Resources, Conservation and Recycling 77 (2013) 13–21

Contents lists available at SciVerse ScienceDirect

Resources, Conservation and Recycling

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

The potential contribution of sustainable waste management to energy use and greenhouse gas emission reduction in the Netherlands

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ARTICLE INFO

Article history:
Received 14 September 2012
Received in revised form 20 March 2013
Accepted 9 April 2013

Keywords:
Sustainable resource management
Recycling
Energy savings
Municipal solid waste
Waste incineration
Material efficiency

ABSTRACT

Future limitations on the availability of selected resources stress the need for increased material efficiency. In addition, in a climate-constrained world the impact of resource use on greenhouse gas emissions should be minimized. Waste management is key to achieve sustainable resource management. Ways to use resources more efficiently include prevention of waste, reuse of products and materials, and recycling of materials, while incineration and anaerobic digestion may recover part of the embodied energy of materials. This study used iWaste, a simulation model, to investigate the extent to which savings in energy consumption and CO_2 emissions can be achieved in the Netherlands through recycling of waste streams versus waste incineration, and to assess the extent to which this potential is reflected in the LAP2 (currently initiated policy). Three waste streams (i.e. household waste, bulky household waste, and construction and demolition waste) and three scenarios compare current policy to scenarios that focus on high-quality recycling (*Recycling+*) or incineration with increased efficiency (*Incineration+*). The results show that aiming for more and high-quality recycling can result in emission reductions of 2.3 $MtCO_2$ annually in the Netherlands compared to the reference situation in 2008. The main contributors to this reduction potential are found in optimizing the recycling of plastics (PET, PE and PP), textiles, paper, and organic waste. A scenario assuming a higher energy conversion efficiency of the incinerator treating the residual waste stream, achieves an emission reduction equivalent to only one third (0.7 $MtCO_2$/year) of the reduction achieved in the *Recycling+* scenario. Furthermore, the results of the study show that currently initiated policy only partially realizes the full potential identified. A focus on highest quality use of recovered materials is essential to realize the full potential energy and CO_2 emission reduction identified for the Netherlands. Detailed economic and technical analyses of high quality recycling are recommended to further evaluate viable integrated waste management policies.

1. Introduction

To avoid major negative impacts of climate change, large reductions in greenhouse gas emissions are necessary. For industrialized countries, like the Netherlands, reductions of 60–80% in greenhouse gas (GHG) emissions are necessary by 2050 (IPCC, 2007). To achieve this, both energy and resources must be used far more efficiently. Secondly, future scarcity is an argument for increasing material efficiency (Allwood et al., 2011; IPCC, 2007). Within decades, shortages are expected for a number of strategic materials that are mainly used in electronic equipment (Cohen, 2007). Companies and countries are already making strategic decisions to ensure access to these essential materials. The European Commission has also recognized the importance of resource efficiency and made it one of the seven flagship initiatives that are part of the Europe 2020 strategy that aims to deliver sustainable, smart and inclusive growth. The focus on resource efficiency should help to achieve the European Union's targets on reducing GHG emissions, improving the security of supply of raw materials, and make the European economy more resilient to price increases of energy and commodities (European Commission, 2011).

Waste management is a key element in achieving sustainable resource management. Ways how waste management can contribute to efficient resource use include waste prevention and reuse and recycling of products and materials, while incineration and anaerobic digestion may recover part of the materials embodied energy of materials. The Netherlands has a long history in (research on) waste-to-energy and saving resources, and has been successful in the past to recover materials from waste. Waste and resource

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http://dx.doi.org/10.1016/j.resconrec.2013.04.002

