

CONTENTS

Foreword by Dr. Patrick Moore	vii
Introduction	1
1. Energy use	4
1.1 Sources of energy	4
1.2 Sustainability of energy	4
1.3 Energy demand	5
1.4 Energy supply	5
1.5 Changes in energy demand and supply	6
1.6 Future energy demand and supply	7
2. Electricity today and tomorrow	10
2.1 Electricity demand	10
2.2 Electricity supply	11
2.3 Fuels for electricity generation today	14
2.4 Provision for future base-load electricity	15
2.5 Renewable energy sources	18
2.6 Coal and uranium compared	21
2.7 Energy inputs to generate electricity	24
2.8 Economic factors	24
3. Nuclear power and its fuels	26
3.1 Mass to energy in the reactor core	26
3.2 Nuclear power reactors – basic design	27
Panel: Components common to most types of nuclear reactors	28
3.3 Uranium availability	29
3.4 Nuclear weapons as a source of fuel	33
3.5 Thorium as a nuclear fuel	35
3.6 Accelerator-driven systems	35
3.7 Physics of a nuclear reactor	36
4. Types of nuclear power reactors	42
4.1 Today’s power reactors	42
4.2 Advanced power reactors	43
4.3 Floating nuclear power plant	46
4.4 Modular light water reactors	46
4.5 High temperature reactors	47
4.6 Fast neutron reactors	48
4.7 Very small nuclear power reactors	50
5. The ‘front end’ of the nuclear fuel cycle	52
5.1 Mining and milling of uranium ore	52
5.2 The nuclear fuel cycle	54
Panel: Uranium enrichment	56
5.3 Thorium cycle	59
6. The ‘back end’ of the nuclear fuel cycle	60
6.1 Nuclear ‘wastes’	60

6.2	Reprocessing used fuel	62
6.3	High-level wastes from reprocessing	64
	Panel: Transporting radioactive materials	65
6.4	Storage and disposal of used fuel	67
6.5	Disposal of solidified wastes	68
6.6	Decommissioning nuclear reactors	71
7.	Other nuclear energy applications	74
7.1	Transport	74
7.2	Hydrogen production and use	75
7.3	Process heat	78
7.4	Desalination	79
7.5	Marine propulsion	81
7.6	Radioisotope systems and reactors for space	84
7.7	Research reactors, making radioisotopes	86
8.	Environment, health and safety	90
8.1	Greenhouse gas emissions	90
8.2	Other environmental effects	91
8.3	Health effects of power generation	93
8.4	Radiation exposure	95
8.5	Reactor safety	97
9.	Avoiding weapons proliferation	102
9.1	International cooperation	102
9.2	International nuclear safeguards	103
9.3	Fissile materials	105
9.4	Recycling military uranium and plutonium for electricity	108
9.5	Australian and Canadian nuclear safeguards policies	109
10.	History of nuclear energy	112
10.1	Exploring the nature of the atom	112
10.2	Harnessing nuclear fission	113
10.3	Nuclear physics in Russia	114
10.4	Conceiving the atomic bomb	114
10.5	Developing the concepts: bomb and boiler	115
10.6	The Manhattan Project	116
10.7	The Soviet bomb	117
10.8	Revival of the ‘nuclear boiler’	118
10.9	Nuclear energy goes commercial	120
10.10	The nuclear power brown-out	120
10.11	Nuclear renaissance	121
	Appendices	
1.	Ionising radiation and how it is measured	122
2.	Some radioactive decay series	124
3.	Environmental and ethical aspects of radioactive waste management	125
4.	Some useful references	126
	Glossary	127
	Index	133

FIGURES AND TABLES

Figures	Page	Tables	Page
Chapter 1			
1. Consumption of fossil fuels	4	1. Electricity production growth	5
2. Primary energy supply	6	2. Fuel energy conversion data	9
3. World primary energy demand	7		
4. World electricity consumption	8		
Chapter 2			
5. Load curves for a typical grid	11	3. Projected capacity additions and investment	13
5A Load curves with overnight charging	13	4. Electricity generating costs and projections	22
6. Fuel for electricity generation	14		
7. Fuel and waste comparison for uranium and coal	20		
8. US electricity production costs	23		
9. Projected electricity costs, Finland	23		
Chapter 3			
10. Fission in conventional and fast neutron reactors	26	5. Nuclear power's role in electricity production	30
11. Pressurised water reactor	28	6. Uranium concentrations in nature	31
12. Known uranium resources & exploration expenditure	33	7. Known recoverable resources of uranium	32
13. World uranium production and demand	34		
14. Neutron cross-sections for fission	37		
15. Distribution of fission products	38		
Chapter 4			
		8. Operable nuclear power plants	42
		9. Advanced nuclear power reactors	44
		10. High temperature reactors	47
		11. Fast neutron reactors	49
Chapter 5			
16. The open nuclear fuel cycle	55		
17. The closed nuclear fuel cycle	58		
18. The fast neutron reactor fuel cycle	59		
Chapter 6			
19. What happens in a light water reactor	61	12. Commercial reprocessing capacity	63
20. Vitrified waste (simulated)	65	13. MOX fuel fabrication capacities	64
21. Fission product decay in used fuel	67		
22. High-level waste from used fuel decay curve	69		
Chapter 8			
23. Greenhouse gas emissions in electricity production	91	14. Energy production accident statistics	93
		15. Energy-related accidents	94
		16. Ionising radiation	96
		17. International Nuclear Event Scale	100
		18. Serious reactor accidents	101
Chapter 9			
24. Plutonium in the reactor core	106	19. Plutonium	107
		20. Safeguards policies	109