AMCA International

Ascertaining Efficiency For Air-Side Equipment

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ebmpapst
The engineer's choice

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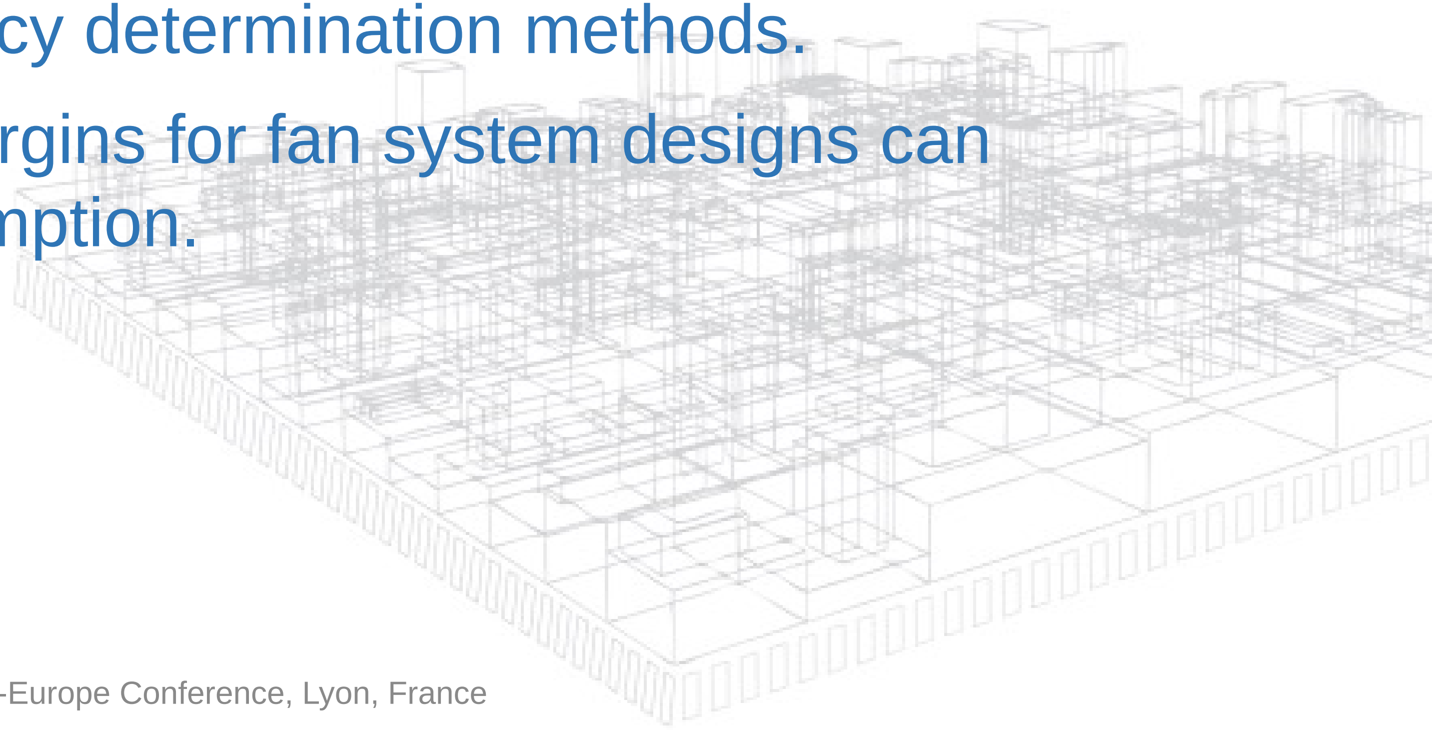
Copyright Materials

Learning Objectives

- Introduce a new performance-based fan energy efficiency metric.
- Compare fan efficiency determination methods.
- Show how safety margins for fan system designs can impact power consumption.



Agenda

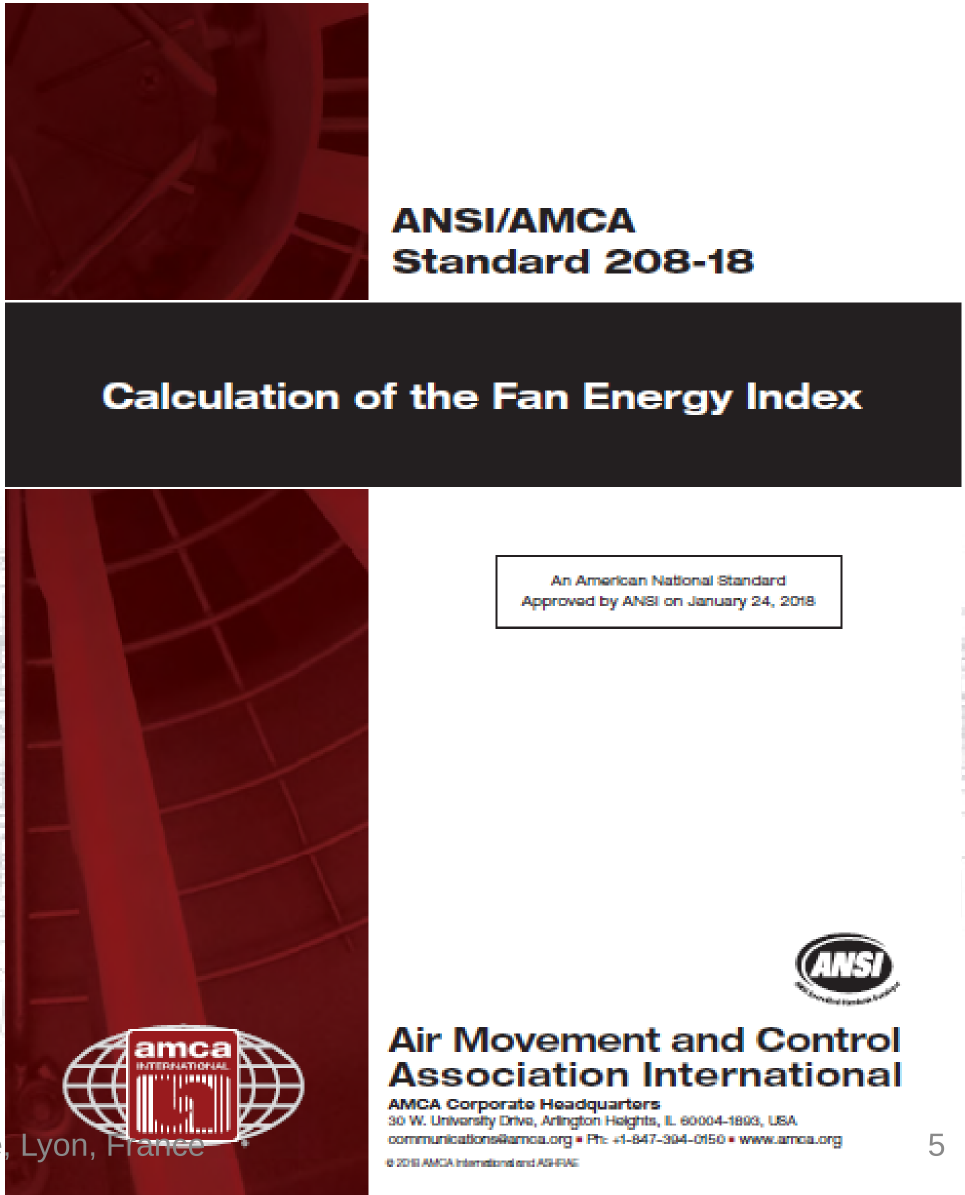
- Introduction of the Fan Energy Index
- Air Side Equipment
- Efficiency of Air-Side Systems
- Component Based Fan Systems
- Fully Integrated and Tested Fan Systems
- Efficiency Characteristics of Fan Systems
- Effects of Safety Factors on Air-Side System Efficiency
- Final Notes

Fan Energy Index
ANSI/AMCA Standard 208

- Calculation method for the fan energy index (FEI)
- Energy efficiency metric for fans includes motor and drive losses.
- Individual calculation at each given fan duty point.
- FEI combines fan performance and efficiency in one value.

<u>Uses:</u>

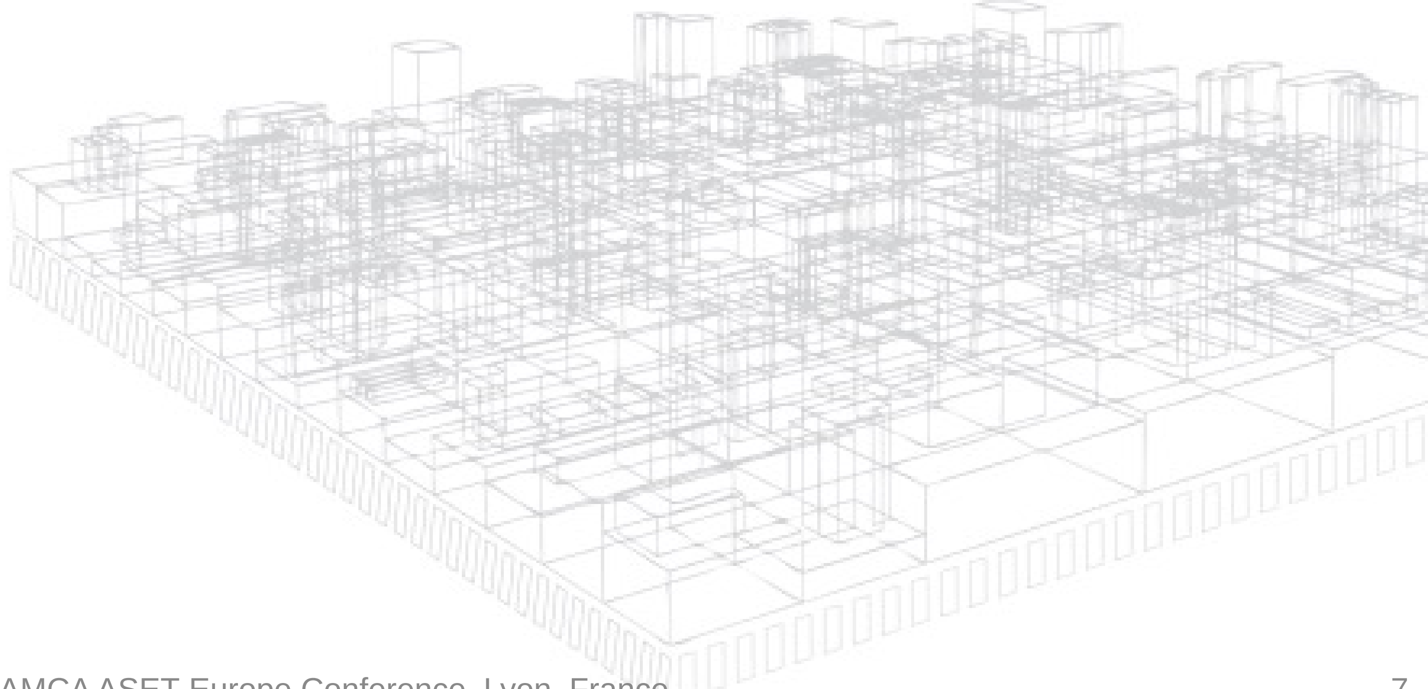
- Standardized and consistent comparison of fans across fan types and sizes.
- Definition of the energy requirements of fans.



