Nuanced analysis regarding the novel technologies using biomass as a renewable energy source for increasing energy efficiency in civil engineering

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1. INTRODUCTION

Biomass is one of the oldest renewable resources whose energy potential can be harnessed by different methods. Through this paper we set out to analyze comparatively, using the decision making methods under risk and uncertainty, extended by using the mathematics of triangular fuzzy numbers, the technologies for energy recovery of biomass with applications in civil engineering.

The panel of biomass technologies is growing. Within them, the process of direct combustion of biomass represents the oldest technology of transformation into energy, but, in order to reduce pollution, it involves the installation of expensive filters. Other methods propose a process of decomposition by pyrolysis of biomass at high temperatures under anaerobic conditions and obtaining secondary fuels then used to produce thermal and electrical energy. The fermentation of biomass under anaerobic conditions and its decomposition until obtaining biogas is another method in increasing the energy efficiency of a residential building in the rural area in particular. At present, work is being done intensively on technologies of recovering biomass through plasma atomic dissociation, where the quality of the biomass can be varied and slightly processed.

The choice of one or another of these presented technologies in the assurance of energy efficiency in the field of civil engineering is a process that takes place under conditions of risk and uncertainty. The use of triangular fuzzy number mathematics in substantiating decisions in conditions of risk and uncertainty is an extremely useful tool in energy management in civil engineering. Thus, we set out to build a model for analyzing the technical-economic potential of each technology in conditions of risk and uncertainty, using triangular fuzzy numbers to evaluate the different quantitative and qualitative weighting factors, which will lead to the identification of the best decision for implementation of a technology to ensure energy efficiency in civil engineering.

2. MATERIALS AND METHODS

2.1. Triangular fuzzy numbers and associated indicators

A triangular fuzzy number (NFTr) can be represented in different forms, starting from the definition given by Zadeh and up to the theoretical and practical developments utilized in the last decades, (of which Gherasim 2005, Tofan 2007, Maturo 2009, Jachobsen 2004, Wang 2009) are useful to our demonstration.

In view of the objective pursued, a triangular fuzzy number may be represented simply by an ordered triplet of the form $A=(A_s, A_m, A_d) \in$ NFTr having the membership function $\boldsymbol{\mu_A}: \boldsymbol{R} \rightarrow [\boldsymbol{0}, \boldsymbol{1}]$ defined as follows:

$$\boldsymbol{\mu_A}(x)=\begin{cases} \frac{x-A_s}{A_m-A_s} & , A_s \le x \le A_m \\ 1 & , x = A_m \\ \frac{A_d-x}{A_d-A_m} & , A_m \le x \le A_d \\ 0 & , x \notin [A_s, A_d] \end{cases}$$

In order to be able to work with these triangular fuzzy numbers, many simple or synthetic indicators have been defined. Among *the simple indicators* we rememorate :

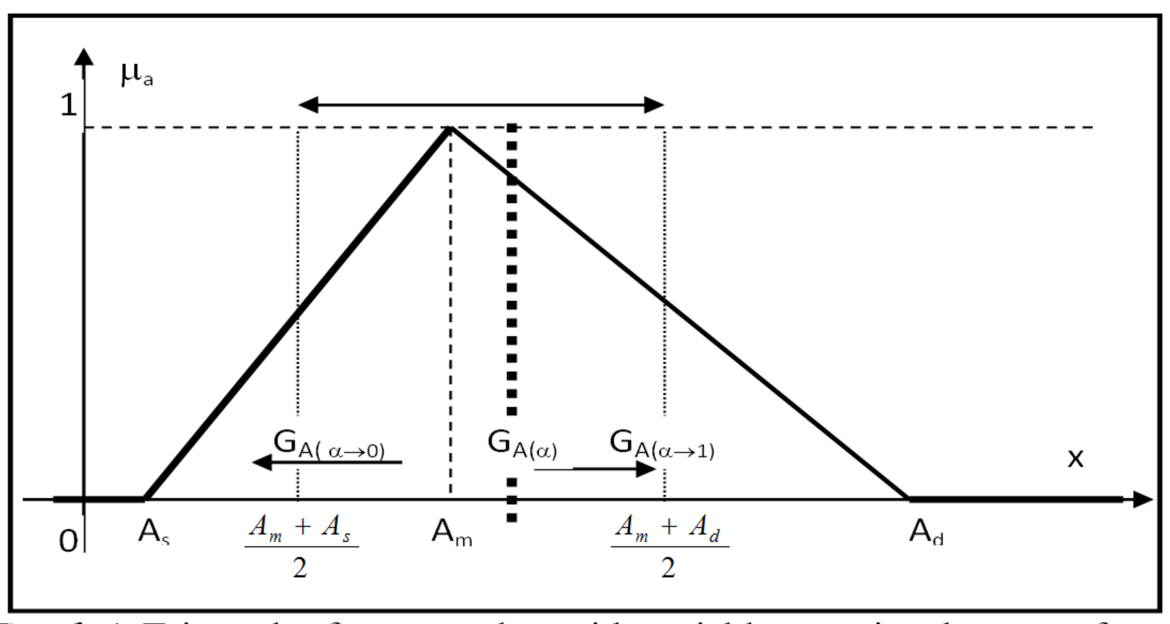
The core (which coincides with a_m ***)***	$N(A)=\{A_m\}$
The support	$Sp(A)=(A_s, A_d)$
The length of the support	$LSP_A=A_d-A_s \ge 0$
The middle of the core	$N_A=A_m$
The middle of the support	$SP_A=\frac{A_s+A_d}{2}$
Area to the left	$S_A^L=\int_{A_s}^{N_A} \mu_A(x)\mathrm{d}x$
Area to the right	$S_A^R=\int_{N_A}^{A_d} \mu_A(x)\mathrm{d}x$
Total area	$S_A=S_A^L+S_A^R$
The sign	$\delta_A=\begin{cases} sign(N_A) & , N_A \neq 0 \\ sign(A_m) & , A_m = 0 \end{cases}$

