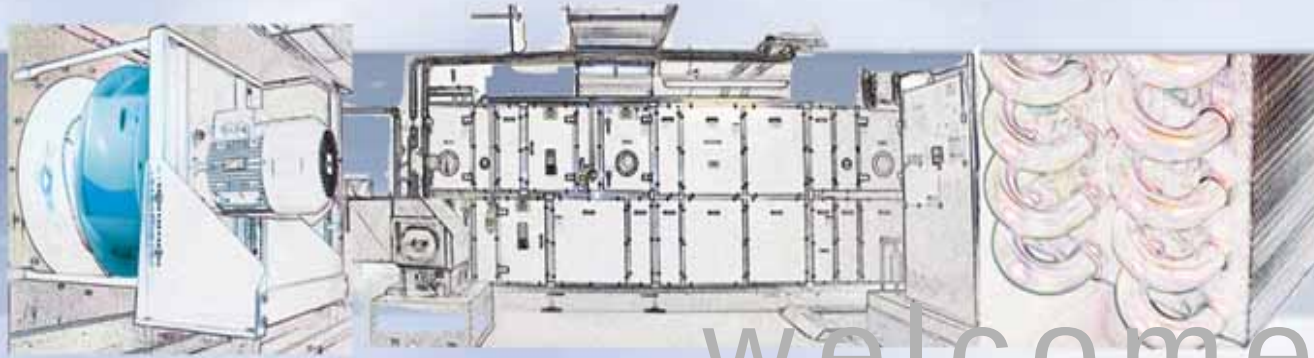


Willkommen



welcome

bienvenu

Study of energy efficiency in air handling units

Heat recovery and electric power efficiencies in AHU's

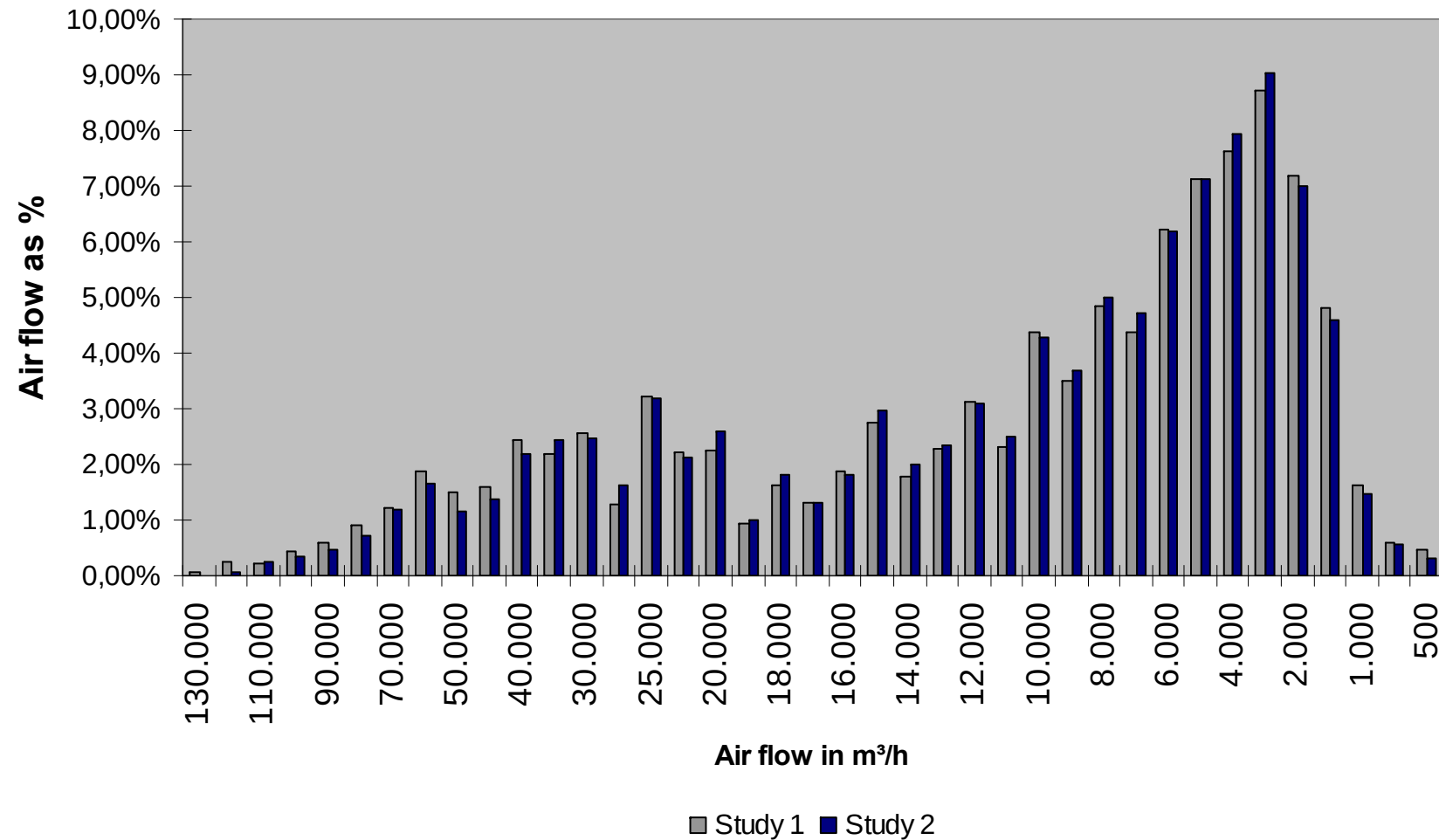
Dr.-Ing. Christoph Kaup

c.kaup@umwelt-campus.de



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Air flow distribution

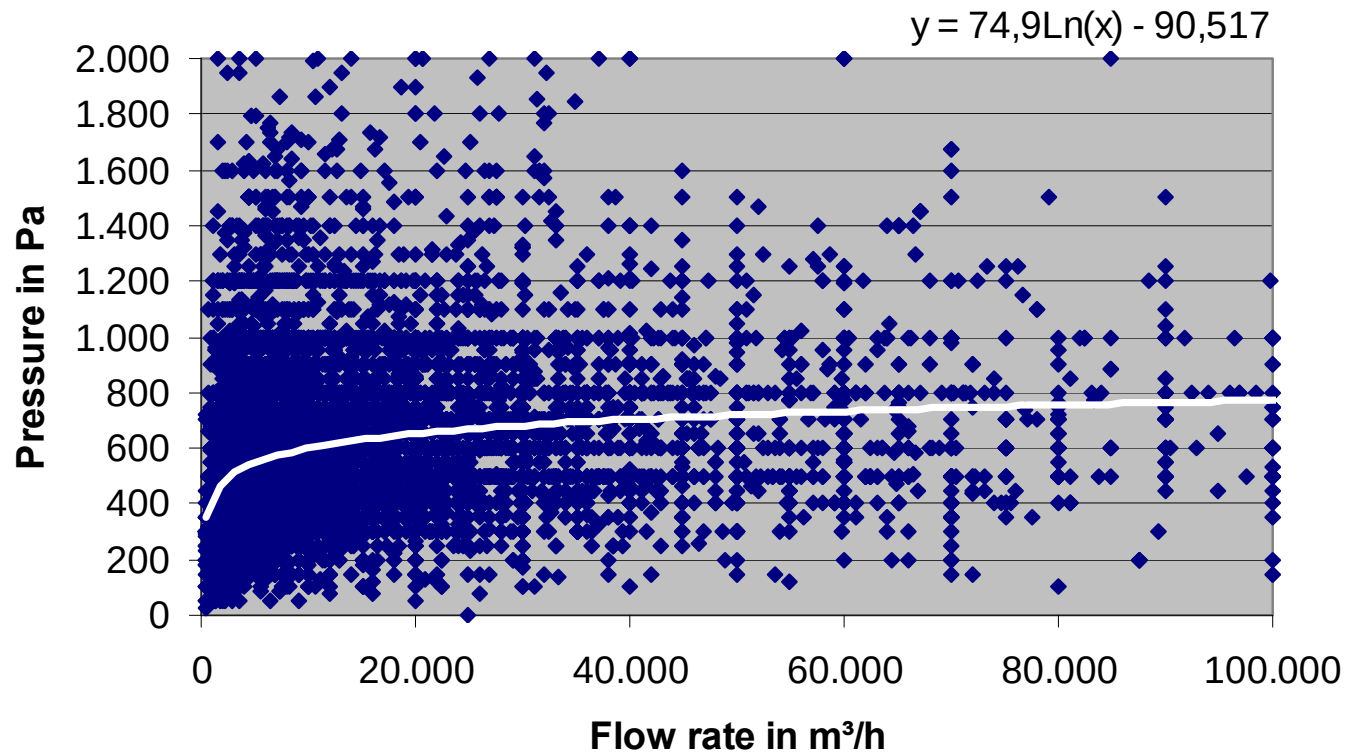


heating and cooling devices of 13.893 units

supply units		13,3 %
exhaust units		5,8 %
combined units		80,9 %
heating devices installed	(11.083 units)	79,8 %
cooling devices installed	(5.630 units)	40,5 %
average heating capacity		96,3 KW
average cooling capacity		88,9 KW

average external pressure loss supply air 587 Pa

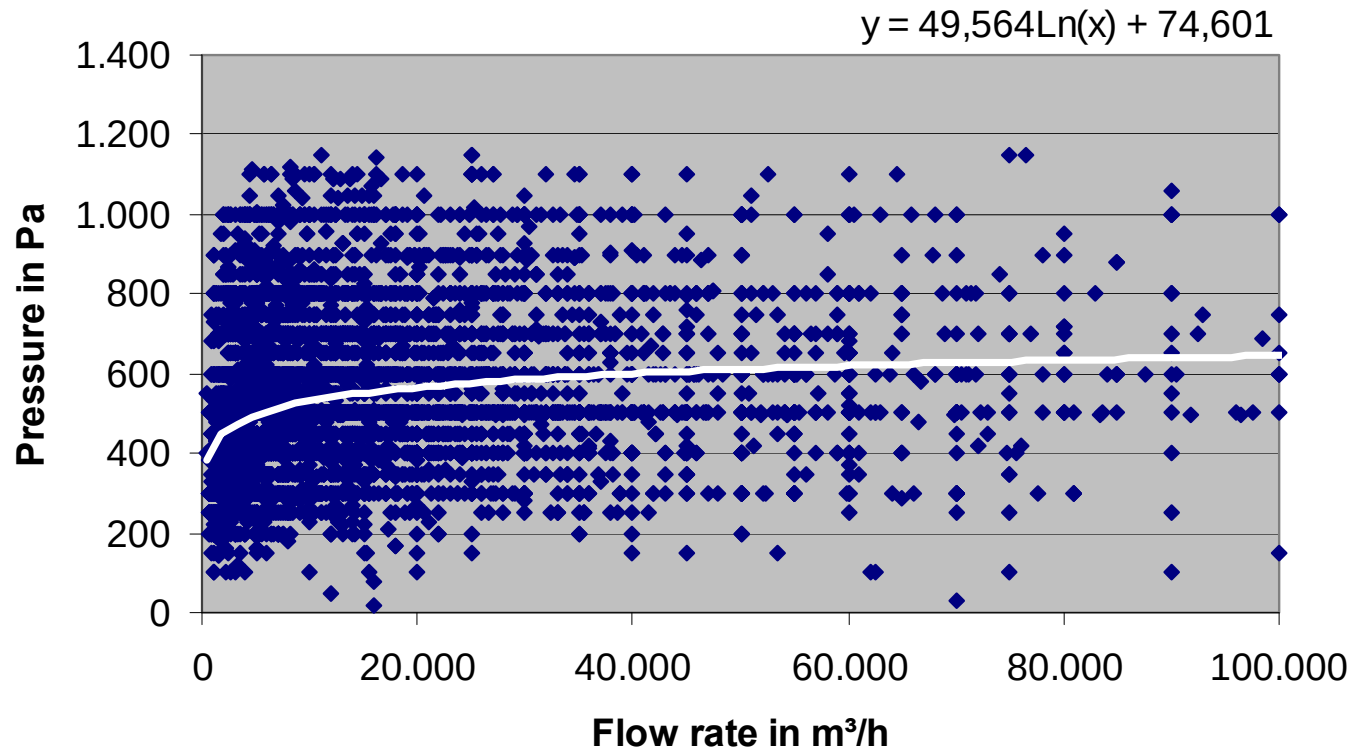
External pressure - flow rate distribution



- ◆ External pressure to supply air flow rate
- Logarithmic (External pressure to supply air flow rate)

average external pressure loss exhaust air 544 Pa

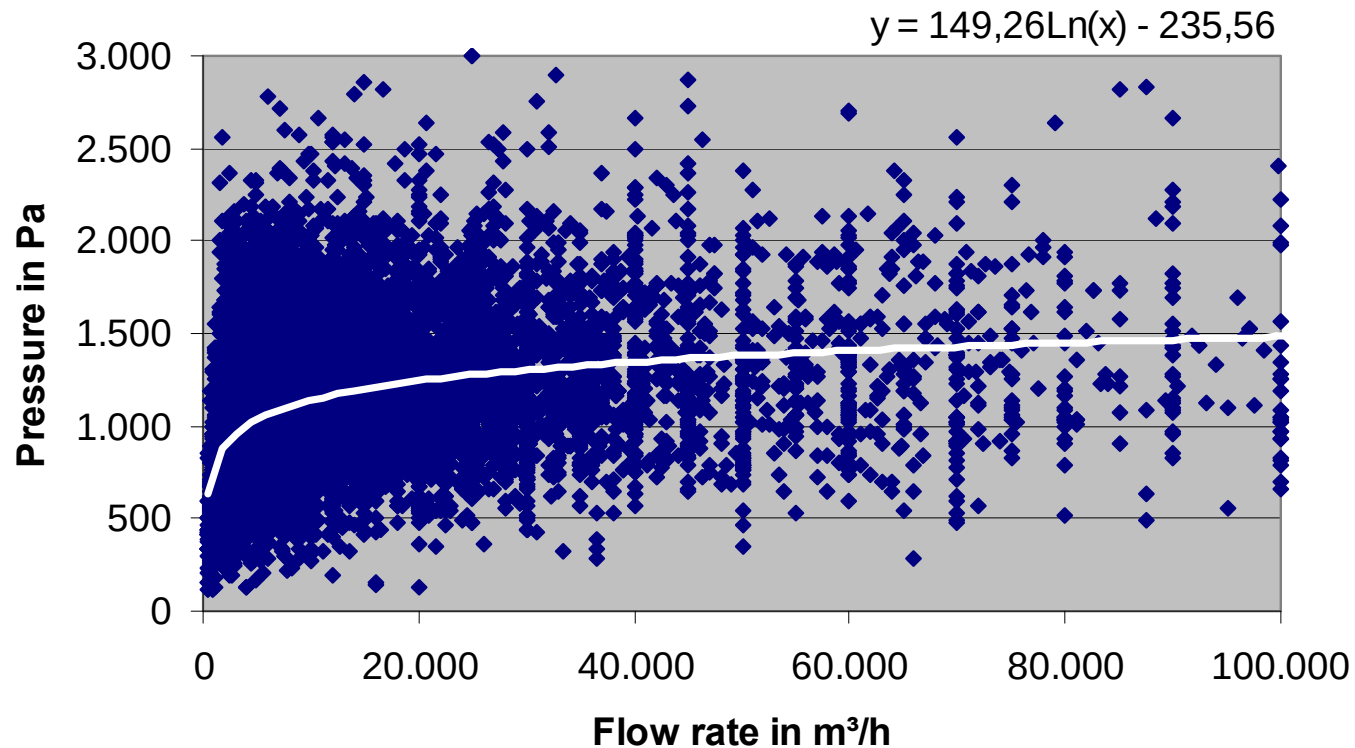
External pressure - flow rate distribution