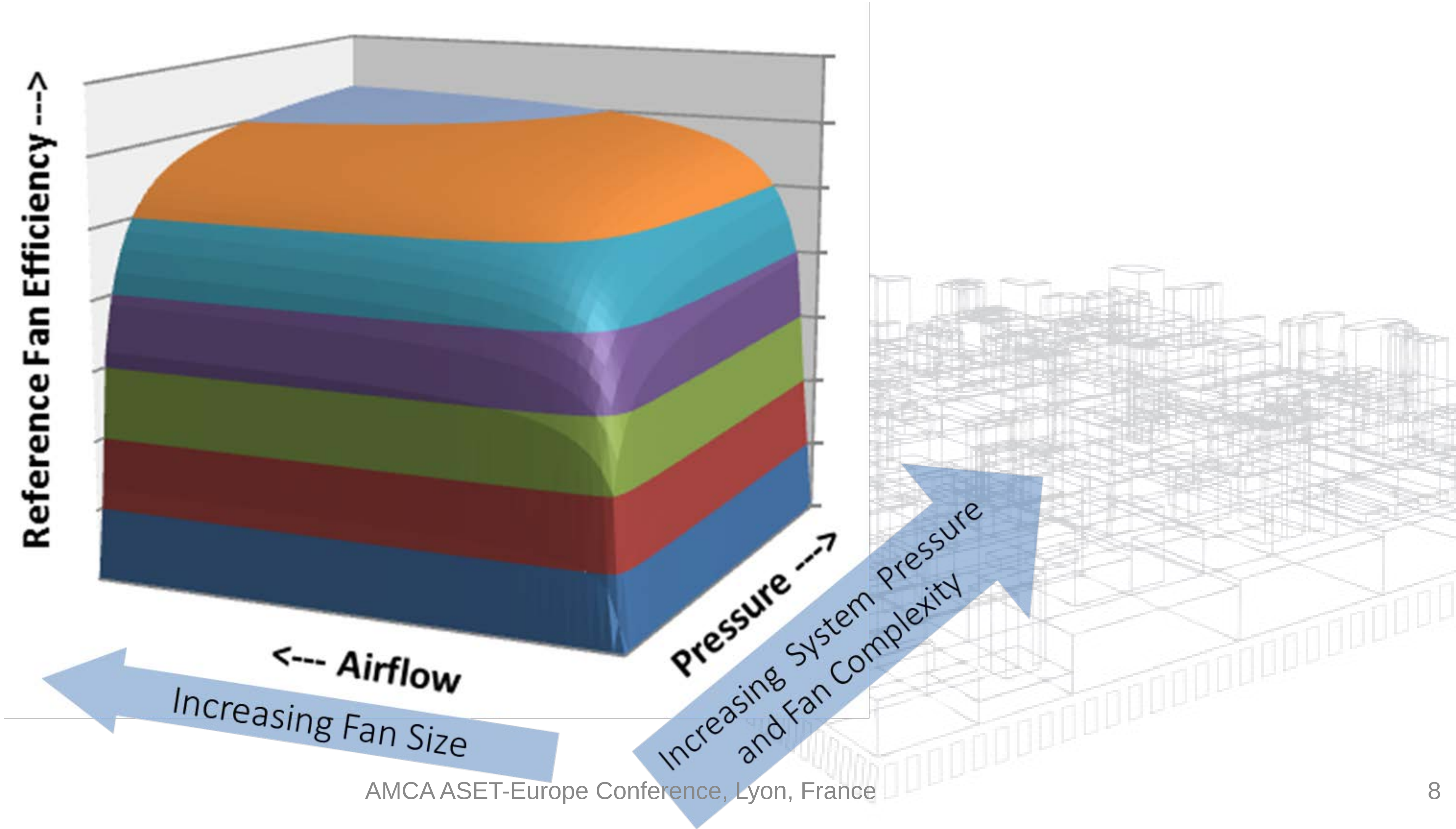
Efficiency metric	Criterion	Rating point	Use
Ecodesign 327/2011 or FMEG Fan Motor Efficiency Grade	Wire-to-air efficiency & Fan type	Best efficiency point	How good is the fan?
FEG Fan Efficiency Grade	Peak Total Efficiency & Diameter	Best efficiency point	How good is the bare-shaft fan?
FEI Fan Energy Index	Electric input power	Selected fan duty point	How good is the fan for its application?

Fan Energy Index
ANSI/AMCA Standard 208

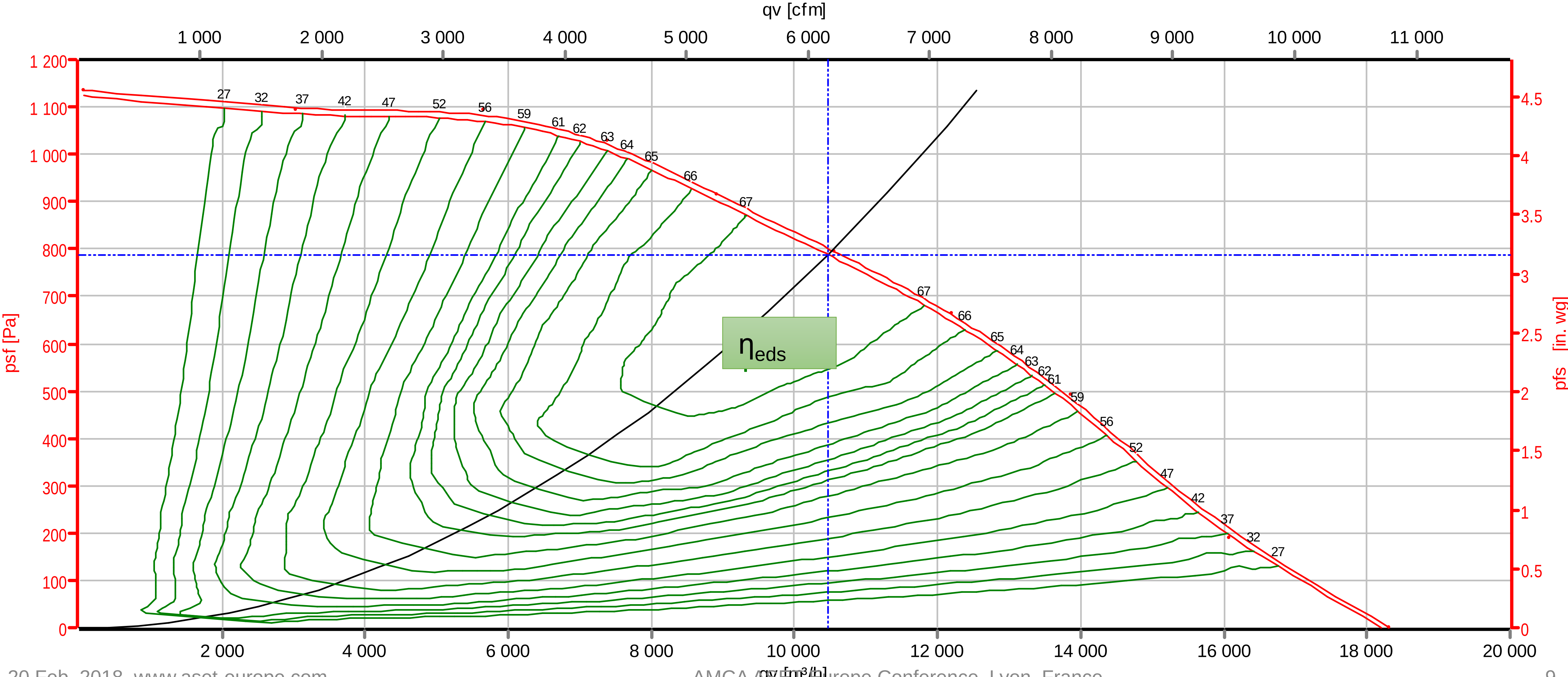
FEI is evaluated at every operating point offered for sale.



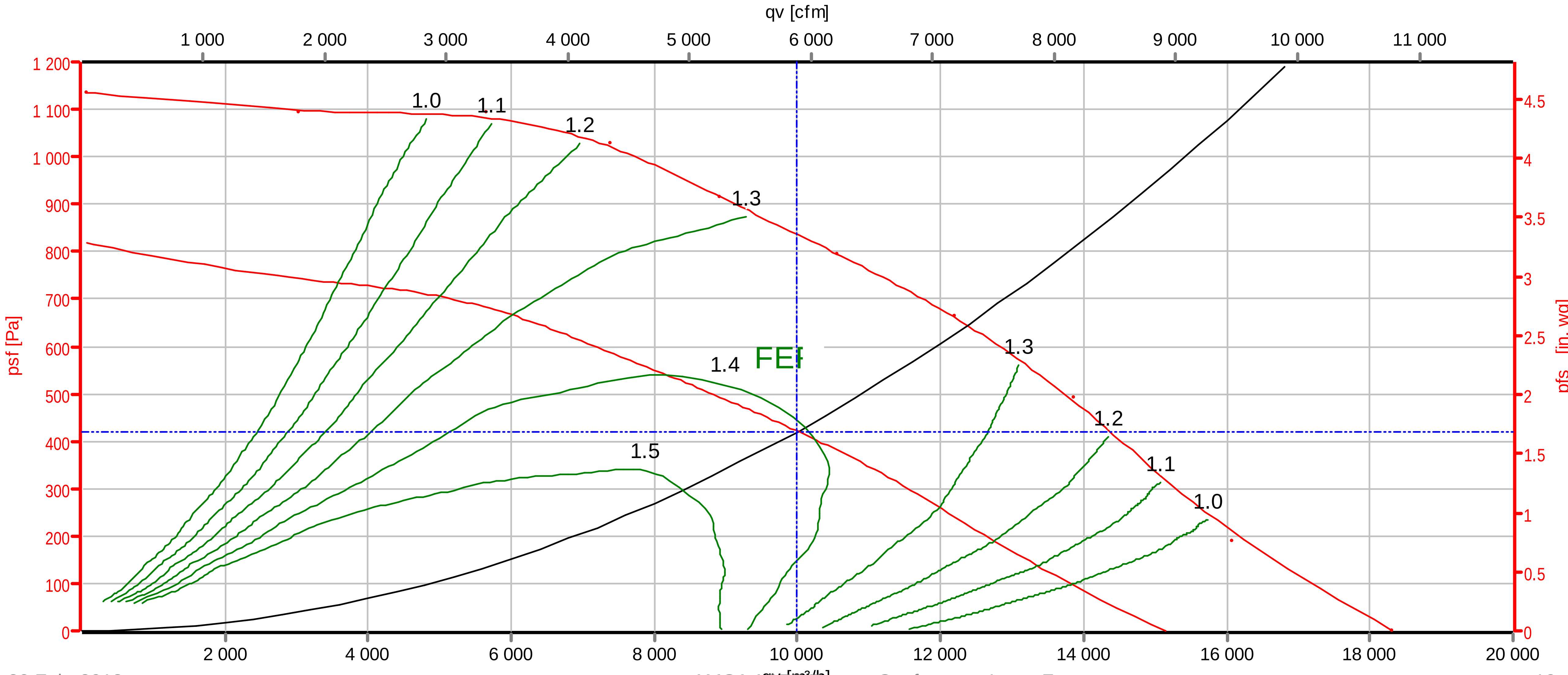
$$FEI = \frac{efficiency\ of\ selected\ fan}{efficiency\ of\ reference\ fan}$$



