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A new indicator to estimate the efficiency of water and energy use in agro-industries

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ABSTRACT

In the search of sustainable practices in agro-food industry, it is compulsory to carry out the adequate assessment and further comparison of their resource consumptions. In this respect, environmental evaluations in industry often just focus on water or energy consumption, avoiding integrated indicators to measure the overall efficiency and environmental sustainability of processes. In this paper, the authors being aware of this lack of integrated indicators in the agro-food sector, have presented a new indicator, the Water and Energy Use Indicator (WEUI). It is operational, easy to interpret and communicate. Its main goal is to evaluate and further assess the global environmental performance of agro-industrial subsectors, and compare the overall efficiency of different industries. Additionally, the indicator allows to check if some proposed measures in an industry, apart from reducing their energy, water and resource consumption, leads to contribute or not to a higher level of environmental sustainability. Four complementary methodologies were adequately integrated into that single indicator: Water Footprint, Water Pinch, Life Cycle Assessment, and Exergy Analysis. Each methodology ranks the performance of a given industry with an index from 1 to 7 by comparing its operational parameters with the reference values within the corresponding agro-food subsector. The final indicator of the WEUI is then the weighted value from those indexes, and it is also ranked from 1 to 7, such as other European labels. Three case studies corresponding to diverse subsectors in the agro-food sector in Aragón (Spain) were tested, and one of these case studies (ready to eat meals) is presented here. Results show an index level of 5 (medium-high) for the WEUI at its present operation. Proposed improvement measures in the industry lead to a slight upgrade in the overall process of efficiency, due mainly to the water savings up to level 6 (high). An online tool for an easy calculation of the WEUI has been implemented. Up to now, 9 agro-food subsectors have been included in the tool, which is also adapted to available information in the companies.

1. Introduction

Industries include the efficiency of water and energy use in their global policies, looking for an improvement in economic competitiveness, operational efficiency and/or compliance with legal requirements. Audits, workshops and seminars are usually carried out for the establishment of techniques for the efficient use of water and energy in industry, after an in-depth evaluation of the production process steps. Therefore, a key goal of industries consists of locating and quantifying the energy and water inefficiencies selecting optimum conditions of design and operation to reduce losses and minimise the impact by optimizing the system's efficiency. However, measures are generally applicable to specific sectors, and only to few documented case studies. Then, to promote an integrated assessment, institutions, governments, organizations, and stakeholders have developed several projects and initiatives (from local to global level) to improve industrial competitiveness of agro-industries, in the field of responsible consumption, efficient resources management and minimization of emissions of greenhouse gases (Government of Aragón, 2016; FIAB, 2016; ENECO2 Project, 2016).

Initiatives in Europe showed that the use of indicators are essential in the development of policies for water and energy resource management, for the optimization of production processes, products and services. There are some important environmental issues to be included in the evaluation, such as energy and raw material consumption, water consumption and pollution rates, and residue minimization (European Commission, 2016a;

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European Commission, 2016b; Spanish Federation of Food and Beverage, 2016). In connection to that, the efficient use of water resources is closely linked to energy demands throughout the food production chain. This interdependence is recognized in Europe (European Commission, 2016a). Following with evaluation criteria, the Best Available Technologies (Spanish Ministry of Agriculture, Food and Environment, 2016) are a good reference to perform the evaluation, to reach the adequate level of energy efficiency and emissions reduction. Seasonality and location of the industry could be considered as well to introduce the importance of local water scarcity in the assessment. These tools should be accessible for industries, with low or free of associated cost of implementation of the evaluation, with periodic updating of data and improvement purposes.

Recent published papers were aimed at the performance of environmental evaluations in the agro-food industry, covering water, energy and integral assessments. The authors of these manuscripts, which are reviewed below (Table 1), applied these methodologies in specific case studies, including oil, sauces and juices, dairy, sugar, meat, wine, seafood and vegetables subsectors.