- ◆ External pressure to exhaust air flow rate
Logarithmic (External pressure to exhaust air flow rate)

average supply air total pressure 1.115 Pa

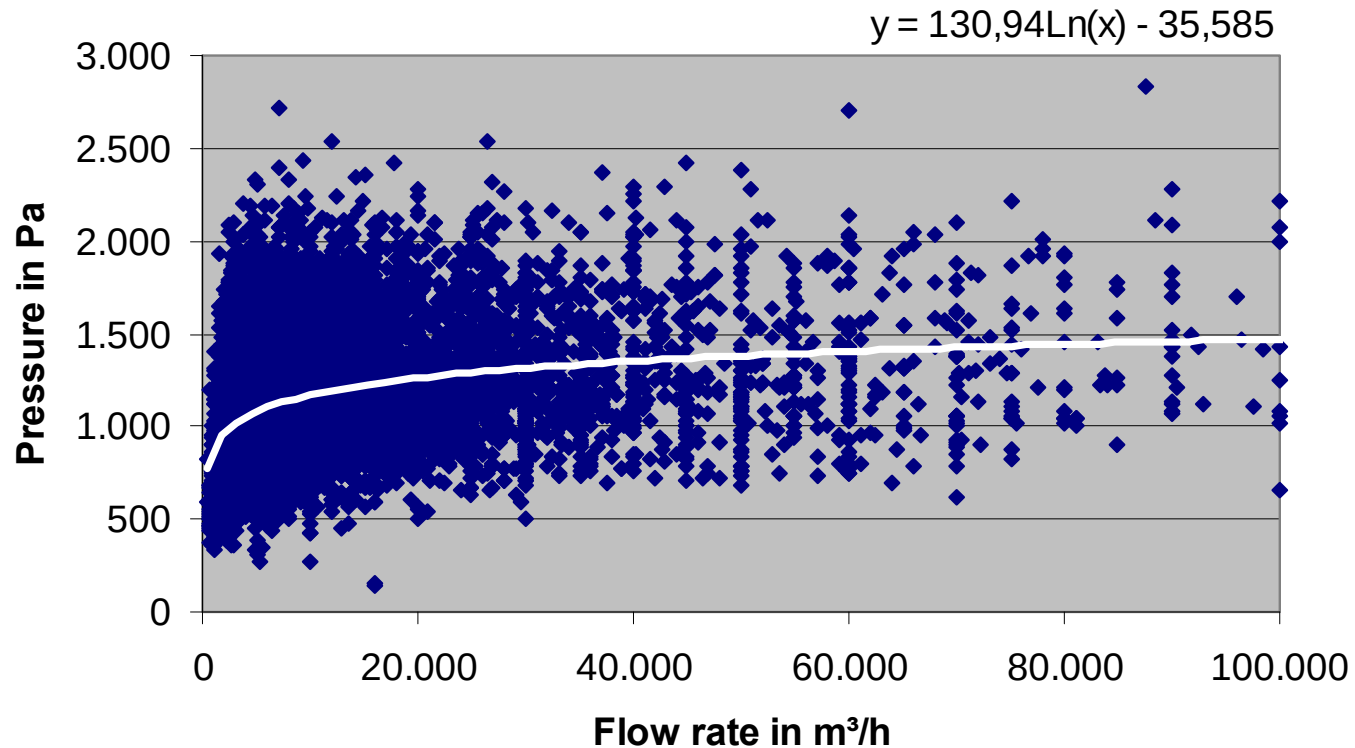
Total pressure - flow rate distribution



- ◆ Total pressure to supply air flow rate
Logarithmic (Total pressure to supply air flow rate)

average exhaust air total pressure 902 Pa

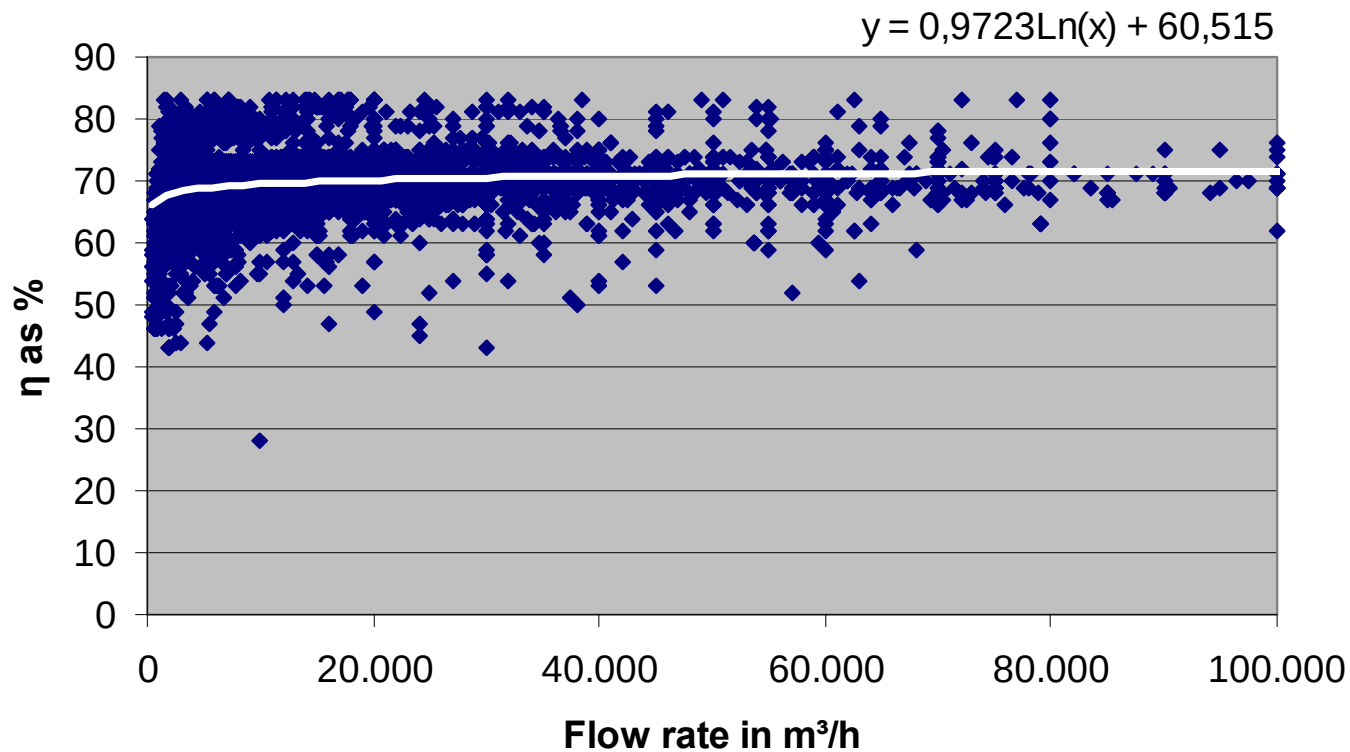
Total pressure - flow rate distribution



- ◆ Total pressure to exhaust air flow rate
Logarithmic (Total pressure to exhaust air low rate)

average fan efficiency supply air 0,692 with $P_s = 6,18$ KW

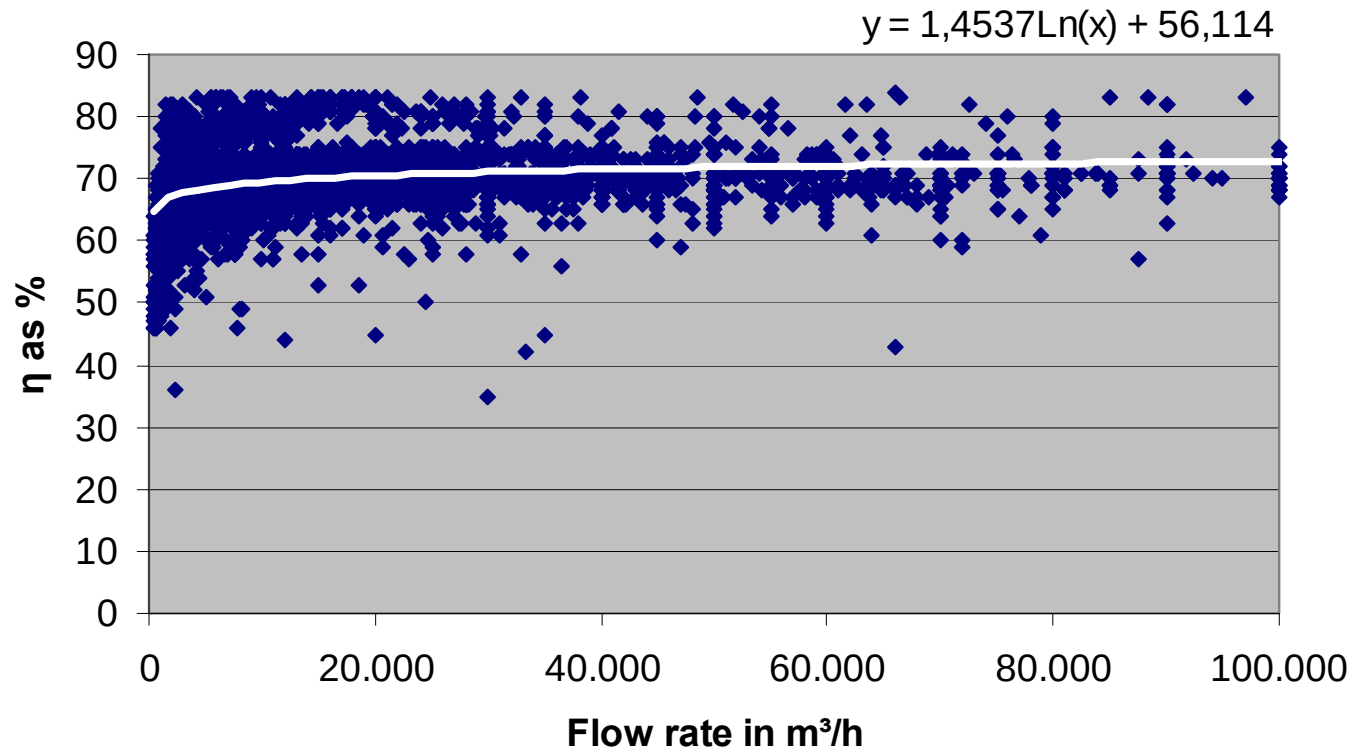
Fan efficiency - flow rate distribution



- ◆ Fan efficiency to supply air flow rate
Logarithmic (Fan efficiency to supply air flow rate)

average fan efficiency exhaust air 0,693 with $P_s = 4,84$ KW

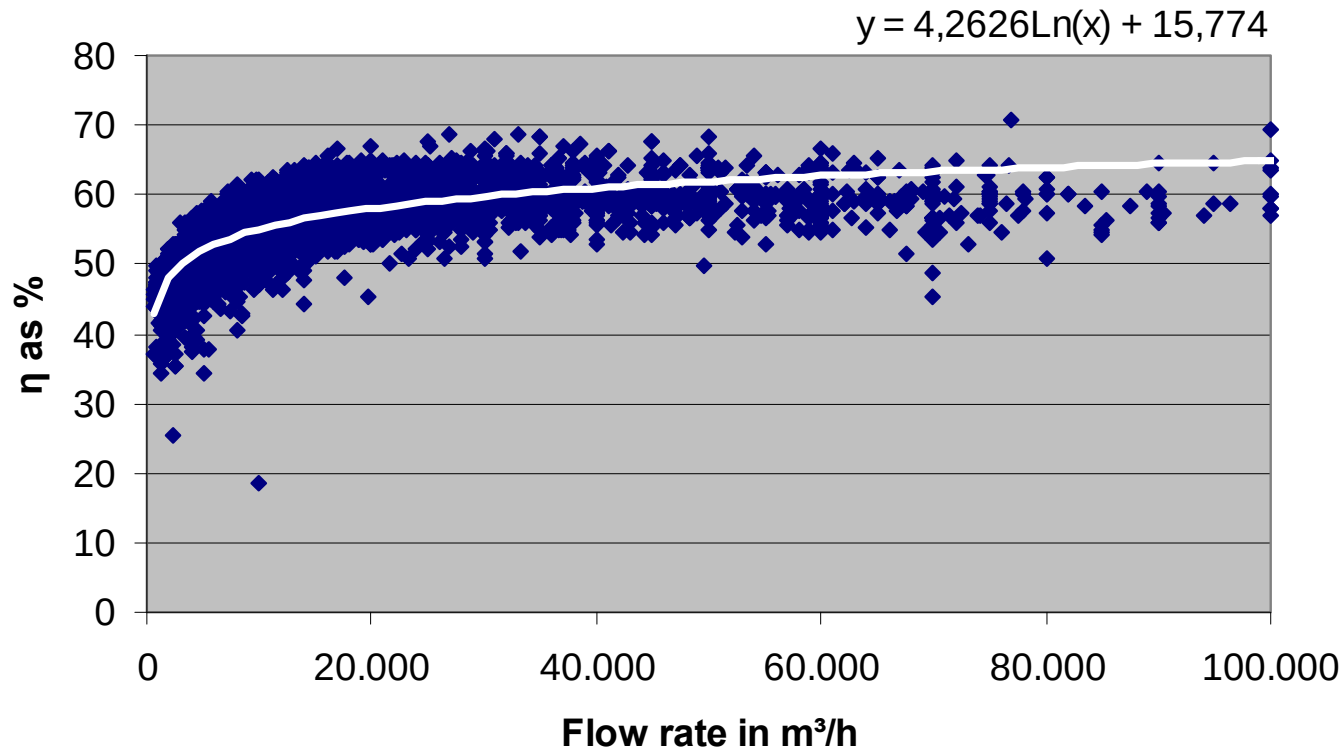
Fan efficiency - flow rate distribution



- ◆ Fan efficiency to exhaust air flow rate
Logarithmic (Fan efficiency to exhaust air flow rate)

average system efficiency supply air 0,545 with $P_m = 7,30$ KW

System efficiency - flow rate distribution

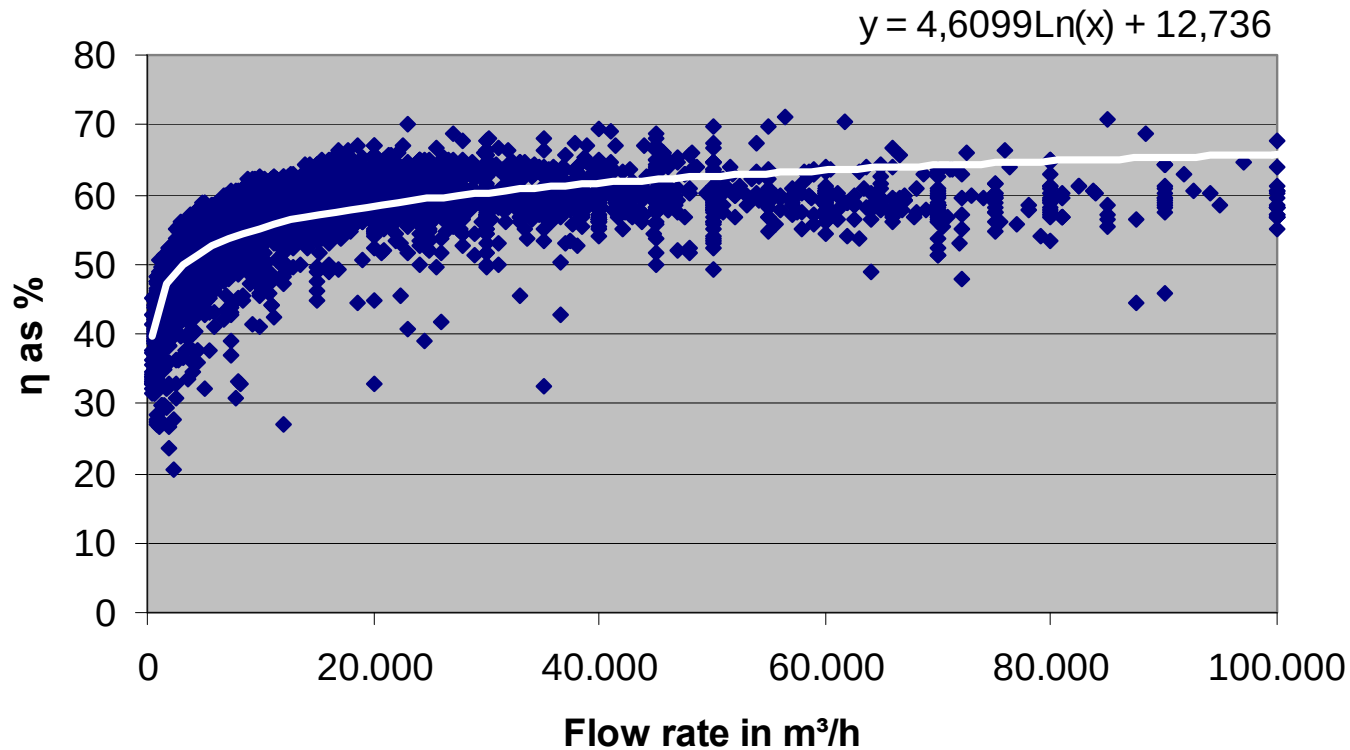


- ◆ System efficiency to supply air flow rate
Logarithmic (System efficiency to supply air flow rate)

average system efficiency exhaust air 0,538 mit $P_m = 5,75$ KW



System efficiency - flow rate distribution



- ◆ System efficiency to exhaust air flow rate
Logarithmic (System efficiency to exhaust air flow rate)