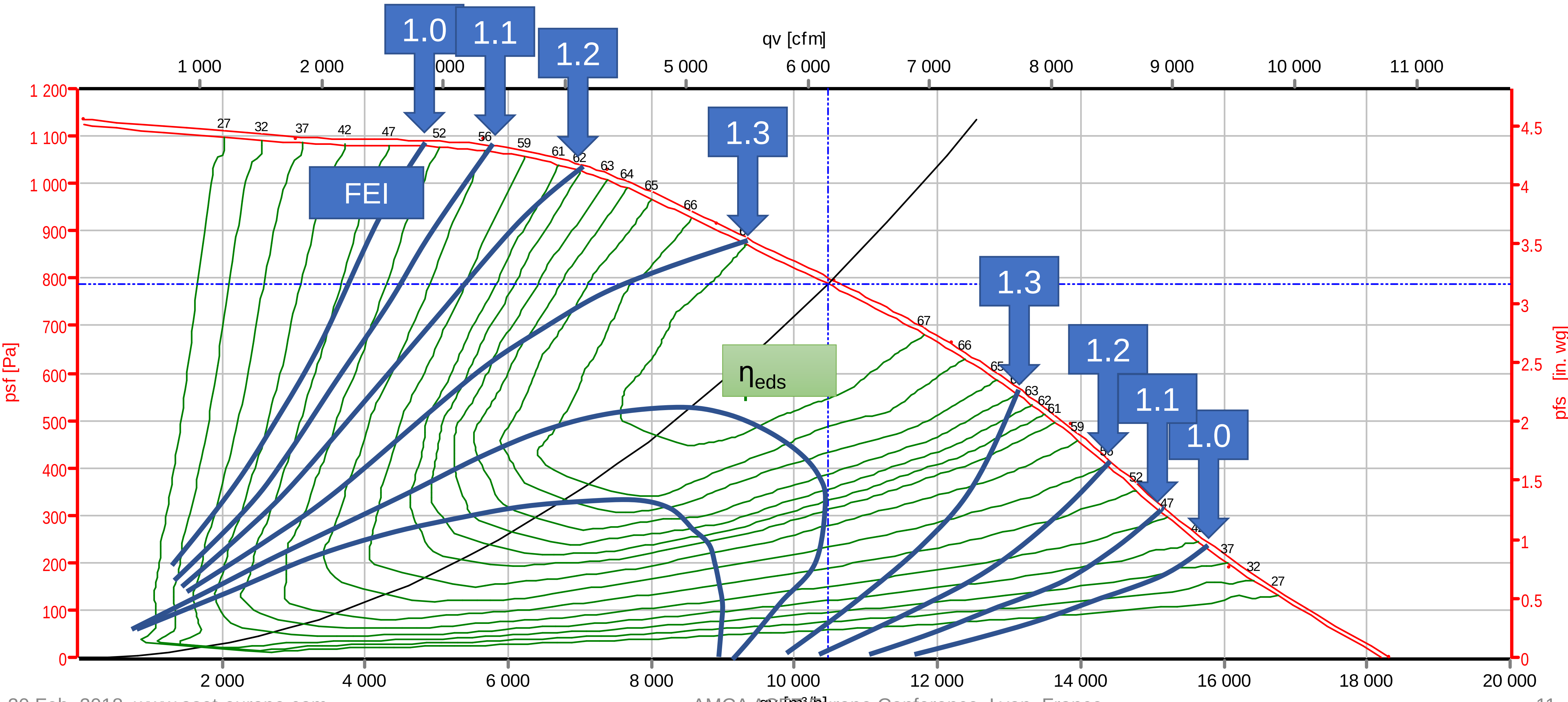
Lines of constant fan efficiency



Lines of constant FEI



Lines of constant FEI



Fan Energy Index summary

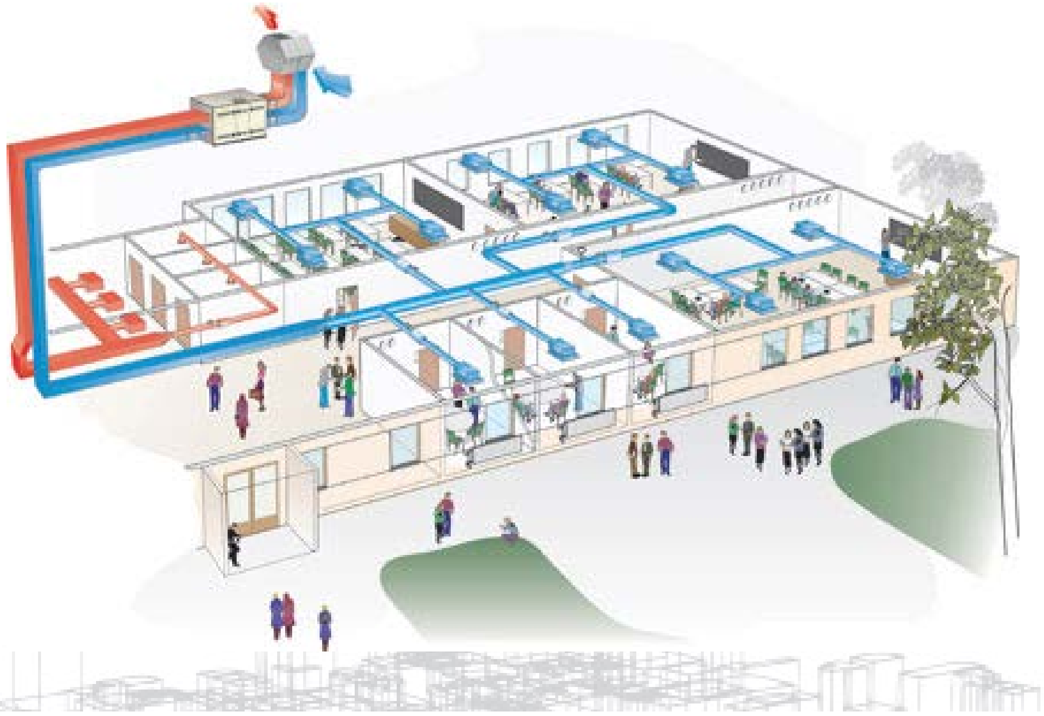
Fan peak efficiency metrics are barely effective if a fan may be selected at a low operational efficiency.

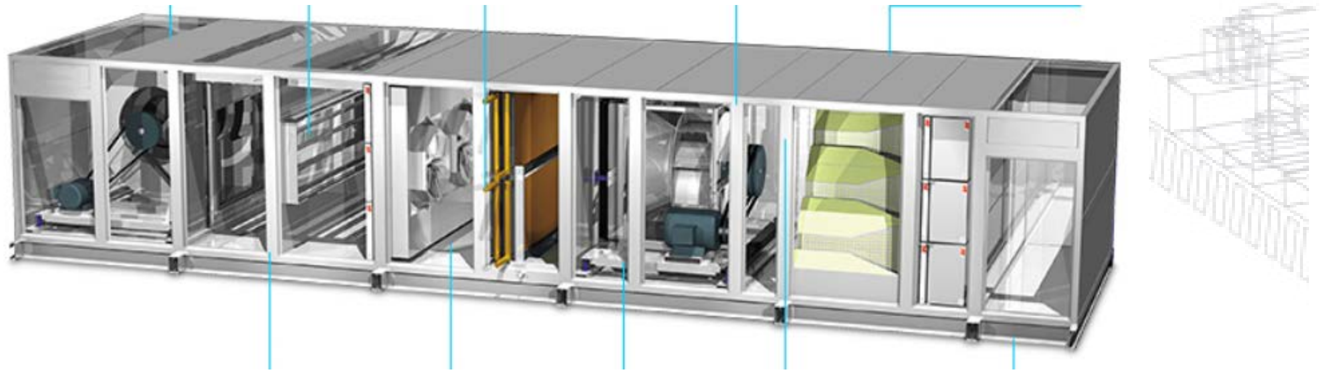
FEI will encourage

- more efficient selections, while driving
- the design of more efficient fans,
- the use of more efficient motors, and
- the use of direct drives.

Air-Side Equipment

Provides defined amounts of treated air to the spaces, people, or processes.



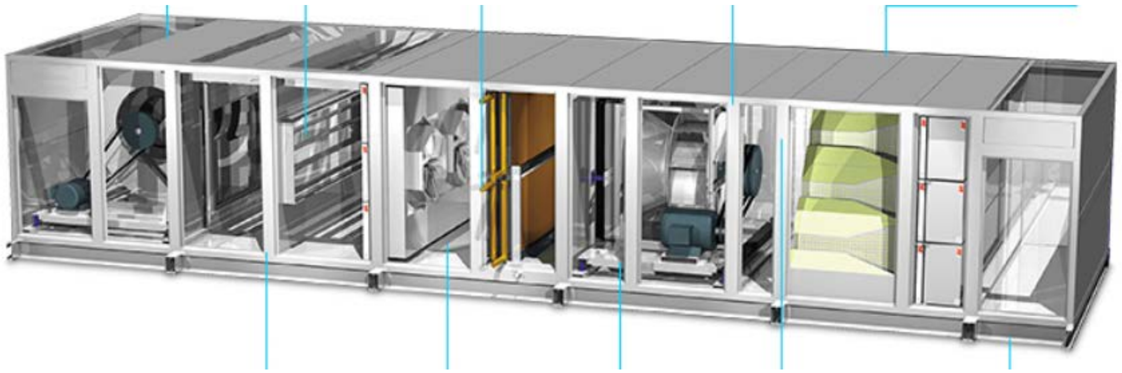


Includes air distribution components and fan-powered units.

- Air handling units (AHU)
- Fan coil units (FCU)
- Roof-top units (RTU)

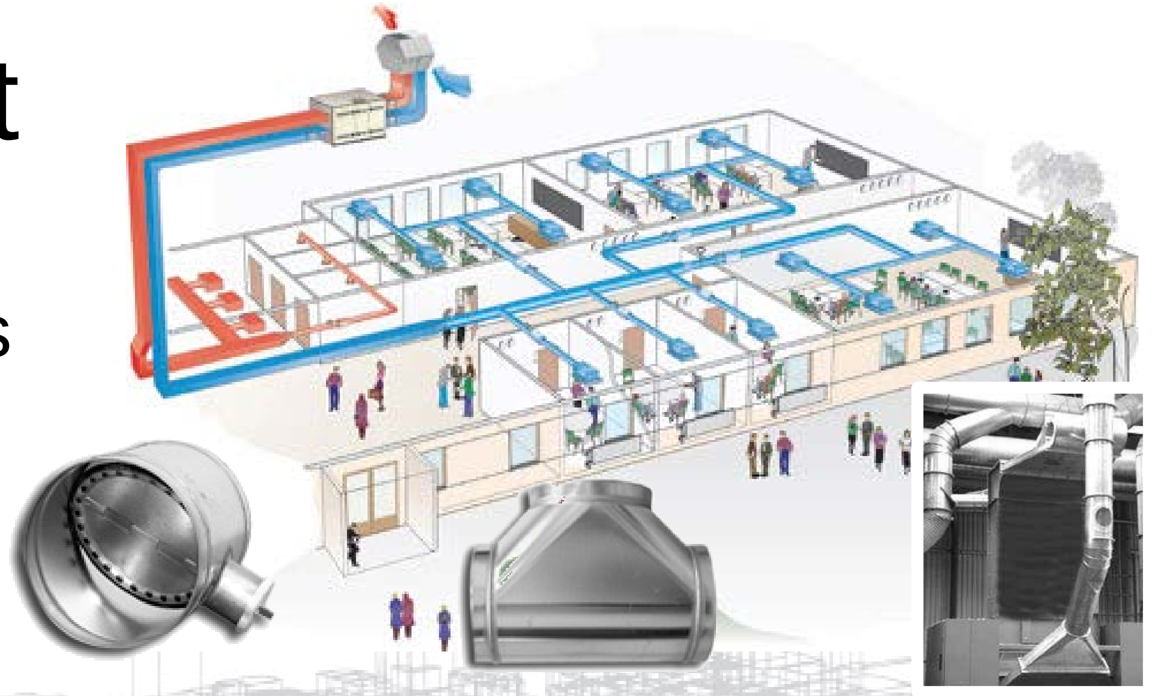
Air-Side Equipment

The air volume requirement is defined by the heat load, cooling load, or ventilation rate for health and comfort.

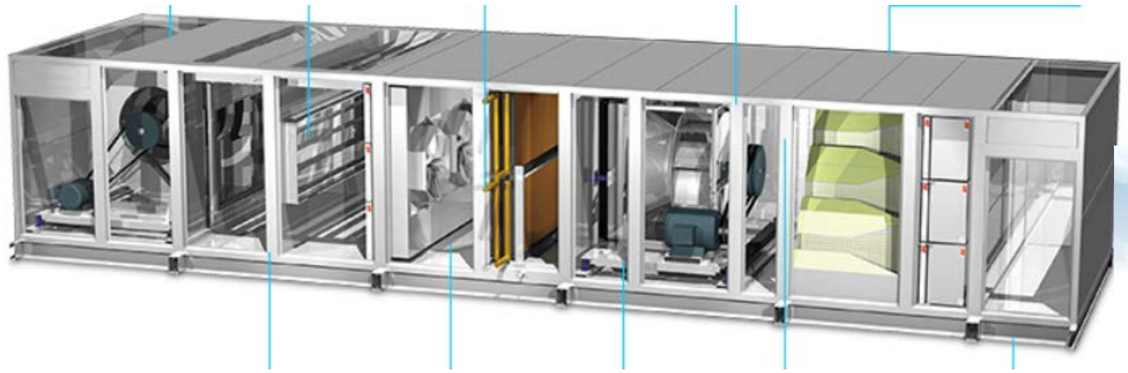


The system that can fulfil all the requirements with the least amount of energy is the most efficient.

Air-Side Equipment



- Air distribution system components cause external pressure losses.



- Air handling unit components cause internal pressure losses.

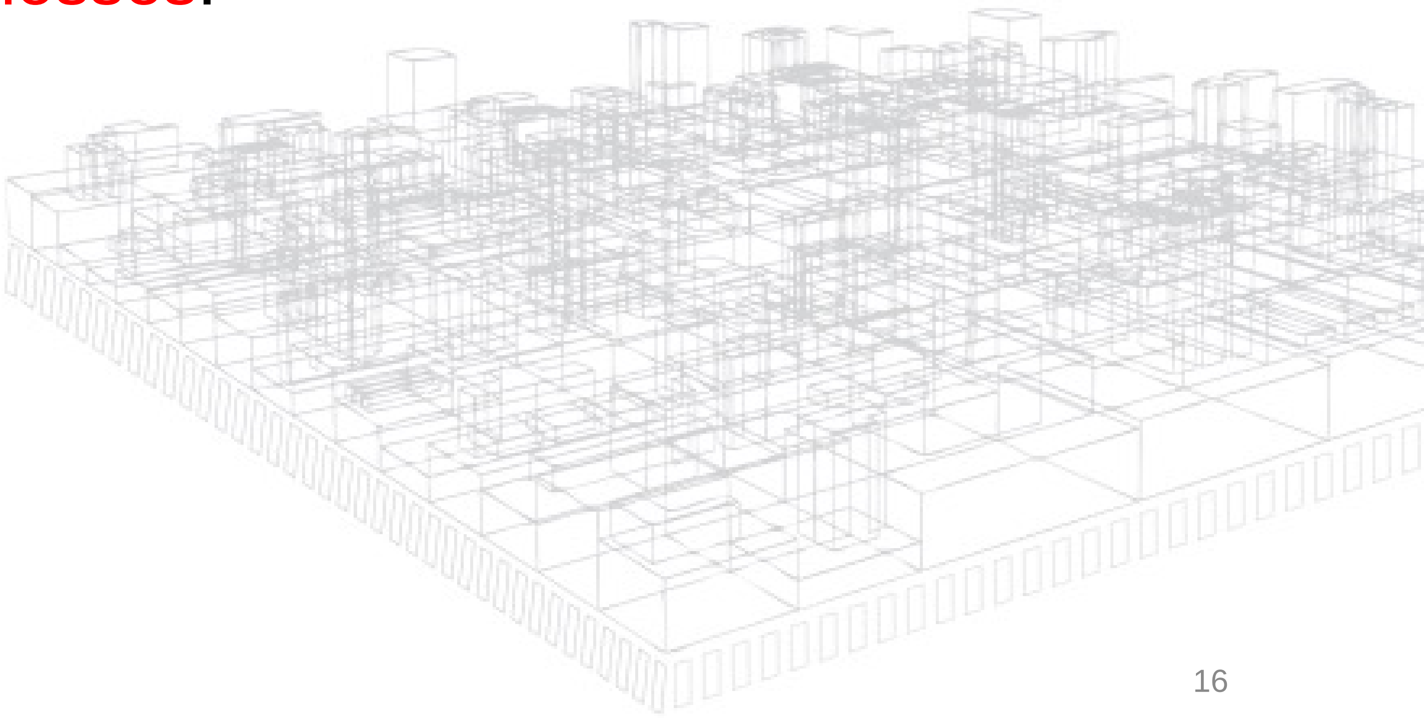
Air-Side Equipment

Defined amounts of treated air to the spaces, people, or processes.

