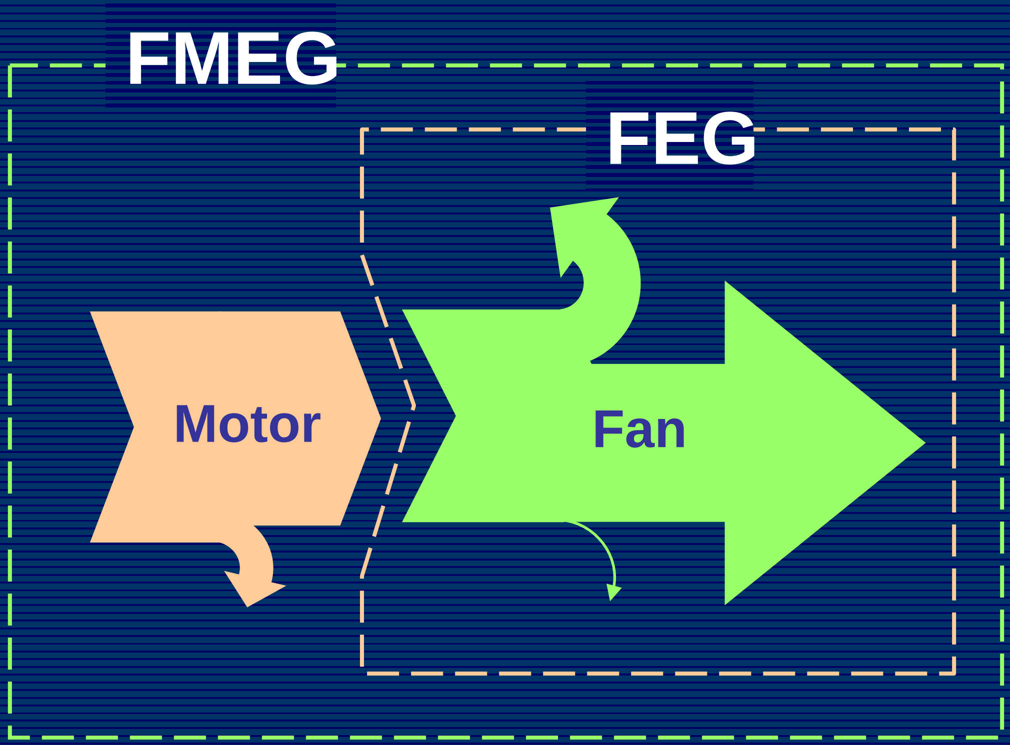
- Input at fan shaft/impeller
- Suitable for fans sold less drive/motor
- Based on fan peak total efficiency
- Accounts for the effects of impeller diameter

Fan Efficiency Grades



Typical Belt Drive Fan

Fan Efficiency Grades



Typical Direct Drive Fan

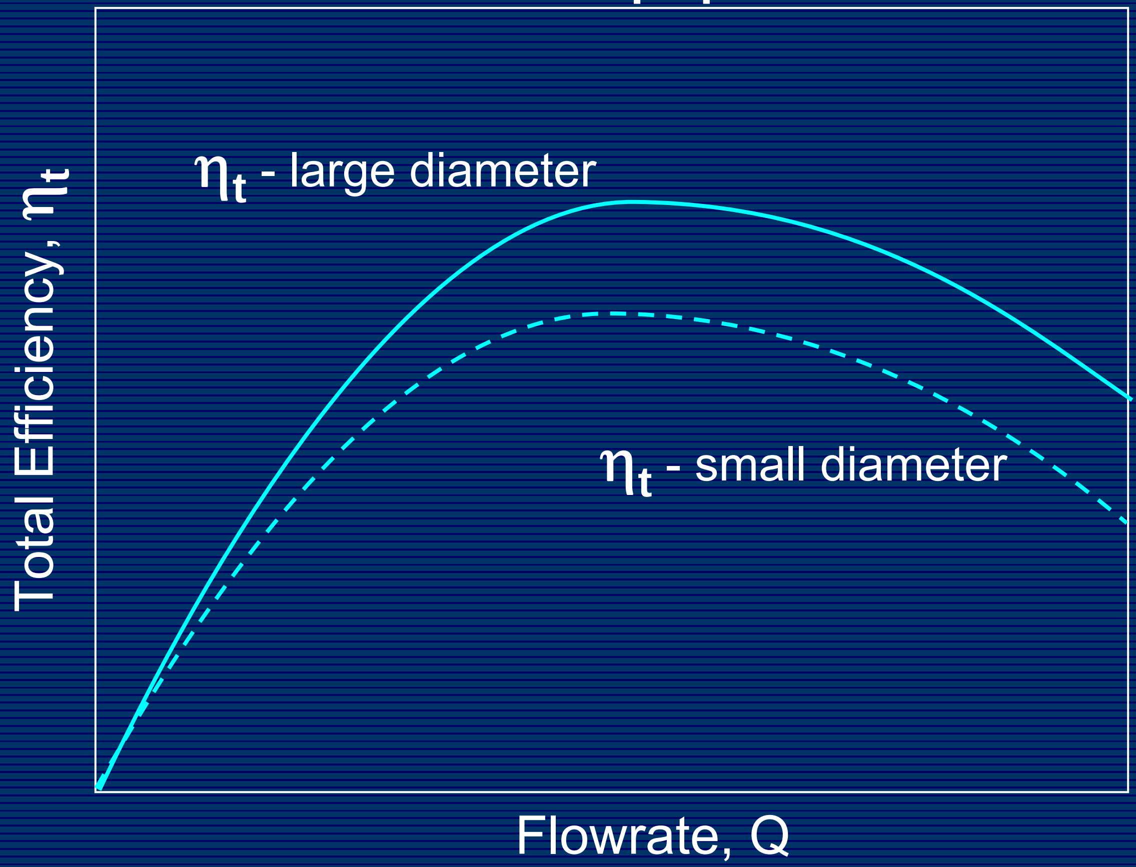
Fan Efficiency

Practical Considerations (FEG)

