

# Contents

|          |  |           |
|----------|--|-----------|
|          | <i>List of Figures</i>   | page x    |
|          | <i>List of Tables</i>  | xiii      |
|          | <i>Preface</i>   | xv        |
|          | <i>Acknowledgements</i>  | xvii      |
| <b>1</b> | <b>Energy Economics and Current Energy Systems</b>                   | <b>1</b>  |
|          | 1.1 What Is Energy Economics?  | 1         |
|          | 1.2 The Role of Energy in an Economic System                         | 3         |
|          | 1.3 Energy Systems and CO <sub>2</sub> Emissions                     | 4         |
|          | 1.3.1 Total Energy Consumption                                       | 4         |
|          | 1.3.2 Energy Consumption by Sector                                   | 6         |
|          | 1.3.3 Energy Demand in the Future                                    | 7         |
|          | 1.3.4 Greenhouse Gas Emissions                                       | 8         |
|          | 1.3.5 The Relationship between Carbon Dioxide and Global Warming     | 11        |
|          | 1.4 Main Problems Resulting from the Current State of Energy Systems | 11        |
|          | 1.4.1 Environmental and Economic Problems                            | 11        |
|          | 1.4.2 Non-renewable Energy Sources                                   | 12        |
|          | 1.4.3 Geopolitics and Security of Energy Supply                      | 13        |
|          | 1.4.4 Inefficiency in the Use of Energy                              | 13        |
|          | 1.5 The Way Ahead: Energy Transition                                 | 14        |
|          | 1.5.1 Energy Transition  | 14        |
| <b>2</b> | <b>Market Failures and Behavioural Anomalies</b>                     | <b>21</b> |
|          | 2.1 Introduction to Market Failures                                  | 21        |
|          | 2.2 Market Failures  | 23        |
|          | 2.2.1 Externalities  | 23        |
|          | 2.2.2 Public Goods and Common Resources                              | 26        |
|          | 2.2.3 Information and Principal–Agent Problems                       | 29        |
|          | 2.2.4 Lack of Competition – Monopoly and Collusive Oligopoly         | 31        |
|          | 2.2.5 Behavioural Anomalies  | 34        |
|          | 2.3 Role of Energy and Climate Policies                              | 39        |
|          | 2.3.1 Energy Policy and Climate Policy Goals                         | 39        |
|          | 2.3.2 Role of Governments in Adaptation Strategies                   | 41        |
|          | 2.3.3 Energy and Development   | 42        |

|          |   |           |
|----------|---|-----------|
| 2.4      | Sustainable Development   | 42        |
| 2.4.1    | Institutional Definition  | 42        |
| 2.4.2    | Definitions Based on Economic Theories: Weak and Strong Sustainability                | 43        |
| 2.5      | Issues in Developing Countries  | 45        |
| 2.5.1    | Traditional Market Failures   | 45        |
| 2.5.2    | Role of Behavioural Anomalies   | 47        |
| 2.5.3    | Review Questions and Problems   | 48        |
| <b>3</b> | <b>Energy Demand–Theory and Empirical Analysis</b>                                    | <b>49</b> |
| 3.1      | Introduction to Energy Demand Analysis  | 49        |
| 3.1.1    | Energy Demand as a Derived Demand for Energy Services and Industrial Goods            | 49        |
| 3.2      | Household Production Theory and Energy Demand   | 50        |
| 3.2.1    | Key Functions of Household Production Theory  | 50        |
| 3.2.2    | Graphical Representation of Household Choices   | 51        |
| 3.2.3    | Analytical Representation of Household Choices  | 55        |
| 3.3      | Empirical Analysis of the Residential Energy Demand                                   | 57        |
| 3.3.1    | Steps in the Empirical Estimation of an Energy Demand Model                           | 58        |
| 3.3.2    | Model Specification   | 59        |
| 3.3.3    | The Typical Functional Forms for Demand Analysis                                      | 60        |
| 3.3.4    | Estimation of a Simple Electricity Demand Function: Example from a Developing Country | 61        |
| 3.3.5    | Estimation of a Capital Stock Demand Model  | 62        |
| 3.3.6    | Estimated Residential Energy Price Elasticities                                       | 63        |
| 3.4      | The Empirical Analysis of the Industrial Energy Demand                                | 65        |
| 3.4.1    | Energy Demand Function  | 67        |
| 3.4.2    | Estimated Industrial Energy Price Elasticities  | 68        |
| 3.5      | Issues in Developing Countries  | 70        |
| 3.5.1    | Household Production Theory in Developing Countries                                   | 70        |
| 3.5.2    | Energy-consuming Asset Ownership and the Role of Income                               | 71        |
| 3.5.3    | Review Questions and Problems   | 72        |
| <b>4</b> | <b>Economic Analysis of Energy Investments</b>  | <b>73</b> |
| 4.1      | Energy–Sector Investments and the Role of Discounting                                 | 73        |
| 4.1.1    | Characteristics of Energy–Sector Investments  | 74        |
| 4.1.2    | Investment and Net Cash Flow of a Typical Energy–Sector Project                       | 75        |
| 4.2      | Investment Criteria: Net Present Value and Internal Rate of Return                    | 76        |
| 4.2.1    | Net Present Value and Internal Rate of Return   | 76        |
| 4.2.2    | Cost of Capital   | 78        |
| 4.2.3    | Importance of Discount Rates in Investment Decisions                                  | 79        |
| 4.2.4    | Example of Investment Analysis for a Power Plant                                      | 79        |