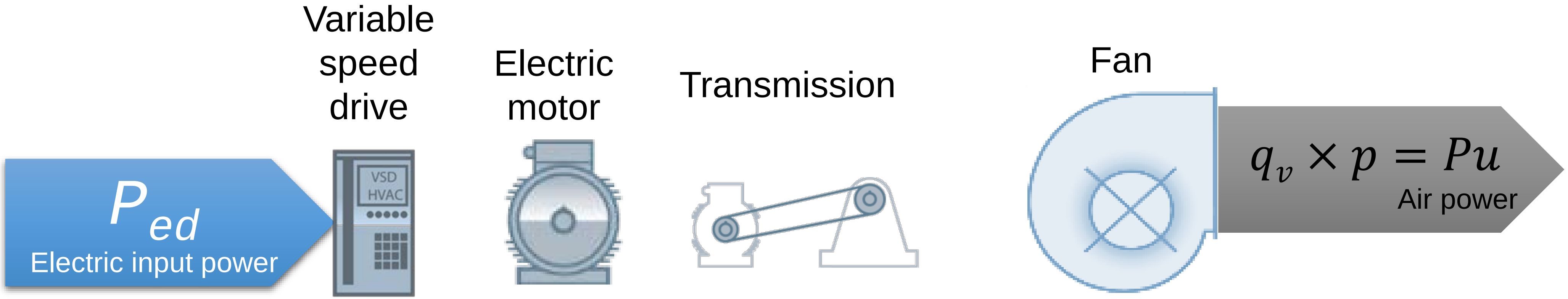
$$q_v \times p = Pu$$

Air power

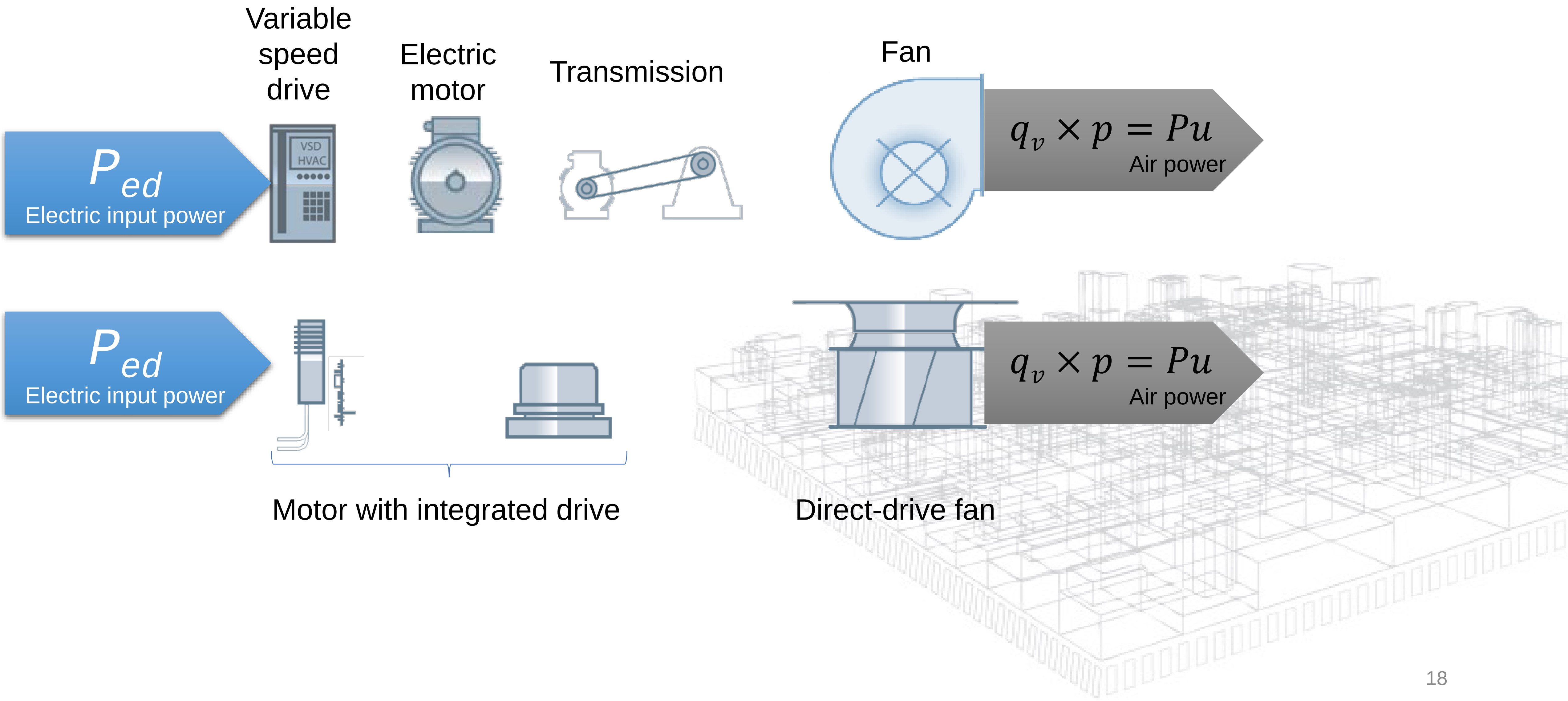
Internal and external pressure losses.



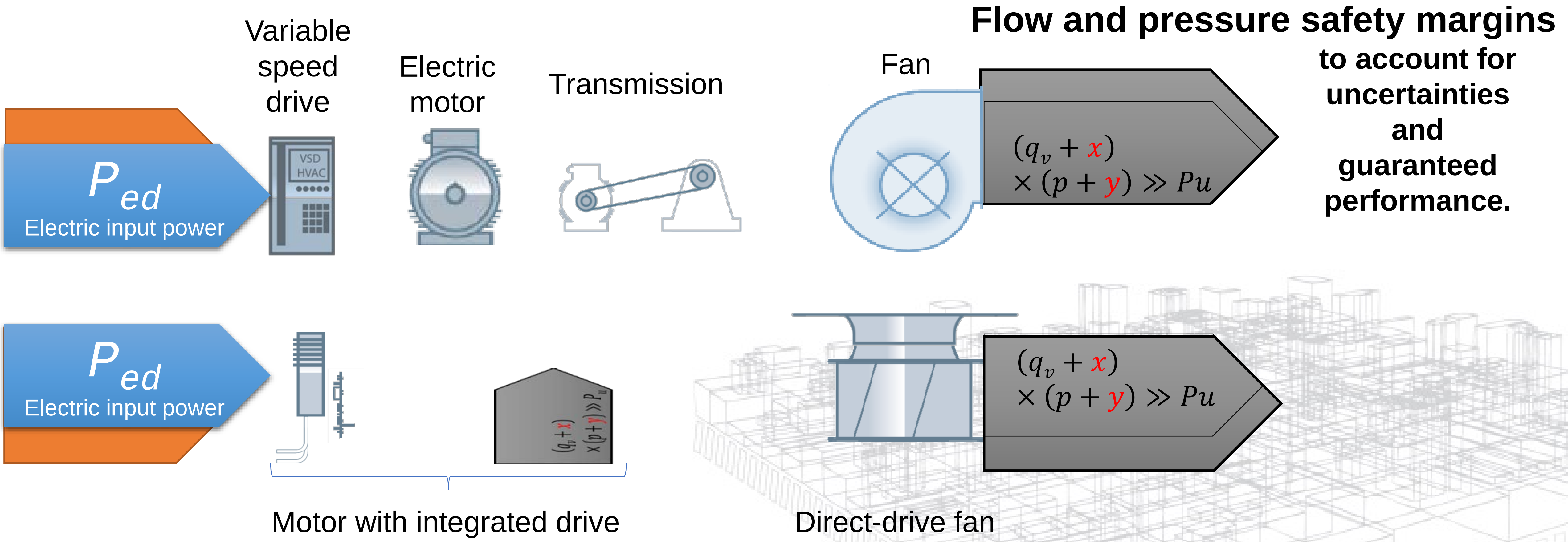
Efficiency of Air-Side Systems



Efficiency of Air-Side Systems



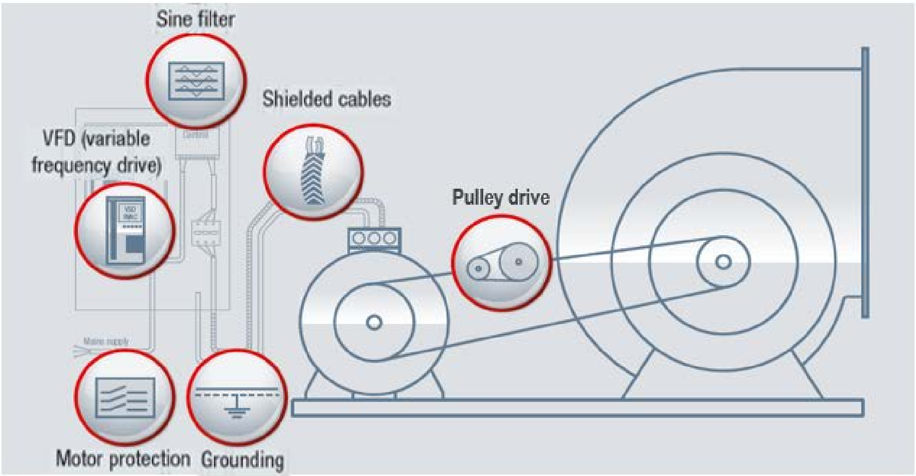
Efficiency of Air-Side Systems

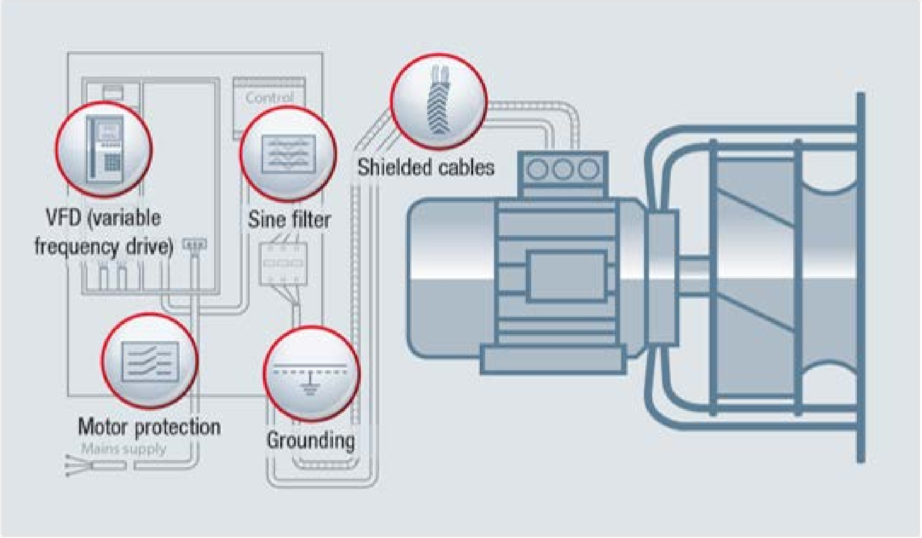


Risk of increased power consumption

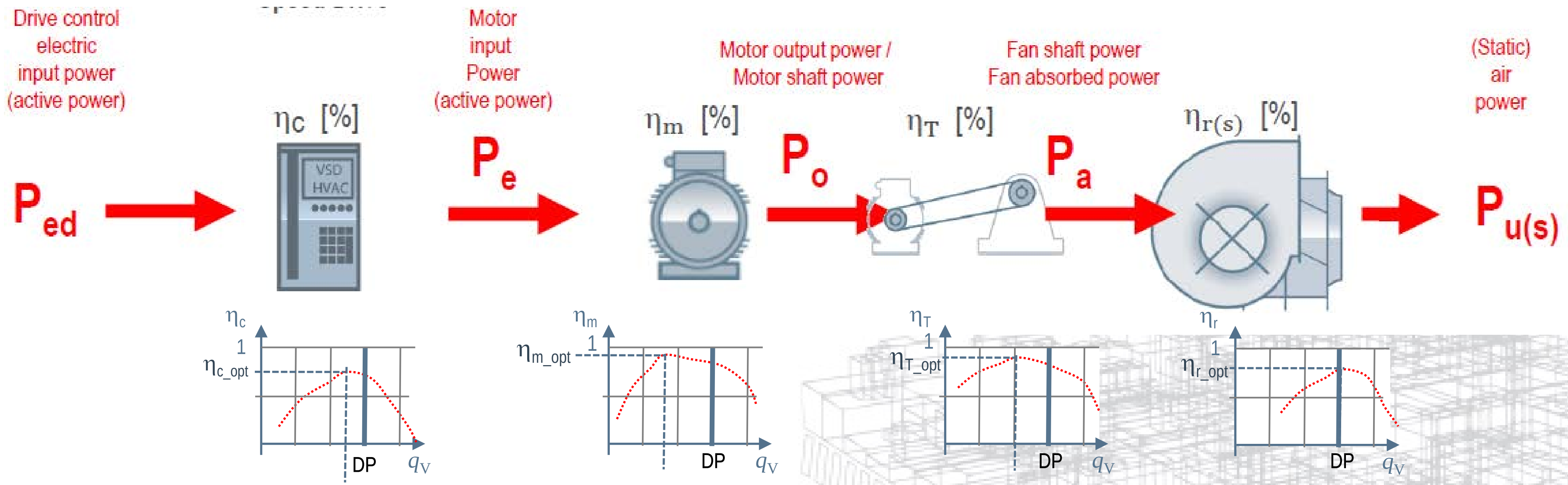
Component-Based Fan Systems

- Each component is tested by itself, not as an entire system.
- Individual datasheets and testing standards for assessing performance and characteristic.
- The contractor is responsible for compliance with relevant standards.
- Component sourcing may be centralized in the project execution or split between contractors (e.g. Variable Frequency Drive, filters, cables) and the OEM (fan impeller, motor, transmission).