- Efficiency varies with fan operating point
- Peak efficiency varies with
  - Fan type
  - Fan tip speed
  - Fan size

Fan Efficiency

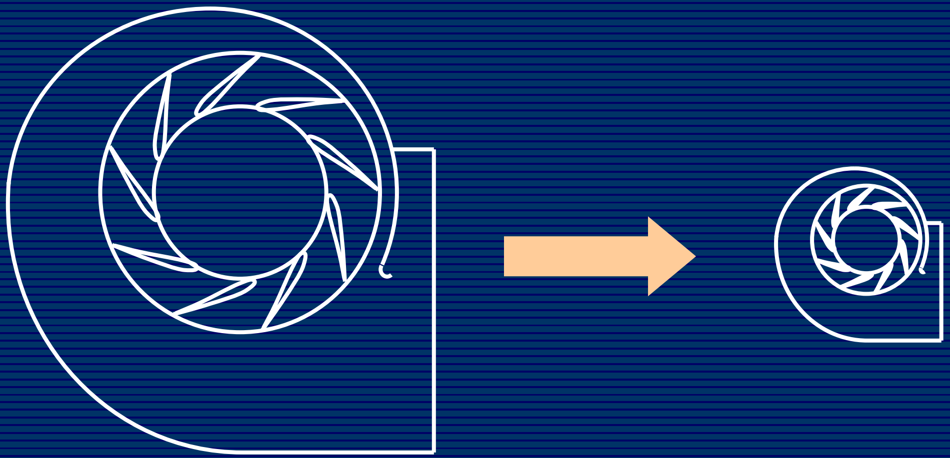
Effect of impeller diameter for geometrically similar fans at same tip speed



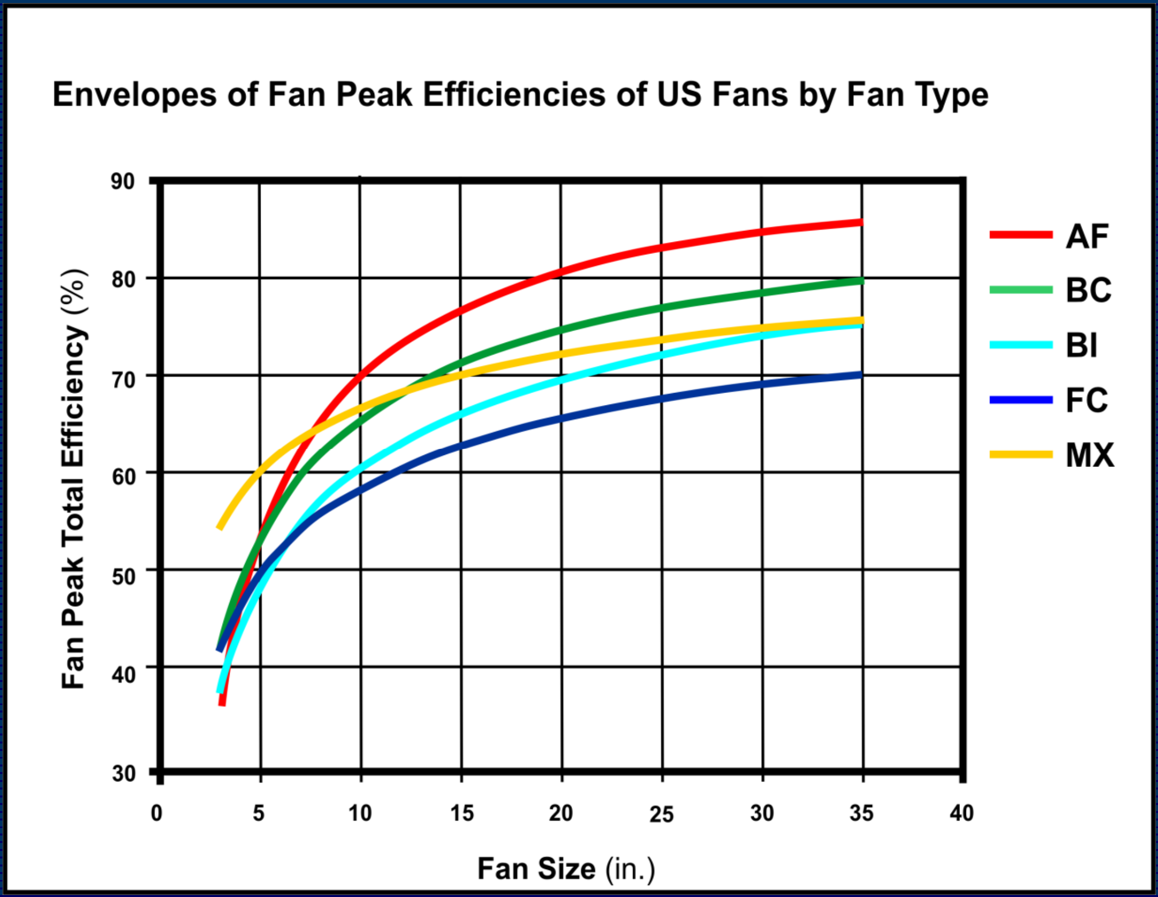
Fan Efficiency

Geometric/Aerodynamic Similarity?