|          |   |            |
|----------|---|------------|
| 4.2.5    | Types of Risks Associated with Investments in the Energy Sector                     | 81         |
| 4.2.6    | Measures of Risk  | 82         |
| 4.3      | The Levelised Cost of Energy  | 85         |
| 4.3.1    | Example of LCoE Calculation for Different Technologies<br>at an International Level | 87         |
| 4.4      | The Learning Curve  | 89         |
| 4.4.1    | The Learning Curve in the Energy Sector   | 89         |
| 4.5      | Social Cost–Benefit Analysis  | 92         |
| 4.5.1    | Steps of Doing a Social Cost–Benefit Analysis                                       | 93         |
| 4.5.2    | Net Present Value Criterion   | 97         |
| 4.5.3    | The Social Discount Rate  | 98         |
| 4.6      | Issues in Developing Countries  | 99         |
| 4.6.1    | Application of Investment Analysis: Growth of Decentralised<br>Energy Systems       | 99         |
| 4.6.2    | Levelised Cost of Energy in Developing Countries                                    | 100        |
| 4.6.3    | Social Discount Rates   | 101        |
| 4.6.4    | Review Questions and Problems   | 101        |
| <b>5</b> | <b>Economics of Energy Efficiency</b>   | <b>102</b> |
| 5.1      | Energy Efficiency   | 102        |
| 5.1.1    | Definition  | 102        |
| 5.1.2    | Reasons for Inefficiencies  | 103        |
| 5.2      | Measurement of Energy Efficiency  | 105        |
| 5.2.1    | Partial Indicators  | 105        |
| 5.2.2    | Econometric Approaches  | 108        |
| 5.3      | Investment in Energy Efficiency   | 110        |
| 5.3.1    | Investment Decisions  | 111        |
| 5.3.2    | Lifetime Cost Calculations  | 112        |
| 5.3.3    | Examples: Comparing Lifetime Costs of Cars and Refrigerators                        | 113        |
| 5.4      | Energy Efficiency Gap   | 114        |
| 5.4.1    | Private and Social Perspectives   | 114        |
| 5.4.2    | Barriers to Energy Efficiency   | 116        |
| 5.5      | Bounded Rationality and Energy-related Financial Literacy                           | 118        |
| 5.5.1    | Decision-making Strategies  | 118        |
| 5.6      | Rebound Effect  | 120        |
| 5.7      | Issues in Developing Countries  | 123        |
| 5.7.1    | Market Failures   | 123        |
| 5.7.2    | Poor Power Quality  | 124        |
| 5.7.3    | Revenue Losses and Investments in Efficient Electricity Networks                    | 125        |
| 5.7.4    | Review Questions and Problems   | 126        |
| <b>6</b> | <b>Energy-related Market Forms</b>  | <b>127</b> |
| 6.1      | Introduction  | 127        |

