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Energy Valorization of Edible Organic Matter for Electrical, Thermal and Cooling Energy Generation: Part Two

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Abstract

This work focuses on energy recovery from residual organic biomass, particularly from food products in large distribution centers beyond their sell-by date and edibility, emphasizing the valorization of material originally considered as waste. Its recovery makes a valuable contribution to resources rationalization and to environmental sustainability.
An integrated system anaerobic reactor, primary plants for electricity and heat production (micro gas turbines, internal combustion engines and solid oxide fuel cells), refrigeration plants for cooling energy generation (absorption and compression cooling plants), fed with the aforementioned organic matter, is presented. The procedure of an integrated system designing is proposed in the first paper: Part One.
This second paper, Part Two, applies the previously mentioned procedure to a case study and presents the results of the various analyzes. Downstream, the matching "energy system-user" analysis is then carried out to assess the most appropriate energy supply strategy and therefore the choice of the most efficient primary plant. Finally, the knowledge of the global energies, of the consumption of biogas, and of the characterization of the organic fraction, allows the dimensioning of the anaerobic reactor and the determination of the quantity of organic matter to be processed for user purposes.
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Keywords: Alternative energy systems, organic matter, biogas, energy rationalization

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Nomenclature

Symbol	*Description*	*Unit of measurement*
PLF	Power Load Following	
HLF	Heat Load Following	
wd	winter day type	
sd	summer day type	
P	power	[W]
h	time (hour)	[h]
I_{PES}	primary energy saving index	[-]
I_{env}	environmental index	[kg_{CO2eq}/y]
V	Volume	[m^3]
SGP	Specific Gas Production	[m^3/kg_{sub}]
TVS	Total Volatile Solids	[kg_{TVS}/d]
OLR	Organic Load Rate	[$kg_{sub}/(m^3 \cdot d)$]
$\dot{V}$	volumetric flow rate	[m^3/d]
$\dot{m}$	mass flow rate	[kg/d]
HRT	Hydraulic Residence Time	[d]
η	efficiency	[-]
$r_{th/el}$	thermo-electric ratio	[-]
integr	external integration	
sat	energy need satisfied by system	
ext	external	
USWOF	urban solid waste organic fraction	

Subscript/superscript

nom	nominal
el	electric term
th	thermal term
cool	cooling term
sub	organic substrate
react	reactor

1. Introduction

Organic waste recovery, whose purpose is aimed at re-use, is a valuable contribution to resources rationalization and to environmental sustainability [1,2,3]. Organic residual matter, which is approximately 30 – 40 % of waste in general, when subjected to anaerobic digestion processes, enables the production of a considerable quantity of renewable biogas, which can be used for energy, helping to reduce use of fossil fuels and reducing waste production [4,5, 6]. The biogas, then used to supply technologically advanced energy systems, adds to the current environmental sustainability for waste avoiding also energy efficiency and reduction of gaseous emissions [7,8,9,10,11,12].

This work focuses on energy recovery from residual organic biomass, particularly of food products.

An integrated system of anaerobic reactor/primary plants for electricity and heat production/refrigeration plants for cooling energy generation fed with the aforementioned organic matter, is proposed for organic valorization. The system, in trigeneration layout, is aimed at the energy autonomy of a user of the tertiary sector.

The present paper, Part Two, applies a design procedure of a self-sustained energy cycle, aimed at the valorization of edible organic fractions to a case study presented in Part One. This section presents the results of the various analysis aimed at assessing the most favorable solution, in order to provide for satisfaction of the user's energy requirements, in terms of plants combination and in terms of the most appropriate strategy of energy service. It presents the user energy profiles, emphasizing the most critical conditions in order to have the maximum