- **Reasonable manufacturing tolerances**
- **Low Reynolds number performance degradation**
- **Mechanical losses don’t follow fan laws**

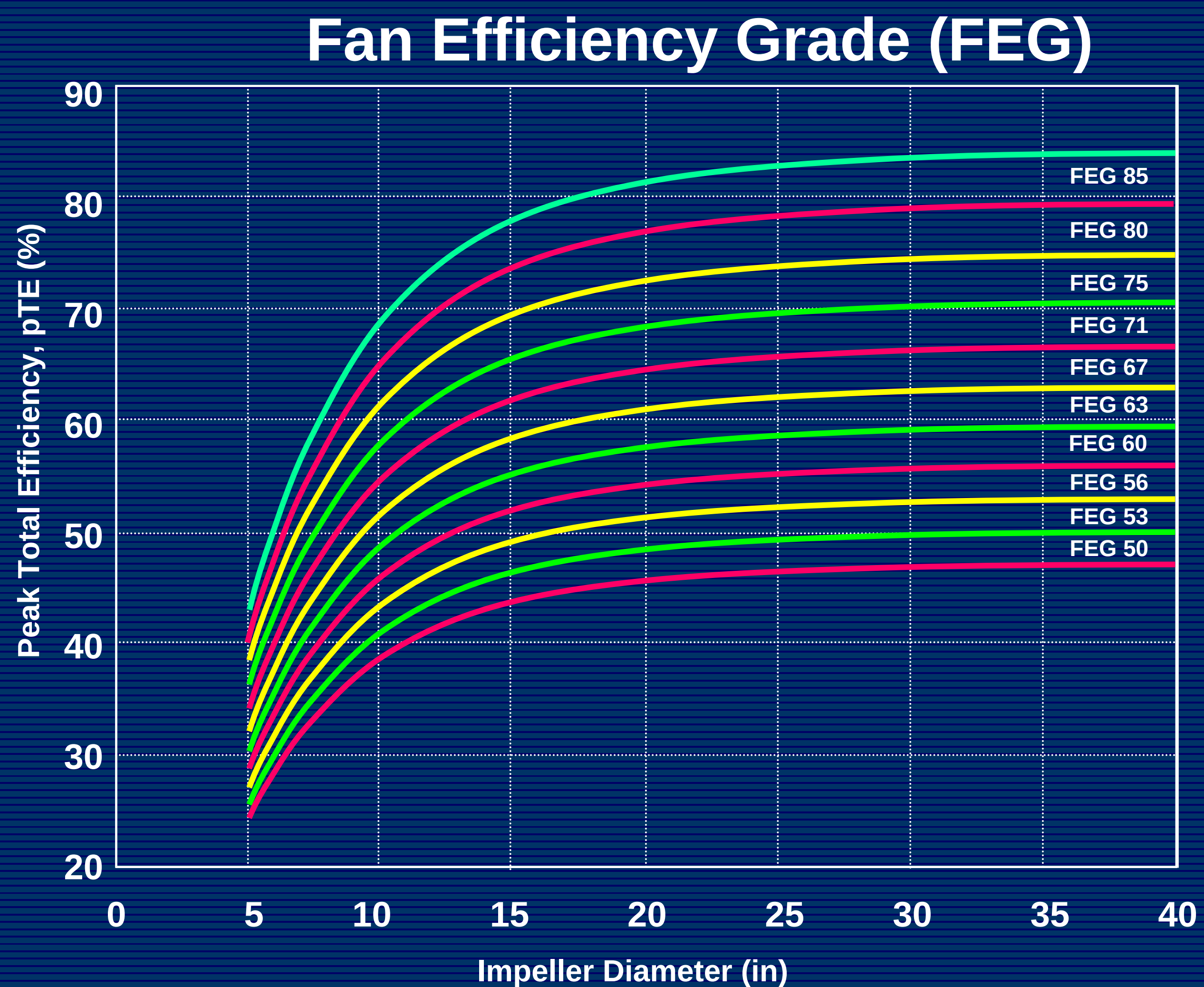


Fan Efficiency

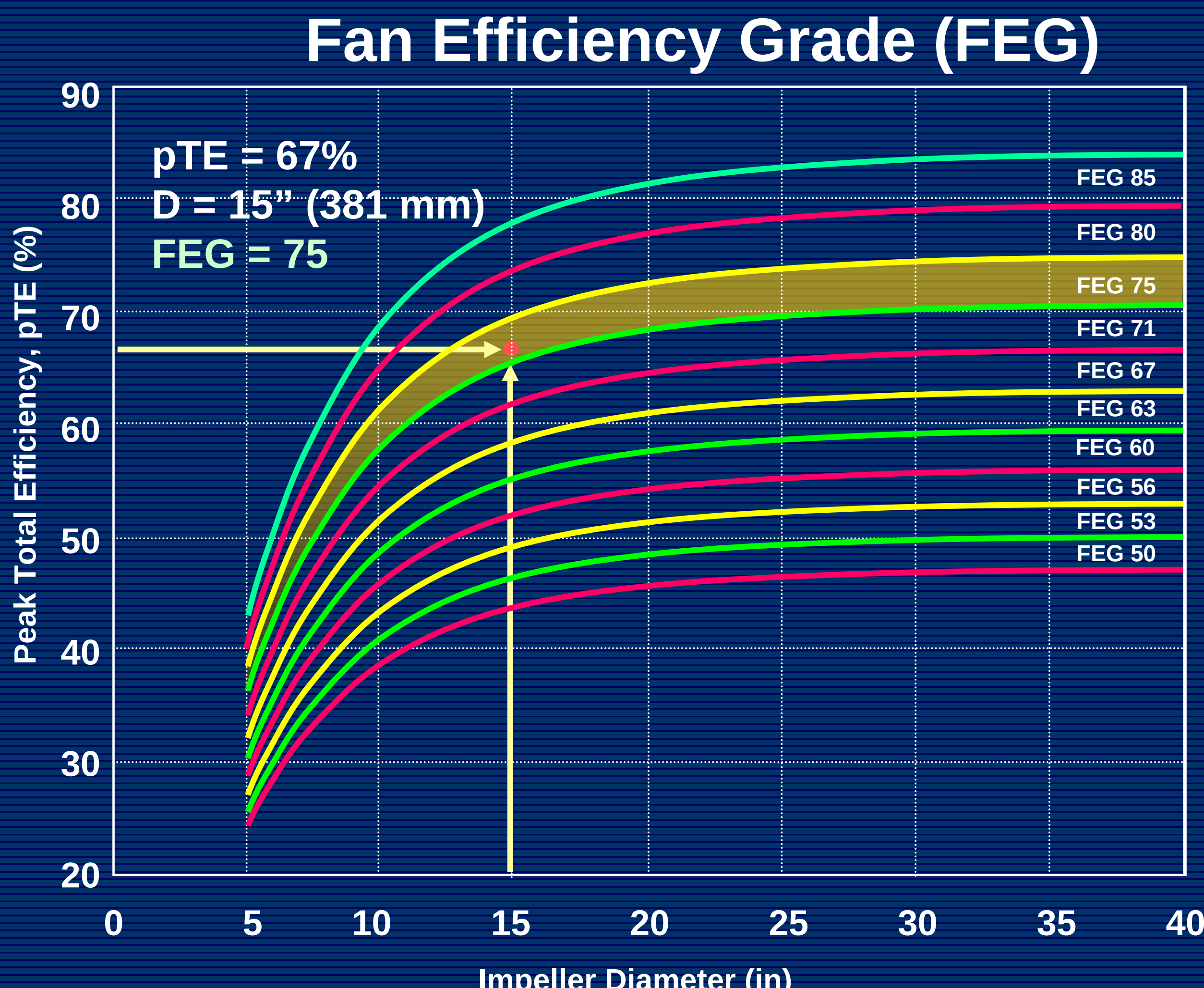


Source: John Cermak

Fan Efficiency



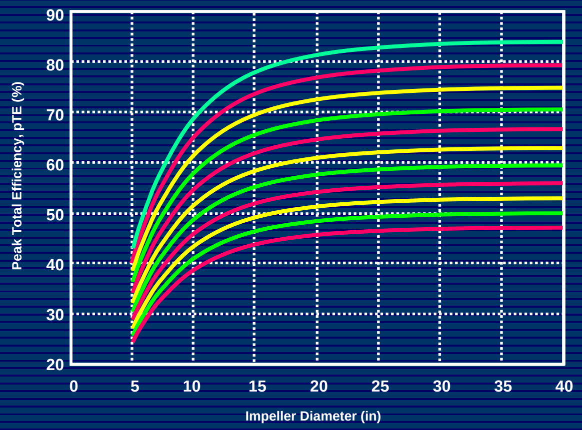
Fan Efficiency



Fan Efficiency

Fan Efficiency Grade (FEG)

- Grade labels in preferred numbers (R40)
- Reference diameter: 40 in (I0I6 mm)
- Minimum defined diameter: 5 in (I25 mm)
- Fans >40 in use reference diameter Grade
- Formula defined - for electronic calculation



Part 2
Draft Standard AMCA 205 & Selection Examples

Fan Efficiency

Standards Activity

- **DIS/ISO I2759 Fans - Efficiency Classification for Fans**
- **AMCA 205 (draft) Energy Efficiency Classification for Fans**

✓ **Fan Efficiency Subcommittee appointed by AMCA Fan Committee - SEP 2008**

✓ **Draft AMCA 205 approved by the AMCA Fan Efficiency Subcommittee - OCT 2009**

✓ **Draft AMCA 205 approved by the AMCA Fan Committee - OCT 2009**

✓ **Draft AMCA 205 out for approval to AMCA Members - DEC 2009**

✓ **Next Steps: Development of a FEG/FMEG AMCA Certification Program**

Draft AMCA 205

Fan Efficiency Grade (FEG)

- The Fan Efficiency Grade FEG is an indicator of the capacity of a Fan to convert Fan shaft power H_{sh} to Fan air power H_o

- The FEG is defined as a function of the Fan Total Peak Efficiency (pTE) and Fan size (impeller diameter)

- Specifications of Minimum FEG shall include a requirement that the Fan Total Efficiency at the actual point of operation be within l0 points of the Fan Total Peak Efficiency.

Draft AMCA 205

Fan Efficiency Grade (FEG)

- **Applies to fans driven by motors > I/6 HP (I25 W)**

- **Applies to fans consuming more than I000 kWh annually**

Fan Selection - Practical Considerations

- **Minimum FEG specification**
  - Would limit available fan ranges
  - Does not guarantee reduced energy consumption
- **Select within l0 pt pTE**
  - Assures selections close to pTE
  - How restrictive?

