Energy Demand and Climate Change

Issues and Resolutions



Contents

Acknowledgements XIII

Prologue XV

Part I Questions

Introduction 3
Recommended Reading 4

- 1 Ancient Days and Modern Times 5 Recommended Reading 7
- 2 Ice Ages Past and Future 9
 The Discovery of Ice Ages 9
 The Heat Balance of the Earth 10
 The Sun and Its Spots 11
 Earth's Orbit 14
 The Discovery of Elliptical Orbits 15
 Precession 16
 Nutation (Wobble) 18
 Volcanic Dust 20
 The Cyclical Nature of Ice Ages 20
 The Croll–Milanković Theory of Ice Ages 21
 Recommended Reading 23
- Global Warming Versus Returning Glaciers 25
 Infrared Radiation and Absolute Temperature 27
 Greenhouse Gases and Global Warming: Fourier, Tyndall, and Arrhenius 28
 CO₂ and Methane 29
 The Big Picture 31
 Recommended Reading 35

4	Earth's Fossil Fuel Supply 37
	Limits of Fossil Fuels 38
	Coal 39
	Natural Gas 39
	Hydrated Natural Gas 40
	Oil 40
	Sequestration of CO ₂ 42
	CO ₂ Level Calculations 43
	The Unending Carbon Cycle 43
	Recommended Reading 45

Farth's Fossil Fuel Supply

5 Nuclear Power 47 Origin of Fuel for Nuclear Fission The Energy in Nuclear Fuel 48 Nuclear Energy Isotopes 50 Limits of Nuclear Fuel 51 The Basics of Nuclear Fission Evolution of Nuclear Reactors 53 Present-day Nuclear Reactors and Power Plants Used Fuel Rods 56 Radiation, Radioactivity, and Health 57 Natural Radiation and Radioactive Waste

Disposal and Storage of Nuclear Waste 59

Part II Answers

Recommended Reading 60

Recommended Reading 80

Introduction

6 Solar Energy 65 Using Solar Energy Development of Solar Cells How Solar Cells Work 69 Multiple-layer Solar Cells 71 Solar Concentrators and Solar Thermal Systems Solar Ponds 76 Solar-powered Air Conditioning 77 Solar Updraft Towers 78 Solar Power Towers 79 Other Thoughts and Possibilities 79

1	Wind, Waves, and lides 81 Wind 81
	Wind 81 Characteristics and Limits of Wind Machines 83
	Tides 86
	Newton, the Moon, and the Tides 87
	Harnessing Tidal Power 87
	Usable Tidal Energy 89
	Tidal Currents 90
	Waves 91
	Recommended Reading 93
8	Going with the Flow: Water, Dams, and Hydropower 95
	Basics of Hydroelectric Power 96
	Water Turbines 98
	Hydropower Problems 99
	Hydropower Schemes 99
	Dam-less Hydropower: Evaporation Schemes 100
	Dam-less Hydropower: Flowing Water 102
	Recommended Reading 103
•	
9	Geothermal Energy: Energy from the Earth Itself 105
	Geothermal Energy 105
	The Structure of the Earth 106
	Carnot's Unbreachable Thermodynamic Limit 109
	Using Water and Soil in Heating and Cooling Systems 110
	Recommended Reading 112
10	Efficiency, Conservation, and Hybrid Cars 113
	Efficiency of Fossil Fuel and Nuclear Power Plants 114
	Cars, Trucks, Trains, Ships, and Planes 118
	Conservation 120
	Recommended Reading 121
	,
11	Energy Storage: Macro to Micro 123
	Pumped Hydropower 124
	Compressed Air 124
	Batteries 126
	Flywheels 129
	Capacitors and Dielectrics 130
	Inductors: Storing Energy with Magnetic Fields 132
	Recommended Reading 133
12	Green Fuel: Biodiesel, Alcohol, and Biomass 135
	Biodiesel 138

Recommended Reading 142

Part III Dreams

Introduction 145

13	Breeding Nuclear Fuel 147	
	Fast Breeder Reactors 148	
	Clinch River Breeder Reactor Project 150	
	Thermal Breeder Reactors 151	
	Breeder Technology Today and Tomorrow	152
	Recommended Reading 153	

14 Nuclear Fusion: Engine of the Sun 155

Cold Fusion versus Cool Fusion versus Hot Fusion 155
Making Fusion Happen 157
ITER, Tokamaks, Magnetic Fields, and Fusion 158
The Combined Fusion—Breeding—Fission Process 160
Inertial Confinement Fusion 161
Accelerator Fusion 161
Fusion of Helium-3 and Deuterium 162
Lunar Resources of Helium-3 163
Recommended Reading 165

Power from the Ocean: Thermal and Salinity Gradients Electric Power from Ocean Thermal Gradients Electric Power from Ocean Salinity Gradients 167 Electric Power from Ocean Salinity Gradients 172 Recommended Reading 176

16 Fuel Cells: Hydrogen, Alcohol, and Coal 177

Fuel Cells and Hydrogen 177
Fuel Cell Efficiency 179
Fuel Cells and Cars 180
Storing Hydrogen 182
Producing Hydrogen 184
Technologies for Hydrogen Production 184
Fuel Cells and Coal 186
Fuel Cells and Alcohol 187
What Happens Now? 187
Recommended Reading 188

17 Magnetohydrodynamics and Power Plants 189 Faraday Induction and the Hall Effect 190

Benefits of MHD Power Generation 192

Recommended Reading 193

18	Thermionics and the Single Fuel Home 195
	How a Thermionic Converter Works 196
	Engineering Thermionic Systems 197
	Recommended Reading 201

Artificial Photosynthesis and Water Splitting 203 Plant Chemistry 205 Artificial Photosynthesis and Water Splitting 206 Recommended Reading 208

20 Planetary Engineering and Terraforming 209 Changing Earth's Albedo: Atmospheric Aerosols 210 Tinkering with Planet Earth 211 Parasols, Artificial Sunspots, Space Mirrors, Solar Sails, and Space Dust 212 White Roads, Reflecting Roofs, and Shiny Balloons 213 Back to Clouds Again 213 Feeding Algae 214 Terraforming Mars (and Maybe Venus) 215 What Can Be Done? 217 Recommended Reading 218

21 Space Solar Power: Energy and the Final Frontier 219 Lagrange and His Famous Points 219 Geosynchronous Orbits and Solar Sails 221 Beamed-power Microwave Transmission 222 Space Elevators 223 Electromagnetic Launching 226 Recommended Reading 227

Part IV Nightmares

Introduction 231

22 Alternative Futures 233

Epilogue: ORBiTuary 237

Credits 239

Appendix I 241 Units for Energy and Power 241

Appendix II 243 Radiation Units 243

Index 245