specific fan power

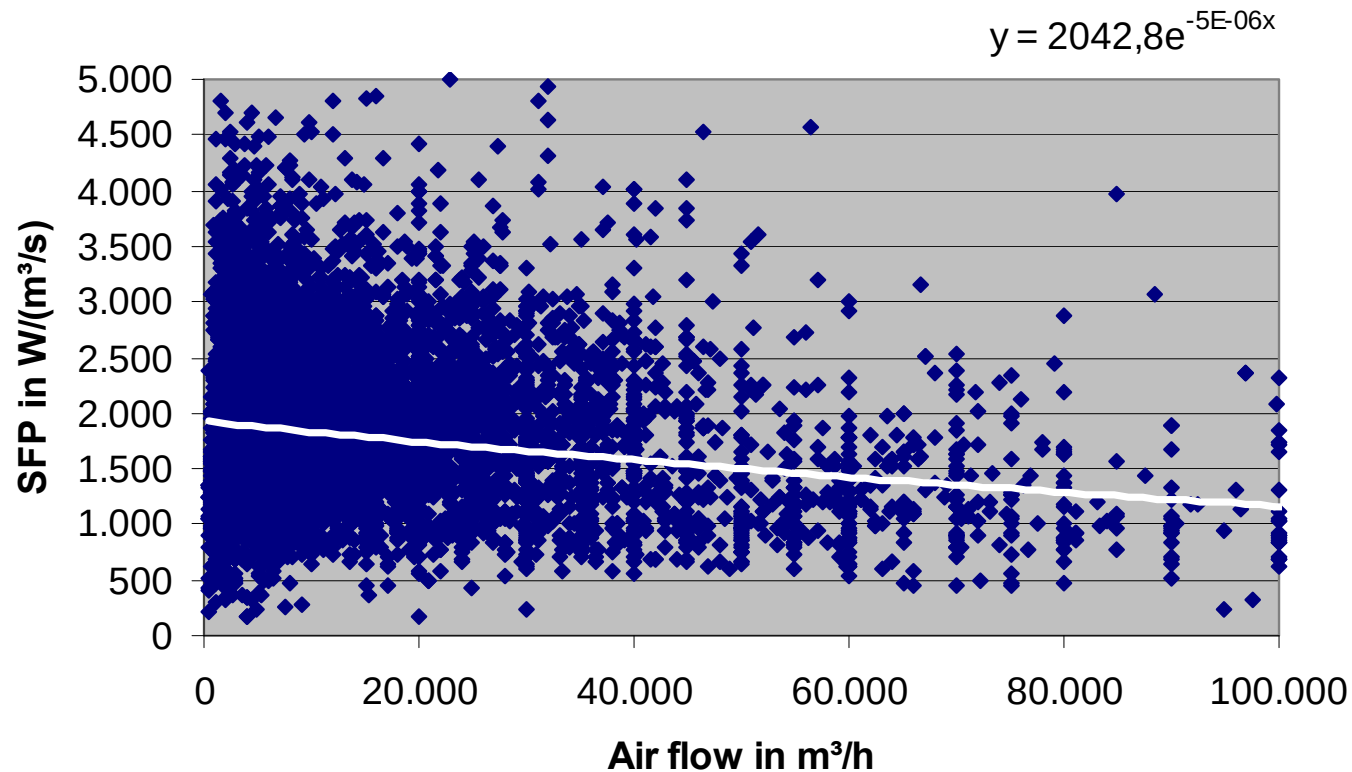


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average supply air SFP 1.916 W/(m³/s)

SFP - flow rate distribution



- ◆ SFP-values to supply air flow rate
- Exponential (SFP-values to supply air flow rate)

specific fan power

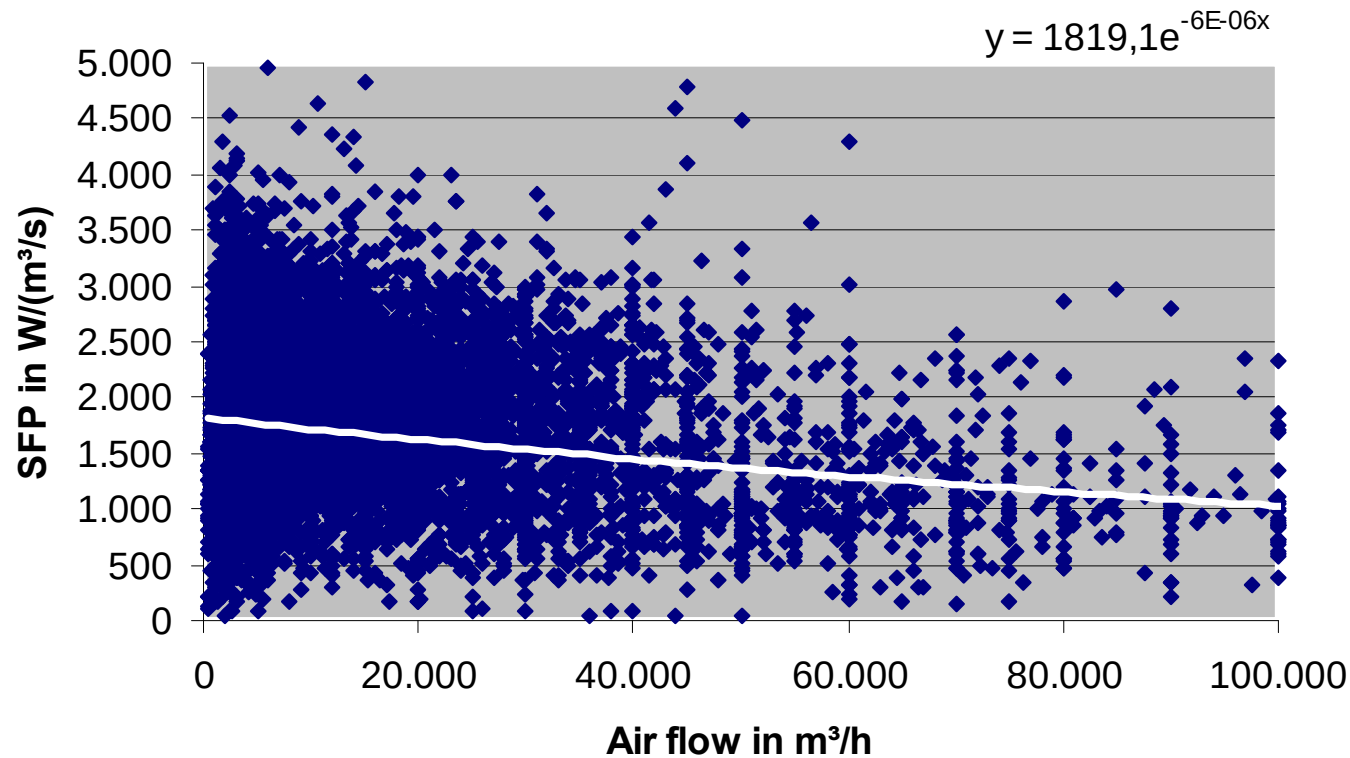


Umwelt-Campus Birkenfeld
FACHHOCHSCHULE TRIER

average supply air SFP 1.799 W/(m³/s) (without add. SFP-values)



SFP - flow rate distribution



- ◆ SFP-values to supply air flow rate
- Exponential (SFP-values to supply air flow rate)

specific fan power

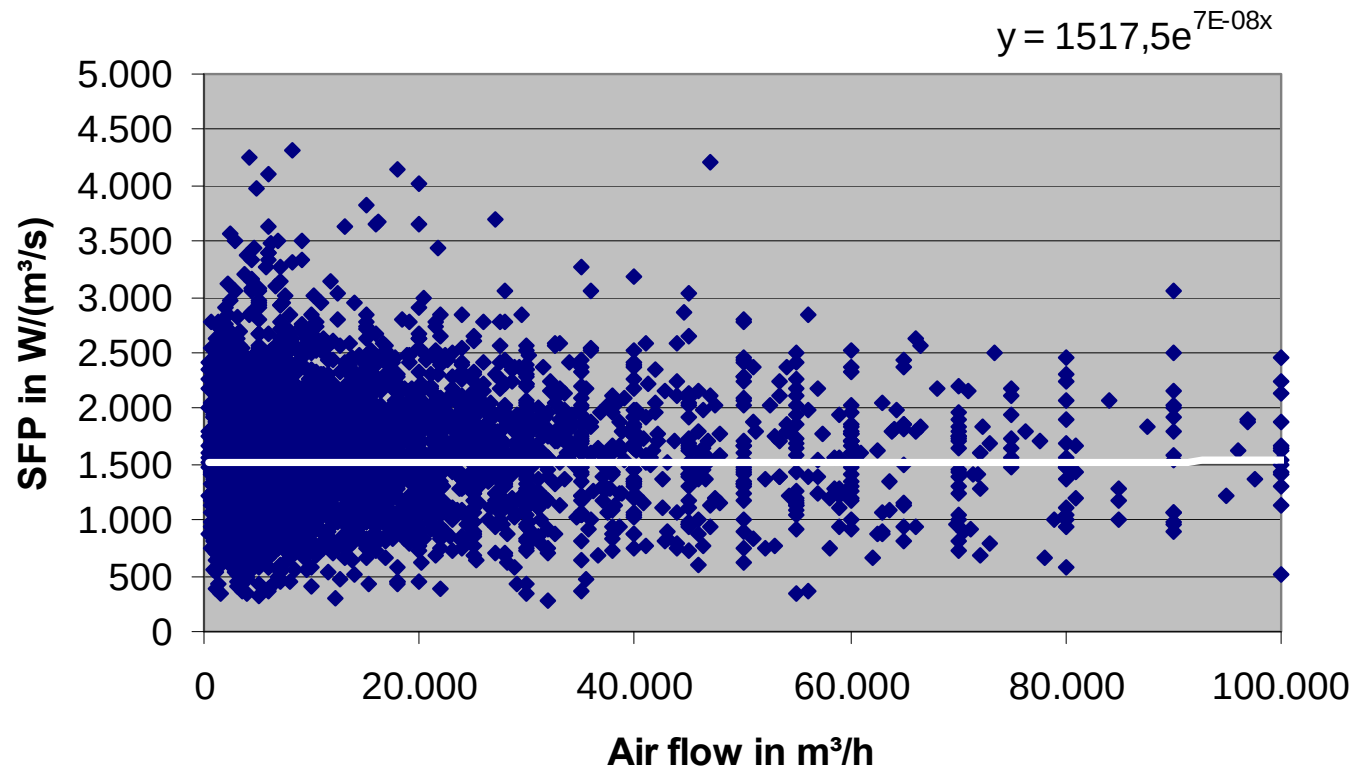


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average exhaust air SFP 1.571 W/(m³/s)

SFP - flow rate distribution



- ◆ SFP-values to exhaust air flow rate
Exponential (SFP-values to exhaust air flow rate)

specific fan power

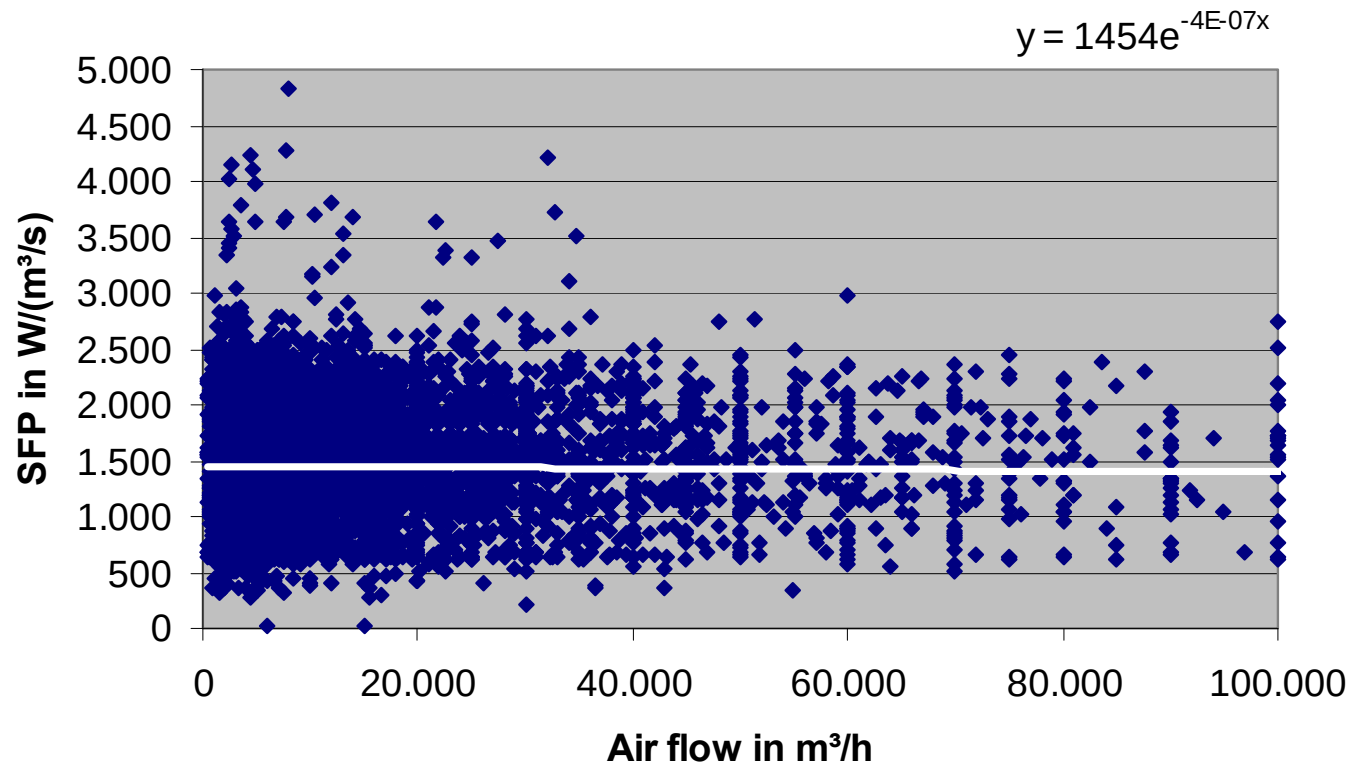


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average exhaust air SFP 1.512 W/(m³/s) (without add. SFP-values)