Next:

✓ Survey various fan types
✓ Selection examples

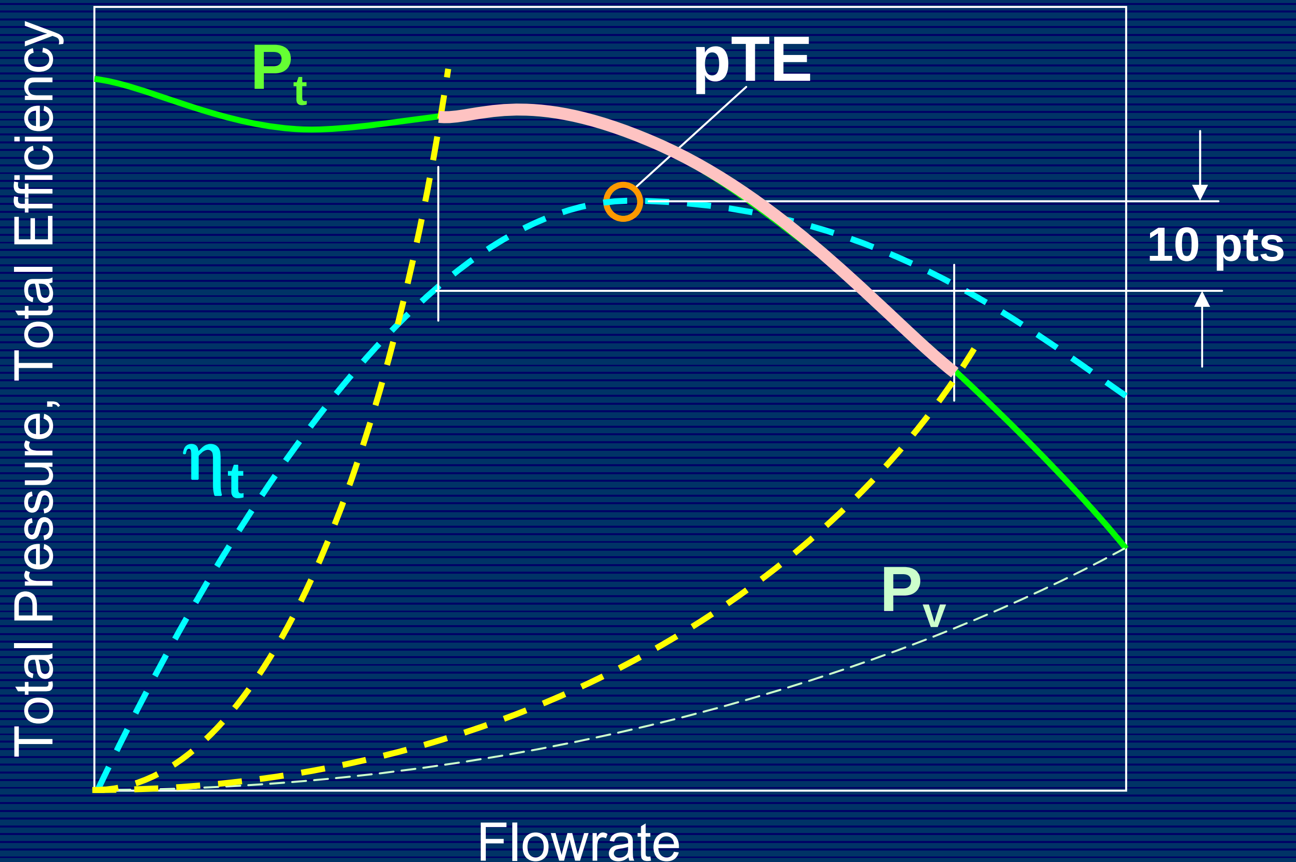
Fan Selection

Achievable Peak Total Efficiency[1]

Fan Type		pTE
Centrifugal	Airfoil	88
	Backward Curved	84
	Backward Inclined	80
	Forward Curved	70
Axial	Vaneaxial	85
	Tubeaxial	75
	Propeller	55
Mixed Flow		75
Tangential		25

1. Radgen, et. al. 2008

Fan Selection



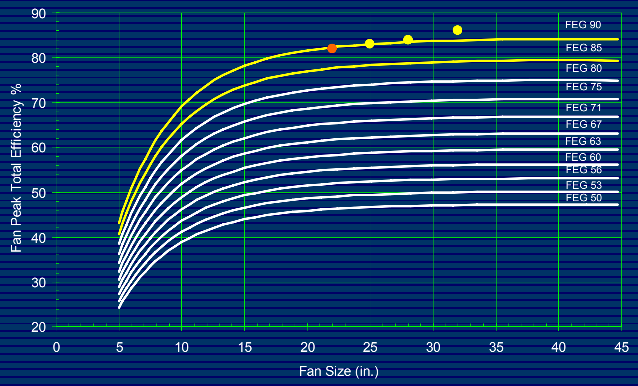
Selection Example

Range: DWDI AF FEG80
Application: 20 Ton RTU
Target Flow: 8000 CFM (13,600 m^3/h)
ISP + ESP: 3 in-wg (750 Pa) P_t

Size	H_{sh} (HP)	N (RPM)	TE	EAE* (kWh)
25”	5.70	1198	66.4%	45987
22”	5.24	1324	72.2%	42276
20”	5.04	1490	75.0%	40662
18”	5.16	1733	73.3%	41630
16”	5.63	2090	67.2%	45422