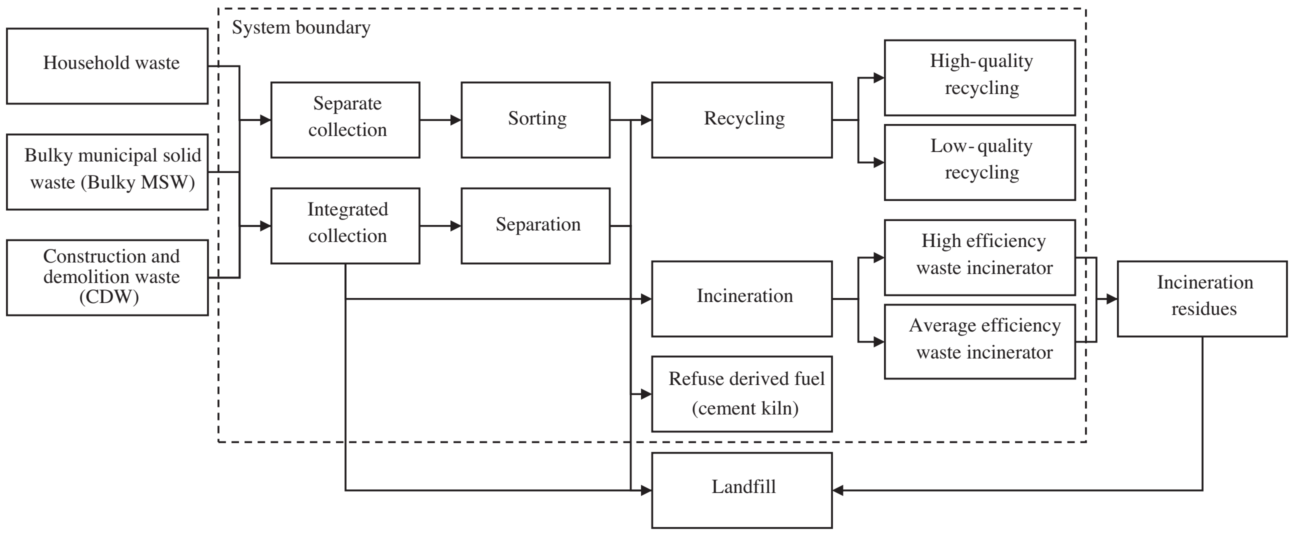

Fig. 1. Schematic representation of the system boundaries in this study. *Note*: between most of the processing steps a transport step is included, which is not depicted.

management was also central to the development of the second National Waste Management Plan (Landelijk Afvalbeheerplan, LAP2) in the Netherlands (VROM, 2010), which is implemented for the period 2009–2021. The LAP2 aims to

- Limit the total waste volume to 68 Mt in 2015 and 73 Mt in 2021 (60 Mt in 2006);
- Increase waste recovery to 85% in 2015;
- Increase municipal waste recovery from 51% in 2006 to 60% in 2015;
- Maintain recovery of construction and demolition waste at the 2006 level of 95%.

The LAP2 should also contribute to the reduction of GHG emissions, as set out in national policy, and will try to achieve this by focusing on recycling, anaerobic digestion and incineration.

This study investigates to what extent a further reduction of energy consumption and CO_2 emissions can be achieved through recycling of materials in selected waste streams, versus waste incineration with energy recovery. For this purpose a simulation model, called *i*Waste, is developed which is used for an exploratory (scenario) analysis of treatment options for selected waste streams in the Netherlands. The *i*Waste model simulates the processing of waste and includes the three waste streams household waste, bulky household waste, and construction and demolition waste. It builds on the life cycle of materials and products in the waste streams, starting with the generation of waste and ending with final processing in the form of recycling, incineration or use as refuse derived fuel, including waste collection, transportation, sorting and separation. This allows various options to be evaluated in an integrated way, while accounting for the characteristics of recycling and alternative waste processing options. Similar waste models are available, but either do not include parameters that significantly influence the results, such as transport and recycling quality (WARM, U.S. EPA, 2006), or are highly detailed life cycle assessment (LCA) tools that focus only on municipal solid waste (Easewaste, Christensen et al., 2009).

Three scenarios are considered in this study, in which the current set of policy measures ("*Successful current policy*") is compared to scenarios that focus on increased recycling ("*Recycling+*") or incineration with increased efficiency ("*Incineration+*").

The next section describes the methodology, explaining the system boundaries, the calculation of energy consumption and CO_2 emissions and the allocation of energy- and emission savings for different waste processing options. In Sections 3 and 4 the details of the selected waste streams and scenarios considered are outlined. The results and discussion are presented in Section 5, followed by the conclusions and recommendations for further research.

2. Methodology

The *i*Waste model is used to evaluate three alternative scenarios for the management of waste streams and their effects on the energy balance and CO_2 emissions. It includes data to simulate waste disposal and processing in the Netherlands in 2008 (reference situation). Parameters can be varied to test different scenarios, which can be compared with the reference situation. The model focuses exclusively on energy consumption (fuel and electricity) and CO_2 emissions and does not yet include other environmental impacts or the economics of various treatment options.

2.1. System boundaries

A schematic representation of the system boundaries is shown in Fig. 1. A careful selection of system boundaries is important in scenario analyses. Recent research by Laurijssen et al. (2010) on recycling of paper has shown that different system boundaries (i.e. taking into account resource constraints or not) can significantly influence conclusions with respect to the CO_2 emissions mitigation potential of recycling. In this study, the system boundaries are therefore carefully and consistently determined. The system boundaries for calculating energy consumption, CO_2 emissions, and savings for the processing of various materials start at the level of waste generation and end at the level of final processing in the form of recycling, incineration in a waste-to-energy plant or use as refuse derived fuel (RDF) (e.g. in industrial processes). Processes included are waste collection, transportation, sorting and separation. Landfilling of waste is not included, as the current policy in the Netherlands is aimed at minimizing waste disposal in landfills and landfill bans exist for many materials. Material losses that occur in the various steps of waste processing are taken into account in the *i*Waste model. The avoided energy consumption and CO_2 emissions are attributed as energy- and CO_2 savings to the specific processing option.

The *i*Waste model includes specific data for the Netherlands on waste stream volumes, composition, and processes (i.e. efficiencies, energy use, CO_2 emissions, and substitution factors), of which a detailed overview can be found in Corsten et al. (2010). All weight