Component-Based Fan Systems



$$\eta_{c\_max} \times \eta_{m\_max} \times \eta_{T\_max} \times \eta_{rs\_max} \neq \eta_{es}$$

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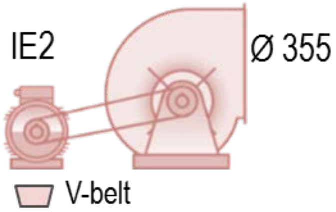
Component-Based Fan Systems

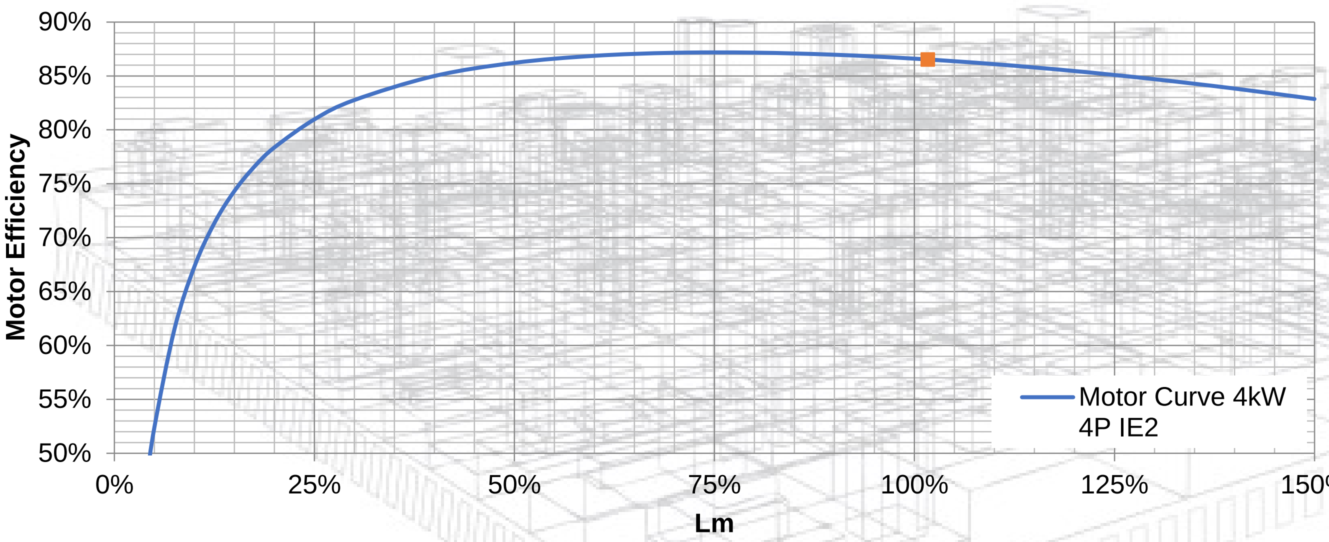


Fan duty point: q_V = **8,800 m³/h** @ p_f = **1,100 Pa**

	AMCA 207	ISO 12759	Wire-to-air test
Fan total efficiency in %			
Impeller shaft power in kW			
Belt efficiency in %			
Motor shaft power in kW			
Motor efficiency in %			
Wire-to-air efficiency in %			
Motor input power in kW			

Component-Based Fan Systems

Motor Selector			Transmission	Fan Data				
MotorPower (kW)	Class	Poles		Q (m^3/s)	Fan P (Pa)	Fan Eff	N	H (kW)
4	IE2	4	ISO V-Belt	2.44	1182	75.7%	1700	3.8
Nom Efficiency	Motor Ns							
86.6%	1500							
Motor Output		Component Efficiencies			Net kW in			
Load Ratio	Power (kW)	Belt ETA	Motor ETA	Net ETA				
101.7%	4.1	93.9%	86.5%	61.5%	4.70			



Component-Based Fan Systems

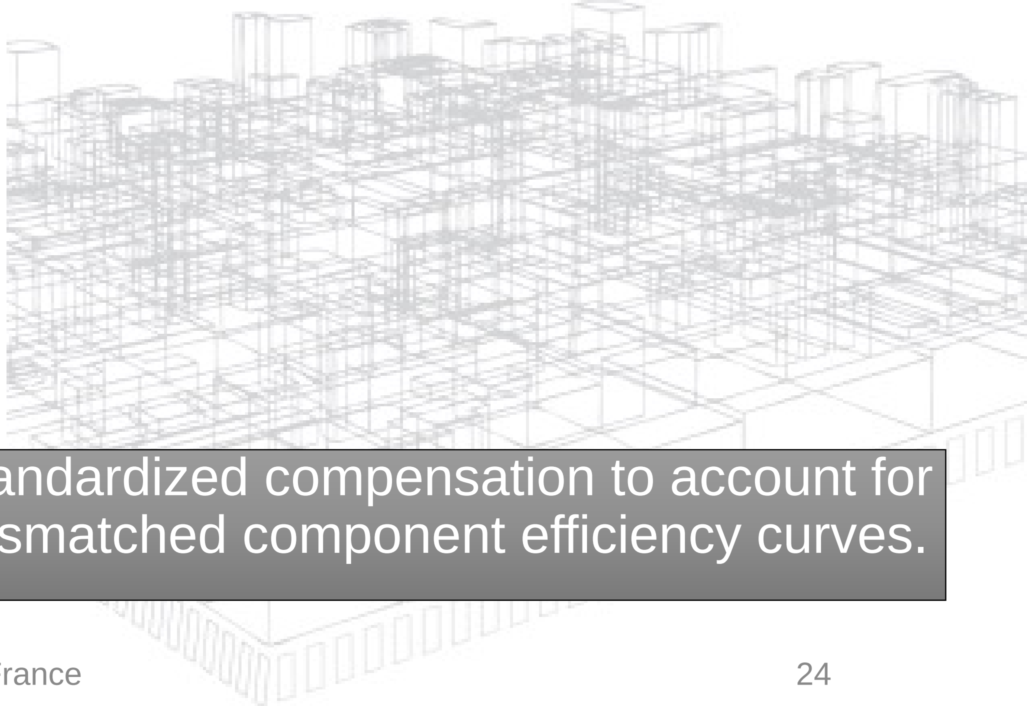
ISO 12759:2010 Fans – Efficiency classification for fans

If fan drives are sold as components and combined without measurement then this standard permits multiplying the component efficiency maxima as follows**:**

$$\eta_e = \eta_r \times \eta_m \times \eta_T \times \eta_c \times C_m \times C_c$$

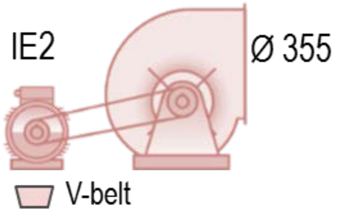
where

- η_e is the overall efficiency;
- η_r is the optimal fan impeller efficiency according to $P_{u(s)}/P_a$, as given in ISO 5801;
- η_m is the motor efficiency;
- η_T is the drive mechanism (transmission efficiency);
- η_c is the variable speed drive efficiency;
- C_m is the compensation factor to account for matching of components = 0,9;
- C_c is part load compensation factor.



Standardized compensation to account for mismatched component efficiency curves.

Component-Based Fan Systems



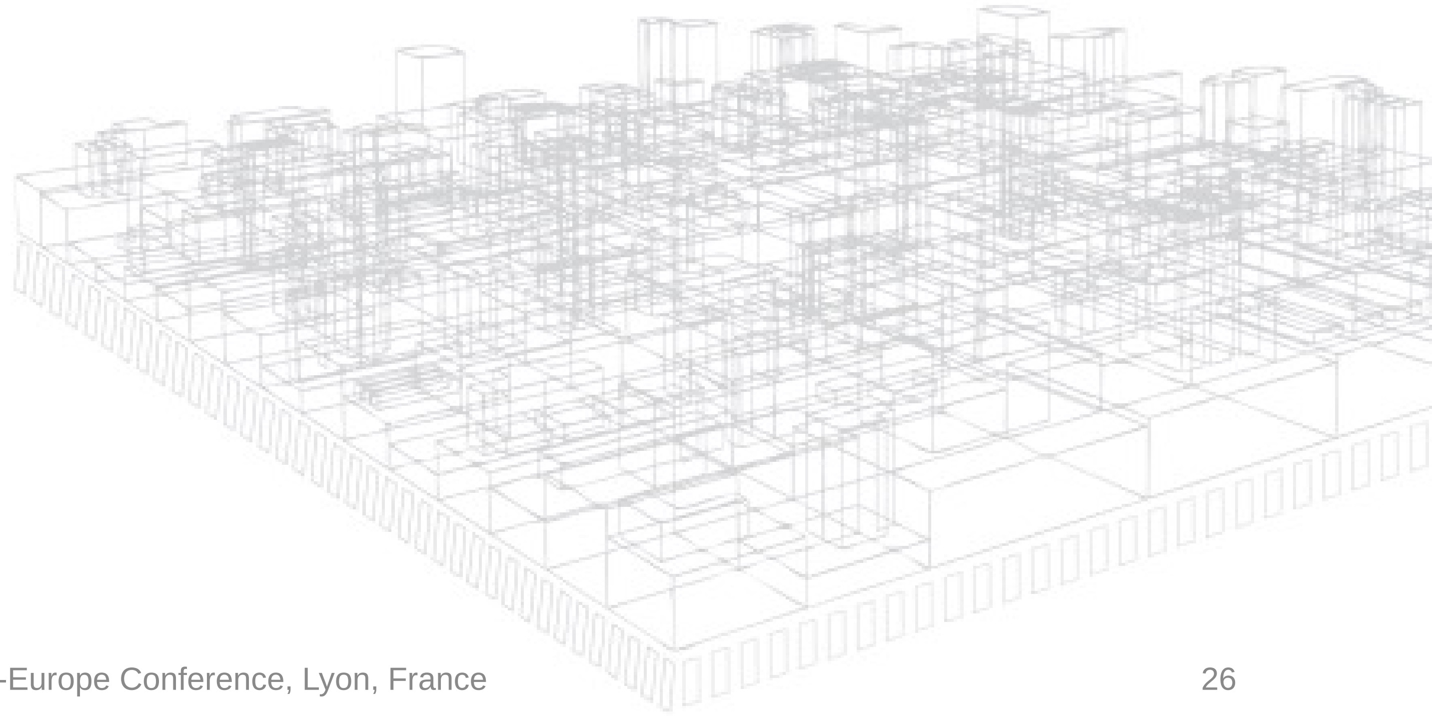
Fan duty point: q_V = **8,800 m³/h** @ p_f = **1,100 Pa**

	AMCA 207	ISO 12759	Wire-to-air test
Fan total efficiency in %	75.7	75.7	
Impeller shaft power in kW	3.82	3.82	
Belt efficiency in %	93.9	94.3	
Motor shaft power in kW	4.10	4.05	
Motor efficiency in %	86.5	86.6	
Wire-to-air efficiency in %	61.5	55.6 incl. C_m	
Motor input power in kW	4.7	5.2	

Component-Based Fan Systems

ISO 12759:2010 Fans – Efficiency classification for fans

"If a fan is sold as a complete assembly, efficiency [..] shall be assessed by direct measurement of P_e or P_{ed} and P_u "



Wire-to-air test method


STANDARD

ANSI/AMCA Standard 210-16/

ASHRAE Standard 51-16

Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating

An American National Standard
Approved by ANSI on August 26, 2016

This standard in English, Chinese, European Spanish, and Latin American Spanish may be purchased at www.amca.org/store.