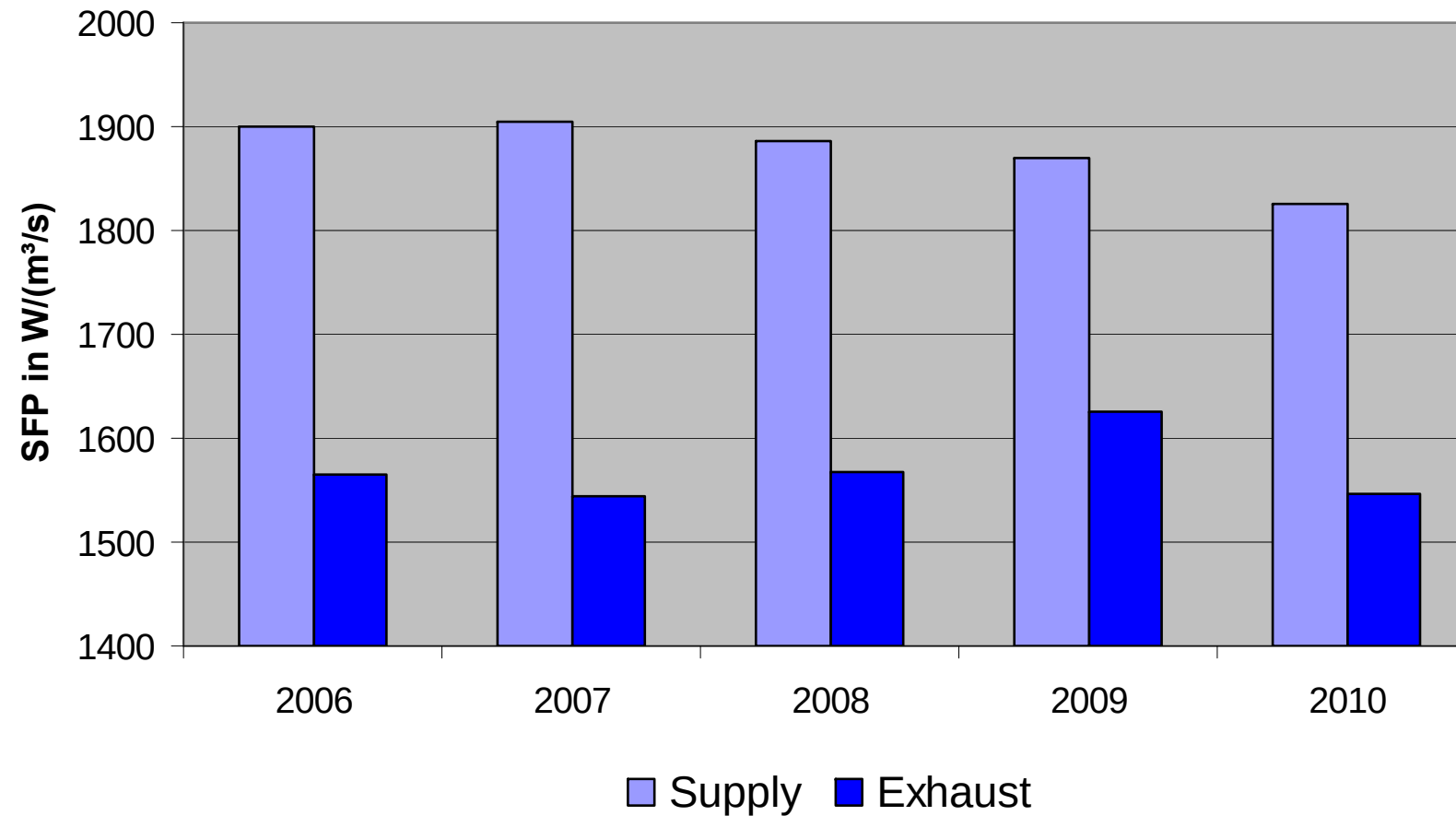


SFP - flow rate distribution



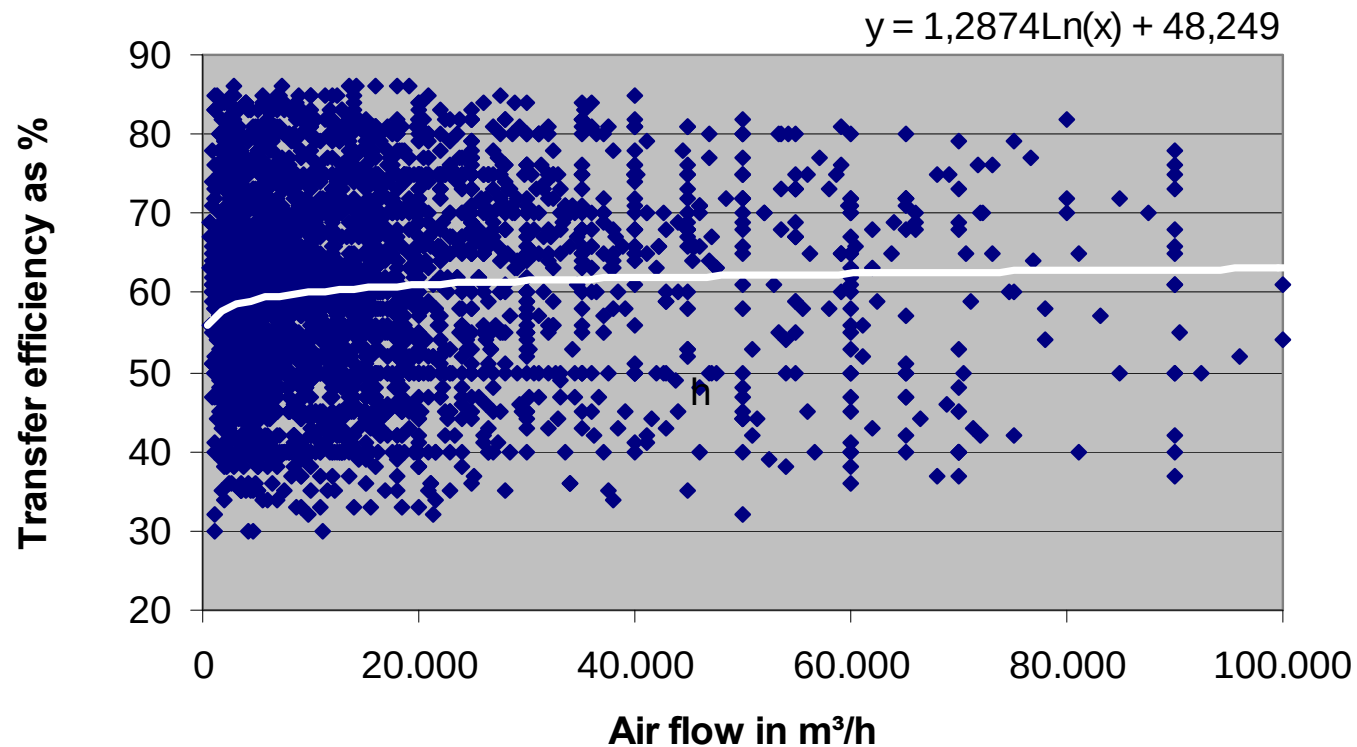
- ◆ SFP-values to exhaust air flow rate
- Exponential (SFP-values to exhaust air flow rate)

Average SFP-values



average transfer efficiency 0,624 at a 52,4 % use of HR

Transfer efficiency - Flow rate distribution

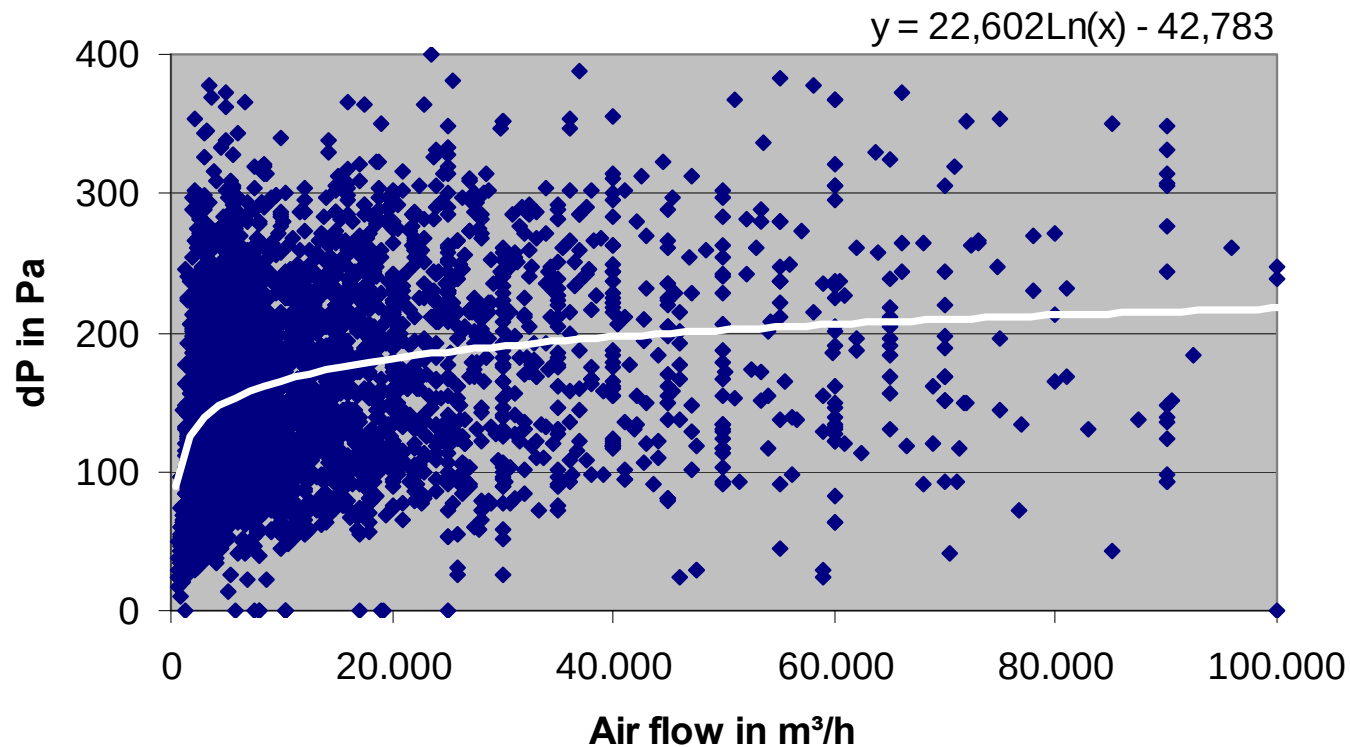


- ◆ Transfer efficiency to air flow rate
Logarithmic (Transfer efficiency to air flow rate)

average HR pressure loss 168 Pa (supply) and 177 Pa (exhaust)



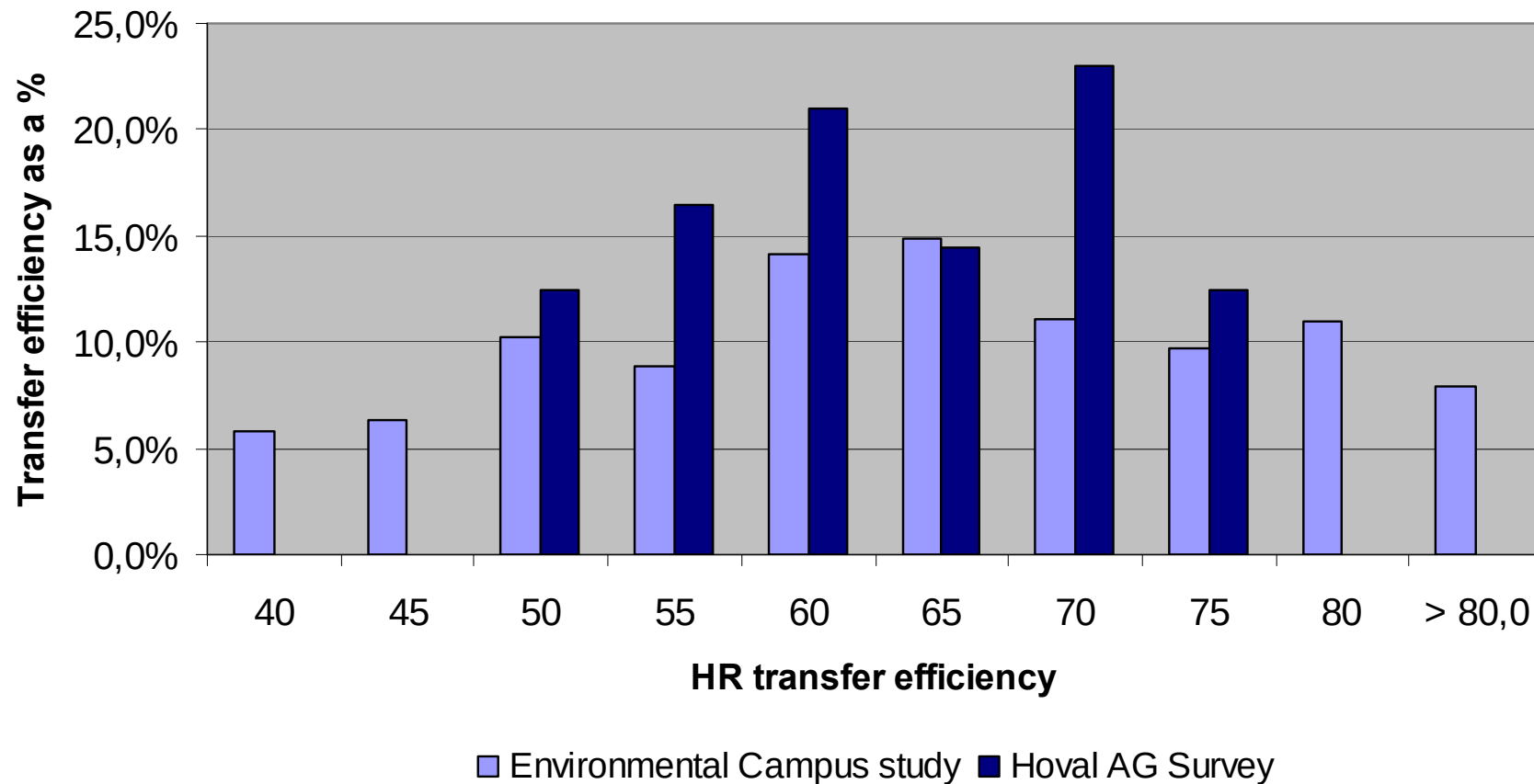
HR dP - Flow rate distribution



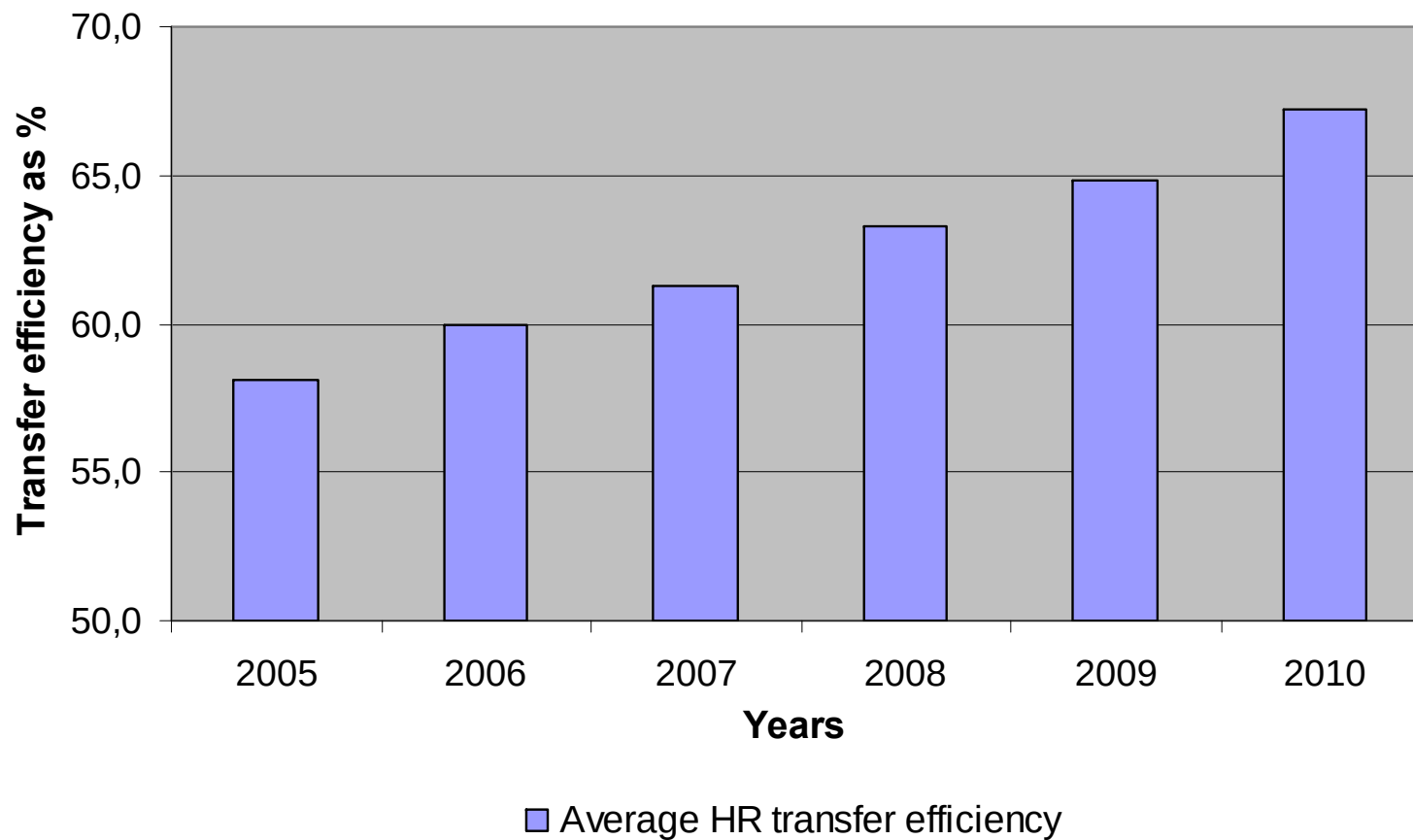
- ◆ HR pressure loss to air flow rate
Logarithmic (HR pressure loss to air low rate)

average transfer efficiency 0,624 (UCB) and 0,628 (Hoval 2009)

