

Recommended modification of slope for fans of 0.75 kW and less

Issue:

Minimum target efficiencies for fans of 0.75 kW and less

Recommendation:

Reduce the target efficiency for fans below 0.75 kW by making a new slope that is 5 % below the combined Fan Motor slope from directive 327-2011 EU and Motor slope from IEC 60034-30-1.

Background:

The directive 327-2011 EU for "Ecodesign requirements for fans driven by motors" takes 125 W as the starting point, see the tables 1&2 below for the FMEG's (Fan Motor Efficiency Grade abbreviated as N_G) and the formulas for arriving at the Fan & Motor efficiency.

Target Fan Motor efficiency grades for different fan types			
Fantype	Category	Static/ total	FMEG 20 15
Axial	A,C	Static	40
	B,D	Total	58
Backward curved centrifugal with housing	A,C	Static	61
	B,D	Total	64
Backward curved centrifugal w/o housing	A,C	Static	62
Forward curved or radial bladed centrifugal	A,C	Static	44
	B,D	Total	49
Mixed flow	A,C	Static	50
	B,D	Total	62
Cross flow	B,D	Total	21

Table 1: Target Fan Motor Efficiencies (as of 1.1.2015)

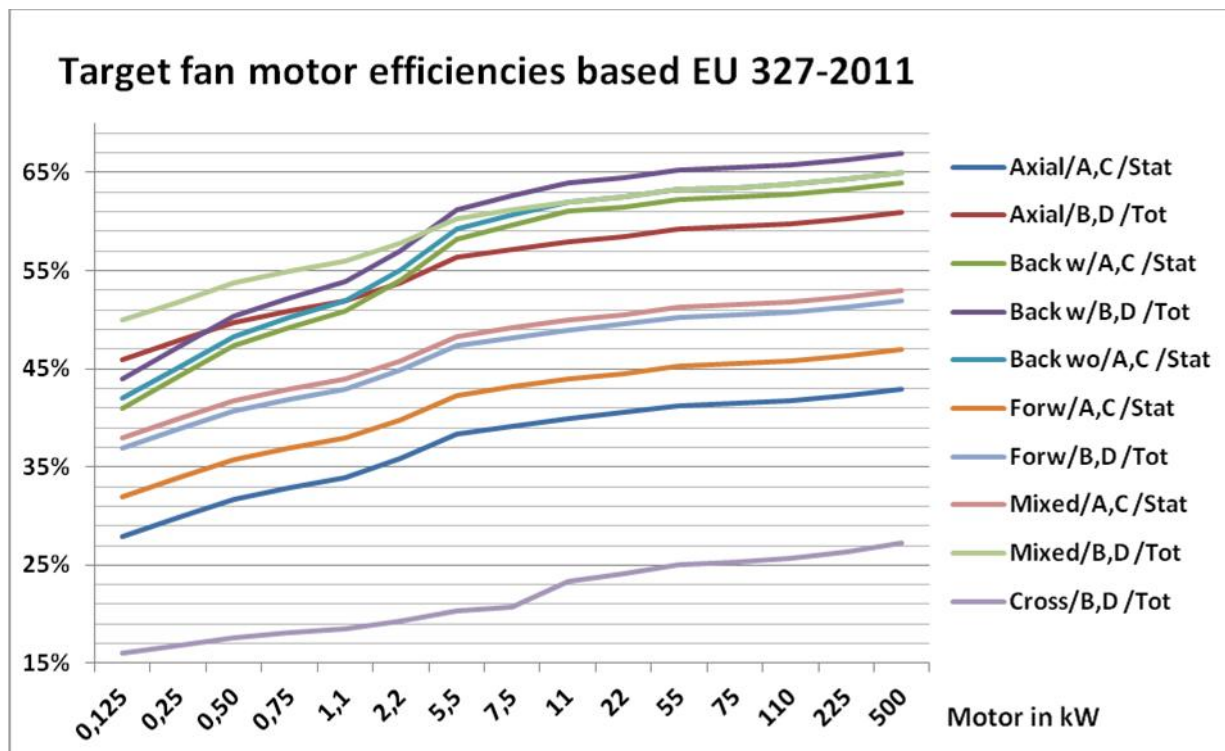
	Axial, Forward Curved & Radial, Centrifugal fans, Mixed flow fans	Backward Bladed Centrifugal fans with or without housing	Cross flow fans
<10 kW	$\eta_{opt} = 2.74 \cdot \ln(P_e) - 6.33 + N_G$	$\eta_{opt} = 4.56 \cdot \ln(P_e) - 10.5 + N_G$	$\eta_{opt} = 1.14 \cdot \ln(P_e) - 2.6 + N_G$
≥ 10 kW	$\eta_{opt} = 0.78 \cdot \ln(P_e) - 1.88 + N_G$	$\eta_{opt} = 1.1 \cdot \ln(P_e) - 2.6 + N_G$	$\eta_{opt} = N_G$

