Energy xxx (2017) 1–11

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Waste to energy plant operation under the influence of market and legislation conditioned changes

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ARTICLE INFO

Article history:
Received 31 December 2016
Received in revised form
7 April 2017
Accepted 14 April 2017
Available online xxx

Keywords:
Waste-to-energy
Combined heat and power
District heating
Power market
Dynamic heat market
Waste management legislation

ABSTRACT

In this paper, gate-fee changes of the waste-to-energy plants are investigated in the conditions set by European Union legislation and by the introduction of the new heat market. Waste management and sustainable energy supply are core issues of sustainable development of regions, especially urban areas. These two energy flows logically come together in the combined heat and power facility by waste incineration. However, the implementation of new legislation influences quantity and quality of municipal waste and operation of waste-to-energy systems. Once the legislation requirements are met, waste-to-energy plants need to be adapted to market operation. This influence is tracked by the gate-fee volatility. The operation of the waste-to-energy plant on electricity markets is simulated by using EnergyPLAN and heat market is simulated in Matlab, based on hourly marginal costs. The results have shown that the fuel switch reduced gate-fee and made the facility economically viable again. In the second case, the operation of the waste-to-energy plant on day-ahead electricity and heat market is analysed. It is shown that introducing heat market increased needed gate-fee on the yearly level over the expected levels. Therefore, it can be concluded that the proposed approach can make projects of otherwise questionable feasibility more attractive.

1. Introduction

A large generation of waste per capita, out of which over a quarter is Municipal Solid Waste (MSW), classifies waste management (WM) as one of the core issues in sustainable development of EU regions. This problem is even more emphasized in urban and metropolitan areas with higher population density. With increasing population, energy consumption also increases. For that reason, urban energy systems have been analysed in many previous research papers. Urban solutions for district heating (DH), the data, and technologies, have been recently discussed in Ref. [1]. For such urban applications, optimal planning methods have been elaborated in Ref. [2], with the case of Russia. Relevant is also the study of the integration of high share of renewable energy sources [3], which stipulated that energy-only markets need to be addressed for the correct price signals and the flexible measures are of the key relevance for the high RES integration. In this context, flexible WtE CHP plant is a relevant factor in two energy markets: electricity and heat market. Therefore, integration of waste and energy systems represents the logical path in the sustainable development of regions. The importance of the usage of local energy sources in local energy systems, as well as their positive influence on the overall EU energy system, is emphasized in Heat Roadmap Europe [4], [5]. In this study, waste was classified as one of the primary heat sources in district heating systems (DHS). While waste and its energy recovery may seem as an ideal energy source for usage in urban areas, EU has identified the material potential of waste, which can be utilized through its material recovery. The first step in this direction was taken by Waste Framework Directive [6] which sets waste hierarchy by which primary step for recovery of produced waste is recycling (material recovery), while energy recovery is subordinated to it. A step further in the direction of material recovery was made by the Circular Economy Package [7] which defines more

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http://dx.doi.org/10.1016/j.energy.2017.04.080
0360-5442/

rigorous goals by increasing the share of MSW, which needs to be primarily separated and prepared for material recovery. These legislative changes have a great influence on waste quantities that are available for usage in waste-to-energy (WtE) based systems [8]. These changes in WMS can put feasibility of incineration-based WtE systems in question as burnable waste quantity decreases. This problem can be compensated by the introduction of new fuels such as biomass. Woody biomass, agricultural and forest residue [9], as well as biomass from short rotation coppice grown on unused agricultural land [10], showed great potential for use in energy systems and sustainability. Efficient use of locally available biomass was analysed in Ref. [11].

The use of biomass in WtE DH plant has proven to be a viable practice, as well as in co-combustion regime and as the use of mixed wastes (MW) for base load and biomass for peak load coverage [12], but time changes in waste quantity are not tracked. Use of WtE in conjunction with energy storage in variable electricity pricing environment, on industry scale, has been analysed and proven to justify a higher establishment cost of WtE [13].