EAE = Estimated Annual Energy Usage
- 90% motor efficiency
- 90% drive efficiency
- I00% duty cycle

Selection Example



Range: DWDI AF FEG85
Application: Size 50 AHU
Target Flow: 25,000 CFM (42,500 m^3/h)
ISP + ESP: 6 in-wg (l,500 Pa) P_t

Fan Selections

Size	η_t	pTE	pTE-η_t	H_{sh} (HP)	Meets the 10 pt limit	Drive Power H_{dc} (HP)	Specific Fan Power (HP/1000 cfm)	Duty Cycle	EAE (kWh)
32"	0.86	0.86	0	27.5	Yes	30.8	1.23	24 h/day	201141
28"	0.81	0.84	3	29.2	Yes	32.7	1.31	24 h/day	213558
25"	0.76	0.83	7	31.1	Yes	34.8	1.39	24 h/day	227607
22"	0.67	0.82	15	35.3	No	39.5	1.58	24 h/day	258281

EAE = Estimated Annual Energy Usage
- 94% motor efficiency
- 95% drive efficiency

Selection Example

Range: DWDI AF FEG85
Application: Size 50 AHU
Target Flow: 25,000 CFM (42,500 m^3/h)
ISP + ESP: 6 in-wg (I,500 Pa) P_t

Energy Usage and Cost Estimate

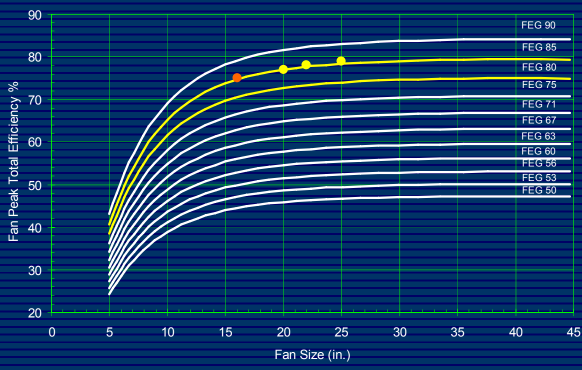
Size	EAE (kWh)	Annual Cost	Annual Cost (rel. 32")	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
32"	201141	$22,126							
28"	213558	$23,491	$1,365	$2,730	$4,095	$5,460	$6,825	$8,190	$9,555
25"	227607	$25,037	$2,911	$5,822	$8,733	$11,644	$14,555	$17,466	$20,377
22"	258281	$28,400	$6,274	$12,548	$18,822	$25,096	$31,370	$37,644	$43,918

EAE = Estimated Annual Energy Usage
• 94% motor efficiency
• 95% drive efficiency

Electricity cost: $0.11 / kWh

Selection Example

Range: Direct Drive Plenum FEG80
Application: Size 25 AHU
Target Flow: 12,000 CFM (20,350 m^3/h)
ISP + ESP: 5 in-wg (I,250 Pa) P_s



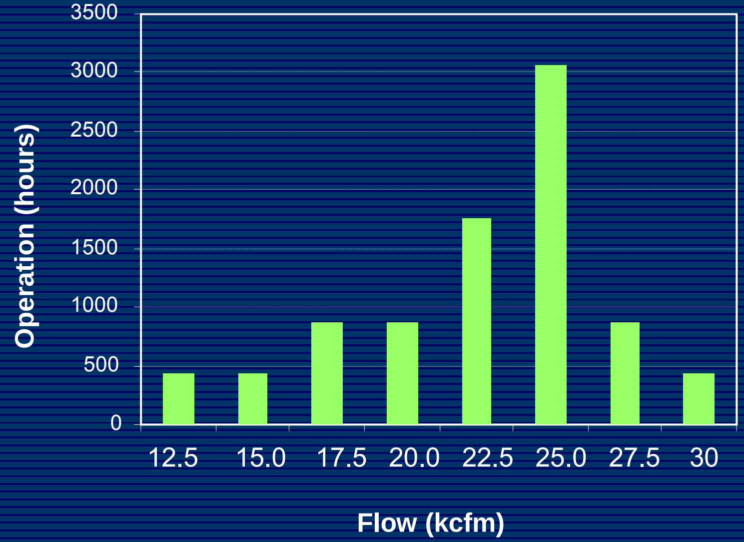
Size	P_t	η_t	pT E	pTE - η_t	Hi (HP)	Meets I0 pts limit	η_m	Drive Power H_{dc} (HP)	Specific Fan Power HP/1000 cfm	Duty Cycle	EAE (kWh)
25"	5.55	0.79	0.79	0 pt	13.3	Yes	0.93	14.3 HP	1.19	24 h/day	93,352
22"	5.90	0.73	0.78	5 pt	15.3	Yes	0.93	16.4 HP	1.37	24 h/day	107,396
20"	6.55	0.66	0.77	11 pt	18.8	No	0.93	20.2 HP	1.68	24 h/day	131,873
16" x 3	5.31	0.74	0.75	1 pt	13.6	Yes	0.90	15.1 HP	1.26	24 h/day	98,528

