

Contents

Acronyms	xiii
1 Introduction and Fundamentals	1
1.1 The Starting Point: Sustainability and Global Change	1
1.2 Systems and Balances	5
1.2.1 Types of Systems and General Balances	5
1.2.2 Example: Historical Development of Atmospheric CO ₂ Concentration	7
1.2.3 Characteristics of Dynamic Systems	9
1.3 Thermodynamics: The Different Forms of Energy	17
1.3.1 The First Law of Thermodynamics	17
1.3.2 The Second Law of Thermodynamics	19
1.3.3 Non-equilibrium Thermodynamics: Complex Behavior and Formation of Structures	22
References	24
2 Biogeosphere as Environment for Life	27
2.1 Planet Earth and the Present Biogeosphere	27
2.2 Historical Development of the Biogeosphere	32
2.2.1 Formation of Earth and Driving Forces for Change	32
2.2.2 Atmosphere	34
2.2.3 Climate	38
2.2.4 Life	42
2.2.5 Civilization	46
References	50
3 Energy Balance of the Earth	53
3.1 Energy Exchange by Radiation	54
3.2 Role of the Atmosphere and Greenhouse Effect	56
3.3 Spatio-Temporal Variations	61
3.4 Photosynthesis	65

3.5	Energy Balance and Climate	72
3.5.1	Snowball Earth: Ice-Albedo Feedback and Multiple Climate States	72
3.5.2	Simple Models for the Self-Regulating Behavior of the Earth System	75
3.5.3	Global Climate Models	79
	References	80
4	Global Material Cycles.	83
4.1	The Carbon Cycle	84
4.2	The Oxygen Cycle	89
4.3	The Water Cycle	91
4.4	The Nitrogen Cycle	95
4.5	The Sulfur Cycle	98
4.6	The Phosphorus Cycle	100
4.7	The Chlorine Cycle	102
4.8	Interaction of Material Cycles	107
	References	109
5	Anthropogenic Material and Energy Flows	111
5.1	Changes in the Natural Carbon Cycle	111
5.1.1	Overview of Factors and Phases	111
5.1.2	Phase 10 000–250 Years Ago	114
5.1.3	Phase 250 Years Ago Until Today	116
5.2	Other Anthropogenic Material Flows	119
5.3	Global Utilization of Primary Energy	121
5.4	Energy Flows in Germany	123
5.4.1	Overview	123
5.4.2	Energy Flows Related to Mobility and Transport	127
5.4.3	Energy Flows Related to Industry	130
5.4.4	Energy Flows Related to Buildings and Domestic Use	132
5.5	Correlation Between Energy Flows and Carbon Flows	134
	References	138
6	Limits for Anthropogenic Material and Energy Flows	141
6.1	Reserves and Resources of Raw Materials	141
6.1.1	Fossil Energy Sources	142
6.1.2	Other Important Materials	146
6.2	Net Primary Production of Photosynthesis <i>NPP</i>	149
6.3	Renewable Energy Sources	151
6.4	Local and Regional Ecosystems	152
6.5	Impact on Climate System	154
	References	155

7 Approaches to Global Development	159
7.1 Criteria and Aims of Future Development.	159
7.2 Examples of Sustainable Technologies	162
7.2.1 Electrical Energy Generation.	162
7.2.2 Heat Generation	166
7.2.3 Energy Supply for Mobility and Transport	170
7.2.4 Bioenergy.	174
7.2.5 Hydrogen	178
7.2.6 Chemical Fuels from Electricity	179
7.3 Climate Engineering.	181
7.4 Individual Living Conditions and Lifestyles	183
7.5 Global CO ₂ Emission and Atmospheric Carbon Inventory Scenarios	189
7.6 Transition of the Energy System – Example Germany (Energiewende)	194
References	195
8 Conclusions	199
Appendix	203
Glossary	205
List of Symbols	215
Index	219

Energy Flows, Material Cycles and Global Development

A Process Engineering Approach to the Earth System

Schaub, G.; Turek, Th.

2016, XIV, 226 p. 118 illus., 9 illus. in color., Hardcover

ISBN: 978-3-319-29493-3