

Contents

1	Introduction	1
2	Fundamentals of Energy Efficiency	3
2.1	Legal Framework	4
2.2	Considerations on the Systematics of Energy Efficiency	10
2.2.1	General Measures to Improve Energy Efficiency	13
2.3	Methods	18
2.3.1	Technical Analyses	19
2.3.2	Economic Analyses	21
2.3.3	Stationary and Mobile Measurement Technology	38
	Literature	46
3	Electricity-Based Enabling Technologies	51
3.1	Electrical Power Supply	51
3.1.1	Transformers	51
3.1.1.1	Basics	51
3.1.1.2	Power Factor Correction	55
3.1.1.3	Uninterruptible Power Supply	58
3.1.1.4	Cable Dimensioning	58
3.1.2	Recommendations	59
3.2	Electric Lighting	60
3.2.1	Basics	60
3.2.2	Measures	67
3.2.2.1	Energy-Efficient Light Sources and Lighting Technology	68
3.2.2.2	Lighting Management	70
3.2.3	Recommendations	71
3.3	Electric Drives	72
3.3.1	Basics	73
3.3.2	The Economic Efficiency of Drive Systems	78

3.3.3	Measures	80
3.3.3.1	Optimising the Efficiency of the e-Machine	80
3.3.3.2	Optimising the Efficiency of the Drive System	82
3.3.4	Recommendations	85
3.4	Fans	86
3.4.1	Basics	87
3.4.2	Measures	88
3.4.2.1	Correct Dimensioning	88
3.4.2.2	Use of Efficient Fans	88
3.4.2.3	Speed Adjustment	89
3.4.2.4	Maintaining Performance Through Maintenance	90
3.4.3	Recommendations	90
3.5	Pumps	91
3.5.1	Basics	92
3.5.2	Measures	95
3.5.2.1	Dimensioning the Pump	96
3.5.2.2	Optimisation of the Pump System and the Control System	96
3.5.2.3	Optimisation of Existing Pump Systems	103
3.5.3	Recommendations	105
3.6	Electricity-Based Basic Technologies for Heat Generation	106
	Literature	110
4	Fuel-Based Enabling Technologies	113
4.1	Heat Generation by Means of Burners	113
4.1.1	Basics	113
4.1.2	Measures	117
4.1.2.1	Substitution of a Cold Air Burner by a Hot Air, Recuperator or Regenerator Burner	118
4.1.2.2	Substitution of a Regenerator, Recuperator, Hot Air or Cold Air Burner by an Oxygen Burner	118
4.1.2.3	Substitution of a Recuperator or Hot Air Burner by a FLOX Burner	119
4.1.2.4	Substitution of a Recuperator Burner by a Regenerator Burner	120
4.1.2.5	Further Measures	121
4.1.3	Recommendations	121
4.2	Heat Exchangers for Heat Recovery and Waste Heat Utilisation	123
4.2.1	Basics	126
4.2.2	Measures	127
4.2.2.1	Maintenance and Cleaning	128

4.2.2.2	Feeding into Heat Networks	128
4.2.2.3	Mobile Thermal Storage Units	129
4.2.2.4	Use of Waste Water Heat	130
4.2.2.5	Electricity Generation from Waste Heat	131
4.2.3	Recommendations	135
4.3	Heat and Cold Insulation	135
4.3.1	Basics	136
4.3.2	Measures	138
4.3.3	Recommendations	139
	Literature	139
5	Electricity-Based Cross-Section Processes	143
5.1	Compressed Air	143
5.1.1	Basics	144
5.1.2	Measures	147
5.1.2.1	Dimensioning of Compressed Air Systems	148
5.1.2.2	Use of Speed-Controlled Compressor Drives	149
5.1.2.3	Leakage in Compressed Air Systems	150
5.1.2.4	Maintenance	151
5.1.2.5	Waste Heat Recovery from Compressed Air Systems	152
5.1.2.6	Substitution of Compressed Air Applications	152
5.1.2.7	Organisational Measures	152
5.1.3	Recommendations	153
5.2	Data Centers	154
5.2.1	Basics	154
5.2.2	Measures	157
5.2.2.1	Efficient Use of Efficient IT Hardware	157
5.2.2.2	Efficient Storage and Data Management	157
5.2.2.3	Cooling Optimisation	159
5.2.2.4	Optimisation of the Power Supply	163
5.2.3	Recommendations	165
5.3	Electroplating	166
5.3.1	Basics	167
5.3.2	Measures	168
5.3.2.1	Reduction of Voltage Losses	168
5.3.2.2	Optimisation of the Airflow	169
5.3.2.3	Process Heating	172
5.3.2.4	Process Cooling	173
5.3.2.5	Optimisation of the Rectifier	174
5.3.3	Recommendations	175
	Literature	176

