Contents

| 1 | Eme | ergy Syr | nthesis and Ecological Energy Accounting | 1 |
|---|------|----------------------------|--|----|
| | 1.1 | The Ev | volution from Systems Theory to Emergy | 1 |
| | 1.2 | Energy | System Diagrams | 5 |
| | 1.3 | Emerg | y Values and Their Transformation | 6 |
| | 1.4 | The Ec | cological Energy Calculation Method | 9 |
| | | 1.4.1 | Definitions of Exergy, Emergy, and Transformity | 9 |
| | | 1.4.2 | General Emergy Calculation Method | 10 |
| | 1.5 | Indices | S Used in Emergy Synthesis | 11 |
| | 1.6 | Emergy Balance and Storage | | |
| | 1.7 | | gical Energy Accounting for Tourism | 15 |
| | 1.8 | Conclu | asions | 20 |
| | Refe | erences | | 21 |
| 2 | Fco | logical l | Energy Accounting for Macao's Socioeconomic and | |
| _ | | | Systems | 27 |
| | 2.1 | | and Economic Characteristics of Macao | 27 |
| | 2.2 | Emerg | Emergy Synthesis for Macao's Eco-economic System in 2004 | |
| | 2.3 | •••• | | 38 |
| | | 2.3.1 | Comparison of the Emergy Components | 42 |
| | | 2.3.2 | Emergy Density, Emergy Use, and Fuel Use per Person . | 42 |
| | | 2.3.3 | $E_{\rm m}$ /\$ Ratio and Emergy Investment Rate (EIR) | 43 |
| | | 2.3.4 | Emergy Exchange Ratio (EER) | 44 |
| | | 2.3.5 | Renewable Resources Proportion (%Ren), Emergy | |
| | | | Sustainability Index (ESI), and Net Emergy Ratio (NER) | 45 |
| | 2.4 | Time S | Series for Macao's Emergy and Emergy-Based Indices | 45 |
| | | 2.4.1 | The Components of Emergy Use | 46 |
| | | 2.4.2 | Per Capita Electricity Emergy, Fuel Emergy, and Emergy | |
| | | | Density (U /area) | 50 |
| | | 2.4.3 | %Ren and Emergy Self-sufficiency Ratio (ESR) | 50 |
| | | 2.4.4 | Emergy Exchange Ratio (EER) and Emergy Yield Ratio | |
| | | | (EYR) | 51 |
| | | | | |

Contents

| | | 2.4.5 | Total Emergy Used (U) , Emergy Money Ratio $(E_{\rm m}/\$)$, Proportion of Waste Emergy (W) , and Per Capita Emergy | 51 | | | |
|---|------|--|--|----------|--|--|--|
| | | 2.4.6 | Use | 31 | | | |
| | | 2.4.0 | Ratio (ELR), and Emergy Sustainability Index (ESI) | 53 | | | |
| | | 2.4.7 | Net Emergy (NE) and the Net Emergy Ratio (NER) | 54 | | | |
| | 2.5 | | Series for Emergy Flows of Italy, Sweden, and Macao | 51 | | | |
| | | | na | 55 | | | |
| | | 2.5.1 | %Ren | 55 | | | |
| | | 2.5.2 | Emergy Use Per Capita | 58 | | | |
| | | 2.5.3 | Emergy Money Ratio $(E_{\rm m}/\$)$ | 58 | | | |
| | | 2.5.4 | Integrated Emergy Index: The Environmental | | | | |
| | | | Sustainability Index (ESI) | 59 | | | |
| | | 2.5.5 | Storage Indices: NE and NER | 61 | | | |
| | 2.6 | Statist | ical Analyses of Emergy-Based Indicators of Macao | 62 | | | |
| | 2.7 | | usions | 62 | | | |
| | Refe | | | 64 | | | |
| 3 | Eme | near Can | nthesis and Simulatian for Magaa | 67 | | | |
| 3 | 3.1 | Emergy Synthesis and Simulation for Macao | | | | | |
| | 3.1 | | nics Context | 68 | | | |
| | 3.2 | | ation Methodology Using the STELLA Modeling Software | 69 | | | |
| | 3.3 | | Use and Reclamation in Macao | 69 | | | |
| | 3.4 | | ation Results and Analyses | 71 | | | |
| | 3.5 | | usions | 78 | | | |
| | | | | 85 | | | |
| | | | | 0.5 | | | |
| 4 | | | nalysis for Tourism Systems: Principles and a Case | 0.7 | | | |
| | | dy for M | | 87 | | | |
| | 4.1 | | uction to Ecological Emergy Accounting for Tourism | 87 | | | |
| | 4.2 | | dology | 88 | | | |
| | | 4.2.1 | Approaches Used in Tourism Emergy Accounting | 88 | | | |
| | | 4.2.2 | Two Emergy Flows for Tourism: What You Paid for and | 0.2 | | | |
| | 4.2 | Г | What You Got | 93 | | | |
| | 4.3 | | y Analysis and Discussion: A Case Study of Tourism | 0.4 | | | |
| | | 1n Mac | | 94 | | | |
| | | 4.3.1 | Introduction to Tourism in Macao | 94 94 | | | |
| | 4.4 | 4.3.2 Concli | e . | 103 | | | |
| | | 001201 | | 103 | | | |
| | | | | 104 | | | |
| 5 | | - | Energy Accounting for the Gambling Sector: A Case | | | | |
| | | | acao | 107 | | | |
| | 5.1 | | uction to Macao's Gambling Sector | 107 | | | |
| | 5.2 | An Overview of Macao and Its Gambling Sector | | | | | |
| | 5.3 | | Methodology | 109 | | | |
| | 5.4 | Result | s and Discussion | 110 | | | |

