Future Energy: Improved, Sustainable and Clean Options for our Planet

Edited by

TREVOR M. LETCHER
Emeritus Professor
University of KwaZulu-Natal
Durban, South Africa
Contents

Foreword xi
Preface xiii
Introduction xv
List of Contributors xix

Part I  Fossil Fuel and Nuclear Energy 1

1 The Future of Oil and Gas Fossil Fuels 3
   A. R. H. Goodwin
   1. Introduction 3
   2. Hydrocarbon Reservoirs 4
   3. Hydrocarbon Recovery, Reserves, Production and Consumption 11
   4. Global Warming, Alternative Energy and CO$_2$ Sequestration 17
   5. Conclusion 19
   References 19

2 The Future of Clean Coal 25
   M. Balat
   1. Introduction 25
   2. Coal and Environmental Problems 28
   3. Clean Coal Technologies 30
   4. Costs and Plant Characteristics for Coal-fired Power Plants with Capture of CO$_2$ 36
   5. Conclusion 36
   References 37

3 Nuclear Power (Fission) 41
   S. Green and D. Kennedy
   1. Introduction 41
3. Other Recent Studies on Nuclear Generation Costs 47
4. Global Prospects for Nuclear Power 54
5. Conclusions 56
References 56

4 The Alberta Oil Sands: Reserves and Supply Outlook 59
F. Rahnama, K. Elliott, R. A. Marsh and L. Philp

1. Introduction 59
2. Bitumen Reserves in Alberta 61
3. Reserves Under Active Development 63
4. Bitumen Recovery Techniques 65
5. Short-term Bitumen Supply in Alberta 67
6. Long-term Bitumen Supply in Alberta 70
7. Supply Costs of Bitumen Production in Alberta 72
8. Conclusion 74
References 75

5 The Future of Methane and Coal to Petrol and Diesel Technologies 77
A. C. Vosloo

1. Brief Description of the Methane and Coal to Petrol and Diesel Technologies 77
2. Factors that will Influence the Future Demand for CTL and GTL Technologies 84
3. Environmental Factors that will Influence the Application of CTL and GTL Technologies 88
4. Future Developments to Reduce the Capital and Operating Costs of CTL and GTL Plants 89
5. Conclusions 89
References 90

Part II Renewable Energy 93

6 Wind Energy 95
L. Staudt

1. History and Present Status 95
2. Technical Issues 97
3. Commercial Issues 104
4. Environmental Issues 106
5. Conclusions 110
References 110
Recommended Websites 110
## Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Authors</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Tidal Current Energy: Origins and Challenges</td>
<td>A. Owen</td>
<td>111-128</td>
</tr>
<tr>
<td></td>
<td>1. Introduction</td>
<td></td>
<td>111</td>
</tr>
<tr>
<td></td>
<td>2. Tidal Current Drivers</td>
<td></td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>3. Devices</td>
<td></td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>4. Anchors and Fixings</td>
<td></td>
<td>122</td>
</tr>
<tr>
<td></td>
<td>5. Biofouling</td>
<td></td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>6. Conclusion</td>
<td></td>
<td>127</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td></td>
<td>127</td>
</tr>
<tr>
<td></td>
<td>Further Reading</td>
<td></td>
<td>128</td>
</tr>
<tr>
<td>8</td>
<td>Wave Energy</td>
<td>R. Alcorn and T. Lewis</td>
<td>129-149</td>
</tr>
<tr>
<td></td>
<td>1. Background, Context and Drivers of Wave Energy</td>
<td></td>
<td>129</td>
</tr>
<tr>
<td></td>
<td>2. What is Ocean Wave Energy?</td>
<td></td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>3. The Energy Resource and How it is Measured</td>
<td></td>
<td>133</td>
</tr>
<tr>
<td></td>
<td>4. Forecasting and Prediction</td>
<td></td>
<td>135</td>
</tr>
<tr>
<td></td>
<td>5. Challenges and Benefits</td>
<td></td>
<td>136</td>
</tr>
<tr>
<td></td>
<td>6. Converter Types</td>
<td></td>
<td>137</td>
</tr>
<tr>
<td></td>
<td>7. Device Rating</td>
<td></td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>8. Modern Devices</td>
<td></td>
<td>142</td>
</tr>
<tr>
<td></td>
<td>9. Economics of Wave Energy</td>
<td></td>
<td>143</td>
</tr>
<tr>
<td></td>
<td>10. Alternative Output</td>
<td></td>
<td>147</td>
</tr>
<tr>
<td></td>
<td>11. The Future</td>
<td></td>
<td>148</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td></td>
<td>149</td>
</tr>
<tr>
<td>9</td>
<td>Biomass</td>
<td>P. Champagne</td>
<td>151-169</td>
</tr>
<tr>
<td></td>
<td>1. Introduction</td>
<td></td>
<td>151</td>
</tr>
<tr>
<td></td>
<td>2. Biomass Resources</td>
<td></td>
<td>154</td>
</tr>
<tr>
<td></td>
<td>3. Bioenergy and Biofuels</td>
<td></td>
<td>158</td>
</tr>
<tr>
<td></td>
<td>4. Biomass to Energy Conversion Processes</td>
<td></td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>5. Bioeconomics</td>
<td></td>
<td>166</td>
</tr>
<tr>
<td></td>
<td>6. Limitations and Knowledge Gaps</td>
<td></td>
<td>168</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td></td>
<td>169</td>
</tr>
<tr>
<td>10</td>
<td>Concentrating Solar Power</td>
<td>R. Pitz-Paal</td>
<td>171-191</td>
</tr>
<tr>
<td></td>
<td>1. Introduction – Concept and Basic Characteristics</td>
<td></td>
<td>171</td>
</tr>
<tr>
<td></td>
<td>2. State of the Art</td>
<td></td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>3. Cost Reduction Potential</td>
<td></td>
<td>184</td>
</tr>
<tr>
<td></td>
<td>4. Potential Impact of CSP Until 2050</td>
<td></td>
<td>186</td>
</tr>
<tr>
<td></td>
<td>5. Further Options</td>
<td></td>
<td>191</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td></td>
<td>191</td>
</tr>
</tbody>
</table>
11 Hydroelectric Power  193
M. Balmer and D. Spreng