|          |  |            |
|----------|--|------------|
| 6.2      | Economies of Scale and Scope   | 129        |
| 6.2.1    | Economies of Scale   | 129        |
| 6.2.2    | Economies of Scope and Economies of Vertical Integration                           | 133        |
| 6.3      | Monopoly   | 135        |
| 6.3.1    | Monopolies in the Energy Sector  | 135        |
| 6.3.2    | Application: Resource Rent in the Hydropower Sector                                | 136        |
| 6.3.3    | Application: Natural Monopoly  | 137        |
| 6.3.4    | Regulation Methods   | 138        |
| 6.4      | Perfect Competition  | 142        |
| 6.4.1    | Application: The Electricity Market  | 143        |
| 6.4.2    | Goals and Trade-offs of the Reforms  | 149        |
| 6.5      | Monopolistic Competition   | 150        |
| 6.6      | Oligopoly  | 152        |
| 6.6.1    | Cartel Model   | 152        |
| 6.6.2    | Application: OPEC  | 154        |
| 6.6.3    | Dominant Firm Model and the Oil Market   | 155        |
| 6.7      | Issues in Developing Countries   | 158        |
| 6.7.1    | Electricity Market Reform: A Comparison of Industrialised and Developing Countries | 159        |
| 6.7.2    | The Resource Curse   | 160        |
| 6.7.3    | Review Questions and Problems  | 161        |
| <b>7</b> | <b>Market-based Economic Instruments</b>   | <b>162</b> |
| 7.1      | Energy and Climate Policy: Goals and Instruments                                   | 162        |
| 7.1.1    | The Purpose of Energy and Climate Policy   | 162        |
| 7.1.2    | Types of Energy and Climate Policy Instruments                                     | 165        |
| 7.1.3    | Market Failures and Policy Instruments   | 167        |
| 7.2      | Monetary Market-based Instruments  | 169        |
| 7.2.1    | Pollution Taxes, Product Taxes, and Energy Taxes                                   | 169        |
| 7.2.2    | Subsidies  | 181        |
| 7.2.3    | Pollution Permit Trading Systems   | 187        |
| 7.2.4    | Behavioural Anomalies and Monetary Market-based Instruments                        | 191        |
| 7.3      | Non-monetary Market-based Instruments  | 194        |
| 7.3.1    | Information and Educational Programmes   | 194        |
| 7.3.2    | Nudges   | 195        |
| 7.4      | Issues in Developing Countries   | 199        |
| 7.4.1    | A Comparison of Product Taxes and Pollution Taxes in Developing Countries          | 199        |
| 7.4.2    | A Comparison of Carbon Taxes and Permit Trading Systems in Developing Countries    | 199        |
| 7.4.3    | Inefficiency of Fossil Fuel Subsidies  | 200        |
| 7.4.4    | Unintended Effects of Market-based Instruments in Developing Countries             | 201        |
| 7.4.5    | Review Questions and Problems  | 202        |

---

|          |  |     |
|----------|--|-----|
| <b>8</b> | <b>Non-market-based Instruments</b>  | 203 |
| 8.1      | Standards  | 203 |
| 8.1.1    | Pollution Standards  | 206 |
| 8.1.2    | Energy Standards   | 211 |
| 8.2      | Direct Control Measures  | 214 |
| 8.3      | Non-market-oriented Instruments and Behavioural Anomalies                    | 216 |
| 8.4      | Voluntary Agreements   | 218 |
| 8.5      | Issues in Developing Countries   | 218 |
| 8.5.1    | Enforcement of Standards   | 219 |
| 8.5.2    | Role of Information Provision in Facilitating the Effectiveness of Standards | 220 |
| 8.5.3    | License Plate-based Driving Restrictions                                     | 220 |
| 8.5.4    | Review Questions and Problems  | 221 |
| <b>9</b> | <b>Policy Choice and Evaluation</b>  | 222 |
| 9.1      | Policy Evaluation Criteria   | 222 |
| 9.2      | Distributional Issues and Acceptance of Policy Instruments                   | 225 |
| 9.3      | Policy Evaluation Methods  | 227 |
| 9.3.1    | Modelling the Economic Effects   | 228 |
| 9.3.2    | Modelling the Impact of Policies   | 232 |
| 9.3.3    | Review Questions and Problems  | 242 |
|          | <i>Special Terms</i>   | 243 |
|          | <i>References</i>  | 245 |
|          | <i>Index</i>   | 254 |

Additional Resources for this publication at <https://wp-prd.let.ethz.ch/exercisesfortextbookeep/>