Table 2: Formulas to determine the optimal target efficiency

Using table 2 the optimal efficiency for the combination of fans and motors for different fan types, Installation categories and motor sizes can be calculated. Table 3 and graph 1 shows the combined efficiencies for selected motor sizes.

Calculation of target fan motor efficiency				Motor in kW														
Fan type	Category	Static/total	FMEG 15	0,125	0,25	0,50	0,75	1,1	2,2	5,5	7,5	11	22	55	75	110	225	500
Axial	A,C	Static	40	28%	30%	32%	33%	34%	36%	38%	39%	40%	41%	41%	41%	42%	42%	43%
	B,D	Total	58	46%	48%	50%	51%	52%	54%	56%	57%	58%	59%	59%	59%	60%	60%	61%
Backward curved centrifugal with housing	A,C	Static	61	41%	44%	47%	49%	51%	54%	58%	60%	61%	62%	62%	62%	63%	63%	64%
	B,D	Total	64	44%	47%	50%	52%	54%	57%	61%	63%	64%	65%	65%	65%	66%	66%	67%
Backward curved centrifugal w/o housing	A,C	Static	62	42%	45%	48%	50%	52%	55%	59%	61%	62%	63%	63%	63%	64%	64%	65%
Forward curved or radial bladed centrifugal	A,C	Static	44	32%	34%	36%	37%	38%	40%	42%	43%	44%	45%	45%	45%	46%	46%	47%
	B,D	Total	49	37%	39%	41%	42%	43%	45%	47%	48%	49%	50%	50%	50%	51%	51%	52%
Mixed flow	A,C	Static	50	38%	40%	42%	43%	44%	46%	48%	49%	50%	51%	51%	51%	52%	52%	53%
	B,D	Total	62	50%	52%	54%	55%	56%	58%	60%	61%	62%	63%	63%	63%	64%	64%	65%
Cross flow	B,D	Total	21	16%	17%	18%	18%	19%	19%	20%	21%	23%	24%	25%	25%	26%	26%	27%

Table3: Calculation of target fan motor efficiencies based on the FMEG's of directive 327-2011 EU



Graph 1: Target efficiencies for all the fan types and installation categories covered in 327-2011 EU

For the electrical motors the starting point had been set at 750 W in the IEC standard 60034-30.

