Contents

Summary i

Zusammenfassung v

Acknowledgements ix

Thesis Publications xiii

Contents xv

Chapter 1: Introduction 1

1.1. Hazardous waste incineration 2

1.2. Systematic analysis tools in industrial waste management 3

1.3. Objectives 7

Chapter 2: Optimized Energy Use through Systematic Short-term Management of Industrial Waste Incineration 11

2.1. Abstract 11

2.2. Introduction 11

2.3. Waste management and incineration system 15

2.4. Mathematical formulation 19

2.4.1. Time representation 19

2.4.2. Logistics 20

2.4.3. Waste incineration 23

2.4.4. Objective function 28

2.4.5. Linearization 29

2.5. Case Study 31

2.5.1. System description 33

2.5.2. Illustrative schedule outcome 35

2.5.3. Auxiliary fuel consumption 39

2.5.4. Computational performance 42

2.6. Conclusion 43

2.7. Acknowledgement ... 45
2.8. Funding ... 45
Chapter 3: Hierarchical Integration of Planning and Scheduling for Industrial Waste Incineration 47
3.1. Abstract ... 47
3.2. Introduction ... 47
3.3. Problem statement ... 51
3.4. Methodology ... 53
3.4.1. Hierarchical Integration of Planning and Scheduling ... 55
3.4.2. Planning model ... 56
3.4.3. Scheduling model ... 61
3.5. Results ... 62
3.5.1. System description ... 63
3.5.2. Representation of time ... 63
3.5.3. Illustrative example ... 64
3.5.4. Case Study ... 68
3.6. Conclusion ... 73
3.7. Acknowledgement ... 75
3.8. Funding ... 75
Chapter 4: Novel Hierarchical Integration Methodology of Planning, Scheduling and Real-time Optimization in the Process Industry 77
4.1. Abstract ... 77
4.2. Introduction ... 77
4.3. General integration methodology ... 80
4.4. Hazardous waste incineration ... 83
4.4.1. Application objective ... 84
4.4.2. System overview ... 86
4.4.3. Mathematical model formulations ... 87
4.4.3.1. Planning and Scheduling Models ... 87
4.4.3.2. Real-time optimization ... 89
4.5. Integration methodology for the hazardous waste ... 97
4.5.1. Counteracting deviations between actual and expected performance ... 99

4.5.2. Handling unforeseen events ... 99
4.6. Results ... 100
4.6.1. System description ... 100
4.6.2. Representation of time ... 101
4.6.3. Illustrative example ... 101
4.6.4. Case Study 1 ... 107
4.6.5. Case Study 2 ... 109
4.7. Conclusion ... 113
4.8. Acknowledgement ... 115
Chapter 5: Conclusions 117
Chapter 6: Outlook 121
Appendix A: Nomenclature 125
A.1. Sets ... 125
A.2. Subsets ... 125
A.3. Parameters ... 126
A.4. Variables $\in \mathbb{R}$ ... 130
A.5. Variables $\in \mathbb{R}0+$ ... 130
A.6. Binary variables ... 134
A.7. Abbreviations ... 136
References 139
Academic Achievements 147
Curriculum Vitae 151