1. History and Development  194
2. Technology  197
3. Hydropower and Sustainability  200
4. Economics of Hydropower  203
5. Hydropower in Liberalized Electricity Markets  206
References  208

12 Geothermal Energy  211
J. L. Renner

1. Heat Flow and Subsurface Temperatures  211
2. Tectonic Controls  212
3. Types of Geothermal System  215
4. Worldwide Geothermal Potential  216
5. Worldwide Geothermal Development  217
6. Methods for Electrical Generation  218
7. Direct Use of Geothermal Energy  220
8. Environmental Constraints  220
9. The Future  221
10. Sources of Additional Information  222
References  222

13 Solar Energy: Photovoltaics  225
D. Infield

1. Background  225
2. The Solar Resource  225
3. Outline of the Conversion Process  228
4. Manufacturing Processes  232
5. Applications  235
6. Brief Summary of Research Challenges  237
Acknowledgements  238
References  238

Part III Potentially Important New Types of Energy  239

14 The Pebble Bed Modular Reactor  241
D. Matzner

1. Historical Preface  242
2. Reactor Unit  243
3. Nuclear Safety  248
4. Technological Applications  252
5. Project Status  255
References  256
### Contents

15 Fuel Cells and Batteries 259  
*J. Salminen, D. Steingart and T. Kallio*

1. Fuel Cells 259  
2. Batteries 265  
3. Concluding Remarks 275  
References 275

16 Methane Hydrates 277  
*E. Allison*

1. Background 278  
2. Detection and Quantification 281  
3. Production Technology 283  
4. Economics 288  
5. Time Scale for Development 288  
References 289

17 Nuclear Fusion 291  
*L. R. Grisham*

1. What is Nuclear Fusion? 291  
2. Desirable Characteristics of Fusion Power 293  
3. Why Fusion Power is Challenging 295  
4. Approaches to Fusion Reactors 296  
5. Economics of Fusion Energy 299  
6. Prospects for Fusion Energy 300  
References 301

Part IV New Aspects to Future Energy 303

18 Carbon Capture and Storage for Greenhouse Effect Mitigation 305  
*D. Tondeur and F. Teng*

1. Introductory Aspects 305  
2. Capture Techniques 310  
3. Geological Storage of CO₂ 323  
4. Costs 328  
5. Conclusion 329  
References 330

19 Smart Energy Houses of the Future – Self-supporting in Energy and Zero Emission 333  
*R. D. Wing*

1. Design and Construction of Energy-efficient Buildings 334  
2. Design of Very-low- or Zero-energy Housing 337
### Contents

3. Future Technical Developments and Demonstration Projects 341  
4. Guidelines for Future Energy-efficient Housing 345  
   References 345  

20 The Prospects for Electricity and Transport Fuels to 2050 347  
   A. G. Dutton and M. Page  
1. Introduction 347  
2. Future Energy Scenarios 349  
3. Primary Energy Policy Drivers 356  
4. Future Energy Fuel Options and Supply Structures for Transport 359  
5. Future Energy Supply Structures for Electricity 365  
6. Conclusions 368  
   Acknowledgements 369  
   References 369  

Index 371