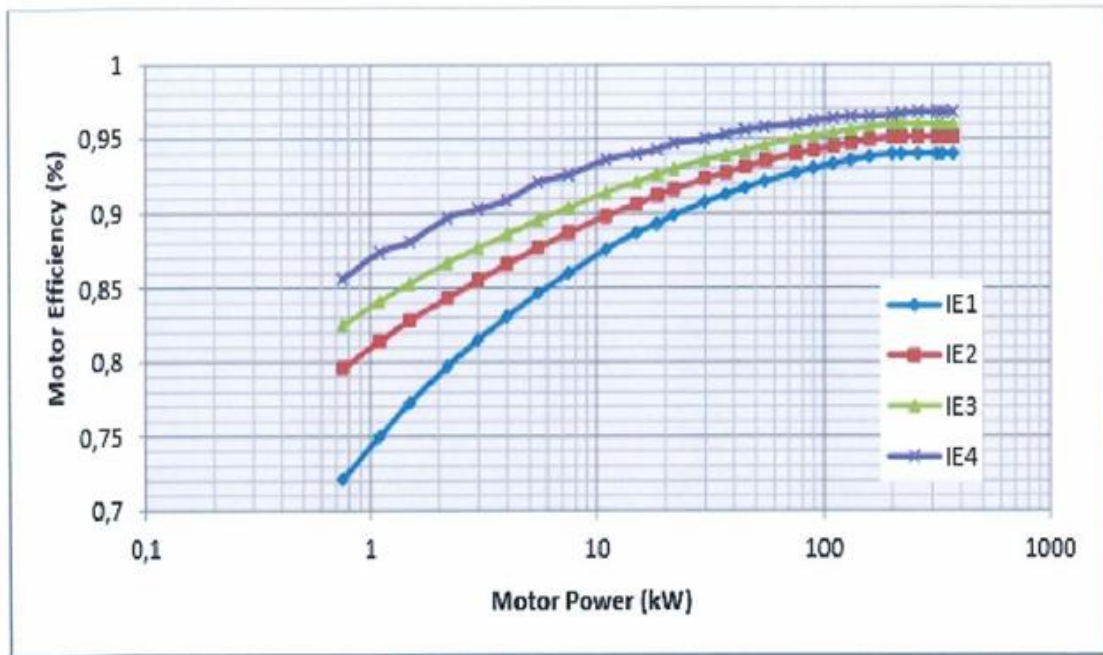
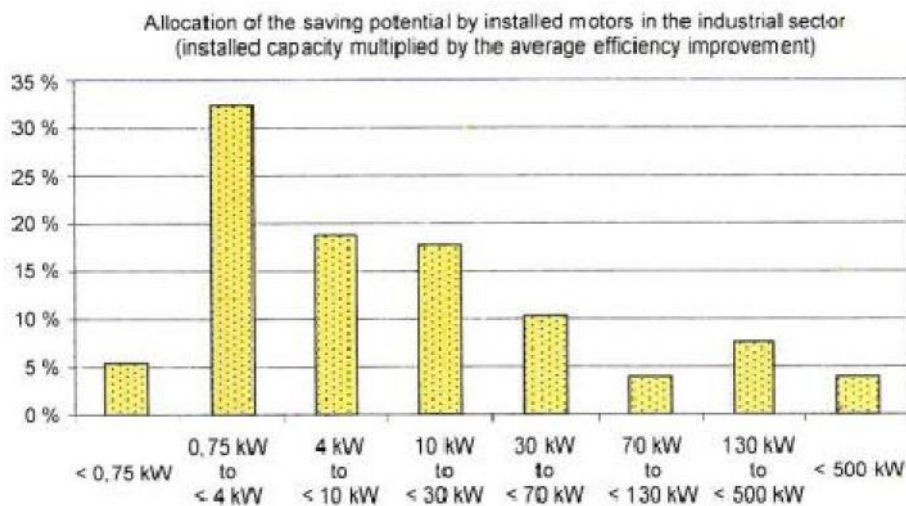


Figure 1-2. IE1, IE2 and IE3 efficiency levels in the IEC 60034-30 standard for 4 poled motors [6] and the new IE4 proposed in the IEC 60034-31 standard [12].

Graph 2: Minimum Motor efficiencies according to IEC 60034-30. IE 2 is the current target efficiency, while IE3 will come into force in 2017.

In the IEC standard it is shown that this starting point was chosen because it was estimated that only 6% of the overall energy savings potential was related to motors smaller than 750W (graph 3).



Sources: 1. SAVE-Report "Improving the Penetration of Energy Efficient Motors and Drives" (1996)
2. CEMEP calculations

IEC 1823/08

Graph 3: Estimate of saving potential according to IEC 60034-30

In the current revision (draft) IEC 60034-30-1 is shown values for target efficiencies also for smaller motors, which are significantly lower than the values for the larger motors (graph 4).