Contents xi

| | | 5.4.1 | Water Emergy | 114 | | | | |
|---|--|---|--|---|--|--|--|--|
| | | 5.4.2 | Electricity Emergy | 114 | | | | |
| | | 5.4.3 | Food and Beverage Emergy | 115 | | | | |
| | | 5.4.4 | Labor Emergy | 115 | | | | |
| | | 5.4.5 | $E_{\rm m}/\$$ Ratio | 116 | | | | |
| | | 5.4.6 | Emergy Yield Ratio | 116 | | | | |
| | | 5.4.7 | Emergy Used per Gambler | 117 | | | | |
| | | 5.4.8 | The Per Capita Electricity Emergy | 118 | | | | |
| | | 5.4.9 | The Ratio of Imported Services to Emergy Used | 118 | | | | |
| | | | Net Emergy and Net Emergy Ratio | 118 | | | | |
| | | | Emergy Exchange Ratio | 118 | | | | |
| | 5.5 | | usions | 119 | | | | |
| | | | | 120 | | | | |
| _ | | | | | | | | |
| 6 | | | nthesis for Waste Treatment in Macao | 123 | | | | |
| | 6.1 | | uction to Waste Treatment in Macao | 123 | | | | |
| | 6.2 | | y Accounting for Macao's Wastes | 124 | | | | |
| | 6.3 | | Emergy and Transformity in Macao | 126 | | | | |
| | | 6.3.1 | Waste Emergy Synthesis for Macao | 126 | | | | |
| | | 6.3.2 | Transformities of Wastes in Macao | 130 | | | | |
| | 6.4 | | usions | 133 | | | | |
| | Refe | erences | | 134 | | | | |
| 7 | | | Resource Consumption and Resource Carrying | | | | | |
| | Capacity: A Comparison of the Sustainability of Macao and 17 | | | | | | | |
| | | | •••••• | 137 | | | | |
| | 7.1 | | uction | 137 | | | | |
| | 7.2 | Metho | | 139 | | | | |
| | | 7.2.1 | The Principle of Environmental Sustainability | 139 | | | | |
| | | 7.2.2 | Resource Consumption and Carrying Capacity | 141 | | | | |
| | 7.3 | D 14 | | | | | | |
| | | | s and Discussion | 143 | | | | |
| | | 7.3.1 | Emergy Consumption by the 17 Nations | 143 | | | | |
| | | 7.3.1 7.3.2 | Emergy Consumption by the 17 Nations | | | | | |
| | | 7.3.1 | Emergy Consumption by the 17 Nations | 143 150 | | | | |
| | | 7.3.1 7.3.2 | Emergy Consumption by the 17 Nations | 143 | | | | |
| | 7.4 | 7.3.1 7.3.2 7.3.3 Compa | Emergy Consumption by the 17 Nations | 143 150 154 156 | | | | |
| | 7.4 7.5 | 7.3.1 7.3.2 7.3.3 Compa | Emergy Consumption by the 17 Nations | 143 150 154 | | | | |
| | | 7.3.1 7.3.2 7.3.3 Compa | Emergy Consumption by the 17 Nations | 143 150 154 156 | | | | |
| | 7.5 7.6 | 7.3.1 7.3.2 7.3.3 Compa Summ Conclu | Emergy Consumption by the 17 Nations | 143 150 154 156 157 | | | | |
| 8 | 7.5 7.6 Refe | 7.3.1 7.3.2 7.3.3 Compa Summ Conclusive rences | Emergy Consumption by the 17 Nations | 143 150 154 156 157 158 | | | | |
