doi:10.46793/ICCBI21.149V

IMPROVING PRODUCTION EFFICIENCY IN THE ICE CREAM INDUSTRY

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Abstract:

The food industry is a large consumer of energy that depends on fossil fuels, the combustion of which releases large amounts of CO2. The paper examines the possibility of reducing the use of non - renewable energy sources through a detailed energy audit and consideration of measures to increase energy efficiency and renewable energy sources in the ice cream craft industry. The cost-effectiveness of the proposed measures is observed for two scenarios. The first scenario covers the current situation in Serbia, in which there are no carbon taxes, and the price of energy is relatively low compared to other countries in Europe. The second "German scenario" implies carbon taxes in the amount of 55€/tCO2, which is expected to, with the same energy prices, significantly reduce the repayment period and affect the ranking of measures. The analysis is performed to consider how the carbon tax reflects on the motivation of craft producers to improve energy efficiency.

Key words: food industry, energy efficiency, carbon tax, ECMs

1. Introduction

The major issue that has attracted increasing attention in recent decades concerns the ways to reduce harmful effects on the environment which does not diminish the quality of people's lives. As energy consumption is a crucial factor for the development of economies, it is necessary to explore all possibilities for the most efficient shift from current systems to innovative, advanced energy conversion systems. Globally, for achievable greenhouse gas savings, reductions in primary energy consumption, and a secure energy supply, improved energy efficiency is essential [1]. The food industry is a large consumer of energy that depends on fossil fuels, the combustion of which releases large amounts of CO2.

A key role in reducing CO2 emissions, which make up two-thirds of all greenhouse gases, is the transition from fossil fuels to low-carbon solutions [2]. CO2 emissions in an industry are highly correlated with the production of that industry [3]. Since the article examines the improvement of production efficiency in the food industry, specifically in the ice cream industry, the basic steps in production are selection and processing of ingredients, dosage, mixing of components, pasteurization, maturation, freezing process, and conservation of ice cream. Within this production process, the critical phases are pasteurization and freezing of the raw product, as an enormous amount of energy is used in the form of steam and electricity, so most of the energy requirements of the industry arise from fossil fuels or electrical power [4].

As one of the most cost-effective ways to reduce CO2 emissions and encourage the use of renewable energy sources, carbon pricing has attracted significant consideration. One way to apply carbon prices is a carbon tax, where the government states the tax rate and the sources that are subject to taxation [5]. At the company level, carbon taxes can be examined as a parameter for optimization [6].

Per the above, the main goal of the paper, which presents a unique case study, is to determine the impact of the introduction of carbon taxes on increasing energy efficiency and the usage of renewable energy sources in the ice cream craft factory in Serbia.

2. Materials and methods

The subject of the examination is a small industrial plant for the production of craft ice cream, in which an energy audit based on ISO 50002 was conducted [7]. The essential characteristics and information about the plant were obtained by communicating to the technical staff and filling out a pre-audit questionnaire during the visit to the company. Data covering energy consumption (such as electricity, heating, and water consumption), as well as data about the volume of production, were collected by reviewing the previous years' bills. Based on available data and the application of specific energy indicators, the following were determined: energy performance of the system, production dependence of energy consumption on the volume of production, and comparison of current system characteristics with systems of similar purpose in the world. In the dairy industry, and therefore in the ice cream industry, the most commonly used indicator of energy consumption is the amount of final energy per unit mass of the product (kWh/kg) [8]. Based on the literature data, it was ascertained that electricity consumption in the ice cream industry varies in the range of 0.13-0.64 kWh/kg [9]-[11]. Based on a detailed analysis of the collected data, measures to increase energy efficiency were proposed, a simple repayment period was determined for each of the measures, as well as a potential reduction in CO2 emissions. The following equation was used to calculate the simple repayment period:

$$PBP = \frac{IIM}{NACI} \quad (1)$$

where:
PBP [year] - payback period
IIM [€] - initial investments
NACI [€/year] - net annual cash inflow
Net annual cash inflow can be calculated as:

$$NACI = ES \times EC \quad (2)$$

where:
ES [kWh/year] or [m^3/year] – annual energy or water savings
EC [€/kWh] or [€/m^3] – energy or water unit cost