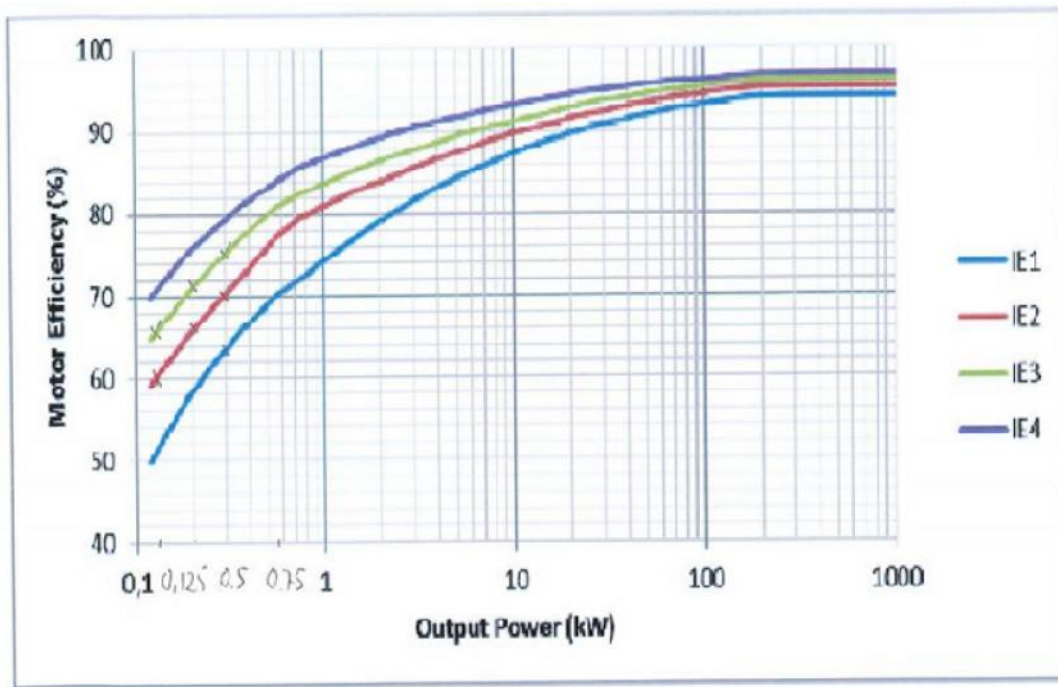


Figure 1-3. Efficiency levels in the draft IEC 60034-30-1 standard for 4 poled motors, 50 Hz

Graph 4: Suggested efficiency levels according to draft standard 60034-30-1

In the motor standard the values for the different motors speeds (poles) are slightly different. Also the standard only covers 2, 4 and 6 pole motors. (This is creating another problem because larger pole motors have in general lower efficiencies than the ones covered by the standard. In a separate analysis the recommended allowance for slow speed motors will be present. Otherwise there is the risk that too large motors are used and only run at half speed significantly underloaded.)

kw\ Pol	2	4	6	Average
0,125	60,0	60,0	60,0	60,0%
0,25	66,0	66,0	66,0	66,0%
0,5	70,0	70,0	70,0	70,0%
0,75	77,4	79,6	75,9	77,6%
1,1	79,6	81,4	78,1	79,7%
2,2	83,2	84,3	81,8	83,1%
5,5	87,0	87,7	86,0	86,9%
7,5	88,1	88,7	87,2	88,0%
11	89,4	89,8	88,7	89,3%
22	91,3	91,6	90,9	91,3%
55	93,2	93,5	93,1	93,3%
75	93,8	94,0	93,7	93,8%
110	94,3	94,5	94,3	94,4%
225	95,0	95,1	95,0	95,0%
500	95,0	95,1	95,0	95,0%