| 8 | 7.5 7.6 Refe | 7.3.1 7.3.2 7.3.3 Compa Summ Conclusive rences | Emergy Consumption by the 17 Nations | 143 150 154 156 157 158 160 | | | | |
| 8 | 7.5 7.6 Refe | 7.3.1 7.3.2 7.3.3 Compa Summ Conclusion | Emergy Consumption by the 17 Nations Per Capita Emergy Consumption for the 17 Nations National Emergy Consumption and Sustainability Conditions arison of the Per Capita Emergy Between 2000 and 2008 tary of the Per Capita Emergy Analysis for Macao usions s and Outlook | 143 150 154 156 157 158 160 163 | | | | |
| 8 | 7.5 7.6 Refe | 7.3.1 7.3.2 7.3.3 Compassion Conclusion Conclusion | Emergy Consumption by the 17 Nations Per Capita Emergy Consumption for the 17 Nations National Emergy Consumption and Sustainability Conditions arison of the Per Capita Emergy Between 2000 and 2008 tary of the Per Capita Emergy Analysis for Macao usions s and Outlook usions Emergy Synthesis and Ecological Energy Accounting | 143 150 154 156 157 158 160 163 163 | | | | |
| 8 | 7.5 7.6 Refe | 7.3.1 7.3.2 7.3.3 Compa Summ Conclusion Conclusion Conclusion 8.1.1 | Emergy Consumption by the 17 Nations Per Capita Emergy Consumption for the 17 Nations National Emergy Consumption and Sustainability Conditions arison of the Per Capita Emergy Between 2000 and 2008 tary of the Per Capita Emergy Analysis for Macao usions s and Outlook usions | 143 150 154 156 157 158 160 163 163 | | | | |

xii Contents

| | 8.1.4 | Emergy Analysis for Tourism Systems: Principles and | |
|---------|---------|--|-----|
| | | a Case Study for Macao | 166 |
| | 8.1.5 | Ecological Energy Accounting for the Gambling Sector: | |
| | | A Case Study in Macao | 167 |
| | 8.1.6 | Emergy Synthesis for Waste Treatment in Macao | 168 |
| | 8.1.7 | Per Capita Resource Consumption and Resource | |
| | | Carrying Capacity: A Comparison of the Sustainability | |
| | | of Macao and 17 Countries | 169 |
| 8.2 | Outloo | ok | 170 |
| | 8.2.1 | Better Statistics and More Exact Transformity Values | 170 |
| | 8.2.2 | The Importance of Wastes and Their Treatment | 171 |
| | 8.2.3 | Integrating Catabolic Processes with Emergy Accounting | 171 |
| Appendi | x A S | upplementary Tables That Summarize the Inflow and | |
| Out | flow En | nergy Values for Macao in 2004 | 173 |
| Appendi | x B S | upplementary Tables That Summarize the Inflows and | |
| the | Outflov | vs of Emergy for Macao in 2007 | 185 |
| Appendi | x C D | Definitions of the Parameters Used in This Book | 195 |