

# Contents

<b>List of Figures</b>	<b>ix</b>
<b>List of Tables</b>	<b>xiii</b>
<b>List of Symbols</b>	<b>xv</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Related Work and Research Questions</b>	<b>5</b>
<b>3 The Renewable Energy Model - REMod</b>	<b>13</b>
3.1 Model History . . . . .	13
3.2 Model Structure . . . . .	15
3.2.1 Required Input Data . . . . .	16
3.2.2 Transport Sector . . . . .	17
3.2.3 Process Heat Supply . . . . .	19
3.2.4 Space Heat and Domestic Hot Water Supply . . . . .	22
3.2.5 Electricity Base Load . . . . .	25
3.3 Objective Function and Model Design . . . . .	27
3.3.1 Objective Function . . . . .	27
3.3.2 Problem Design and Optimisation Algorithm . . . . .	34
3.4 Operating Principle . . . . .	41
3.5 System Components . . . . .	46
<b>4 Modelling of Load Balancing Options</b>	<b>55</b>
4.1 Excursus: Load Forecast . . . . .	55
4.2 Ramping Behaviour of Energy Conversion Technologies . . . . .	59
4.2.1 Term Definitions and Methodological Approach . . . . .	60
4.2.2 Discussion of the Model Extension . . . . .	67
4.3 Battery Electric Drive Concepts . . . . .	68
4.3.1 Modelling Approach . . . . .	68
4.3.2 Discussion of the Model Extension . . . . .	80
4.4 Grid-Supportive Heat Generation . . . . .	81
4.4.1 Operating Principle and Grouping of Heat Generators . . . . .	81

4.4.2	Discussion of the Model Extension . . . . .	84
4.5	Cross-border exchange of electricity . . . . .	85
4.5.1	Data Processing and Power Supply Curve . . . . .	86
4.5.2	Mandatory and Optional Import of Electricity . . . . .	89
4.5.3	Discussion of the Model Extension . . . . .	92
4.6	Power Storages and Production of Synthetic Fuels . . . . .	93
4.6.1	Modelling Approach . . . . .	94
4.6.2	Discussion of the Model Extension . . . . .	97
<b>5</b>	<b>Model Parametrisation</b>	<b>99</b>
5.1	Systems with Non-Predetermined Total Amount . . . . .	99
5.2	Systems with Predetermined Total Amount . . . . .	101
5.3	Time Series and Further Parameters . . . . .	103
5.4	Model Calibration . . . . .	108
<b>6</b>	<b>Results</b>	<b>113</b>
6.1	Flexibility of Thermal Power Plants . . . . .	113
6.1.1	Impact of Ramping Behaviour on the System Configuration . . . . .	114
6.1.2	Assessment of Power Plant Operation . . . . .	117
6.1.3	Variation of Weather Data and Ramping Assumptions . . . . .	120
6.1.4	Summary and Conclusions . . . . .	123
6.2	The Role of Alternative Drive Concepts . . . . .	126
6.2.1	Electrification of the Motorised Road Transport . . . . .	126
6.2.2	Cost Sensitivity Analysis of BEVs . . . . .	129
6.2.3	Assessment of Controlled Vehicle Charging . . . . .	133
6.2.4	Summary and Conclusions . . . . .	138
6.3	Flexibility of Heat Generators and Thermal Energy Storage . . . . .	140
6.3.1	Role of Electric Heat Pumps for the Supply of Space Heat . . . . .	140
6.3.2	Assessment of a Power-Controlled Heat Generation . . . . .	144
6.3.3	Operation of Thermal Energy Storages . . . . .	151
6.3.4	Summary and Conclusions . . . . .	155
6.4	The Value of Demand-Side Management . . . . .	157
6.4.1	Restriction of Key Technologies . . . . .	157
6.4.2	Influence of Weather Data . . . . .	162
6.4.3	Cost Assessment of Demand-Side Management . . . . .	174
6.4.4	Summary and Conclusions . . . . .	182
<b>7</b>	<b>Summary and Outlook</b>	<b>185</b>
<b>A</b>	<b>Model Input Parameters</b>	<b>191</b>
A.1	Power Generators . . . . .	191

A.2 Ramping Parameters . . . . .	195
A.3 Synthetic Fuels and Steam Reforming . . . . .	196
A.4 Storage Technologies . . . . .	197
A.5 Space Heat and Domestic Hot Water Supply . . . . .	199
A.6 Biomass . . . . .	214
A.7 Process Heat Supply . . . . .	220
A.8 Motorised Road Transport . . . . .	225
<b>B Results: Thermal Power Plants</b>	<b>233</b>
<b>C Results: Alternative Drive Concepts</b>	<b>239</b>
<b>D Results: Heat Generators and Thermal Energy Storage</b>	<b>241</b>
<b>E Results: The Value of Demand-Side Management</b>	<b>243</b>
<b>Bibliography</b>	<b>247</b>