Table 4: Calculation of the average motor efficiency for 2,4 and 6 pol motors

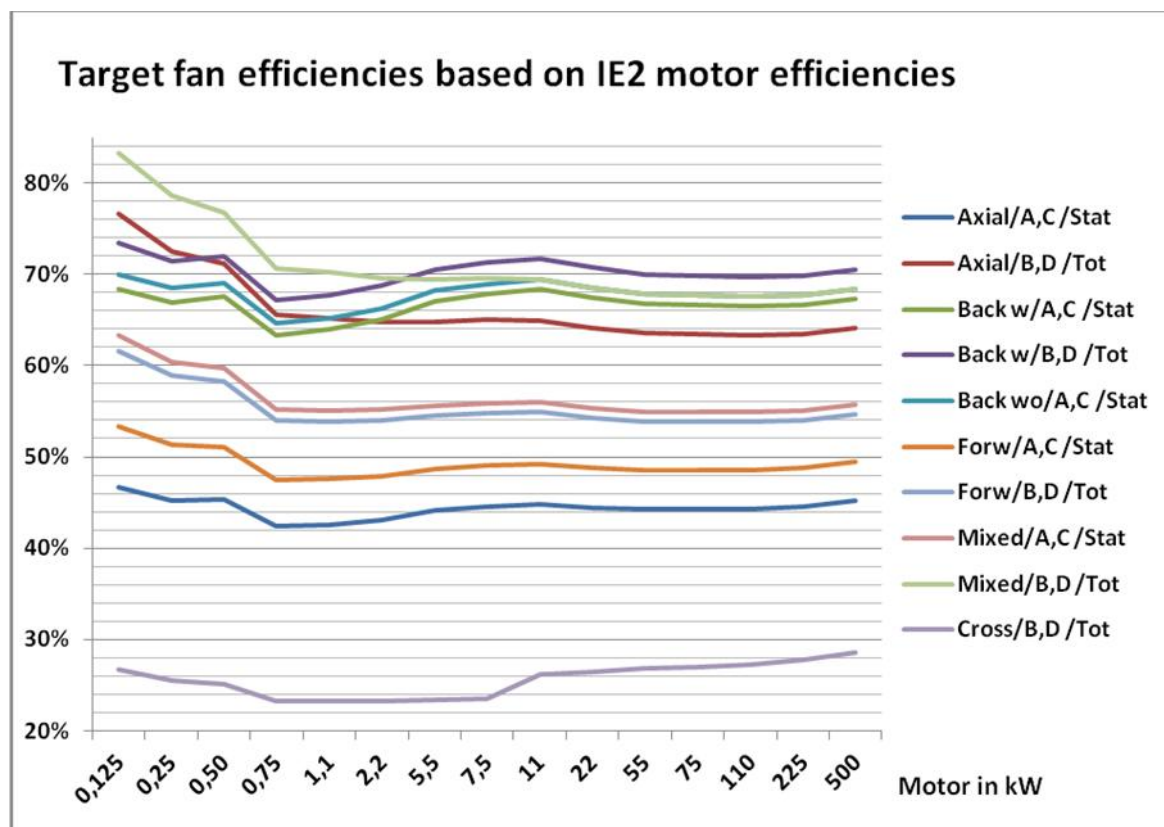
By combining the target efficiencies from the 2 standards one can arrive at an average minimum target efficiency for the fans without the motors.

			Avg IE2 Motor efficiency*		60	66	70	77,6	79,7	83,1	86,9	88	89,3	91,3	93,3	93,8	94,4	95	95
Calculation of target fan efficiency			Motor in kW																
Fantype	Category	Static/ total	0,125	0,25	0,50	0,75	1,1	2,2	5,5	7,5	11	22	55	75	110	225	500		
Axial	A,C	Static	47%	45%	45%	42%	43%	43%	44%	45%	45%	44%	44%	44%	44%	45%	45%		
	B,D	Total	77%	73%	71%	66%	65%	65%	65%	65%	65%	64%	64%	63%	63%	63%	64%		
Backward curved centrifugal with housing	A,C	Static	68%	67%	68%	63%	64%	65%	67%	68%	68%	67%	67%	67%	67%	67%	67%		
	B,D	Total	73%	71%	72%	67%	68%	69%	71%	71%	72%	71%	70%	70%	70%	70%	70%		
Backward curved centrifugal w/o housing	A,C	Static	70%	68%	69%	65%	65%	66%	68%	69%	69%	69%	68%	68%	68%	68%	68%		
Forward curved or radial bladed centrifugal	A,C	Static	53%	51%	51%	48%	48%	48%	49%	49%	49%	49%	49%	48%	49%	49%	49%		
	B,D	Total	62%	59%	58%	54%	54%	54%	54%	55%	55%	54%	54%	54%	54%	54%	55%		
Mixed flow	A,C	Static	63%	60%	60%	55%	55%	55%	56%	56%	56%	55%	55%	55%	55%	55%	56%		
	B,D	Total	83%	79%	77%	71%	70%	70%	69%	70%	69%	69%	68%	68%	68%	68%	68%		
Cross flow	B,D	Total	27%	25%	25%	23%	23%	23%	23%	24%	26%	26%	27%	27%	27%	28%	29%		

*0,125 - 0.5 kW from graph in draft 60034-30-1, 0.125 kW - 500 kW average of 2 -6 pol values from 60034-30

Table 5: Calculation of target fan efficiency using average IE2 motor efficiencies

This can also be shown graphically.