From these environmental evaluations, it can be pointed out that

- Conventional evaluations of water or energy consumption only covered one of these fields, and highlight the difficulty of unlinking water and energy in environmental evaluations. The analysis of specific environmental quality indicators (Kim et al., 2013; Zaharia, 2012; Gómez-Limón and Riesgo, 2012; Avadí and Fréon, 2015) shows that the values of those specific quality indicators were used to calculate an index to express the quality of each environmental issue. In Spain, some examples of indicators that sought intake assessment of water resources in comparative standard with a real industry benchmark, in terms of water consumption and waste water per unit of product for a period of time, are currently used as a standard of water use, and it is promoted by the Generalitat of Catalunya (European Commission, 2016b). A new indicator for agro-industries was also proposed in the EFACUA project (2016).
- To assess a comparative value to measure efficiency, a good solution consists of a given reference and then to consider a dimensionless evaluation scale. Selected references varied among the studies:
  - In some cases, the maximum admissible concentration from the environmental legislation or the limits imposed by the local environmental authorities was considered as a reference, these being usually much severe than standard/legislative viable limits (Zaharia, 2012).
  - Other authors based the evaluation on a percentage scale relative to the highest observed value of each indicator for all products, as a means of standardization (Avadí and Fréon, 2015).
  - Initiatives of relevance in the agro-industry consider that reference should be the average values (resources consumption) of the evaluated subsector for this proposal (EFACUA Project, 2016).
- Regarding the combination of indexes to compose an integrated indicator, the review showed that it is really difficult to propose a standard indicator to give an integrated value that measures the overall efficiency, and definitely, the sustainability of the process. Many of the mentioned authors proposed different individual indexes, such as Seeboonruang (2012), and Guan et al. (2014). Some others (Gómez-Limón and Riesgo, 2012) applied the Principal Component Analysis in the assignation of weights for the calculation of combined indicators. This analysis is applied to the assessment of the WEUI value as is explained in Section 2.

From previous reviews, it can be stated that from the authors knowledge, there is still a lack of a uniformly applied assessment methodology considering all these issues: operationality, terms as legitimity (accepted use, appropriation by stakeholders), interpretability (easy to understand and communicate), genericity (allowing comparison at various spatio-temporal scales), and definition of a finite interval (e.g. 1–5, A–D). The new indicator presented in this paper, the Water and Energy Use Indicator (WEUI) includes in its definition several criteria in accordance to previous initiatives, with the aim of solving some of the limitations of the environmental evaluations already presented.

Consequently, the authors consider that the new indicator WEUI constitutes a good value to completely assess the environmental performance of the agro-food industry. Complementarity of four methodologies follows. Firstly, WEUI calculates the impact of water use (blue and grey water footprint, WF), by the knowledge of the water consumed (blue water) and contaminated by the industry (grey water). According to the new standards for WF (ISO 14046) and its life-cycle approach, WF is considered as an environmental index, in which local water scarcity (WS) has to be taken into account in their assessment. Secondly, by means of the Water Pinch (WP) analysis, the degree of internal water recycle solutions to reduce fresh water consumption in the industry is checked. Thirdly, by means of the LCA, that measures the environmental impact of energy consumption, residues and pollution, residue generation in the plant operation, and raw materials used for construction and building in the industry, are introduced. Finally, the exergy analysis (EA) of the whole set of thermal and chemical processes in the plant allows the assessment of the thermodynamic efficiency of these plant processes. Weighting applied to each methodology for composing of the WEUI is discussed in section 2.4.

As these methods are also labelled from 1 to 7 to compose the WEUI, a good reference to carry out the evaluation will then be required, in order to easily detect if the proposed improvements in the plant that really improved the WEUI value. This reference should obviously be specific for any agro-food subsector.

The WEUI value is also allocated to a scale of 7 levels of efficiency, such as other European Union Energy labels (the energy efficiency label for household appliances, as an example), with the objective of a major inclusion in the sector, and maybe a future standardization of this indicator. Both objectives are based on the continuous updating and feedback from the results obtained in new case studies.

The easy calculation of the WEUI in agro-food industry is also a key point. In this respect, some methodologies included in its calculation such as LCA or exergy analysis are usually complex and expensive, and require a vast amount of data to perform the evaluation. These methodologies have been carefully simplified and adapted in order to require the minimum data (which, in turn, are usually available in all these industries). A computer tool has then been developed for the assessment of the WEUI, in order to guide company managers in the search of a better overall efficiency, and therefore increase the competitiveness of their industries.

To sum up, the WEUI indicator wishes to present an assessment of the global efficiency of water and energy use in agro-food industry, in units and scale so as to be useful in implementing a standard evaluation of the use of this indicator. The diagnosis is performed with respect to the agribusiness sector, and nine subsectors are differentiated. Evaluation may be performed in two different production scenarios for the same plant, or between the diverse agro-food facilities producing the same agro-food portfolio.

Dynamics to define in detail the WEUI indicator and an

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