Preface

Who Should Read This Text?

This text is intended for students and engineers interested in the design of classical and novel waste-to-energy (WTE) systems. It focuses on: (i) the description of processes involved in the conversion of municipal solid waste (MSW) into energy; (ii) key problems concerning corrosion, which negatively affect WTE steam cycle design parameters; (iii) possibilities to increase WTE conversion efficiency and performance through innovative cycles based on integration with gas turbines (GT).

This text has evolved from 3 years of PhD research studies carried out at the DIN—Department of Industrial Engineering, Alma Mater Studiorum—Università di Bologna.

The target readers are graduate students, masters students, or PhD students with a thorough understanding of basic thermodynamic processes in energy systems, and engineers working in the field of energy systems and MSW conversion. Common prerequisites are knowledge of general mechanical engineering topics such as thermodynamics, fluid machines, energy systems, etc.

Why Has This Text Been Written?

Several countries have waste management systems with significant improvement boundaries to reach worldwide state-of-the-art engineering, health, and safety standards. An increase in environmental and health concerns, combined with new possibilities to exploit these ordinary life by-products as a valuable energy resource, has led to the exploration of alternative methods for waste disposal. In this context, the energy conversion of MSW in WTE power plants is one of the principal means of integrated waste management; its potential is increasing throughout Europe, both in terms of plant number and capacity, furthered by legislative directives. The aim of the new Waste Framework Directive 2008/98/EC is to drive WTE facilities to maximize energy recovery and utilization of waste heat, in order to substitute energy

produced with conventional fossil fuel-fired power plants. This calls for novel approaches to maximize the conversion of MSW into energy. In particular, the idea of an integrated configuration made up of a WTE and a GT derives from the desire to eliminate, or at least mitigate, limitations affecting the WTE conversion processes bounding the thermodynamic efficiency of the cycle. The aim of this book is to study and propose innovative integrated WTE cycles. It investigates, from a thermodynamic point of view, integrated WTE–GT system sharing, particularly the steam cycle. The book also proposes and analyzes novel approaches to maximize the conversion of MSW into energy, and discusses, in its final chapters, the difficult task of optimizing conversion efficiency for multi-fuel (MF) energy systems.

What Can Be Learned from This Text?

The primary emphasis explains the basic concepts related to WTE conversion processes, highlighting the most relevant aspects limiting the thermodynamic efficiency of a WTE power plant. In particular, a preliminary thermodynamic analysis is carried out to quantify the influence of the main steam cycle parameters and plant configurations for WTE conversion efficiency. The book's core lesson describes and discusses the integrated WTE–GT concept. Two basic types of hybrid dual-fuel combined cycle arrangements are explained: (i) *steam/waterside integration* and (ii) *windbox repowering*. Focusing on steam/waterside integration, various layouts are proposed; for each analyzed configuration, the optimum WTE–GT plant to maximize steam generation and power output, and to minimize discharged outlet temperatures is identified.

Issues of power output allocation and conversion efficiency for an MF energy system, receiving different type of input fuels and generating a single useful output, are discussed. Based on several performance indexes, specifically introduced to evaluate an MF energy system, different approaches are compared in order to evaluate the WTE–GT integrated system performance.

Finally, a specific case study of a medium-sized WTE facility integrated with different market-available GT units is presented; for each considered, GT units and integrated plant configurations, as well as detailed modifications to the WTE original steam cycle and the resultant achieved performance gains are discussed.

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Bologna, October 2014 *Lisa Branchini*

Book organization

The manuscript is divided into four main parts.

Part I: Presents the outline of the scenarios of interest and describes the fundamental key aspects concerning the waste-to-energy conversion processes. Chap. 2 presents an overview of municipal solid waste production and disposal for both the European and the Italian markets. Chapter 3 introduces and describes the basic concepts related to waste-to-energy conversion processes, highlighting the most relevant aspects circumscribing the thermodynamic efficiency of a WTE power plant.

Part II: In Chap. 4, a thermodynamic analysis is carried out in order to quantify the influence of steam cycle parameters and plant configurations on WTE thermodynamic efficiency. The aim of this preliminary analysis is to understand and compare possibilities and benefits of a thermodynamic cycle upgrade for a WTE facility.

Part III: Explains and discusses the hybrid combined cycle (HCC) concept. Two basic types of hybrid dual-fuel combined cycle arrangements are detailed in Chap. 5: (i) *steam/waterside-integrated* HCC and (ii) *windbox repowering*.

Steam/waterside integration represents a cost-effective method to increase the electric efficiency of a WTE power plant without the necessity of new expensive materials to prevent corrosion risks. Indeed, a further superheating of the steam is performed in a separated heat recovery steam generator (HRSG), by means of a high-grade fuel, that does not cause corrosion problems in the superheater banks.

Windbox repowering, however, due to a considerable increase in combustion gas volumetric flow rate, requires a significant redesign of combustion, convective, and gas cleaning sections.

With reference to WTE–GT steam/waterside integration, the logic governing plant match in terms of steam production as the function of thermal power is investigated and explained. The thermodynamic analysis carried out in Chap. 6 assesses and defines, for given layout and operative conditions, the optimum WTE–GT plant match to maximize steam generation and power output, and to minimize discharged outlet temperatures. Moreover, several proposed WTE–GT steam/waterside-integrated layouts, with reference to one pressure level heat recovery boiler configuration, are presented and detailed.

Part IV: In Chap. 7, open research issues to evaluate the performance and the efficiency conversion of multi-fuel (MF) energy systems are discussed. The difficulty in defining a performance index capable of quantifying the efficiency of

the integrated system, compared to separate generation, lies in assigning the extra power generated as a consequence of systems integration. Thus, in Chap. 7, several performance indexes are proposed and described. Finally, in Chap. 8, detailed modifications to the WTE cycle and the resulting enhancement of its performance are presented for two different WTE–GT integrated cases. Numerical results for a representative WTE plant integrated with different commercial GT units are shown and discussed. The performance indexes and output allocation approaches defined in Chap. 7 are applied to quantify, for each case, integrated system performance.

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