Graph 5: Fan target efficiencies using average IE2 motor efficiencies

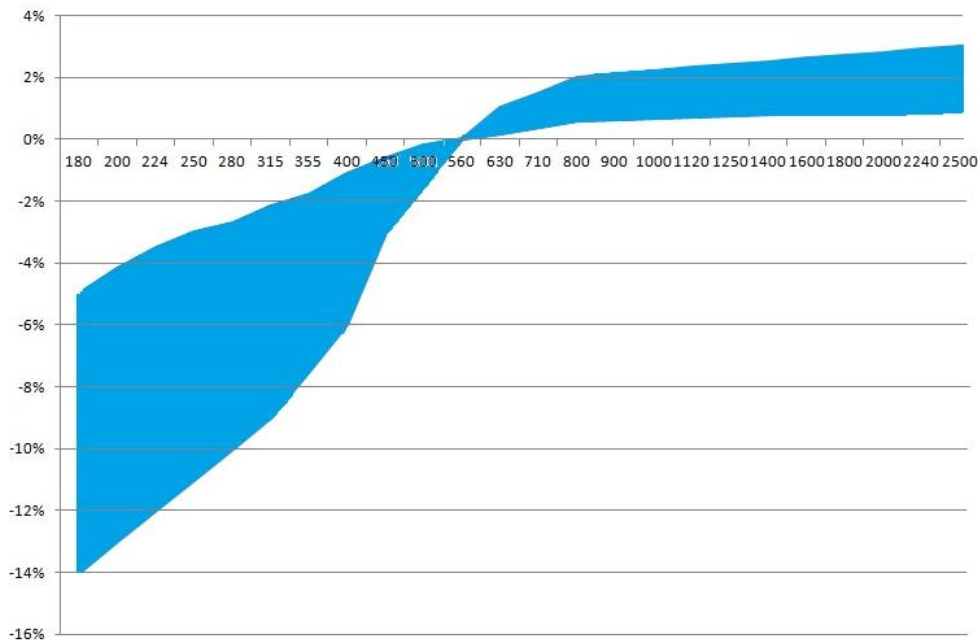
When looking at the graph it becomes immediately obvious that there is a problem with the target efficiencies for fans with smaller motors (less than 1kW). However this is not the whole story. The so called "Fan Laws" describe that, within reason, it is possible to scale fans up or down. For example a fan with exactly the same design as a fan double the size will have double the volume flow rate i.e. $V_1/V_2 = D_1/D_2$, 4 times the pressure increase i.e. $P_1/P_2 = (D_1/D_2)^2$ and the power is 8 times higher i.e. $P_{fan1}/P_{fan2} = (D_1/D_2)^3$. For smaller fans, typically below a diameter of 300 - 400 mm secondary effects reduce the performance.

According to VDI 2044 (2002): "Scaling of efficiency is very complex and Ackeret's formula the best there currently is: $\eta' = 1 - V \times (1 - \eta) \times [1 + (Re/Re')]^{0.2}$ where $V = 0,5$ "

Reason for scale losses are:

