Contents

1 Introduction .............................................. 1
  1.1 Background. ........................................ 1
  1.2 Aim and Structure of the Study .................... 2

  2.1 General Aims of Energy Systems ....................... 5
  2.2 Conceptual Role of Security and Safety for Energy Systems .... 7
  2.3 Robustness as a Basic Aim for Energy System Development .... 8
    2.3.1 Dynamic Stability ................................ 9
    2.3.2 Social Robustness ............................... 13
  2.4 Means for Tackling Complex Social Choices .............. 14
    2.4.1 Safe and Secure Energy Supply Through System Examination .......... 14
    2.4.2 Ethical Decision Support for Energy Transition ............. 23
  2.5 Summary and Conclusions ............................. 33

3 Prospects and Limits of Scientific Policy Advice for Future Energy Systems ........... 35
  3.1 Specific Challenges in Scientific Policy Advice ........... 36
    3.1.1 Academic Research and Scientific Expertise ....... 36
    3.1.2 Epistemic Values Involved in Expert Advice .......... 38
    3.1.3 Non-epistemic Values Involved in Expert Advice ...... 42
  3.2 Dealing with Risks, Uncertainty, and Ignorance in Expert Advice ............ 46
    3.2.1 Knowledge Deficits in Expert Advice ............... 46
    3.2.2 Using Non-epistemic Freedom to Fit Expert Advice to the Purpose ........ 49
  3.3 The Social Aspects of the Concept of Risk ................ 52
  3.4 Typical Characteristics of Uncertainty and the Precautionary Principle .......... 55
3.4.1 Dimensions of Scientific Uncertainty .......... 55
3.4.2 Post-normal Science ........................ 57
3.4.3 The Precautionary Principle ................ 59
3.5 Summary and Conclusions ....................... 65

4 Characterisation of Recent Energy System Analyses .......... 69
  4.1 Characterisation Schemes for System Analyses .......... 70
  4.1.1 From System Correlations to Analyses .......... 70
  4.1.2 Derived Tools for Meta-analysis of Studies ....... 76
  4.2 General Coverage and Actors of Currently Existing System Analyses .................................. 83
    4.2.1 Research Themes ............................. 84
    4.2.2 Institutions and Disciplines Involved .......... 85
    4.2.3 Conclusions ................................. 92
  4.3 Examples of System Analyses Consulted for Specific Questions .............................................. 95
    4.3.1 Official Scenarios for Analysing Germany’s Future Energy System .............................. 96
    4.3.2 Analyses for Deriving Estimates of Balancing and Energy Storage Requirements ............. 105
    4.3.3 Analyses with regard to Non-technical Parts and Framework Conditions ...................... 131
  4.4 Summary and Conclusions ........................... 138

5 Specific Economic Problems and Uncertainties in the Context of Energy Systems ................................. 141
  5.1 Some Problems of Sustainable Energy Policy ........... 142
  5.2 On Discounting: (Un-)Certainty, Time Trends and Generations ............................................. 151
    5.2.1 Theory of Discounting Under Certainty ........ 151
    5.2.2 A Theory of Discounting Under Uncertainty . 152
    5.2.3 Empirics ...................................... 154
    5.2.4 Policy ...................................... 155
  5.3 Oil Price Trends or Random Walk? ....................... 158
    5.3.1 The Growth of Oil Prices from a GARCH Perspective .................................................. 161
    5.3.2 Is Two-Way Causality a Way Out? A Vector-Error Correction Perspective ..................... 163
  5.4 The Impact of the EU-ETS on the Prices of Emission Certificates and Electricity .......................... 166
    5.4.1 CO₂ Cost Pass-Through Under Perfect Competition in Retail Markets .......................... 166
    5.4.2 CO₂ Cost Pass-Through under Imperfect Competition in Retail Markets ........................ 167
5.4.3 Capacity and Uncertainty: Profits in the Wholesale Market ........................................ 168
5.4.4 Empirics: Profit Maximisation and Functional Forms of Price Elasticity Estimates ........ 169
5.4.5 Improving the Empirics of Sluggish Consumer Behaviour ...................................... 170
5.4.6 The Impact of Carbon Prices on Electricity Prices ...................................................... 171
5.5 Summary and Conclusions ................................................................. 174

6 Energy System 2050: Impacts of Uncertainties on the Optimal Electricity Generation Mix ........ 175
6.1 Focus of the Analysis: Future Electricity Generation ................................................... 175
6.2 Energy System 2050: Optimal Electricity Generation Mix? .......................................... 177
   6.2.1 Methodology ................................................................. 177
   6.2.2 Application Case Study .................................................. 179
   6.2.3 Reference Scenario ....................................................... 181
   6.2.4 Sensitivity Analyses ..................................................... 183
6.3 Summary and Conclusions ................................................................. 186

7 Political Challenges in Managing Transitions of Energy Systems Beyond Pure Energy-Economic Modelling ......................................................... 187
7.1 Implications from System Analyses for Governance and Policy Instruments .................. 187
   7.1.1 General Considerations ................................................. 187
   7.1.2 Operational Incentives and Co-ordination ............................................... 189
   7.1.3 Investment Incentives and Co-ordination ............................................. 190
   7.1.4 Regulatory Settings and Co-ordination of Expectations ......................... 191
7.2 Multi-level Governance and Europe’s Energy Transition ............................................ 192
   7.2.1 Energy Transition from a European Perspective ..................................... 192
   7.2.2 The German Energy Transition ........................................... 202
   7.2.3 Challenges to Effective Action ............................................. 204
7.3 Summary and Conclusions ................................................................. 205

8 Conclusions and Recommendations ................................................................. 207
8.1 Reflections on Improving Scientific Policy Advice for Future Energy Systems ................ 207
8.2 Recommendations ................................................................. 212
   8.2.1 General Aims of Scientific Policy Advice ........................................ 212
   8.2.2 Dealing with Uncertainty .................................................. 213
   8.2.3 Practical Implications for the Design of Energy System Studies ..................... 214
   8.2.4 Beyond Pure Techno-Economic Analyses ........................................ 215
Appendix A ................................................. 217
Appendix B ................................................. 225
Appendix C ................................................. 227
Glossary .................................................... 231
References .................................................. 237
List of Authors ........................................... 251

Further volumes of the series *Ethics of Science and Technology Assessment* (Wissenschaftsethik und Technikfolgenbeurteilung) .... 255
Improving Energy Decisions
Towards Better Scientific Policy Advice for a Safe and Secure Future Energy System
2015, XLIII, 257 p. 31 illus., 12 illus. in color., Hardcover
ISBN: 978-3-319-11345-6