During the lifetime of the WtE DH projects, a "business as usual" way of planning the waste incineration implies a constant increase of MSW quantity with a uniform quality. This is connected with increasing waste generation due to the growth of population and standard of living. This trend was already described by Kuznets curve hypothesis (EKC) which claims that economy growth (that can be defined by income per capita) has a negative impact on environment to a certain point after which environmental impact is reducing. This hypothesis was also adapted to MSW and called waste Kuznets curve hypothesis (WKC) and proved that household MSW generation per capita income also follows this correlation [14]. Also, this threshold was already reached by one part of the households/provinces in Japan [14] and Italy [15]. This trend shows that solving waste problem by building new waste disposal facilities can become unviable because increasing tendency in the MSW generation will come to an end. Furthermore, waste policies and instruments that encourage waste prevention can further decrease waste generation [15]. In the EU, the absolute decoupling trend is not present, but the elasticity of waste generation to income drivers is lower than in the past which indicates relative decoupling [16]. Also, current policies do not provide incentives for waste prevention, which will have to change. The introduction of new WM solutions, oriented to the reduction of waste production, re-using and recycling, reduces the amount of waste that needs to be disposed of [17]. The latter effect increases with time and can be viewed as a hazard for the feasibility of WM projects [8]. These effects are emphasized in new EU member states which have to quickly implement new WMS to achieve EU legislation goals but these systems also need to be economically sustainable. This should be done without drastically increasing the price of waste collection for the general population, as it would undermine waste collection system and cause problems such as illegal waste dumping. Therefore, the system needs to be designed to restrict volatility of gate-fees for waste treatment.

Reviewed literature did not sufficiently analyse time change of waste quantity and composition under the influence of WMS changes and its impact on WtE plants. Moreover, only in one paper [8] different ways of compensation of reduced waste quantities are analysed but the influence of secondary separation of waste was not considered. Furthermore, in Refs. [8] and [18] economic analysis of the operation of waste incinerators was considered, but their overall efficiency is rather low because of the emphasis on electricity generation. Also, in these papers the influence of gate-fee change was analysed only through arbitrary sensitivity analysis without consideration of the influence of other parameters on gate-fee value. Papers that analysed co-combustion of biomass with other fuels such as [19] did not deliberate big involuntary fuel substitution to sustain economic viability. The contribution of this work can be found in viability analysis of this possibility. In another part of this work, the focus was given to the market operation of considered facility. The influence which electricity grid tariffs have on flexible power to heat application was investigated in Ref. [20], but more research was done in the field of the possibility of plants operation on the open electricity market [21], [22]. As for the heat energy market, it is still in its infancy as most of the DHS are in public/municipality ownership. However, even in this segment, diversification of ownership is undergoing [23] which inevitably fosters the establishment of heat markets. Open DHS operation was already analysed [24] which consequently led to the analysis of waste incinerator operation on both energy markets in this paper. Upon the possible development of the dynamic heat market in Denmark, WtE plants could face the economic problems as they would not have guaranteed access to the DH market anymore. In addition, a local WtE plant can expect partial fuel switch in the foreseeable future due to a lack of economic feasibility of the waste import [25]. The contribution of this work can also be found in the economic analysis of dynamic WtE which operates on two markets. By introducing new fuel, WtE plant is already switching from operation in regulated conditions without third-party access which means a switch from stable fuel and energy prices to partially market defined fuel prices. On the other hand, after the transition to new WMS, WtE plants need to be ready to compete on open electricity and heat markets. By doing that, a care must be given to the gate-fee volatility, which is unavoidable in open market operations, while at the same time social-economic component of waste quantity and quality represents one more aggravating circumstance.

During the process of defining the case study, big difference in gate-fee values was observed across the EU - up to 176 €/t, calculated as a mean value with the addition of waste incineration tax [26]. Also, the difference in national legislations defines a wide range of tax values for different WM and disposal technologies. This is the result of the organization of the WM and its efficiency. Therefore, in this paper case studies of Croatia, where WMS does not meet EU criteria and has one of the lowest recycling rates, and Denmark, which has greatly exceeded the EU goals and is considered to be one of the most advanced systems that even makes extra income from the import and disposal of waste from neighbouring countries. This comparison extends the current knowledge by comparing the two extremes and leads to the conclusion that the investment in thermal waste treatment can be cost-effective in a wide range of configurations of WM system, without constituting an additional financial burden for the municipality or its citizens.

2. Methods

The influence of adaptation to new WM legislation on WtE plants is tracked by analysing gate-fee volatility. Also, a method for adapting to expected changes in fuel supply of only planned WtE plant in Croatia and its management is proposed. To compensate for reducing the amount of primary fuel (waste), the share of secondary fuel is gradually increased until the final fuel shift is achieved. Fuel substitution is guided by waste amount prognosis in the analysed time period. This trend is pronounced in all new EU countries, which in the next couple of years have to invest a great effort to implement primary separation into WMS. Changes in the waste collection are expected in order to achieve EU goals gradually, but they cannot solve the waste disposal problem completely, so other ways to tackle this problem are explored. Implementation of other technologies, such as Mechanical Biological Treatment (MBT), is expected to further reduce the quantity of waste available

Please cite this article in press as: Tomić T, et al., Waste to energy plant operation under the influence of market and legislation conditioned changes, Energy (2017), http://dx.doi.org/10.1016/j.energy.2017.04.080