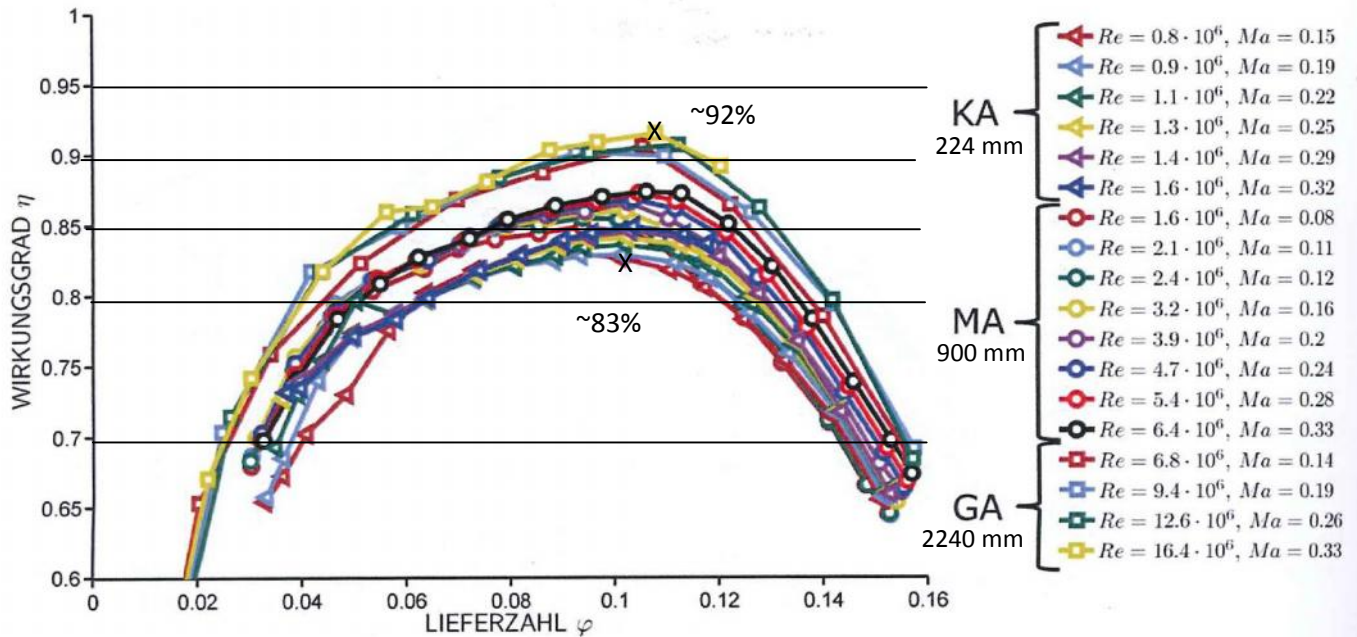
- Bearing friction
- Different Reynolds numbers
- Relatively larger tolerances
- Finite plate sizes
- Increased surface roughness
- Relatively larger motor sizes
- etc.

From experience the difference can be as shown in graph 6.



Graph 6: Typical de-rating of efficiency based on fan diameter for a diameter 560 mm fan.

FLT (Forschungsverein für Luft- und Trocknungstechnik Germany) has made a number of studies concerning the derating. For centrifugal fans between 224 mm diameter and 2.240 mm they found a difference of 9% in total efficiency.