6	Fuel-Based Cross-Sectional Processes	179
6.1	Boilers for Steam Generation	179
6.1.1	Basics	180
6.1.2	Measures	182
6.1.2.1	Installation of a Caustic Expansion and Cooling System	183
6.1.2.2	Installation of an Economiser	183
6.1.2.3	Benefits of Condensing Boiler Technology	184
6.1.2.4	Installation of a Closed Condensate Return System	185
6.1.2.5	Heat Recovery from Steam	186
6.1.2.6	Stepless Burner Control	186
6.1.2.7	Measures from Other Basic and Cross-Cutting Technologies	186
6.1.3	Recommendations	187
6.2	Industrial Furnaces	188
6.2.1	Basics	188
6.2.2	Measures	191
6.2.2.1	Improvement of the Wall Structure by Means of Insulation	192
6.2.2.2	Heating and Optimisation of Burner Technology	194
6.2.2.3	Waste Heat Recovery	195
6.2.2.4	Intelligent Control and Regulation Technology	196
6.2.3	Recommendations	196
6.3	Drying Plants	197
6.3.1	Basics	200
6.3.2	Measures	202
6.3.2.1	Mechanical Pre-Drying	202
6.3.2.2	Optimisation of Heating and Insulation	203
6.3.2.3	Hot Steam drying Instead of Fresh Air Drying	203
6.3.2.4	Dry Air Drying by Means of Refrigeration Dryers	204
6.3.2.5	Improving Process Control	204
6.3.2.6	Alternative Drying Processes	205
6.3.3	Recommendations	208
6.4	Painting Systems	209
6.4.1	Basics	210
6.4.2	Measures	214
6.4.2.1	Planning and Organisational Measures	214
6.4.2.2	Optimisation of Pre-treatment	216
6.4.2.3	Optimisation in the Area of Paint Application	220
6.4.2.4	Optimisation of the Paint Drying/Curing Process	224
6.4.3	Recommendations	228
	Literature	229

7	Coupled and Other Cross-Sectional Processes	233
7.1	Combined Production and Use of Electricity and Heat	233
7.1.1	Basics	234
7.1.1.1	Combined Heat and Power Plants	235
7.1.1.2	Steam Turbine	238
7.1.1.3	Heat Pumps and Chillers	240
7.1.2	Measures	243
7.1.3	Recommendations	244
7.2	Heating, Ventilation and Air-conditioning Systems for Industrial Buildings	246
7.2.1	Basics	247
7.2.2	Measures	247
7.2.2.1	Heat Recovery	248
7.2.2.2	Maintenance and Servicing	250
7.2.2.3	Ceiling Spotlights	250
7.2.2.4	Optimisation of Building Operation	251
7.2.3	Recommendations	252
7.3	Refrigeration	253
7.3.1	Basics	256
7.3.2	Measures	260
7.3.2.1	Drawing up an Inventory of Refrigeration Systems and Operating Methods	261
7.3.2.2	Minimisation of the Cooling Demand	262
7.3.2.3	Reduction of Electricity Consumption for Refrigeration	263
7.3.2.4	Control Optimisation of Refrigeration Systems	264
7.3.2.5	Optimisation of Power, Pressure and Temperature Levels	266
7.3.3	Recommendations	267
7.4	Other Cross-Cutting Processes	268
7.4.1	Conveyor Technology	268
7.4.2	Handling Technology	269
7.4.3	Industrial Gases	271
7.4.4	Welding	274
7.4.5	Waste Water Treatment	275
7.4.6	Vacuum Technology	276
	Literature	278
8	Industries with Their Highly Specialized or Energy-Intensive Processes	283
8.1	Manufacture of Basic Chemicals	286
8.1.1	The Sector	287
8.1.2	Fundamentals of the Technology	287

8.1.3	Individual Processes and Measures	293
8.1.3.1	Ethylene	293
8.1.3.2	Propene	294
8.1.3.3	Methanol	295
8.1.3.4	Benzene	297
8.1.3.5	Chlorine	299
8.1.3.6	Ammonia	301
8.1.3.7	Soda Ash	302
8.1.3.8	Phosphoric Acid	303
8.1.4	Recommendations for Energy Optimisation in the Chemical Industry	304
8.1.5	Savings Potential Curve	304
8.2	Manufacture of Iron and Steel	307
8.2.1	The Sector	308
8.2.1.1	Fundamentals of the Technology	308
8.2.2	Individual Processes and Measures	309
8.2.2.1	Dry Coke Cooling	309
8.2.2.2	Gas Recirculation on Sintering Equipment	310
8.2.2.3	Energy Efficiency Measures at the Blast Furnace and Steelworks	310
8.2.2.4	Energy Efficiency Measures for Electric Arc Furnaces	312
8.2.2.5	Alternative Reduction Processes	314
8.2.2.6	Secondary Metallurgy, Primary Forming, Rolling, Bending, Surface Treatment	315
8.2.2.7	Cross-Process Energy Efficiency Measures	316
8.2.2.8	Recommendations for Energy Optimisation in Iron/Steel Production	317
8.2.3	Savings Potential Curve	318
8.3	Production of Aluminium and Non-ferrous Metals	322
8.3.1	The Sector	323
8.3.2	Fundamentals of the Technology	324
8.3.3	Individual Processes and Measures	326
8.3.3.1	Energy Efficiency Measures in Primary Aluminium Electrolysis	326
8.3.3.2	Efficiency Potentials in Anode Production	328
8.3.3.3	Optimisation of Copper Production	329
8.3.4	Recommendations for the Energetic Optimisation of Metal Production	333
8.3.5	Savings Potential Curve	333