EAE = Estimated Annual Energy Usage
• variable motor efficiency

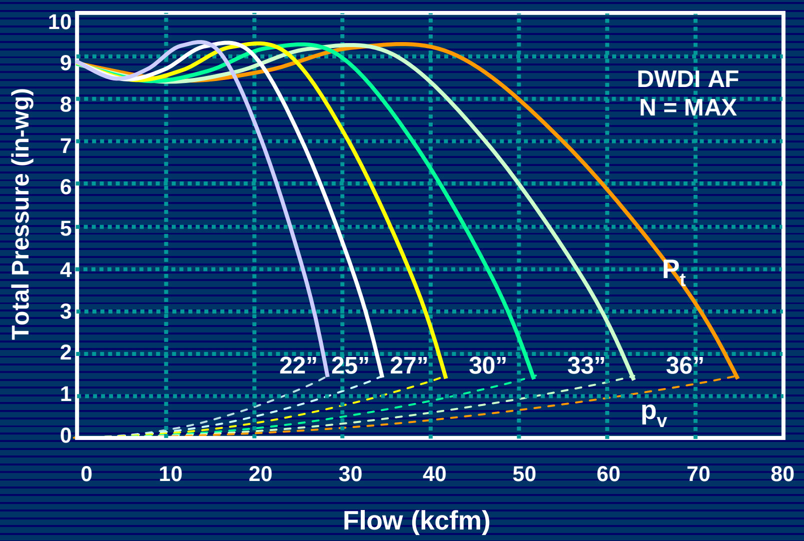
Selection Example

Range: DWDI AF FEG75
Baseline: 25,000 cfm @ 6 in-wg (P_t)
VAV System Control: 0.75 in-wg