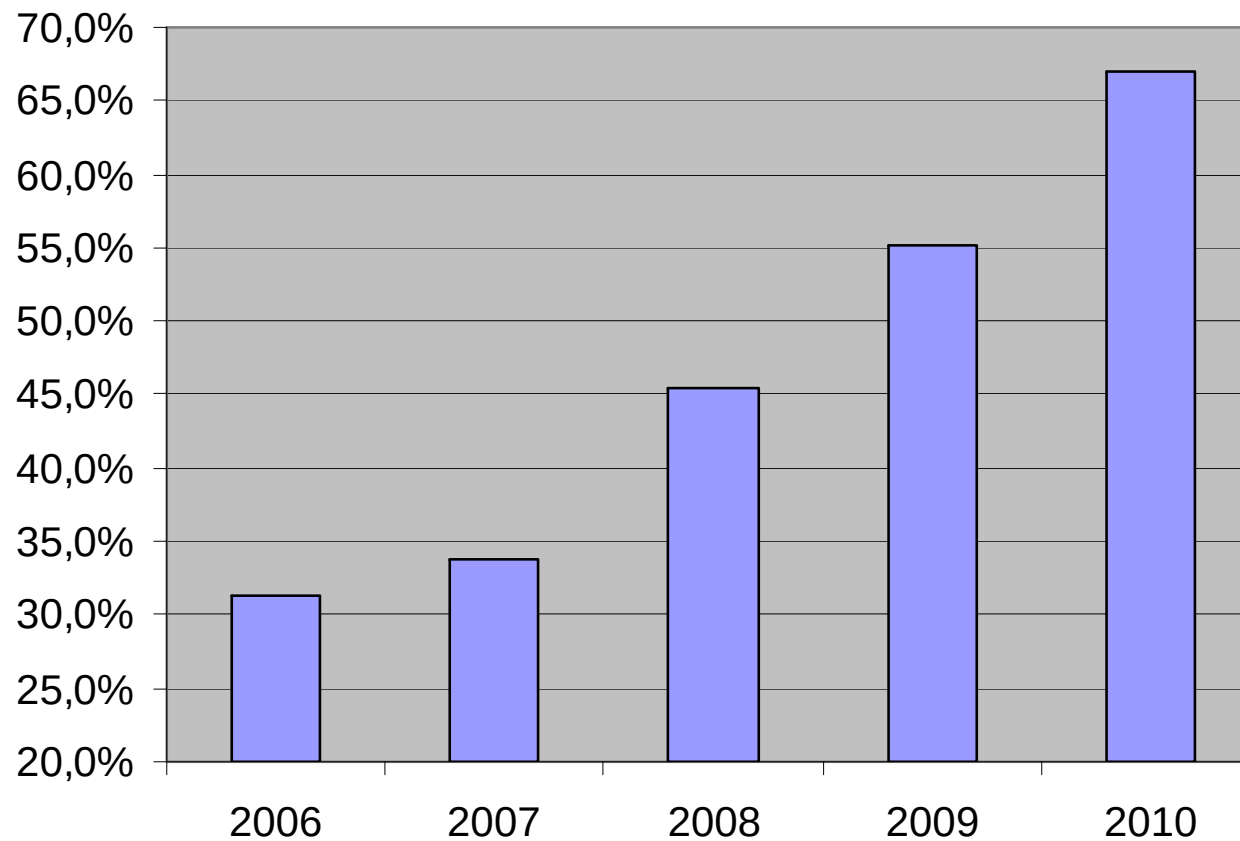
Distribution of heat recovery transfer efficiency



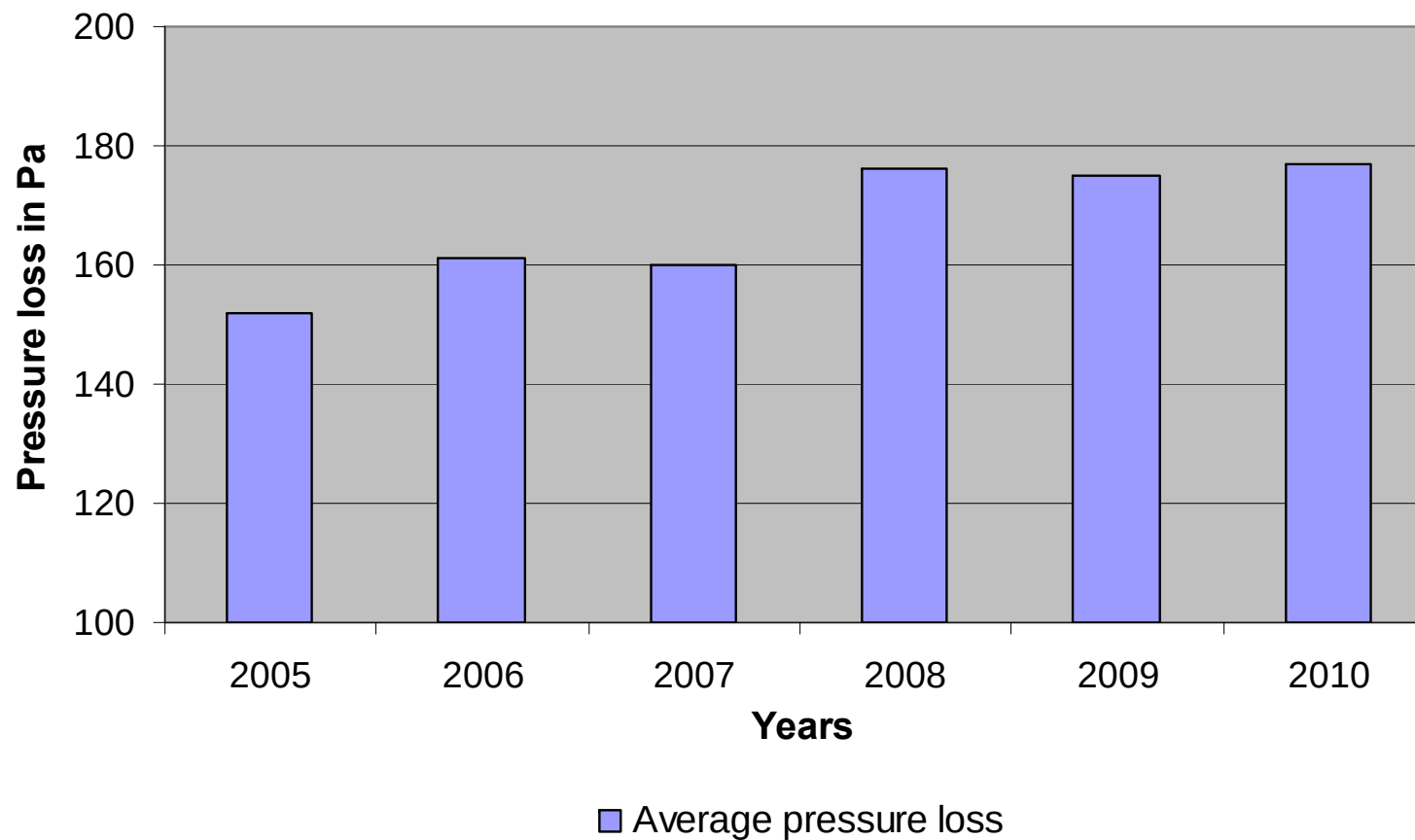
Average HR transfer efficiency



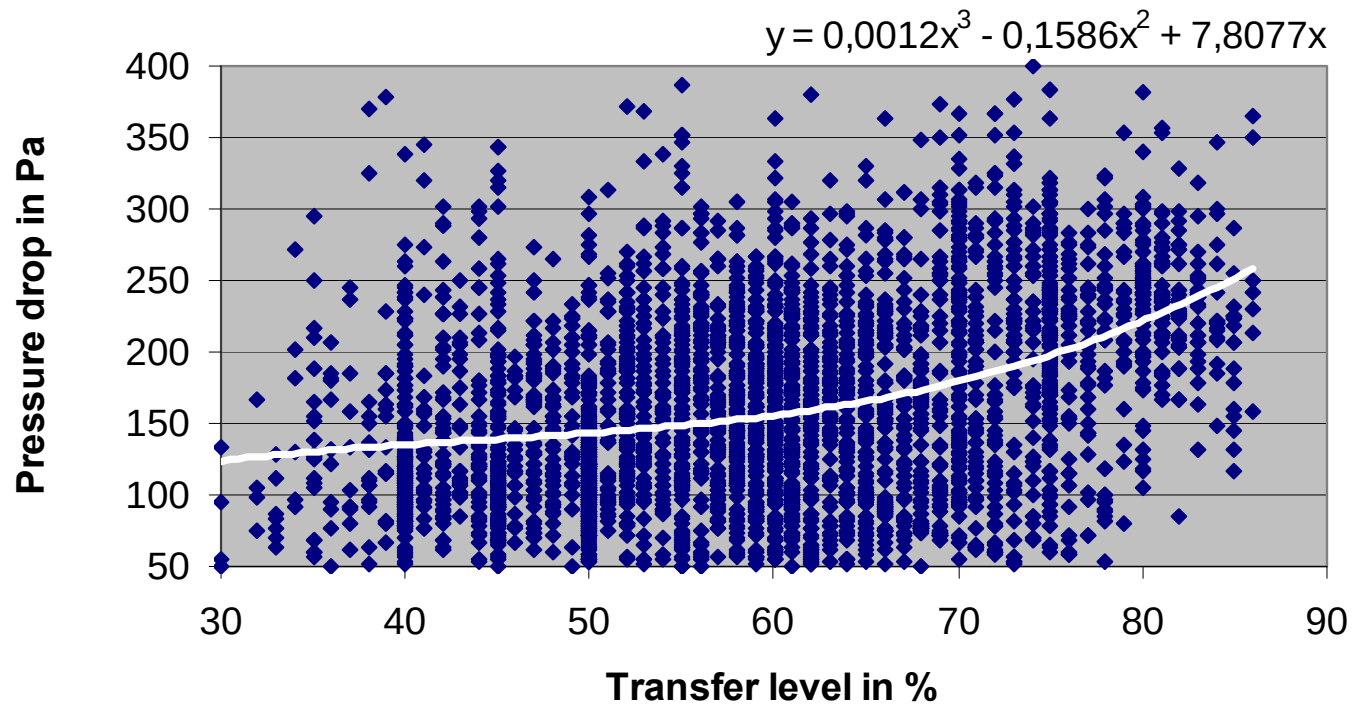
The use of heatrecovery



Average HR pressure loss



Transfer efficiency - pressure drop distribution



◆ Transfer efficiency to air flow rate

Polynomic (Transfer efficiency to air flow rate)

market datas RLT (survey RLT)

Year	Turn-over Mio.€	Export Mio.€	Export %	Units	with HR	HR %
2006	323,8	88,1	27,2	43.759	11.108	31,1
2007	365,5	106,2	29,1	43.656	11.941	33,4
2008	431,4	111,3	25,8	42.236	15.569	45,5
Ø	373,6	101,9	27,4	43.217	12.873	36,7

market datas RLT (survey RLT)

Year	Turn-over Mio.€	Export Mio.€	Export %	Units	with HR	HR %
2008	431,4	111,3	25,8	42.236	15.569	45,5
2009	379,4	96,6	25,5	33.476	15.148	55,1
2010	390,4	103,2	26,4	36.476	19.791	67,0
Ø	400,4	101,9	25,9	37.396	16.836	55,3



market datas RLT (survey RLT)

turnover of association 400,4 Mio. €

additional turnovers 167,6 Mio. €

total 568,0 Mio. €

ratio RLT **70,5 %**

(acc. Dissertation Dr. Beck 2000 University Kassel 70 %)

market datas RLT

possible Units (AHU) with heatrecovery 80,5 %

(Study Dr. Kaup 2009 UCB university of applied science Trier)

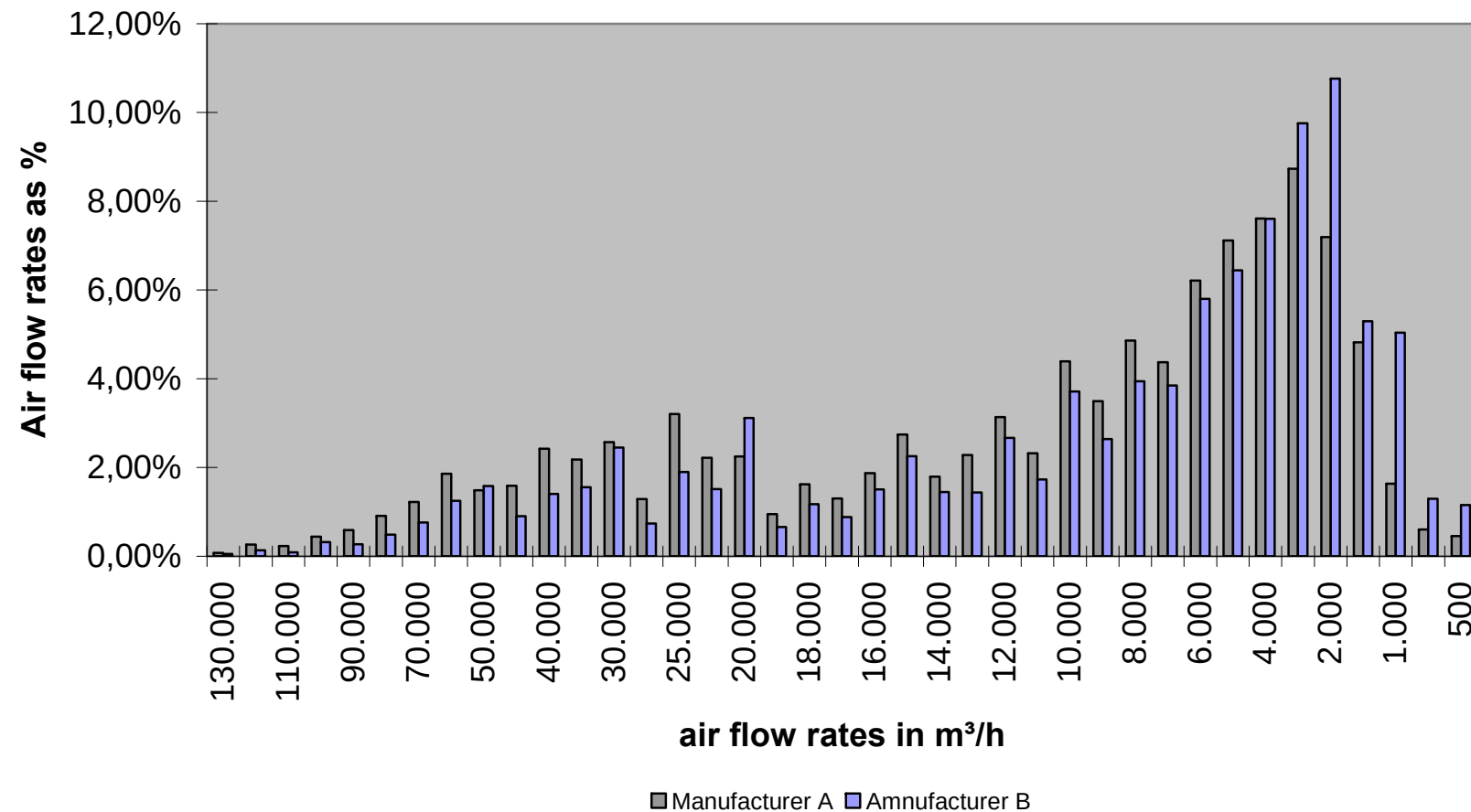
average overall ratio HR (RLT Ø 08 bis 10) 44,5 %