CO2 emissions were calculated by applying conversion factors for the Republic of Serbia (Table 1), obtained from the Manual for Energy Managers in the field of building energy [12]. To determine the impact of the introduction of carbon taxes in small enterprises, as a measure to reduce CO2 emissions, for the necessities of examination, the so-called "German scenario" is introduced, which takes into account the price of the carbon tax of 55eur/tCO2. During the calculation, the average price of electricity in Serbia of 0.09 €c/kWh was used, while the adopted price of natural gas is 0.034 €c/kWh.

Table 1. Specific CO2 emission for fuels

Fuel	Emission per energy unit
Electricity	0,53 kg/kWh
Natural gas	0,20 kg/kWh
Distric heating	0,33 kg/kWh

3. Results and discussions

The analyzed production plant is located in Central Serbia and consists of two interconnected units. In the first part, there is an office space connected to the production hall by a corridor. There are two

separate cooling chambers next to the work area for storing products. Ice cream is stored in the chambers at temperatures of 4ºC and -24ºC. The plant is connected to the city water supply, sewerage, and electricity distribution network. There is one gas boiler in the plant, and the thermal energy is used only to heat the office and workspace during the heating season. Only electricity is used in the production process itself. Based on the bills, it was determined that about 2,700 kWh of electricity and 80m3 of water are consumed on an average monthly level. The increased water consumption is explained by the water cooling of the mixer and ice cream pasteurizer. During that process, the water is drained into the sewer and reused from the water supply system. The values of specific energy consumption indicators are shown in Table 2.

Table 2. The values of performance indicators

Electricity	kWh/kg of ice cream	0,18
Water	l/kg of ice cream	5.33

Further analysis of electricity consumption explicated that most energy is utilized in the production process for pasteurization, mixing, and cooling (67%), accompanied by the preparation of sanitary hot water (15%) and storage of products (8%). The lighting, which consists of fluorescent tubes with a unit nominal power of 36W and a light flux of 1620 lumens, uses 4% of the total delivered energy.

Based on the conducted energy audit, measures for increasing energy efficiency were determined (Table 3.). For each measure, final energy savings, implementation costs, simple repayment period, and reduction of CO2 emissions were calculated. The mentioned parameters were calculated for the current energy situation in Serbia and for the hypothetical German scenario.

Table 3. Summary of ECMs

	ESM	Energy savings (kWh)	CO2 emission reduction (tCo2/year)	Implementation costs (€)	PBP	
					Current scenario	German scenario
1	PV solar system	10 402	5,5	6750	7,22	5,45
2	Solar collectors for DWH	2880	1,53	2106	8,13	6,13
3	Change of existing lighting system	691	0,37	48	0,77	0,58
4	Improvement of the building envelope	9112	2,1	2628	8,48	6,18

Based on the data presented in Table 3, it is noticed that all the proposed measures lead to a significant reduction in energy consumption. The implementation of this approach results in a reduction in national energy requirements, but also benefits for the business owner himself. Based on conversations with the owner and technical staff in the analyzed plant, it is concluded that the introduction of carbon tax collection measures would contribute not only to reducing CO2 emissions, but also to increasing the ambition to invest in environmental solutions, to save money. The benefit of these measures would have additional effects if, in addition to this type of collection, the price of energy also increased, in line with the average prices in the EU. It is noted that the authors of the paper, in addition to the measures shown in Table 3, also propose the installation of water reuse system, because this measure can achieve savings of as much as 88 liters of water per day. As the implementation of this measure does not lead to a reduction in CO2 emissions, it was not the subject of a financial analysis of the return on investment.

4. Conclusions

The introduction of measures, such as penalties for CO2 emissions, is a suitable incentive to switch to renewable energy sources, both in large companies and companies that maintain their production at the craft level. In addition to micro-benefits, which is shown in the paper, carbon taxes also contribute

to macro-benefits by stimulating sustainable economic growth and creating green jobs, which leads to less environmental pollution.

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