Graph 7: Efficiency for 3 backward curved centrifugal fans/identical design

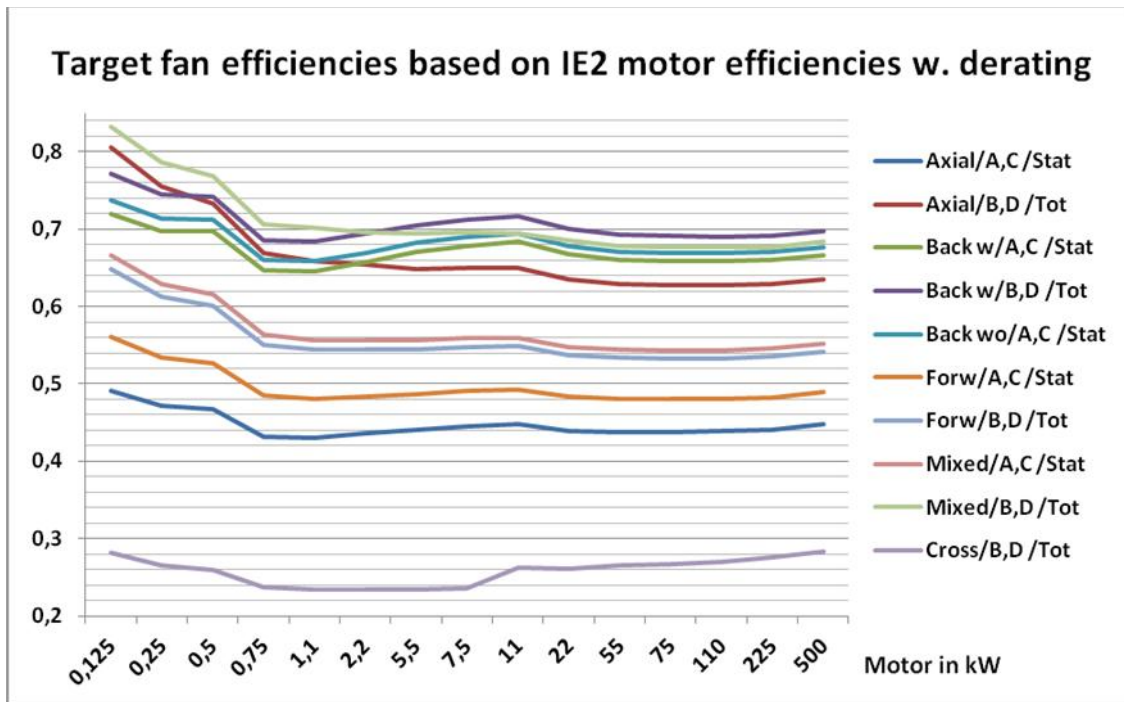
Quelle: FLT, Heft L235 – Wirkungsgradaufwertung Radialventilatoren.

If a modest "de-rating" as it is popularly called of -5 to + 1% is taken into account, the disadvantage for smaller fans is even more pronounced. See table 6 and graph 7.

Derating**			95	96	97	98	99	99	100	100	100	101	101	101	101	101	101
			Motor in kW														
Fantype	Category	Static/total	0,125	0,25	0,50	0,75	1,1	2,2	5,5	7,5	11	22	55	75	110	225	500
Axial	A,C	Static	49%	47%	47%	43%	43%	44%	44%	45%	45%	44%	44%	44%	44%	44%	45%
	B,D	Total	81%	76%	73%	67%	66%	65%	65%	65%	65%	63%	63%	63%	63%	63%	64%
Backward curved centrifugal with housing	A,C	Static	72%	70%	70%	65%	65%	66%	67%	68%	68%	67%	66%	66%	66%	66%	67%
	B,D	Total	77%	74%	74%	69%	68%	69%	71%	71%	72%	70%	69%	69%	69%	69%	70%
Backward curved centrifugal w/o housing	A,C	Static	74%	71%	71%	66%	66%	67%	68%	69%	69%	68%	67%	67%	67%	67%	68%
Forward curved or radial bladed centrifugal	A,C	Static	56%	53%	53%	48%	48%	48%	49%	49%	49%	48%	48%	48%	48%	48%	49%
	B,D	Total	65%	61%	60%	55%	54%	54%	54%	55%	55%	54%	53%	53%	53%	53%	54%
Mixed flow	A,C	Static	67%	63%	62%	56%	56%	56%	56%	56%	56%	55%	54%	54%	54%	55%	55%
	B,D	Total	88%	82%	79%	72%	71%	70%	69%	70%	69%	68%	67%	67%	67%	67%	68%
Cross flow	B,D	Total	28%	27%	26%	24%	23%	23%	23%	24%	26%	26%	27%	27%	27%	28%	28%

** Derating in % taken as an indicate value from VDI 2044 for demonstration purposes.

Table 6: Calculation of target fan efficiency w. derating.



Graph 8: Fan target efficiencies using average IE2 motor efficiencies with a modest de-rating

For smaller fans it would mean that they would have to be 20 - 25 % better than the larger fans. This is putting physics on it's head. Given that for fans over 1 kW it has been recognized that fans improve their efficiency with size, this certainly cannot have been intended. Some form of correction is necessary.

Conclusion:

- 1) The slopes for smaller fans (0.75 kW and less) must be corrected.
- 2) The correction must take into account the minimum target efficiencies for smaller motors as proposed in 60034-30-1.
- 3) It also should take into account a certain de- rating for smaller motor, for example up to 5%.