Possible ratio HR **55,3 %**

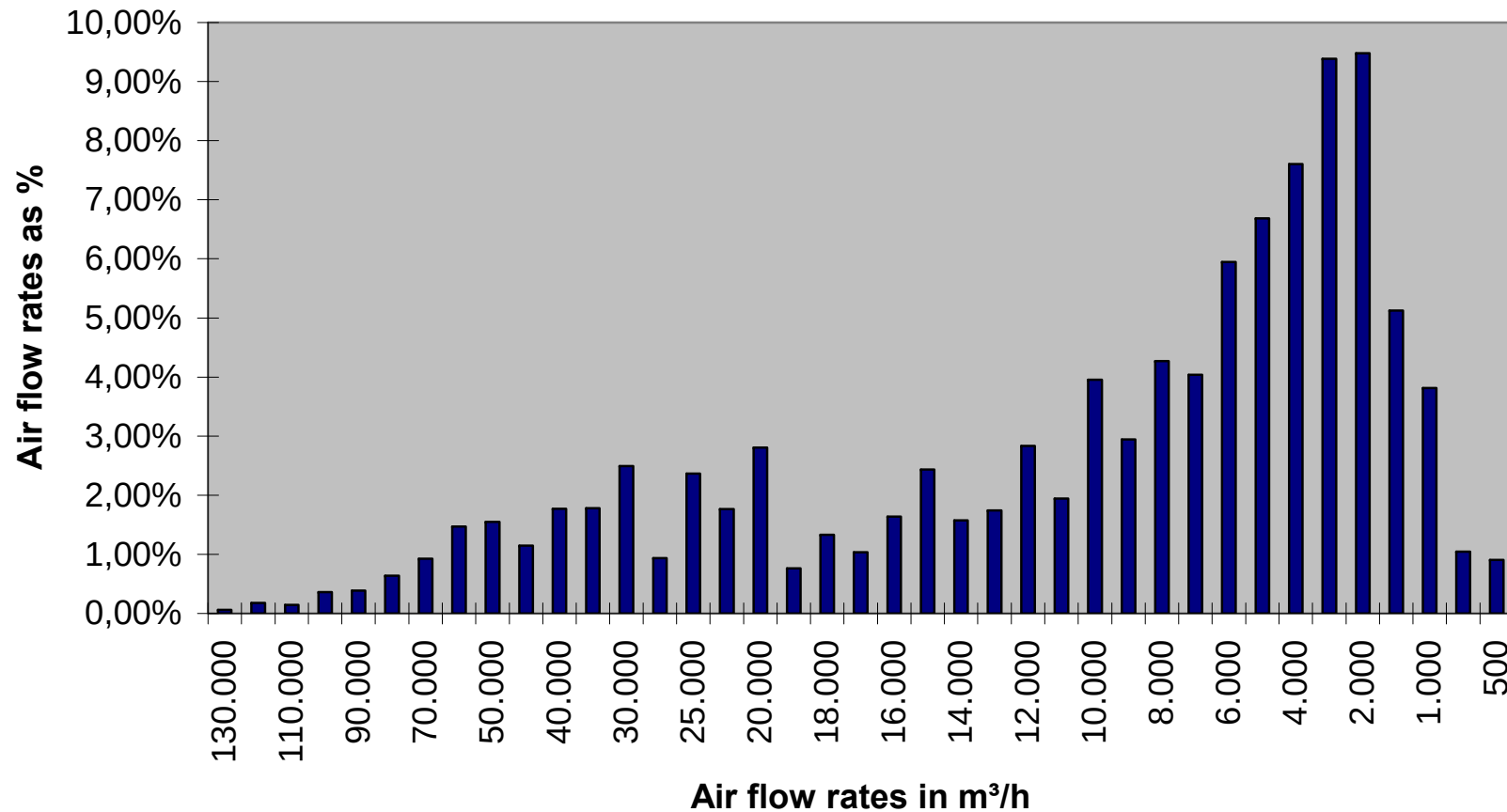
strong positiv development

2010 ratio 55,1 % in total or (possible units) **67,0 %**

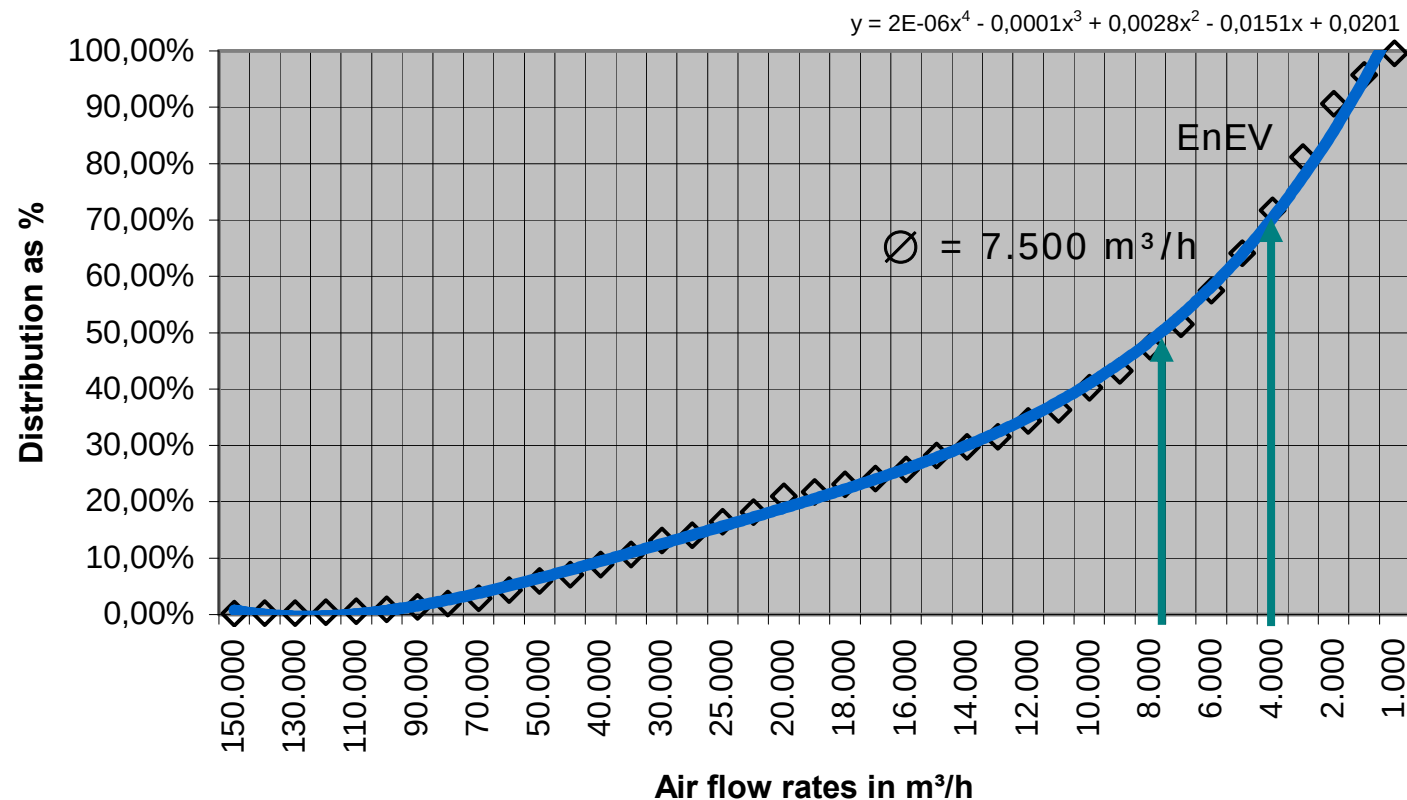
Distribution of air flow rates AHU



Average distribution of air flow rates AHU



Distribution of air flow rates AHU



♦ Air flow rates (Distribution summ) — Polynomic air flow distribution

heat energies

specific energy for heating (24 h/d) 31,33 kWh/(m³/h)/a

(Disseration Dr. Beck 2000 University Kassel)

operating time (average) 2.350 h

(Disseration Dr. Beck 2000 University Kassel)

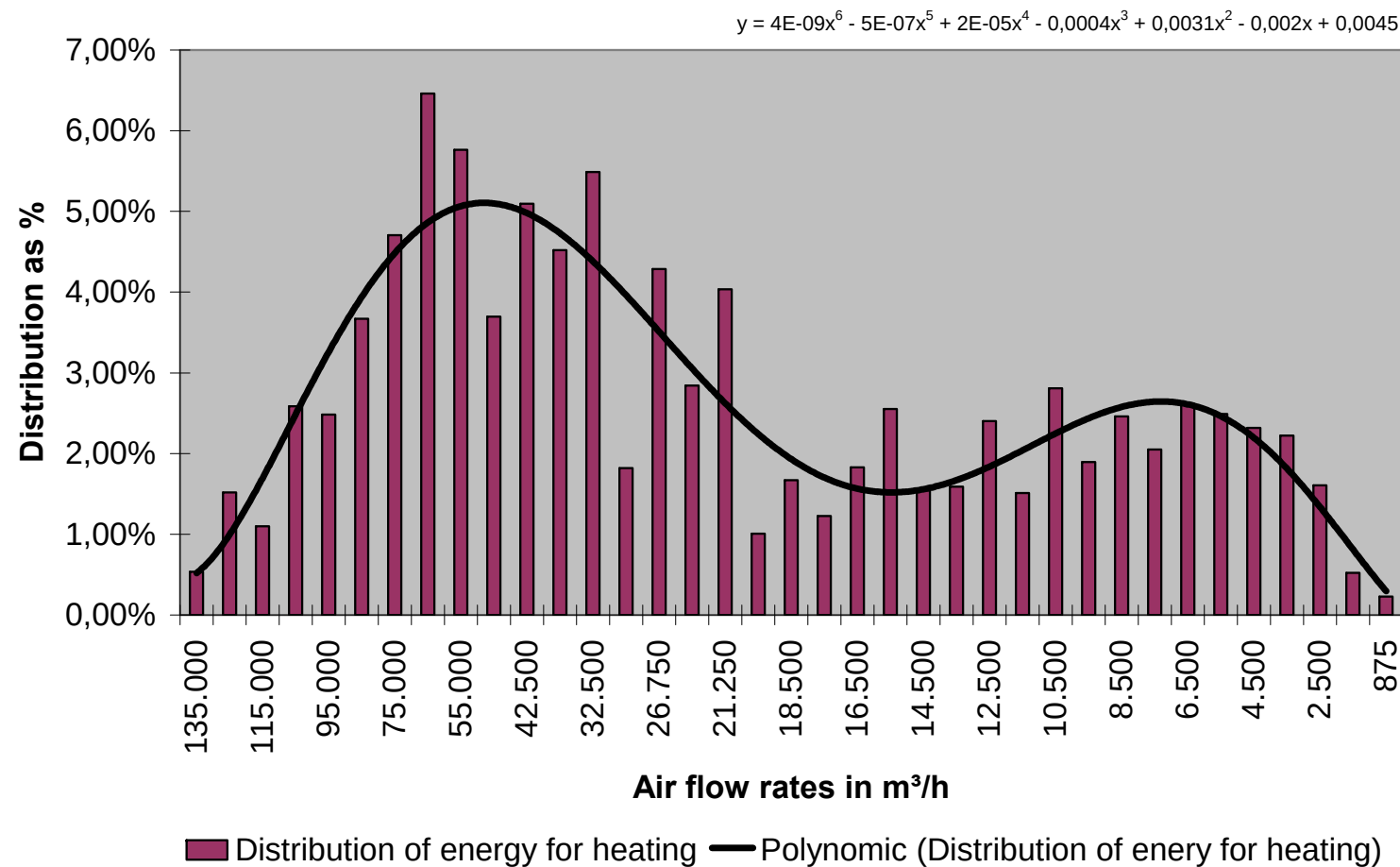
specific energy for heating at 2.350 h **8,4** kWh/(m³/h)/a

lifetime of the units 20,0 years

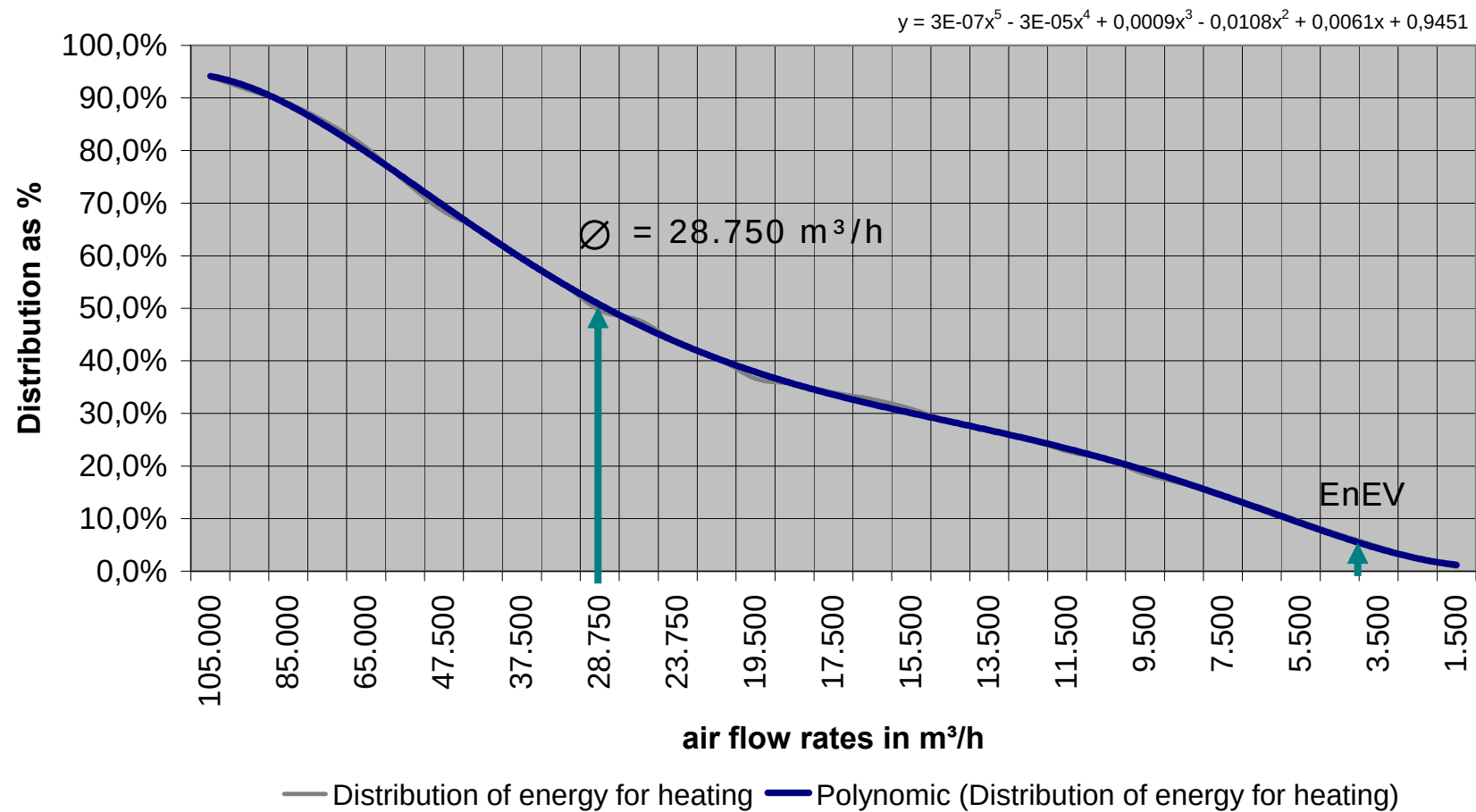
rated lifetime (base interest 2 %) 13,4 years

(1 % new units [38.000 in ´97 to 43.200 in ´09] + 1 % waste rate)

Distribution of energy for heating



Summ of energy for heating



energy saving potential in Germany 2010

AHU's	53.043 units
airflow 2010 (without export)	562,5 Mio. m ³ /h
heat energy demand	4.724.806 MWh/a
HR-ratio	54,3 %
efficiency	67,2 %
HR potential	1.722.716 MWh/a
CO ₂ Saving	566.774 to/a
installed electric power	492.633 KW/a



energy linked to the Gross domestic product

electroenergy demand in germany 492.633 kW/a

GDP Germany 3.667,5 Bil. \$

value $= 492.633 / 3.667,5 \cdot \text{GDP}$

AHU electric power demand EU



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<i>base 2008</i>	<i>population</i>		<i>GDP</i> <i>Bil. \$</i>		<i>demand</i> <i>kW/a</i>
Belgium	10.666.860	2,1%	506,39	2,8%	68.020
Bulgaria	7.606.551	1,5%	51,99	0,3%	6.983
Denmark	5.475.791	1,1%	342,93	1,9%	46.064
Germany	81.882.342	16,4%	3.667,51	19,9%	492.633
Estonia	1.342.000	0,3%	23,23	0,1%	3.120
Finland	5.326.314	1,1%	273,98	1,5%	36.802
France	62.793.432	12,6%	2.865,73	15,6%	384.935
Greece	11.141.740	2,2%	357,55	1,9%	48.027
Great Britain	61.113.205	12,3%	2.674,09	14,5%	359.193
Irland	4.239.848	0,9%	273,33	1,5%	36.715
Italy	60.245.846	12,1%	2.313,89	12,6%	310.810
Latvia	2.261.294	0,5%	34,05	0,2%	4.574
Lithuania	3.354.700	0,7%	47,30	0,3%	6.354
Luxembourg	493.300	0,1%	54,97	0,3%	7.384

AHU electric power demand EU



Umwelt-Campus Birkenfeld
FACHHOCHSCHULE TRIER

<i>base 2008</i>	<i>population</i>		<i>GDP</i> <i>Bil. \$</i>		<i>demand</i> <i>kW/a</i>
Malta	410.290	0,1%	8,34	0,0%	1.120
Netherlands	16.493.156	3,3%	868,94	4,7%	116.719
Austria	8.376.761	1,7%	415,32	2,3%	55.787
Poland	38.153.389	7,7%	525,74	2,9%	70.619
Portugal	10.617.575	2,1%	244,49	1,3%	32.841
Romania	21.498.616	4,3%	199,67	1,1%	26.820
Sweden	9.269.986	1,9%	484,55	2,6%	65.086
Slovakia	5.455.407	1,1%	95,40	0,5%	12.814
Slovenia	2.019.614	0,4%	54,64	0,3%	7.339
Spain	46.661.950	9,4%	1.611,77	8,8%	216.499
Czechia	10.501.197	2,1%	217,08	1,2%	29.159
Hungary	10.020.000	2,0%	156,28	0,8%	20.992
Cyprus	950.000	0,2%	23,45	0,1%	3.150
sum	498.371.164	100,0%	18.392,61	100,0%	2.470.561