Air Movement and Control Association International

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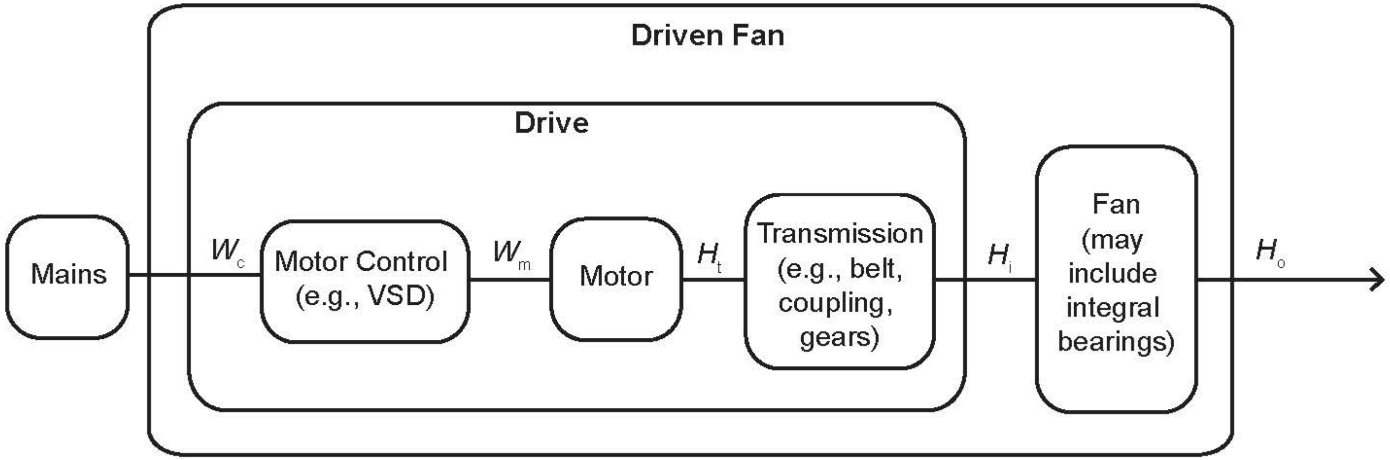

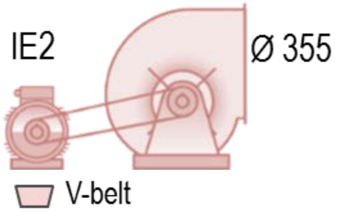

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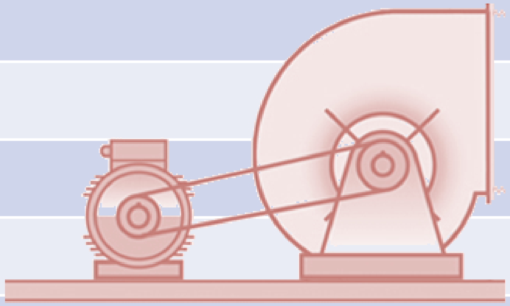
Fan total efficiency in %	75.7	75.7	
Impeller shaft power in kW	3.82	3.82	
Belt efficiency in %	93.9	94.3	
Motor shaft power in kW	4.10	4.05	
Motor efficiency in %	86.5	86.6	
Wire-to-air efficiency in %	61.5	55.6 incl. C_m	54.5
Motor input power in kW	4.7	5.2	5.3

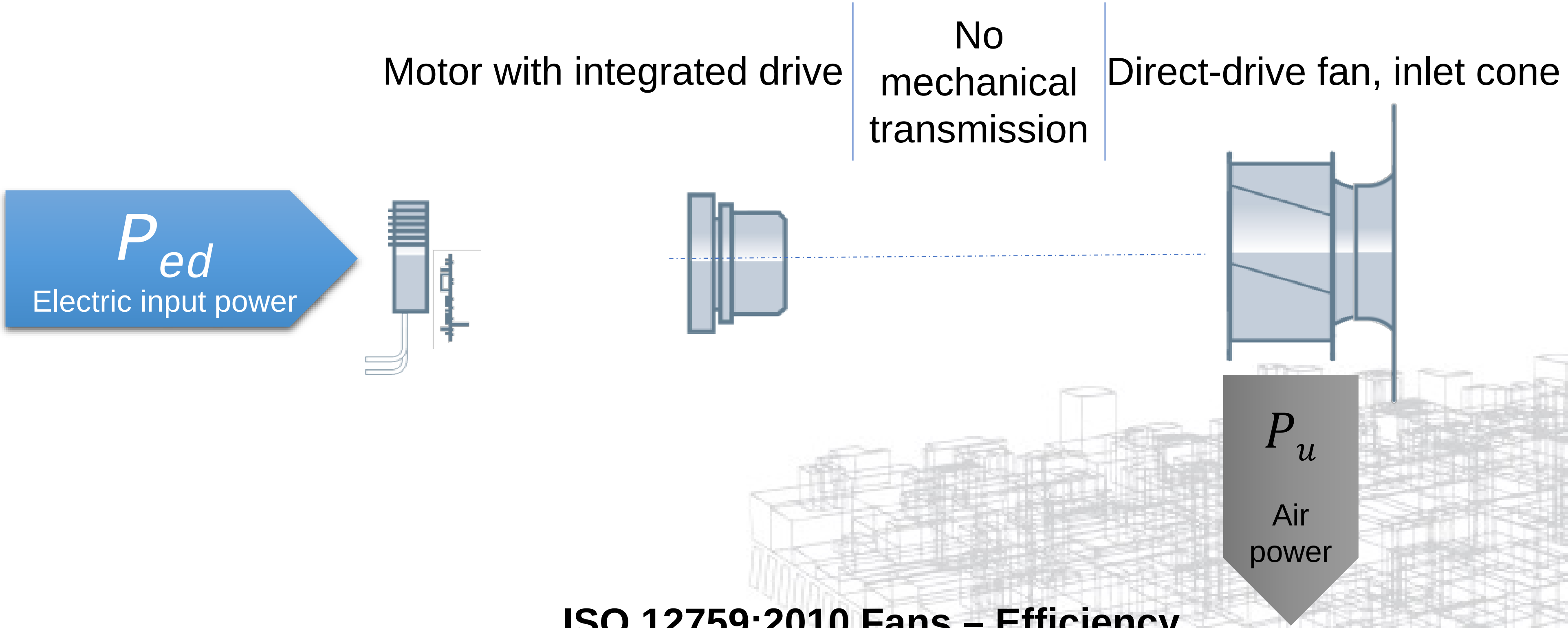
Fully Integrated Fan System Example:

Centrifugal fan

Impeller, structure (housing, inlets, struts), motor, variable speed drive, electric filters

- Tested as a complete system
- Compliant with relevant standards (motor protection, electromagnetic compatibility)

Fully Integrated & Tested Fan Systems



ISO 12759:2010 Fans – Efficiency classification for fans

"If a fan is sold as a complete assembly, efficiency [..] shall be assessed by direct measurement of P_e or P_{ed} and P_u “

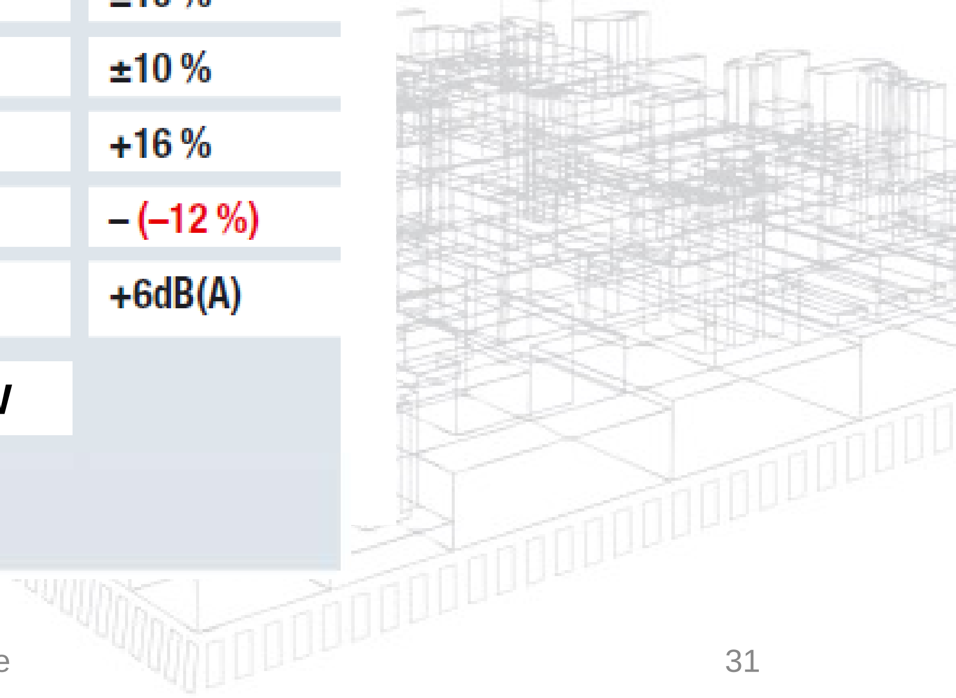
Fully Integrated & Tested Fan Systems

*Fig. 1: Accuracy class as per DIN 24166 (ISO 13348)**

Performance characteristics	Limiting deviation in class			
	0 (AN1)	1 (AN2)	2 (AN3)	3 (AN4)
Air flow q_v	±1 %	±2.5 %	±5 %	±10 %
Static pressure increase Δp_{stat}	±1 %	±2.5 %	±5 %	±10 %
Drive performance P_{ed}	±2 %	+3 %	+8 %	+16 %
Static efficiency η_{stat}	-1 %	-2 %	-5 %	– (–12 %)
Sound power level db(A)	+3dB(A) (+2dB(A))	+3dB(A)	+4dB(A)	+6dB(A)
Lower power limit per DIN 24166			**> 10 kW**	

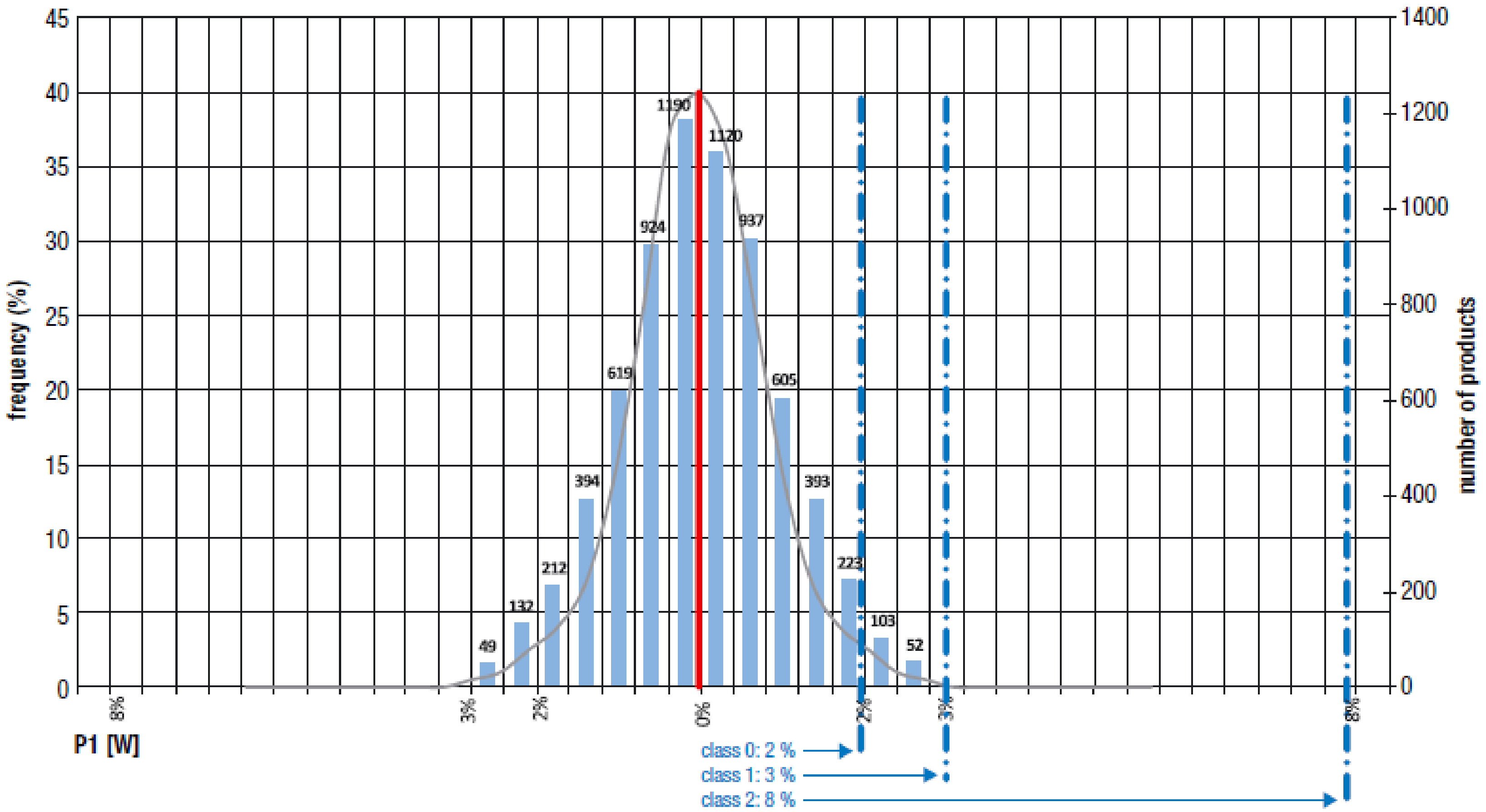
* – ISO 13348 with other designations and slightly different values