Starting from the general definition of the variable center of gravity associated with a general fuzzy number (Alecu, Idei si Valori, 2012), we propose as a synthetic way of defining the variable associated center of gravity for a triangular fuzzy number:

$$\boldsymbol{G_{A(\alpha)}=N_A+(\alpha-1)\cdot S_A^L+\alpha\cdot S_A^R}$$

where: $\boldsymbol{\alpha} \in [\boldsymbol{0}, \boldsymbol{1}]$ - is an indicator of absorption / uncertainty management.

Graphically, a triangular fuzzy number with the associated variable center of gravity is represented in the following graph, where one can notice how the uncertainty and its management can be rendered by the associated indicator variability.



Graph 1 Triangular fuzzy number with variable associated center of gravity

2.2. Basic operations with triangular fuzzy numbers and associated indicators

Let there be triangular fuzzy numbers with variable centers of gravity:
$A_\alpha=(A_s; A_m; A_d)_\alpha$, $B_\beta=(B_s; B_m; B_d)_\beta$ si $C_\gamma=(C_s; C_m; C_d)_\gamma \in$ NFT$_r$, where $\alpha, \beta, \gamma \in [0,1]$ the two assumed levels of absorption of uncertainty, the specific gravity centers with respectively $G_{A(\alpha)}$, $G_{B(\beta)}$ and $G_{C(\gamma)}$

The addition :

$$C_\gamma=\mathrm{A}_\alpha(+)B_\beta \stackrel{\text{def}}{=} \begin{cases} (A_s+B_s; A_m+B_m; A_d+B_d)_\gamma \\ \gamma=(\alpha(A_s+B_s)+\beta(A_d+B_d))/(A_s+B_s+A_d+B_d) \end{cases}$$

The multiplication

$$C_\gamma=\mathrm{A}_\alpha(*)B_\beta \stackrel{\text{def}}{=} \begin{cases} \frac{A_\alpha * G_{B(\beta)}+B_\beta * G_{A(\alpha)})}{2} \\ \gamma=(\alpha*\beta)/(\frac{\alpha+\beta}{2}) \end{cases},$$

The subtraction

$$C_\gamma=\mathrm{A}_\alpha(-)B_\beta \stackrel{\text{def}}{=} \begin{cases} \mathrm{A}_\alpha(-)B_\beta \stackrel{\text{def}}{=} (A_s-B_s; A_m-B_m; A_d-B_d)_\gamma \\ \gamma \stackrel{\text{def}}{=} (\alpha(A_s+B_s)+(1-\beta)(A_d+B_d))/(A_s+B_s+A_d+B_d) \end{cases}$$

The division

$$C_\gamma=\mathrm{A}_\alpha(/)B_\beta \stackrel{\text{def}}{=} \begin{cases} \frac{A_\alpha * G_{B(\beta)}+B_\beta * G_{A(\alpha)})}{2*(G_{B(\beta)})^2} \\ \gamma=\frac{\alpha*(1-\beta}{\frac{\alpha+(1-\beta)}{2})} \end{cases}.$$

The ordering of the triangular fuzzy numbers with variable centers of gravity is done upon the basis of several successive criteria: the gravity center criterion, the core means criterion , the criterion of the sign lengths of the supports .

3. RESULTS AND DISCUSSION

From our point of view, the biomass can be processed by classical methods (obtaining biogas) or can be transferred to plasma installations that convert this waste into electricity / heat syngas thus supplying the industrial sectors with renewable raw materials or provides renewable energy to industrial and civil buildings.

Plasma gasification is a technology that could be used to convert biomass that is currently being sent to landfill. The plasma gasification process is able to produce a clean synthetic gas that can be used to generate electric energy in CHP gas engines or can substitute natural gas. The thermal energy resulting from the gaseous products can be used in a variety of ways. These include the production of steam for generating electricity and thermal energy for the production of heat. The design of the post-treatment equipment used to clean the effluent gases is also crucial for the viable operation of a plasma gasification plant. Advanced emission control systems are required to meet regulatory standards (Achinas S. 2019).

In this paper, with applications in civil engineering, we compare two traditional type of technologies for energy recovery of biomass with a third one, the plasma processing technologies.

In our analysis we considered several indicators that characterize the energy balance, economic results, sustainability and financial results.

These were evaluated by two groups of experts with technological specialization, and respectively, economic specialization.

Managing the data, we obtained a matrix of consequences with three rows and five columns, in which several numerical criteria were combined with a series of qualitative criteria.

4. Conclusions

The plasma gasification process leads to an improved heat transfer and high energy capacity.

The variable gravity center associated of fuzzy numbers becomes an important construct for absorbing uncertainty in management techniques. Through a guided manipulation thereof, one can define a threshold in assuming one direction of action at the expense of another based upon long-term strategies a company is constantly investing in. This opens up new horizons for the theoretical approach of using these mathematical constructs in the management of uncertainty.

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