

CONTENTS

PREFACE	5
1. INTRODUCTION	7
2. ENERGY ANALYSIS.....	11
2.1. Energy balance equation.....	11
2.2. Basic energy forms	13
2.2.1. Heat.....	13
2.2.2. Mechanical work	14
2.2.3. Energy of a substance	15
2.3. Energy balance of simple systems	18
2.3.1. Steam turbine	18
2.3.2. Heater.....	20
2.3.3. Expansion tank.....	21
2.3.4. Mixing of two fluids	22
2.3.5. Circulation pump	23
2.3.6. Compressor	25
2.4. Case study calculations.....	26
2.4.1. Gas fired boiler	26
2.4.2. Counter pressure steam co-generated heat and power (CHP) plant ...	31
2.4.3. Discharge-condensing co-generated heat and power (CHP) plant ...	36
2.4.4. Air handling unit – supply air.....	41
2.4.5. Air handling unit – inlet-exhaust ventilation system.....	44
2.4.6. Compressor heat pump	51
2.4.6. Single stage absorption water chiller.....	55
2.4.7. Single flash geothermal power plant	57
2.4.8. Double flash geothermal power plant.....	61
2.4.9. Geothermal ORC based CHP plant	64
3. EXERGY ANALYSIS.....	71
3.1. Exergy balance equation.....	71
3.2. Principles of exergy calculations.....	74
3.2.1. Exergy of a substance	74
3.2.2. The change of exergy of an external heat source	77
3.3. Exergy balance calculations for simple systems	77
3.3.1. Water radiator.....	77
3.3.2. Water air heater	79
3.3.3. Steam turbine	83
3.3.4. Compressor	85
3.3.5. Mixing chamber of an air handling unit	86
3.4. Exergy calculations for complex energy systems.....	90
3.4.1. Counter pressure steam co-generated heat and power (CHP) plant....	90
3.4.2. Exergy balance calculations for the compressor heat pump.....	97

3.4.3. Mechanical ventilation system	102
3.4.4. Exergy balance of a water based heating system.....	110
3.4.5. Exergy balance of a single stage absorption water chiller.....	117
4. ECONOMIC ANALYSIS	121
4.1. Overview of economic methods	121
4.2. Simple payback time.....	121
4.2.1. The <i>SPBT</i> method description	121
4.2.2. The <i>SPBT</i> case study calculation.....	122
4.3. Net present value	123
4.3.1. The <i>NPV</i> method description.....	123
4.3.2. The <i>NPV</i> case study calculation	124
4.4. Internal rate of return	126
4.4.1. The <i>IRR</i> method description	126
4.4.2. The <i>IRR</i> case study calculations	127
4.5. Total operating cost	129
4.5.1. The <i>TOC</i> method description.....	129
4.5.2. The <i>TOC</i> case study calculation	129
5. MULTICRITERIA EVALUATION.....	133
5.1. A general approach	133
5.2. Weighted sum method	134
5.3. Electre III outranking method	138
5.4. Examples of multicriteria evaluation	140
5.4.1. Multicriteria design aid of an integrated heating-cooling system ..	140
5.4.2. Multicriteria decision aid in local energy planning.....	150
5.4.3. Multicriteria selection of heat recovery device in a ventilation system.....	156
APPENDIX	167
A1. Specific molar physical enthalpy of gases.....	167
A2. Specific molar chemical enthalpy and exergy of substances	170
A3. Saturated pressure of water.....	171
A4. Specific heat of saturated water.....	172
A5. Specific enthalpy of water evaporation	173