Example:
DIN 24166 permits
class 3 for fans < 10 kW



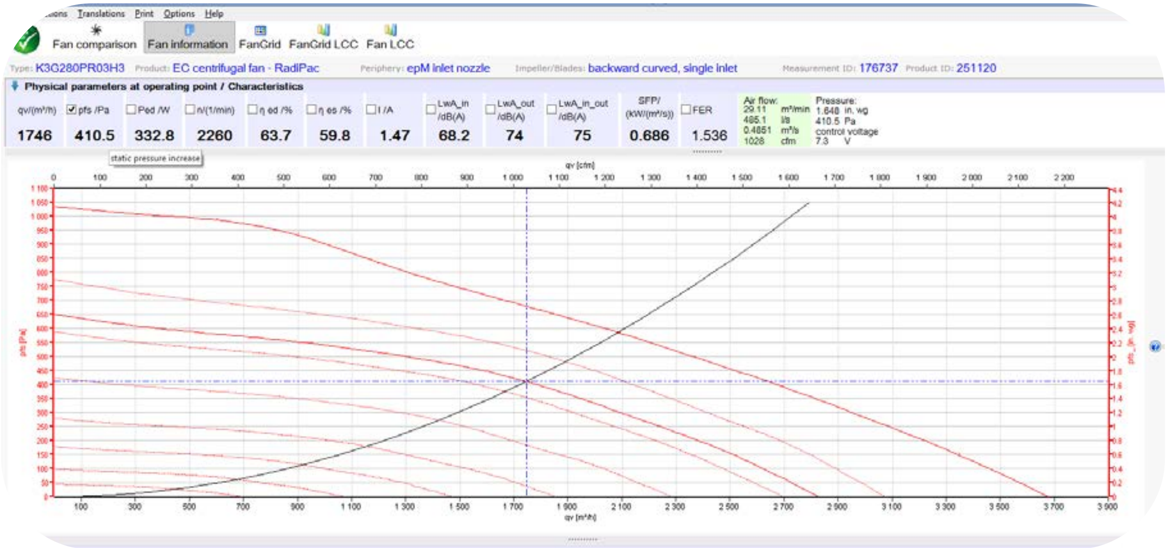
Fully Integrated & Tested Fan Systems

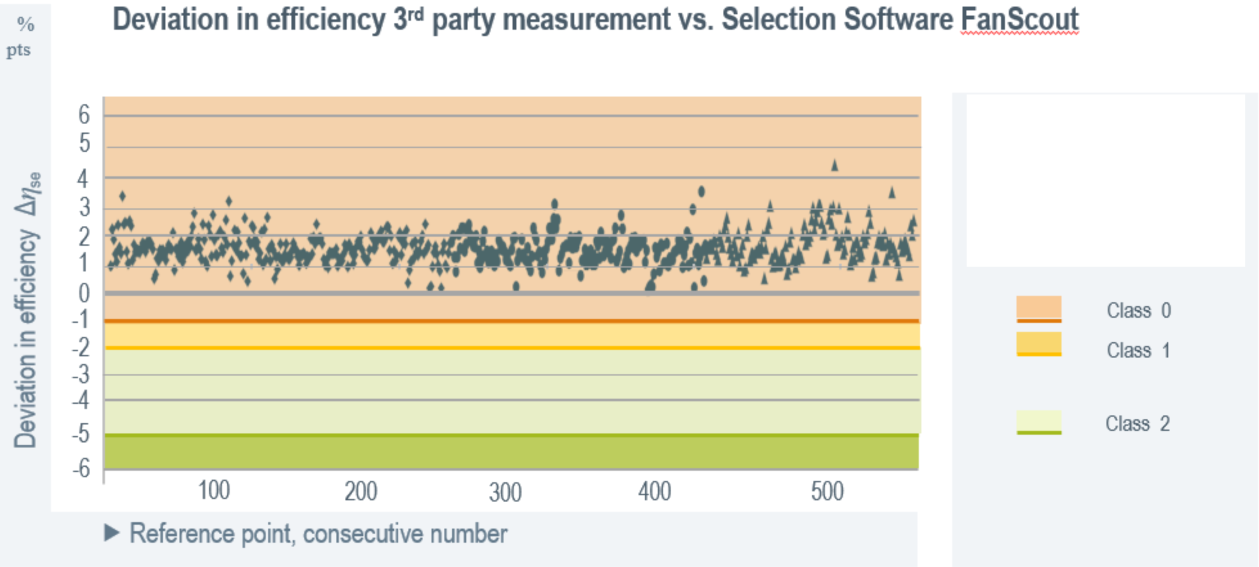
Electric input power deviation of 6953 motorized plenum fans in serial production factory.



This product range covers 1–12 kW. It meets accuracy Class 1 of DIN 24166.

Fully Integrated & Tested Fan Systems





38 fan types with 15 reference points each = 570 reference points

$\Delta\eta_{se} = \eta_{se\ \text{TÜV-Reference}} - \eta_{se\ \text{Product Selector}}$

$\Delta\eta_{se} > 0$: Actual efficiency ($\eta_{se\ \text{TÜV reference}}$) is higher than efficiency in product selector ($\eta_{se\ \text{Product Selector}}$)

Fan Selection Software for AHU manufacturers accounts for fan accuracy classes

Fully Integrated & Tested Fan Systems

*Fig. 1: Accuracy class as per DIN 24166 (ISO 13348)**

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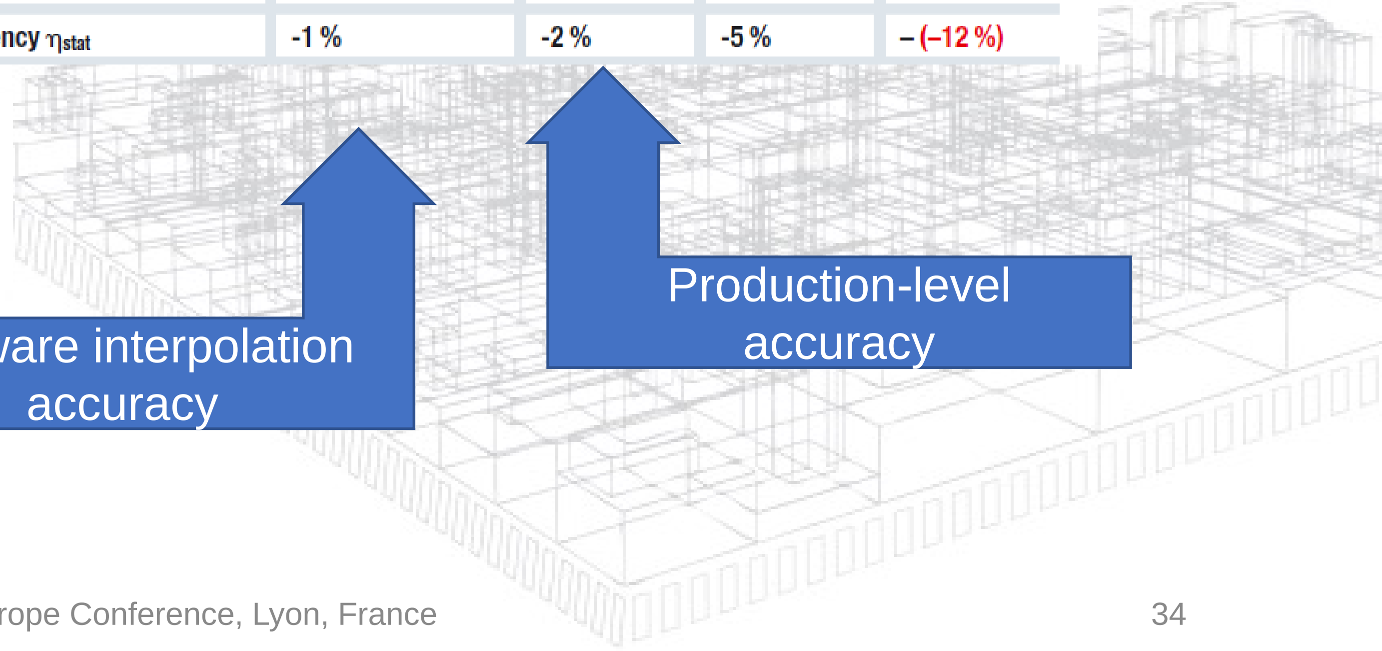
Static pressure increase Δp_{stat}	±1 %	±2.5 %	±5 %	±10 %
Drive performance P_{ed}	±2 %	+3 %	+8 %	+16 %
Static efficiency η_{stat}	-1 %	-2 %	-5 %	– (–12 %)

Tabelle der Berechnungsgenauigkeitsklassen

Betriebswert	Grenz-Abweichung zur Klasseneinteilung		
	B0	B1	B2
Volumenstrom	± 1 %	± 2,5 %	± 5 %
Druckerhöhung	± 1 %	± 2,5 %	± 5 %
Antriebsleistung	+ 2 %	+ 3 %	+ 8 %
Wirkungsgrad	- 1 %	- 2 %	- 5 %



Software interpolation accuracy

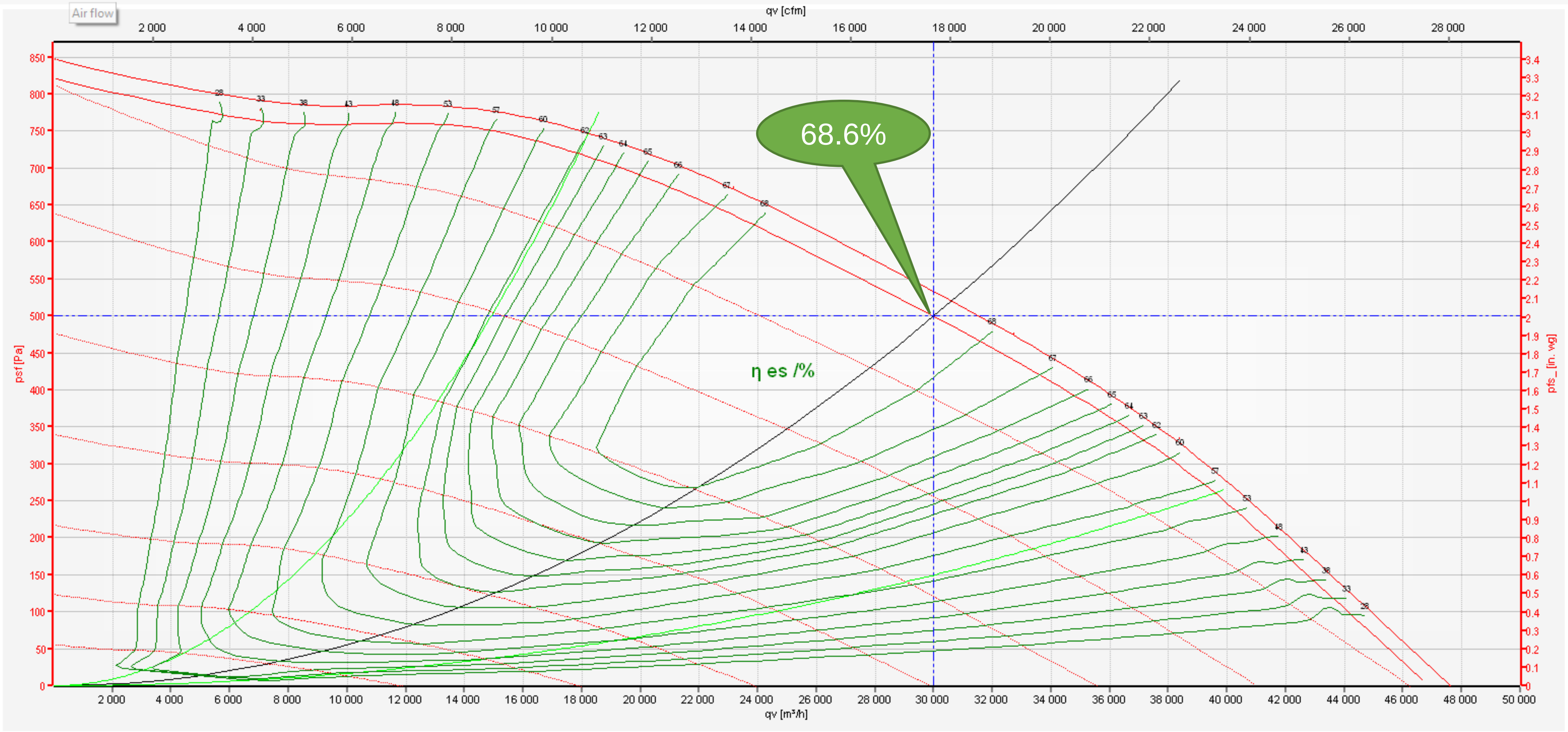
Production-level accuracy

Example Specification: 30.000 m³/h at 500 Pa

Physical parameters at operating point / Characteristics

qv/(m³/h)	☑ pfs /Pa	☐ Ped /W	☐ n/(1/min)	☐ η ed /%	☐ η es /%	☐ I /A	☐ LwA_in /dB(A)	☐ LwA_out /dB(A)	☐ LwA_in_out /dB(A)	SFP/ (kW/(m³/s))	☐ FER
30000	500	6070	737.1	74	68.6	9.35	77.1	80.4	82.1	0.728	1.392