AHU saving potential in europe 2011

electroenergy demand base Lifetime 13,4 a and 2.350 h/a	77,80 TWh/a
CO ₂ equivalent Base 541 g/kWh Mix.	42,09 Mil.to/a
saving potential Base 20 % increase of efficiency	15,56 TWh/a
CO ₂ saving	8,42 Mil.to/a

units linked to the gross domestic product

AHUs in germany

53.043 units

GDP Germany

3.667,5 Bil. \$

value

$$= 53.043 / 3.667,5 \cdot \text{GDP}$$

link to population

value

$$= 53.043 / 81.882.342 \cdot P$$

<i>base 2008</i>	<i>population</i>		<i>GDP</i> <i>Bil. \$</i>		<i>units</i>
Belgium	10.666.860	2,1%	506,39	2,8%	7.324
Bulgaria	7.606.551	1,5%	51,99	0,3%	752
Denmark	5.475.791	1,1%	342,93	1,9%	4.960
Germany	81.882.342	16,4%	3.667,51	19,9%	53.043
Estonia	1.342.000	0,3%	23,23	0,1%	336
Finland	5.326.314	1,1%	273,98	1,5%	3.963
France	62.793.432	12,6%	2.865,73	15,6%	41.447
Greece	11.141.740	2,2%	357,55	1,9%	5.171
Great Britain	61.113.205	12,3%	2.674,09	14,5%	38.675
Irland	4.239.848	0,9%	273,33	1,5%	3.953
Italy	60.245.846	12,1%	2.313,89	12,6%	33.466
Latvia	2.261.294	0,5%	34,05	0,2%	492
Lithuania	3.354.700	0,7%	47,30	0,3%	684
Luxembourg	493.300	0,1%	54,97	0,3%	795

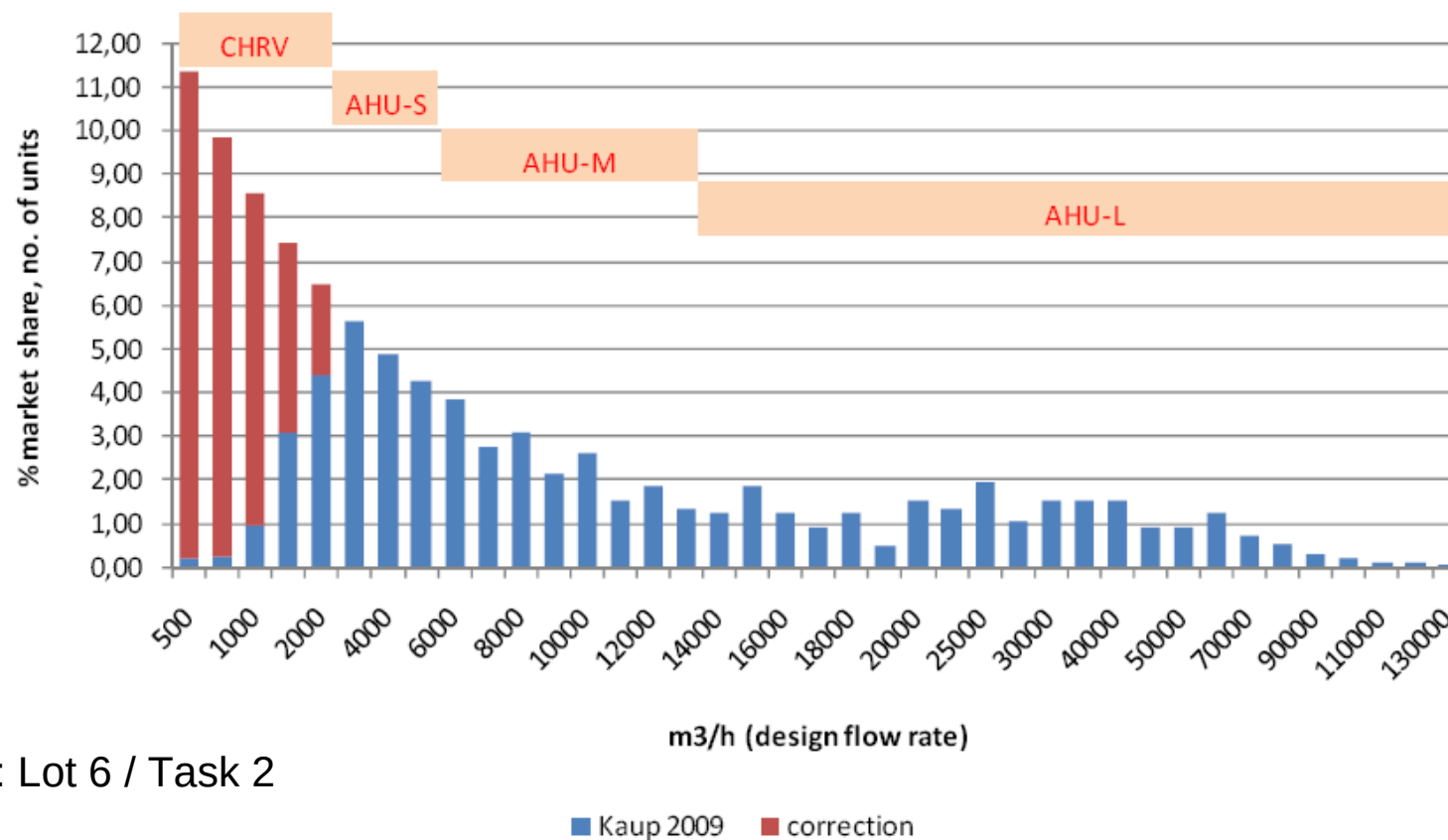
<i>base 2008</i>	<i>population</i>		<i>GDP</i> <i>Bil. \$</i>		<i>units</i>
Malta	410.290	0,1%	8,34	0,0%	121
Netherlands	16.493.156	3,3%	868,94	4,7%	12.567
Austria	8.376.761	1,7%	415,32	2,3%	6.007
Poland	38.153.389	7,7%	525,74	2,9%	7.604
Portugal	10.617.575	2,1%	244,49	1,3%	3.536
Romania	21.498.616	4,3%	199,67	1,1%	2.888
Sweden	9.269.986	1,9%	484,55	2,6%	7.008
Slovakia	5.455.407	1,1%	95,40	0,5%	1.380
Slovenia	2.019.614	0,4%	54,64	0,3%	790
Spain	46.661.950	9,4%	1.611,77	8,8%	23.311
Czechia	10.501.197	2,1%	217,08	1,2%	3.140
Hungary	10.020.000	2,0%	156,28	0,8%	2.260
Cyprus	950.000	0,2%	23,45	0,1%	339
sum	498.371.164	100,0%	18.392,61	100,0%	266.011

AHU market 2011

number of production	266.011 units
+34,8 % CHRV units	356.455 units
AHU's + CHRV's base Lot 6 / Task 2	320.000 units
check (link to population)	322.843 Units (AHU)
	435.192 Units (incl. CHRV)

AHU market 2011

EU-2008 sales size distribution, AHU & CHRV (100%= 320.000 units)



source: Lot 6 / Task 2

energy linked to the gross domestic product

thermal energy saving in germany 1.722.716 MWh/a

GDP Germany 3.667,5 Bil \$

average temp. in Germany 9,0 °C

heatrecovery use • efficiency 36,4 %

nominal supply temperature 21,0 °C

heatrecovery value (U) = $36,4 \% / (21 - 9) \cdot (21 - T)$

energy = $1.722.716 / 3.667,5 / 36,4 \cdot U$
• $GDP / (21 - 9) \cdot (21 - T)$

AHU heat consumption EU



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<i>base 2008</i>	<i>GDP</i>	<i>HR (U)</i>	<i>average</i>	<i>heat</i>	<i>HR</i>
<i>target 21°C</i>	<i>Bil. \$</i>	<i>%</i>	<i>°C</i>	<i>MWh/a</i>	<i>MWh/a</i>
Belgium	506,39	33,4	10,0	598.011	199.871
Bulgaria	51,99	31,9	10,5	58.606	18.697
Denmark	342,93	39,4	8,0	478.608	189.048
Germany	3.667,51	36,4	9,0	4.724.806	1.722.716
Estonia	23,23	50,1	4,5	41.150	20.630
Finland	273,98	48,5	5,0	470.620	228.791
France	2.865,73	30,3	11,0	3.076.569	934.792
Greece	357,55	9,1	18,0	115.157	10.497
Great Britain	2.674,09	33,4	10,0	3.157.913	1.055.459
Ireland	273,33	33,4	10,0	322.784	107.883
Italy	2.313,89	19,7	14,5	1.614.684	318.896
Latvia	34,05	46,7	5,6	56.295	26.341
Lithuania	47,30	44,0	6,5	73.631	32.440
Luxembourg	54,97	36,4	9,0	70.817	25.821

AHU heat consumption EU



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<i>base 2008</i>	<i>GDP</i>	<i>HR (U)</i>	<i>average</i>	<i>heat</i>	<i>HR</i>
<i>target 21 °C</i>	<i>Bil. \$</i>	<i>%</i>	<i>°C</i>	<i>MWh/a</i>	<i>MWh/a</i>
Malta	8,34	6,1	19,0	1.791	109
Netherlands	868,94	34,9	9,5	1.0772.801	374.857
Austria	415,32	34,9	9,5	512.758	179.167
Poland	525,74	45,5	6,0	846.630	385.863
Portugal	244,49	12,1	17,0	104.991	12.760
Romania	199,67	34,9	9,5	246.514	86.137
Sweden	484,55	41,0	7,5	702.269	288.062
Slovakia	95,40	42,8	6,9	144.411	61.868
Slovenia	54,64	33,1	10,1	63.939	21.176
Spain	1.611,77	12,1	17,0	692.141	84.121
Czechia	217,08	39,7	7,9	305.297	121.518
Hungary	156,28	34,3	9,7	189.589	65.094
Cyprus	23,45	0,0	21,0	0	0
sum	18.392,61	33,2	10,9	19.742.781	6.572.614



AHU saving potential in europe 2011

heating demand	19.724.781MWh/a
heatrecovery	6.572.614MWh/a
CO ₂ saving base 329 kg/MWh	2.162.195 to/a
electroenergy demand	2.470.561 KW/a

AHU saving potential in europe 2011

heating demand during lifetime base Lifetime 13,4 a and 2.350 h/a	264,55 TWh/a
heatrecovery state of the art 2010	<u>88,00</u> TWh/a
CO ₂ saving equivalent base 329 kg/MWh	28,98 Mil.to/a
average heatrecovery 0,58 average efficiency and 47 % use	53,28 TWh/a
max. potential heatrecovery base 0,75 efficiency and 81 % balanced units	146,62 TWh/a

energy linked to the gross domestic product

colth energy saving in germany 111.273 MWh/a

GDP Germany 3.667,5 Bil. \$

average temp. in Germany 9,0 °C

nominal ODA temperature for cooling 25,0 °C

cooling factor relativ to germany $f = (25 - 9) / (25 - T)$

energy demand $= 111.273 / 3.667,5 \cdot \text{GDP} \cdot f$

(sensible capacity without dehumification)

energy recovery $= \text{energy} \cdot U$

AHU colth consumption EU



Umwelt-Campus Birkenfeld
FACHHOCHSCHULE TRIER

<i>base 2008</i>	<i>GDP</i>	<i>HR (U)</i>	<i>colling</i>	<i>colth</i>	<i>HR</i>
<i>target 16 °C / 25 °C</i>	<i>Bil. \$</i>	<i>%</i>	<i>factor</i>	<i>MWh/a</i>	<i>MWh/a</i>
Belgium	506,39	33,4	1,07	45.022	15.023
Bulgaria	51,99	31,9	1,10	4.782	1.523
Denmark	342,93	39,4	0,94	26.902	10.609
Germany	3.667,51	36,4	1,00	305.694	111.273
Estonia	23,23	50,1	0,78	1.511	756
Finland	273,98	48,5	0,80	18.269	8.867
France	2.865,73	30,3	1,14	272.988	82.806
Greece	357,55	9,1	2,29	68.120	6.199
Great Britain	2.674,09	33,4	1,07	237.750	79.329
Irland	273,33	33,4	1,07	24.301	8.109
Italy	2.313,89	19,7	1,52	293.893	57.946
Latvia	34,05	46,7	0,82	2.341	1.093
Lithuania	47,30	44,0	0,86	3.410	1.500
Luxembourg	54,97	36,4	1,00	4.582	1.668

AHU heat consumption EU



Umwelt-Campus Birkenfeld
FACHHOCHSCHULE TRIER

<i>base 2008</i>	<i>GDP</i>	<i>HR (U)</i>	<i>cooling</i>	<i>colth</i>	<i>HR</i>
<i>target 16 °C / 25 °C</i>	<i>Bil. \$</i>	<i>%</i>	<i>factor</i>	<i>MWh/a</i>	<i>MWh/a</i>
Malta	8,34	6,1	2,67	1.854	112
Netherlands	868,94	34,9	1,03	74.764	26.080
Austria	415,32	34,9	1,03	35.734	12.465
Poland	525,74	45,5	0,84	36.902	16.791
Portugal	244,49	12,1	2,00	40.757	4.945
Romania	199,67	34,9	1,03	17.180	5.993
Sweden	484,55	41,0	0,91	36.926	15.121
Slowakia	95,40	42,8	0,88	7.029	3.006
Slovenia	54,64	33,1	1,07	4.891	1.617
Spain	1.611,77	12,1	2,00	268.688	32.601
Czechia	217,08	39,7	0,94	16.930	6.727
Hungary	156,28	34,3	1,05	13.622	4.669
Cyprus	23,45	0,0	4,00	7.818	0
sum	18.392,61	33,2		1.872.662	516.828

AHU electric power demand EU+



Umwelt-Campus Birkenfeld
FACHHOCHSCHULE TRIER

<i>base 2008</i>	<i>population</i>		<i>GDP</i> <i>Bil. \$</i>		<i>demand</i> <i>kW/a</i>
Albania	3.170.048	1,0%	12,96	0,3%	1.741
Andorra	83.888	0,0%	3,50	0,1%	470
Belarus	9.489.000	3,0%	60,29	1,6%	8.098
Bosnia-Herzegovina	4.552.000	1,4%	18,47	0,5%	2.481
Georgia	4.693.892	1,5%	22,02	0,6%	2.958
Croatia	4.489.409	1,4%	69,33	1,8%	9.313
Macedonia	2.063.122	0,6%	9,57	0,3%	1.285
Moldava	4.455.421	1,4%	6,12	0,2%	822
Norway	4.825.500	1,5%	456,23	12,0%	61.282
Russia	142.400.000	44,4%	1.676,59	44,1%	225.206
San Marino	31.538	0,0%	1,18	0,0%	159
Swiss	7.701.900	2,4%	492,60	13,0%	66.168
Serbia-Montenegro	10.829.175	3,4%	54,88	1,4%	7.372

AHU electric power demand EU+



Umwelt-Campus Birkenfeld
FACHHOCHSCHULE TRIER

<i>base 2008</i>	<i>population</i>		<i>GDP</i> <i>Bil. \$</i>		<i>demand</i> <i>kW/a</i>
Turkey	75.863.600	23,7%	729,44	19,2%	97.981
Ukraine	45.994.247	14,3%	179,73	4,7%	24.142
Monaco	32.796	0,0%	3,67	0,1%	493
Lichtenstein	35.789	0,0%	4,93	0,1%	662
sum	320.711.325	100,0%	3.801,51	100,0%	510.632

AHU heat consumption EU+



Umwelt-Campus Birkenfeld
FACHHOCHSCHULE TRIER

<i>base 2008</i>	<i>GDP</i>	<i>use</i>	<i>average</i>	<i>heat</i>	<i>HR</i>
	<i>Bil. \$</i>	<i>%</i>	<i>°C</i>	<i>MWh/a</i>	<i>MWh/a</i>
Albania	12,96	15,2	16,0	6.957	1.057
Andorra	3,50	33,4	10,0	4.133	1.381
Belarus	60,29	47,3	5,4	100.972	47.860
Bosnia-Herzegovina	18,47	27,3	12,0	17.846	4.880
Georgia	22,02	24,6	12,9	19.148	4.713
Croatia	69,33	30,3	11,0	74.431	22.615
Macedonia	9,57	33,4	10,0	11.301	3.777
Moldava	6,12	38,5	8,3	8.344	3.220
Norway	456,23	45,5	6,0	734.694	334.847
Russia	1.676,59	47,3	5,4	2.807.908	1.330.932
San-Marino	1,18	19,7	14,5	823	163
Swiss	492,60	39,1	8,1	682.206	267.395
Serbia-Montenegro	54,88	30,3	11,0	58.918	17.902

