Contents

Ac	ronyn	ns		хi						
1	Introduction and Fundamentals									
	1.1 The Starting Point: Sustainability and Global Change									
	1.2		ns 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	Therm	nodynamics: 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									
2	Biogeosphere as Environment for Life									
	2.1									
	2.2									
		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						
	Refe	erences		50						
3	Energy Balance of the Earth									
	3.1	Energy Exchange by Radiation 5								
	3.2		of the Atmosphere and Greenhouse Effect							
	3.3		-temporal Variations							
	3.4	Photos	synthesis	64						

digitalisiert durch DEUTSCHE NATIONAL BIBLIOTHEK

viii Contents

	3.5	Energy Balance and Climate	70
		3.5.1 Snowball Earth: Ice-Albedo Feedback	
			70
		3.5.2 Simple Models for the Self-Regulating Behavior	
		•	72
		3.5.3 Global Climate Models	74
	Refe	erences	77
4	Clo	bal Material Cycles	79
•	4.1		, , 80
	4.2		84
	4.3		86
	4.4		90
	4.5		93
	4.5	•	95 95
	4.0		95 96
	4.7	The Chlorine Cycle	
	Keie	erences	U3
5	Ant	hropogenic Material and Energy Flows1	
	5.1	Changes in the Natural Carbon Cycle	
		5.1.1 Overview of Factors and Phases	
		5.1.2 Phase 10 000–250 Years Ago	07
		5.1.3 Phase 250 Years Ago Until Today	
	5.2	Other Anthropogenic Material Flows	13
	5.3	Global Utilization of Primary Energy	15
	5.4	Energy Flows in Germany	16
		5.4.1 Overview	
		5.4.2 Energy Flows Related to Mobility and Transport	20
		5.4.3 Energy Flows Related to Industry	23
		5.4.4 Energy Flows Related to Buildings and Domestic Use 12	
	5.5	Correlation Between Energy Flows and Carbon Flows	27
	Refe	erences	31
5	T :	its for Anthropogenic Material and Energy Flows	22
•	6.1	Reserves and Resources of Fossil Fuels	<i>33</i>
	6.2	Net Primary Production of Photosynthesis NPP	
	6.3	Local and Regional Ecosystems	
	6.4	Impact on Climate System	
	Kele	rences	+3
7	App	roaches to Global Development	
	7.1	Criteria and Aims of Future Development	
	7.2	Examples of Sustainable Technologies	
		7.2.1 Electrical Energy Generation	48

Contents ix

		7.2.2	Heat (Genei	ratio	n													. 152
		7.2.3	Energ																
		7.2.4	Bioen																
		7.2.5	Hydro	gen.															. 163
	7.3		Climate Engineering																
	7.4	Individ	ndividual Living Conditions and Lifestyles										. 166						
	7.5	Global	CO ₂ E	miss	ion a	and	Atr	nos	phe	eric	Ca	rbo	n In	iven	tor	y S	cen	arios	170
	Refe	erences.	• • • • •		• • •	• • •									• • •				. 175
8	Con	clusions	s																. 177
Glo	ossary	•				• • •													. 181
No	mencl	ature																	. 191
Ind	lex																	. .	. 195