Air flow:		Pressure:	
500	m³/min	2.007	in. wg
8333	l/s	500	Pa
8.333	m³/s	control voltage	
17660	cfm	9.6	V



Impact of Safety Factors on Fan Efficiency & FEI

SCENARIO 1	TSP	AIRFLOW	POWER INPUT	FEI	η	IMPACT FACTOR
DESIGN	500 Pa	30.000 m³/h	6070 W	1.58	68.6 %	-
- 10% pressure	450 Pa	30.000 m³/h	5509 W	1.60	68.1 %	99.3%
- 20% pressure	400 Pa	30.000 m³/h	4926 W	1.63	67.7 %	98.7%
- 30% pressure	350 Pa	30.000 m³/h	4370 W	1.66	66.7 %	97.2%
- 40% pressure	300 Pa	30.000 m³/h	3829 W	1.69	65.3 %	95.2%
- 50% pressure	250 Pa	30.000 m³/h	3293 W	1.73	63.3 %	92.3%

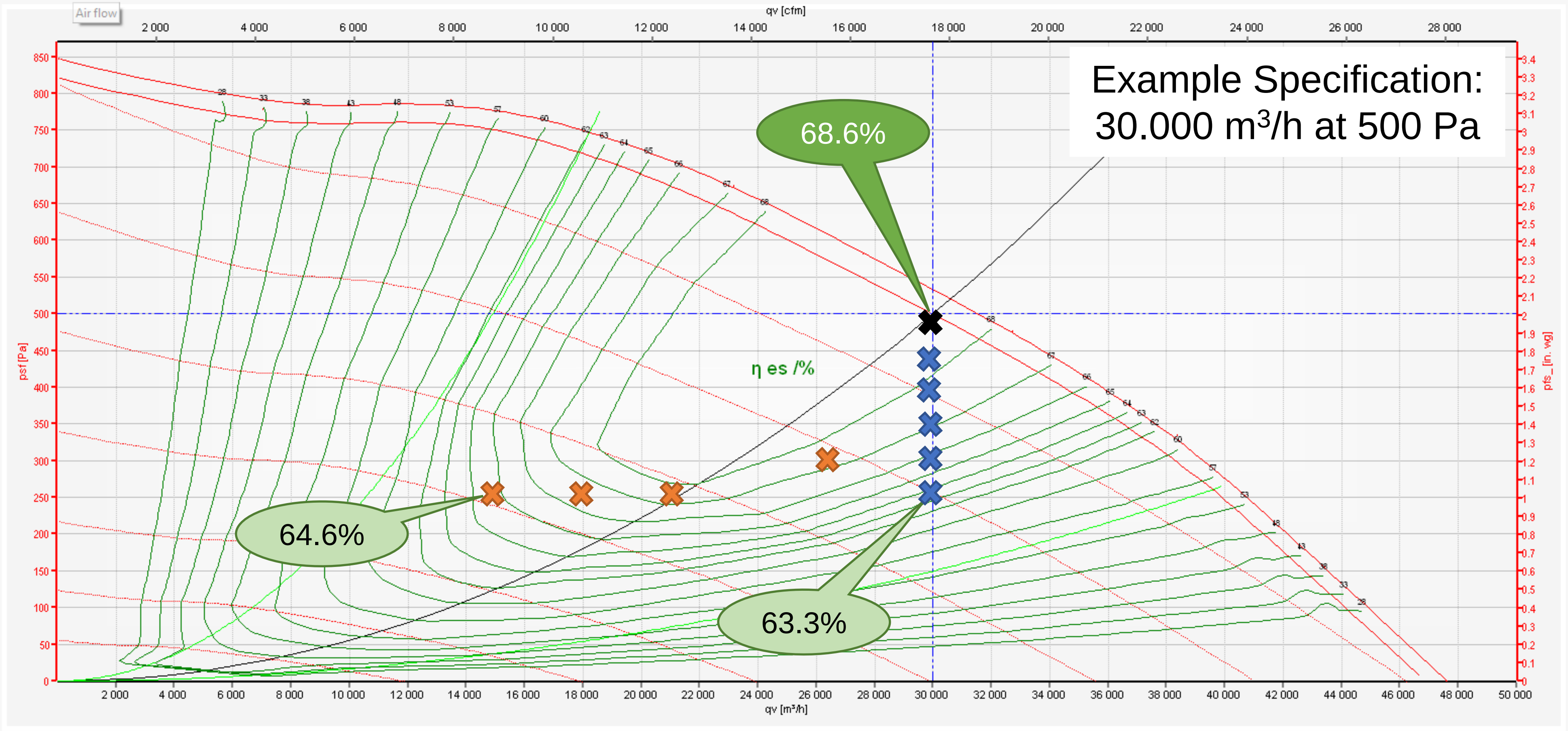
SCENARIO 2	TSP	AIRFLOW	POWER INPUT	FEI	η	IMPACT FACTOR
DESIGN	500 Pa	30.000 m³/h	6070 W	1.58	68.6 %	-
- 30 % pressure / - 10% flow	350 Pa	27.000 m³/h	3876 W	1.69	67.7 %	98.7%
- 40 % pressure / - 12% flow	300 Pa	24.000 m³/h	2966 W	1.93	67.4 %	98.3%
- 50 % pressure / -30% flow	250 Pa	21.000 m³/h	2179 W	1.87	66.9 %	97.5%
- 50 % pressure / -40% flow	250 Pa	18.000 m³/h	1904 W	1.85	65.6 %	95.6%
- 50 % pressure / -50% flow	250 Pa	15.000 m³/h	1614 W	1.85	64.6 %	94.2%

Effects of Safety Factors on System Efficiency

Physical parameters at operating point / Characteristics

qv/(m³/h)	pfs /Pa	Ped /W	n/(1/min)	η ed /%	η es /%	I /A	LwA_in /dB(A)	LwA_out /dB(A)	LwA_in_out /dB(A)	SFP/ (kW/(m³/s))	FER
30000	500	6070	737.1	74	68.6	9.35	77.1	80.4	82.1	0.728	1.392

Air flow:		Pressure:	
500	m³/min	2.007	in. wg
8333	l/s	500	Pa
8.333	m³/s	control voltage	
17660	cfm	9.6	V



Discoveries During Retrofits

ESCO report prior to retrofitting:

DESCRIPTIONS	DETAILS of Centrifugal Fan @ Full Load	OPERATING CONDITION
LOCATION / AHU REF	AHU 2-4	
AHU MODEL		
FAN MODEL	Design	Measured
AIR FLOW	8500 m3/hr	6380 m^3/hr
FAN STATIC PRESSURE (P1-P2)	880 Pa	250 Pa

Selection based on design

Type: K3G500PB2403 Product: EC centrifugal fan - RadiPac

Physical parameters at operating point / Characteristics

qv/(m³/h)	☑ pfs /Pa	☐ Ped /W	☐ n/(1/min)	☐ η ed /%	☐ η es /%
8500	880	3105	1800	70.3	66.9

Speed-controlled to actual condition

Type: K3G500PB2403 Product: EC centrifugal fan - RadiPac

Physical parameters at operating point / Characteristics

qv/(m³/h)	☑ pfs /Pa	☐ Ped /W	☐ n/(1/min)	☐ η ed /%	☐ η es /%
6380	250	779.9	1103	62.5	56.8

Input power

Efficiency drops by factor 0.85

Selection based on actual condition

Type: K3G560PB3171 Product: EC centrifugal fan - RadiPac

Physical parameters at operating point / Characteristics

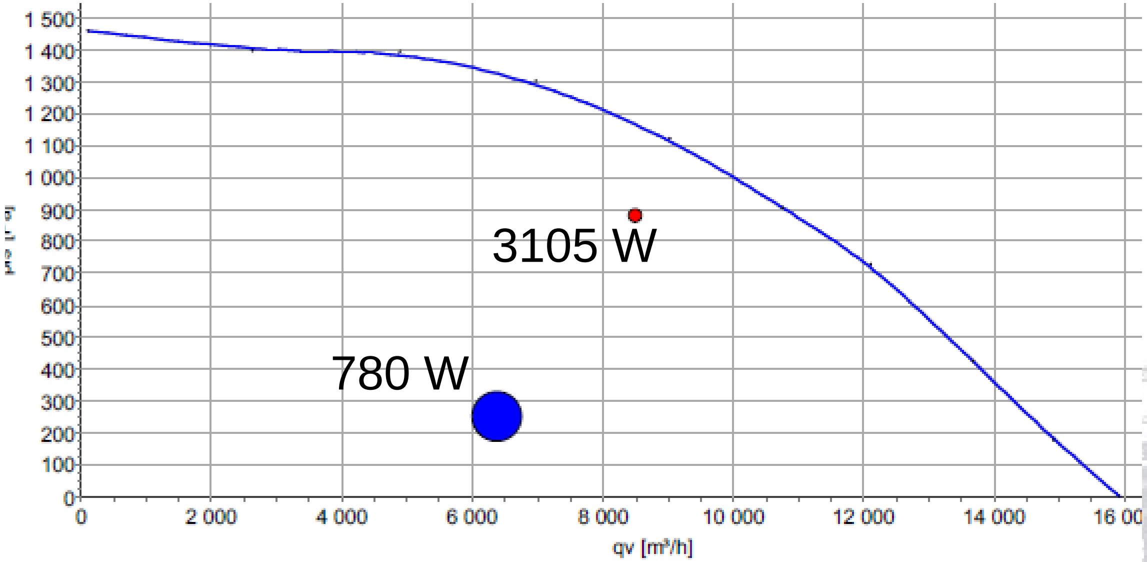
qv/(m³/h)	☑ pfs /Pa	☐ Ped /W	☐ n/(1/min)	☐ η ed /%	☐ η es /%
6380	250	698.5	899.6	67.6	63.4

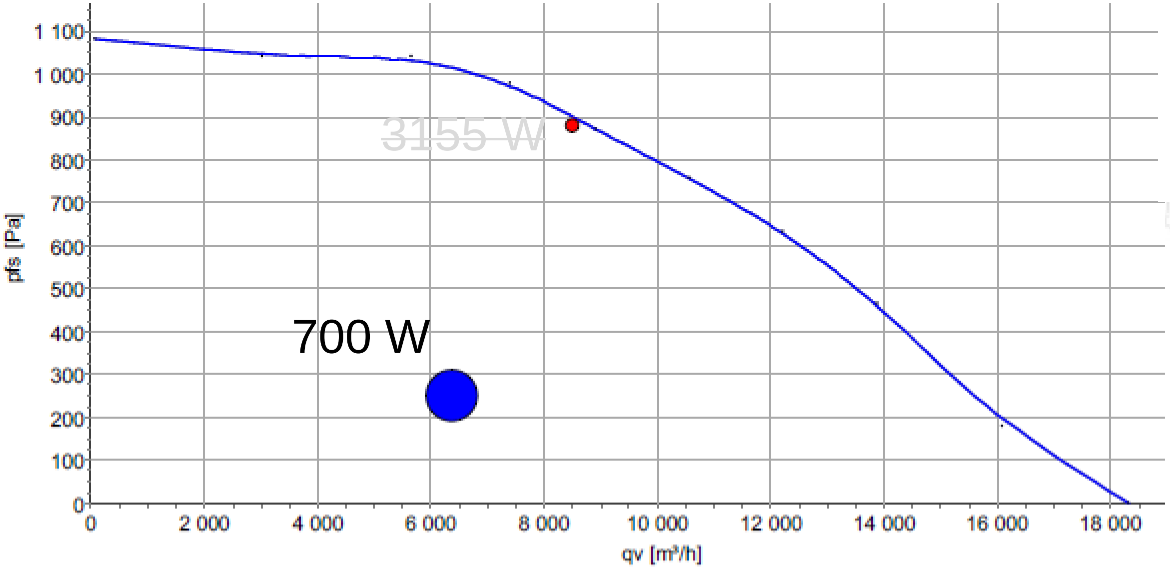
10% input power saving through better fan sizing.

Discoveries During Retrofits

DESCRIPTIONS	DETAILS of Centrifugal Fan @ Full Load	OPERATING CONDITION
LOCATION / AHU REF	**AHU 2-4**	
AHU MODEL		
FAN MODEL	Design	Measured
AIR FLOW	8500 m3/hr	**6380 m³/hr**
FAN STATIC PRESSURE (P1-P2)	880 Pa	**250 Pa**

Initial retrofit option: Fan size 500 mm





Alternate retrofit option: Fan size 560 mm

- Measurements and analyses prior to retrofits provide additional saving potential through right-sizing.
- Safety factor reduction for new construction has similar effects!

Summary

- The efficiency guarantee for highly efficient air-side equipment requires a close interaction: The mechanical designer of the building, the equipment manufacturer, and the fan system supplier.
- Fully tested fan systems with a tight accuracy class enables everyone to reduce safety factors to a minimum. Right-sized fan systems have minimal impact on design efficiency.
- For best results in retrofitting, representative measurements prior to retrofitting are recommended. The design vs. actual operation differs significantly in many cases.
- Understanding safety factors and fan system behavior supports better designs:
→ improved efficiency and modulation range → lower operational expenses
→ right-sized fan systems → lower capital expense
→ optimum return on investment

Questions?

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