AHU Heat consumption EU+



Umwelt-Campus Birkenfeld
FACHHOCHSCHULE TRIER

<i>base 2008</i>	<i>GDP</i>	<i>use</i>	<i>average</i>	<i>heat</i>	<i>HR</i>
	<i>Bil. \$</i>	<i>%</i>	<i>°C</i>	<i>MWh/a</i>	<i>MWh/a</i>
Turkey	729,44	19,7	14,5	509.019	100.530
Ukraine	179,73	42,5	7,0	270.134	114.910
Monaco	3,67	14,0	16,4	1.812	253
Lichtenstein	4,93	31,2	10,7	5.451	1.706

sum	3.801,51	42,5	8,5	5.314.100	2.258.142
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Thank you



for your Attention

Study of energy efficiency in air handling units

Heat recovery and electric power efficiencies in AHU's

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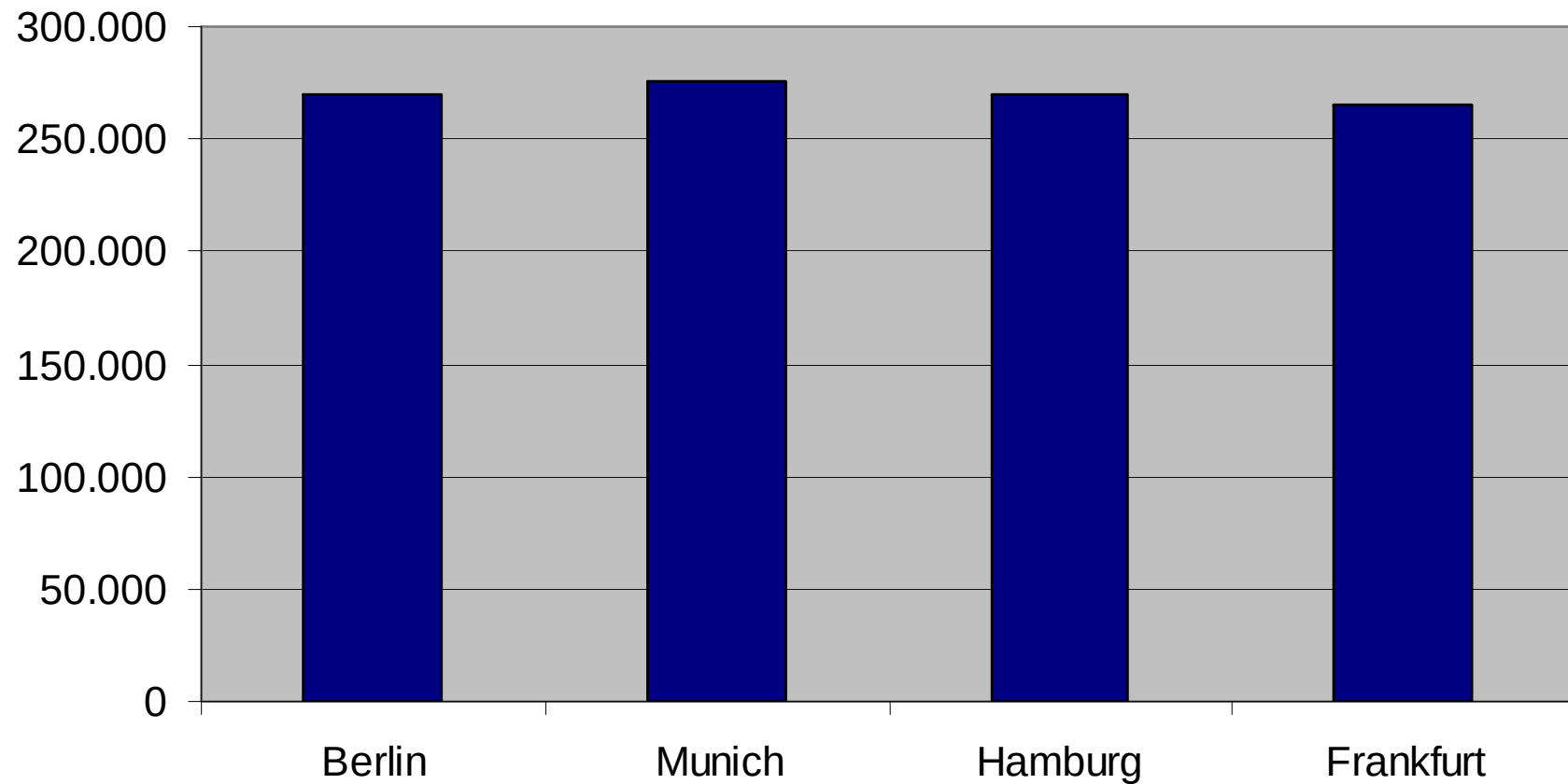
LCC influence - location



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LCC Total in €



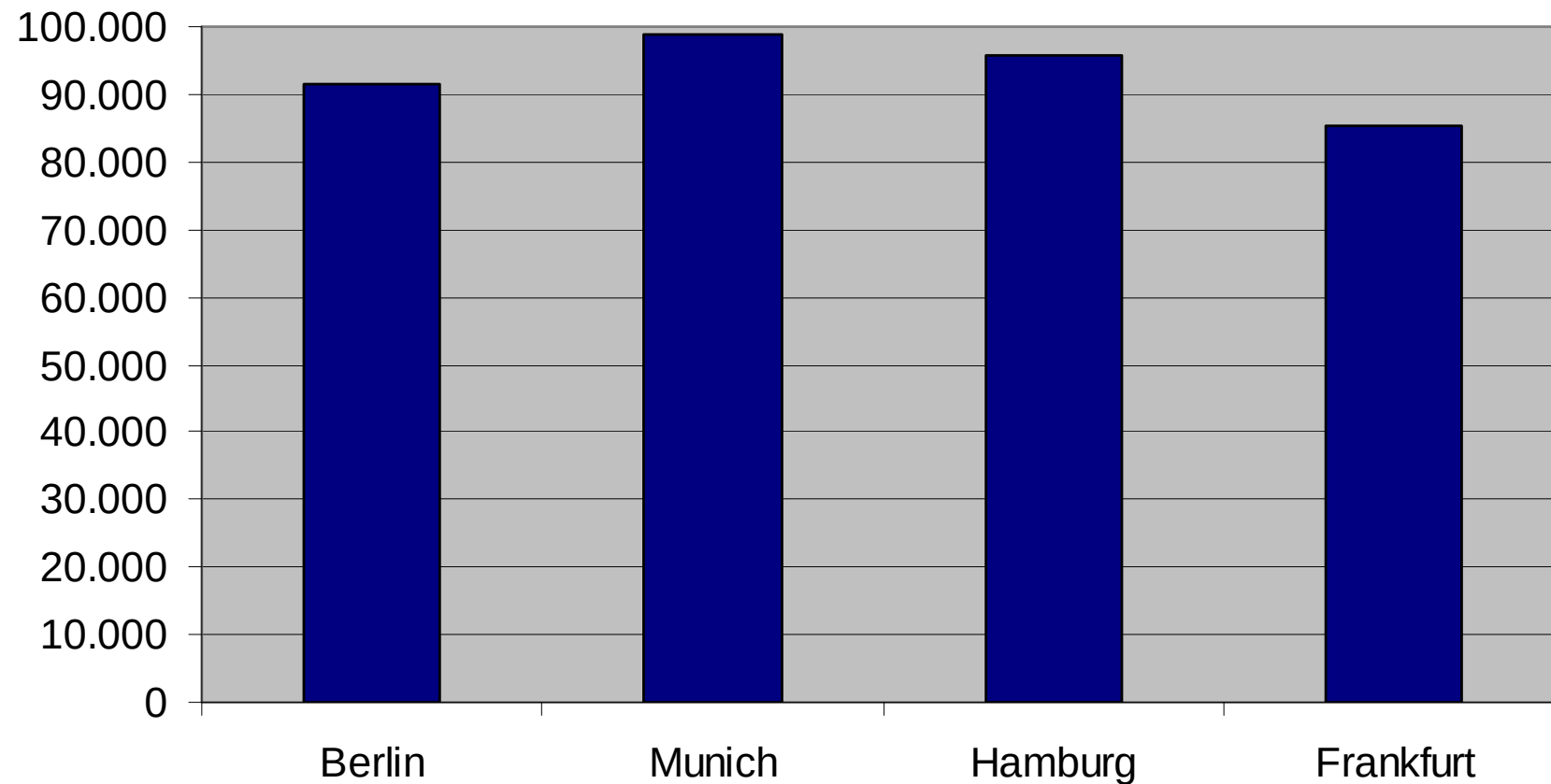
LCC influence - location



Umwelt-Campus Birkenfeld
FACHHOCHSCHULE TRIER



LCC heating in €



<i>calculation variant</i>	<i>extract air conditions winter/summer</i>	<i>supply air conditions winter/summer</i>
1	20 / 26 °C Higher load	21 / 19 °C Higher heat demand
2	18 / 24 °C Lower load	21 / 19 °C Higher heat demand
3	20 / 26 °C Higher load	20 / 18 °C Lower heat demand
4	18 / 24 °C Lower load	22 / 20 °C High heat demand
5	20 / 26 °C Higher load	18 / 16 °C High cooling demand

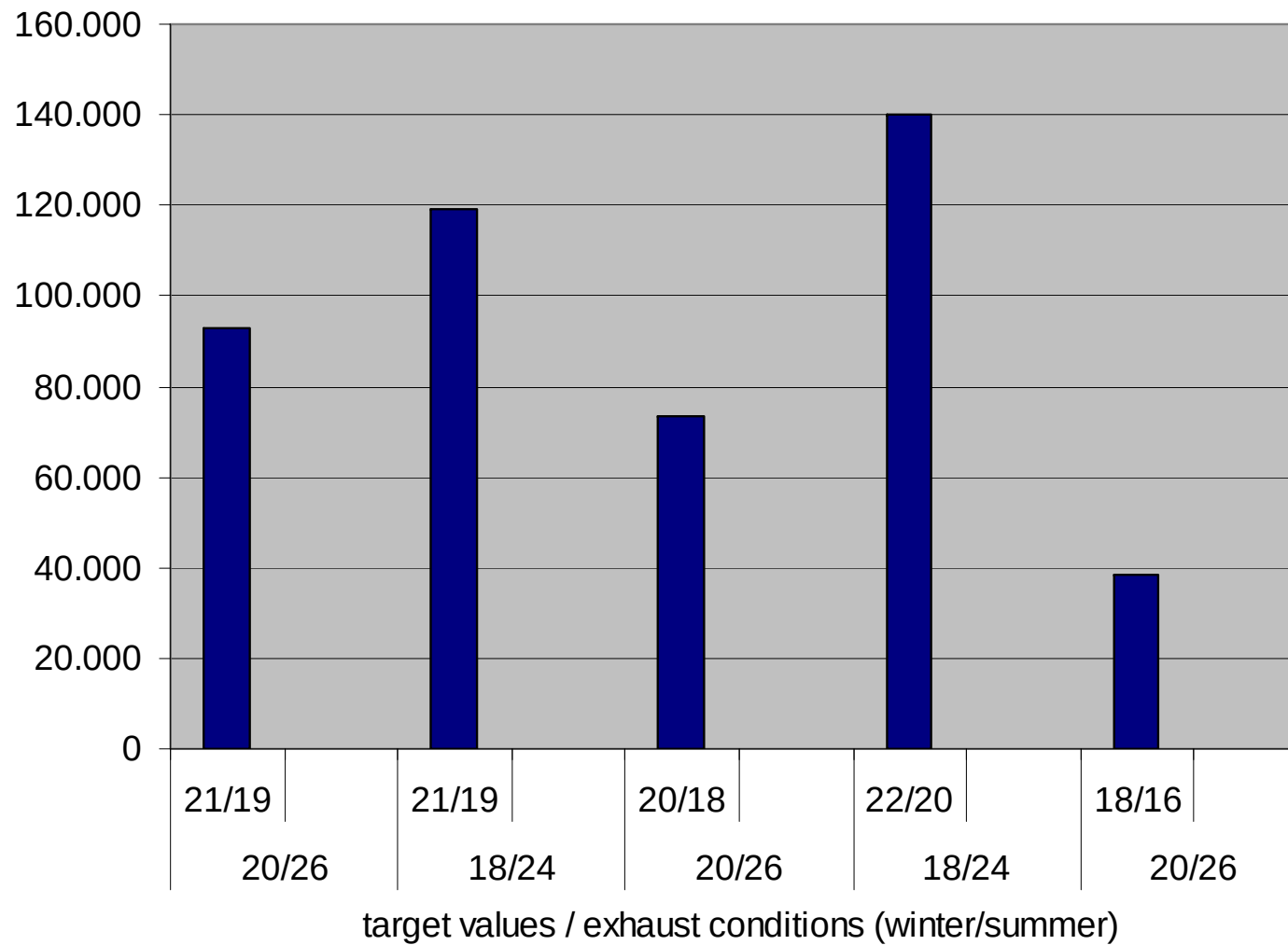
LCC influence - conditions



Umwelt-Campus Birkenfeld
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LCC heating in €



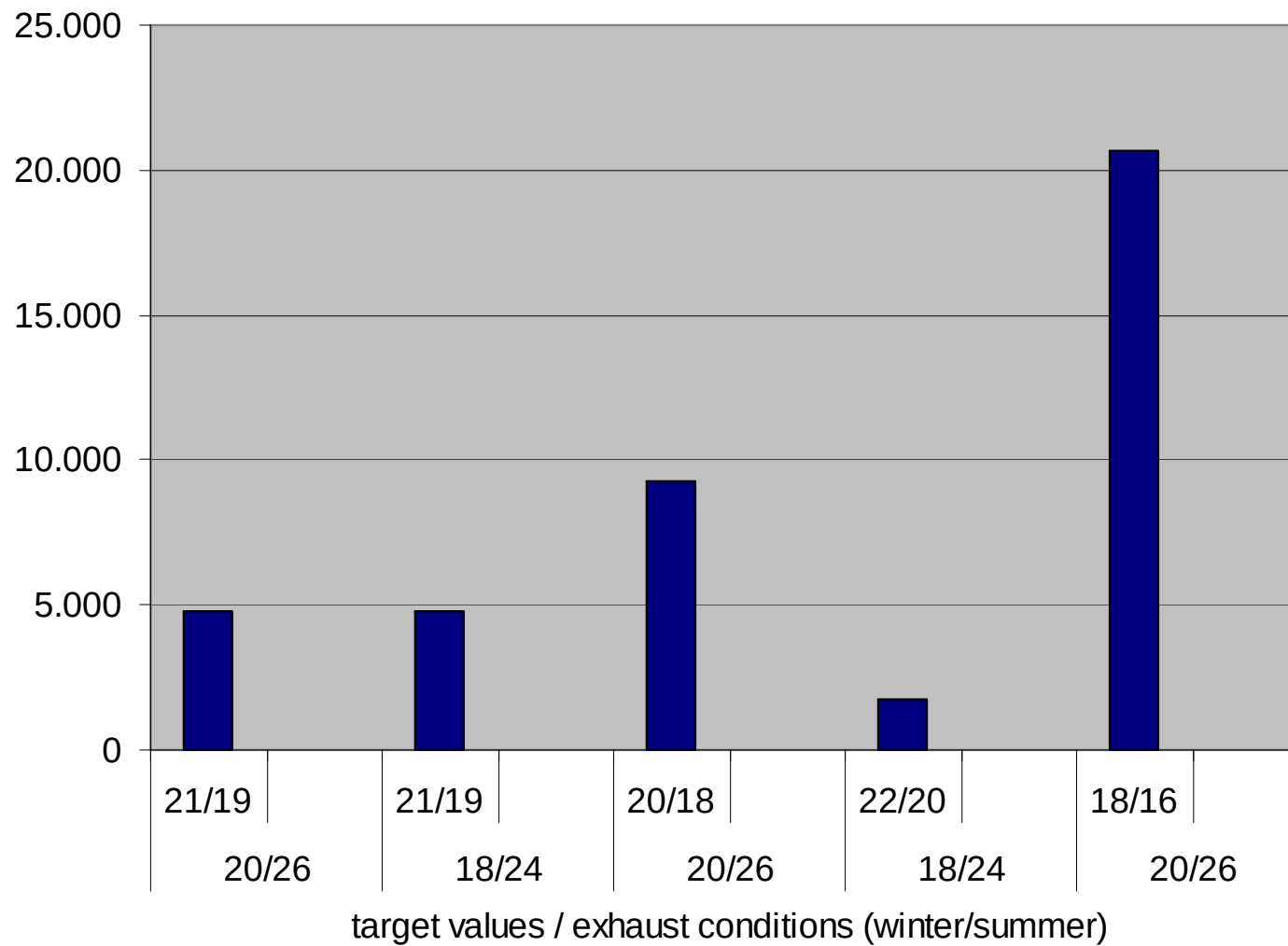
LCC influence - conditions



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LCC cooling in €



LCC influence - conditions



Umwelt-Campus Birkenfeld
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LCC Total in €