8.4	Manufacture of Glass and Ceramics	335
8.4.1	The Sector	335
8.4.2	Fundamentals of the Technology	335
8.4.2.1	Optimum Composition of the Charge	337
8.4.3	Individual Processes and Measures	338
8.4.3.1	Optimisation of the Furnace and Firing System	338
8.4.3.2	Recommendations for the Energetic Optimisation of Glass Production	341
8.4.4	Savings Potential Curve	342
8.5	Production of Cement	344
8.5.1	The Sector	344
8.5.2	Fundamentals of the Technology	344
8.5.3	Individual Processes and Measures	347
8.5.3.1	Burning Clinker in the Kiln Process	347
8.5.3.2	Grinding of Clinker and Additives to Cement	348
8.5.3.3	Overall Process Optimisation	349
8.5.3.4	Recommendations for Energy-Efficient Cement Production	351
8.5.4	Savings Potential Curve	351
8.6	Manufacture of Mechanical Pulp, Paper and Paperboard	354
8.6.1	The Sector	354
8.6.2	Fundamentals of the Technology	354
8.6.3	Individual Processes and Measures	360
8.6.3.1	Optimised Paper Drying Through Adjusted Temperature and Pressure Parameters	360
8.6.3.2	Optimisation of the Paper Machine Operation	361
8.6.3.3	Thermal Recovery of Black Liquor	362
8.6.3.4	Recommendations for Energy-Efficient Paper Production	362
8.6.4	Savings Potential Curve	362
8.7	Processing of Metals	364
8.7.1	Casting	365
8.7.1.1	Optimisation of Melting and Furnace Technology	366
8.7.1.2	Optimisation of the Ladle Economy	375
8.7.1.3	Avoidance of Heat Loss	376
8.7.1.4	Optimisation of Mould and Core Production	376
8.7.1.5	Increasing Yield and Quality	378
8.7.1.6	Heat Recovery	379
8.7.1.7	Recommendations for the Energetic Optimisation of the Casting Process	380
8.7.2	Solid Forming	381
8.7.2.1	Increase of the Material Utilisation Rate	382

8.7.2.2	Reduction of the Heating Energy Used	383
8.7.2.3	HR and Waste Heat Utilisation	384
8.7.2.4	Use of Efficient Equipment and Equipment Components	384
8.7.2.5	Recommendations for the Energetic Optimisation of the Solid Forming Process	385
8.7.3	Sheet Metal Forming	386
8.7.3.1	Use of Efficient Equipment and Equipment Components	387
8.7.3.2	Increase of the Material Utilisation Rate	387
8.7.3.3	Use of Lubricants	388
8.7.3.4	Consideration of the Entire Process Chains and Application of New Processes	389
8.7.3.5	Recommendations for the Energetic Optimisation of the Sheet Metal Forming Process	390
8.8	Processing of Foodstuffs	391
8.8.1	The Sector	391
8.8.2	Fundamentals of the Technology	393
8.8.3	Dairies	394
8.8.4	Breweries	398
8.8.5	Meat Processing Industry	402
8.8.6	Industrial Bakeries	405
8.8.7	Savings Potential Curve	409
8.9	Processing of Plastics	416
8.9.1	The Sector	416
8.9.2	Fundamentals of Technology	418
8.9.2.1	Production Process Steps in Plastics Processing	418
8.9.2.2	Methods of Shaping	419
8.9.3	Individual Processes and Measures	422
8.9.3.1	Pre-Treatment Measures	423
8.9.3.2	Measures in the Field of Extrusion	425
8.9.3.3	Measures in the Field of Injection Moulding	425
8.9.3.4	Measures in the Blow Moulding Sector	427
8.9.3.5	Measures in the Field of Thermoforming	428
8.9.4	Savings Potential Curve	429
	Literature	431
9	Energy Efficiency from an Energy Economic Perspective	443
9.1	Prospects for Energy Efficiency in Germany and Europe	443
9.2	Potentials	446
9.2.1	Energy Savings Potential for Germany	446
9.2.2	Potential Energy Savings for the EU28	448

9.3	Barriers to the Implementation of Energy Efficiency Measures	451
9.3.1	Causes of Market Failure	452
9.3.2	Overcoming the Barriers	454
9.3.2.1	Approaches to Overcoming Barriers Using the Example of the Swedish Iron and Steel Industry	455
9.3.2.2	Energy Efficiency Networks	457
9.4	Energy and Economic Effects of a Stronger Energy efficiency Strategy	460
9.4.1	Rebound Effect	462
9.4.2	Carbon Leakage	463
9.4.3	Employment Effect	464
	Literature	465
10	Summary and Perspectives	469
10.1	Generalised Motives Guiding Action	469
10.2	Need for Further Research	471
	Appendix	473
	Index	477