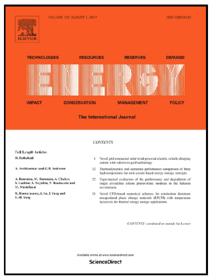
Accepted Manuscript



The Energy Performance of Vacuum Evaporators for Liquid Digestate Treatment in Biogas Plants

Marek Vondra, Vítězslav Máša, Petr Bobák

PII:	S0360-5442(17)31133-7
DOI:	10.1016/j.energy.2017.06.135
Reference:	EGY 11143
To appear in:	*Energy*
Received Date:	18 February 2017
Revised Date:	26 May 2017
Accepted Date:	22 June 2017

Please cite this article as: Marek Vondra, Vítězslav Máša, Petr Bobák, The Energy Performance of Vacuum Evaporators for Liquid Digestate Treatment in Biogas Plants, *Energy* (2017), doi: 10.1016/j. energy.2017.06.135

Word count: 10190

The Energy Performance of Vacuum Evaporators for Liquid Digestate Treatment in Biogas Plants

Marek Vondra*, Vítězslav Máša, Petr Bobák

Brno University of Technology, Institute of Process Engineering & NETME Centre,
Technická 2896/2, 616 69 Brno, Czech republic
m.vondra@vut.cz

Keywords: vacuum evaporation; liquid digestate; anaerobic digestion; biogas plant; energy consumption; nutrient recovery

Highlights:

- vacuum evaporation as an effective way of liquid digestate treatment in biogas plants,
- energy and mass balance models of three industrial evaporators suitable for digestate thickening,
- comparison of the evaporators in terms of their energy performance,

Vacuum evaporation is an efficient method for reducing the volume of liquid digestate (LD) from biogas plants (BGP). Furthermore, thickening LD in BGP contributes to the efficient utilization of waste heat and also reduces fossil fuel consumption that is needed for transporting LD. However, the utilization of vacuum evaporation must be reasonable, and a comprehensive study should precede the integration of evaporation technology in a particular BGP. For this purpose, this study compares selected parameters of three types of industrial evaporators which may be suitable for LD thickening. Furthermore, this study provides a mathematical model that describes the mass and energy balances of the chosen evaporators and is able to evaluate their energy performance for a given set of input variables.

It was concluded that the forced-circulation evaporator has the highest energy requirements and also requires a high cooling performance. This type of evaporator will be interesting for the plant owners only if the cost of power generation is extremely low. In terms of consumption of energy and cooling duty, the multi-stage flash evaporator is the most efficient and it also requires the least heat transfer area. The falling-film evaporator provides only slightly worse performance.

1. Introduction

One of the biggest challenges currently facing society is to decrease impact of human activities on the environment while maintaining potential for sustainable future development and the wellbeing of future generations. The European Union has been a world-leader and strong promoter of environmentally-friendly initiatives and measures. The EU has adopted the so called 20-20-20 Strategy, which aims to reduce EU carbon dioxide emissions by 20 % (compared to 1990 levels), increase the share of renewable energy sources to 20 %, and increase efficiency in energy production by 20 % (in comparison with 2007 predictions) [1].

One of the consequences of this EU policy has been an immense increase in the number of BGP. There were more than 17 thousand plants in Europe in 2015, and their total capacity exceeds 8.3 GW_{el} [2]. The BGP boom was, among others, supported by significant financial aid, which made BGP an attractive investment opportunity and facilitated the expansion of this environmentally-friendly technology.

1.1 Waste heat in biogas plants

Despite the above developments, BGP also has several disadvantages. One of the most significant is the ineffective use of the heat that is produced in cogeneration units. BGP generally uses only 20–40 % of the heat and the rest is considered to be waste heat, and is usually not used at all [3], [4]. Yet, there are theoretically several ways to utilize the waste heat. The produced heat must be used for heating the fermentor (the main consumer of the heat). In addition to this, the heat from BGP could be used in a district heating system, drying digestate, sludge or wood sawdust, cooling, and additional power production using ORC or Kalina cycle [3]. One interesting option is the use of waste heat for heating greenhouses, in which heat consumption represents the dominant part of total crop production costs [5]. It is the distance between BGPs and industrial or populated areas which is often cited as a reason that these possible methods for utilization of the heat are rarely explored and executed. Other reasons include the quantity and quality of the heat, which ranges from 80–450 °C, seasonal fluctuations in heat demands (most heat is produced in the summer) and the low price of fossil fuels [3]. The ORC process is not economically