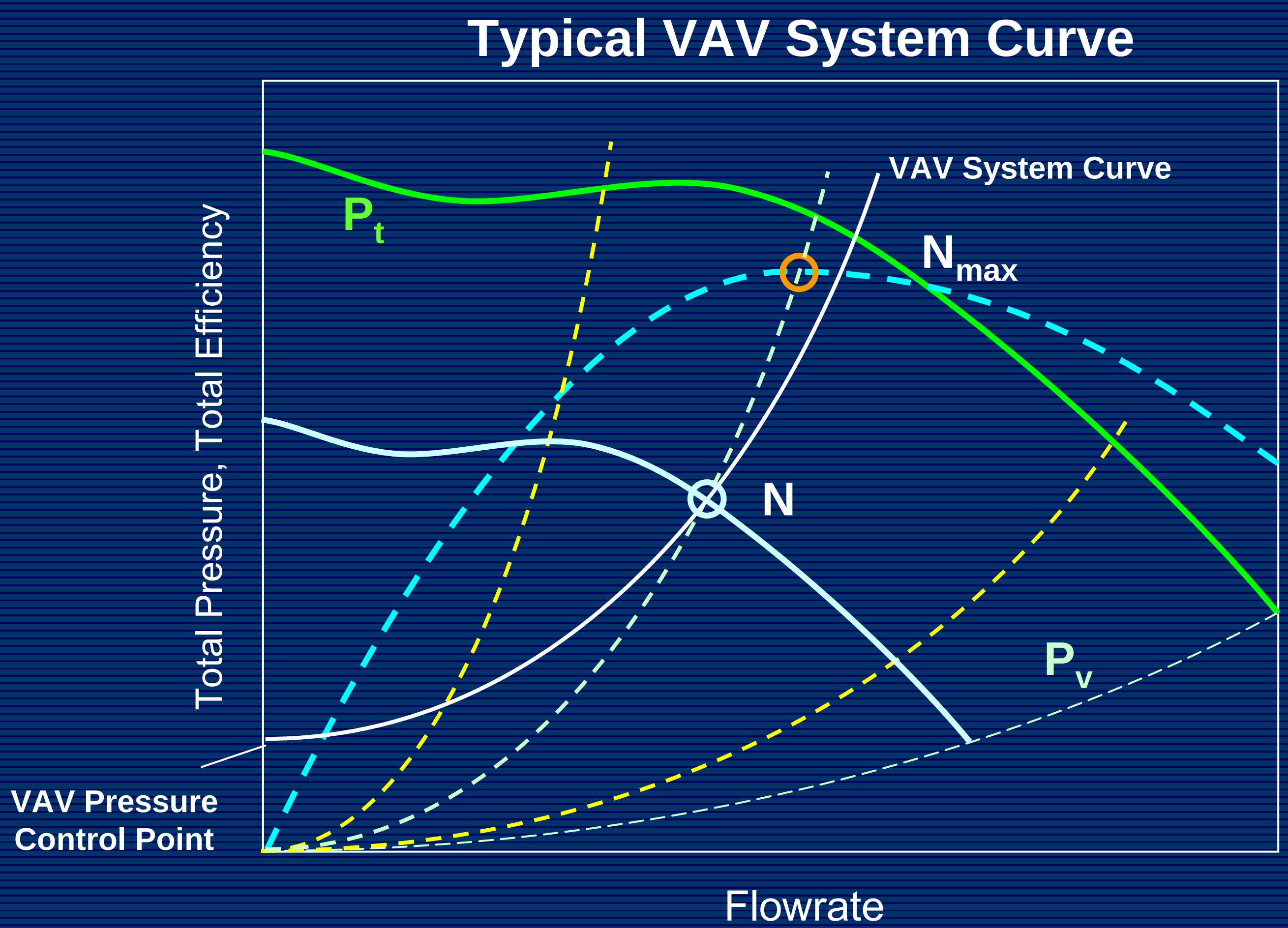
Load Profile



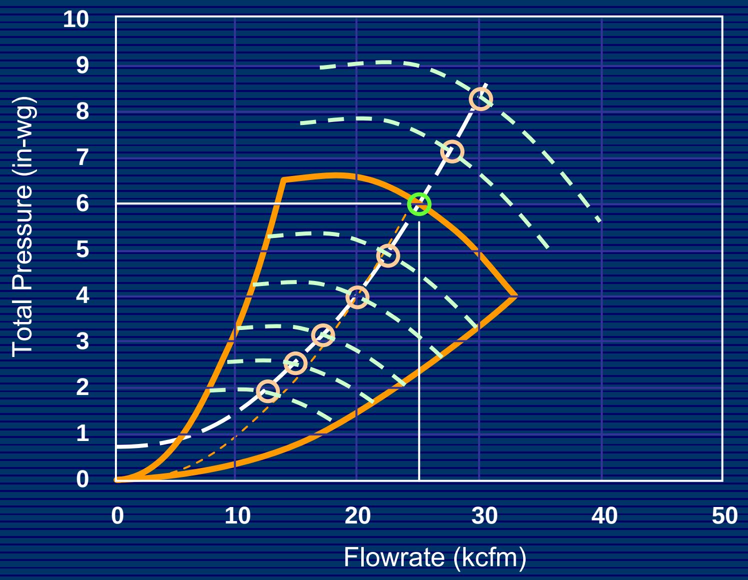
Fan Range



Selection Example



Selection Example

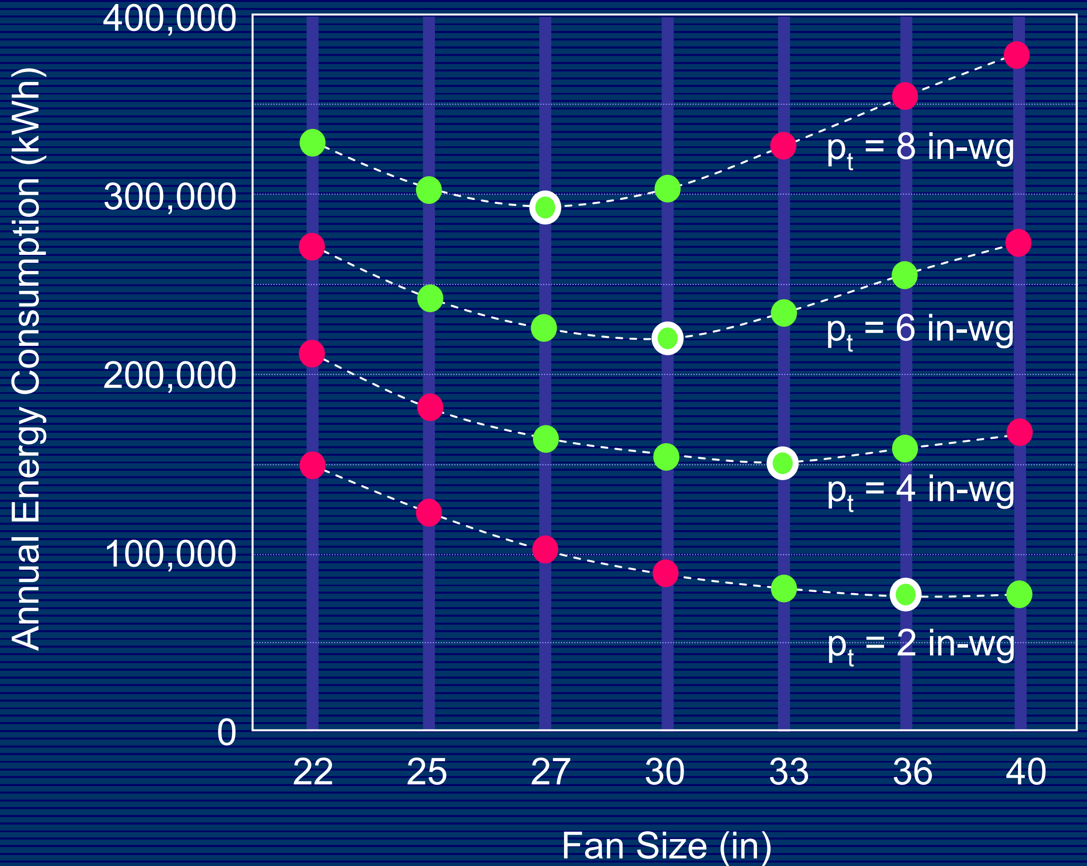


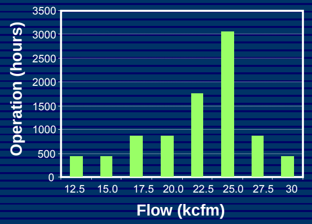
Energy consumption must include contribution from each operating point on the VAV schedule

$$EAE = H_{dc1}\Delta t_1 + H_{dc2}\Delta t_2 + H_{dc2}\Delta t_2 + \ldots$$

Selection Example

Effect of baseline pressure





Best TE
Acceptable
Unacceptable

Estimated Annual Energy Usage
- **90% motor efficiency**
- **90% drive efficiency**
- **l00% duty cycle**

Summary

Serious efforts to reduce HVAC energy consumption

System wide approach:

- ✓ **Minimize flow restriction in achieving HVAC goal (greatest impact)**
- ✓ **Maximize motor/control/drive efficiency**
- ✓ **Maximize fan efficiency**

Rating fans for efficiency capability:

- ✓ **FEG - fan grade based on shaft/impeller power**
- ✓ **FMEG - packaged fan/motor/drives**

- ✓ **Effective only if selection are made close to pTE (l0 pts)**

Questions