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The role of energy management in the agricultural sector: key prerequisites and impacts

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Abstract. Agriculture is one of the most energy-consuming sectors in the EU's economy. Implementing sustainable agriculture to reduce GHG emissions and increase energy efficiency through energy management is a crucial strategy to tackle climate change. In this paper, the role of energy management in the agricultural sector is studied, and experiences from Europe and the world have been considered. Literature analysis regarding the chosen topic has been conducted, including the methodology of energy management plan development and its implementation in the case study of Latvia. Data from Latvia's agricultural and other sectors have been analysed and compared. Latvia's Inventory Report regarding GHG emissions in the agricultural sector was reviewed, and all emission sources in the agricultural sector were highlighted. The primary purpose of the study is to find out if energy management were introduced in an agricultural company, what would be the potential GHG emission, energy savings and additional advantages. Two companies working in Latvia were surveyed, and potential emission and energy consumption reduction measures in agriculture that would be applied to companies were developed. The research showed that by implementing the basic principles of energy management, it would be possible to reduce the average energy consumption by 17%. If measures are applied to reduce GHG emissions from agricultural companies, the average emissions would be reduced by 43%.

Key words: agriculture, benchmarking, indicators, energy efficiency, GHG emissions, sustainability.

INTRODUCTION

Energy production and consumption is the primary source of greenhouse gas (GHG) production not only in Latvia but also in Europe (Agency, n.d.), (Intergovernmental Panel on Climate Change (IPCC), n.d.). In 2020, the energy sector was the largest source of GHG emissions, generating 64.8% of total GHG emissions in Latvia, including indirect carbon dioxide (CO_2) emissions. Part of these emissions was created by the agricultural sector (Center of Environment, 2022). In addition to energy emissions, the agricultural sector generated 21.5% of total emissions in Latvia in 2020, including indirect CO_2 emissions (Center of Environment, 2022).

Energy consumption within the agriculture sector and its greenhouse gas emissions are essential topics to policymakers, as agricultural activities must meet food safety objectives and ensure proper economic, environmental, and social impacts (Streimikis et al., 2022).

The issues of energy management and the amount of produced emissions are also topical since the European Union (EU) has set the goal to reduce GHG emissions, including in the agricultural sector. Energy management and agriculture can be linked together since the agricultural sector uses energy and generates GHG emissions, which can be reduced by implementing resource management measures. Within the framework of the EU's Climate and Energy policy, the member states of the EU must achieve a reduction of greenhouse gases of at least 55% by 2030 (including agriculture, land use, and forestry). Additionally, the member states must achieve at least 27% in the share of renewable energy compared to 1990 ('The 2030 climate and energy framework - Consilium,' n.d.).

To reduce impact on the environment and economics, wise and practical resource management is necessary at all supply chain stages, as well as proper measures of impact reduction are advisable.

As surveys show, with an increase in manufacturing intensity, the amount of produced GHG emissions increases simultaneously (Bais-Moleman et al., 2019). GHG emissions will only increase as production increases if the company's management is not effective and sustainable, for instance, when in a livestock farm, no management system controls cattle, their feed, and manure, as well as energy and fuel consumption. Efficient livestock farms must have a resource management system designed and planned to reduce greenhouse gas emissions (Fiore et al., 2018). Thereby the agricultural sector should introduce low-emission practices and effective methods, for example:

Agricultural practices, which would preserve lands' fertility, increase organic matter content and release atmospheric carbon;

Better animal health and welfare management would reduce the cattle's infertility and increase their comfort level and health condition, which would also increase productivity (Fiore et al., 2018; Batlle-Bayer et al., 2019);

As agricultural product manufacturing and land-use change in land cultivation would significantly increase the amount of greenhouse gas emissions (Yan et al., 2017; Rose et al., 2019), shifting towards sustainable agriculture by introducing integrated farm management (Shen et al., 2022);

Reducing GHG emissions through the use of urease inhibitors (Adu-Poku et al., 2022);

Implementing common agricultural policy (Bradfield et al., 2022).

Carbon dioxide (CO_2) is claimed to be the most critical GHG emission in the energy sector and CH_4 and N_2O (Priedniece, Kirsanovs, Freimanis, Veidenbergs, & Blumberga, n.d.). Li et al. (2016) examined and analyzed the main drivers of energy-related CO_2 emissions in various European agricultural sectors. Two main directions have been studied in the mentioned research: 1) Index Division Analyse (IDA) that has been supplemented with Shapley Index and is used to identify significant CO_2 emission drivers; 2) Slack-based model (SBM) was applied to rate environmental performance of European agricultural sectors. Applying these technologies makes achieving environmental efficiency and shadow price measures possible, encouraging discussions regarding CO_2 emission reduction activities in the agricultural sector. Because of the importance of GHG emissions, an integrated approach to CO_2 analysis is developed based on advanced decomposition and efficiency analysis models. The research covers eighteen European countries, and the applied methodology divides installments into CO_2 emissions in regions and factors (Li et al., 2016). The results of IDA showed that the reduction of energy intensity is the leading factor in reducing CO_2 emissions. The lowest carbon shadow prices were observed in France, Finland, Sweden, Denmark, the Netherlands, Poland, and Belgium, thereby having the highest CO_2 emission reduction potential. Also, measures directed at increasing energy efficiency are the most profitable way to reduce the amount of CO_2 (Li et al., 2016).

To reduce GHG and NH_3 emissions, optimizing the new livestock spatial management system and using it as a basis for future policy success is necessary. Instructions for the policy and farmers should concentrate on properly managing manure and livestock feed and optimizing industrial production systems and pig and poultry sectors in suburban areas (Aan den Toorn et al., 2021; Jahangir et al., 2022; He et al., 2023). The United Kingdom has developed a national strategy that states that by 2030 greenhouse gas emissions need to be decreased by 50% compared to 1990 (Rose et al., 2019). It was evaluated that technological improvements in the agricultural sector are required to achieve this goal by reducing livestock farming production intensity by 30% (Rose et al., 2019).

Sufficient animal feed and manure management can reduce methane and nitrogen oxide emissions in the agricultural sector (Escribano et al., 2022; Hossain et al., 2023). All agricultural segments have management possibilities to reduce the negative environmental impact (Bumbiere et al., 2022). Lovendahl et al. wrote that GHG emission reduction is possible if different types of cattle are chosen for cultivation - the type whose genetics have been modified and improved, making the nutrient digestion process faster and who, during their metabolic processes, produce less methane (CH_4) (Lovendahll et al., 2018).

Agriculture is Latvia's second most significant source of GHG emissions (‘Ministry of Agriculture of the Republic of Latvia LATVIAN AGRICULTURE 2020,’ n.d.). The agricultural sector emitted 21.5% of Latvia's total greenhouse gases in 2020 (‘Ministry of Agriculture of the Republic of Latvia LATVIAN AGRICULTURE 2020,’ n.d.). Latvia has developed a national-level strategy to increase energy efficiency and decrease GHG emissions (‘National Energy and Climate Plan for 2021–2030 | Ekonomikas ministrija,’ n.d.). In Latvia, 9.1% of all agricultural lands are biologically or organically cultivated, and the product market is still growing. It is one of the good examples of effective land cultivation and low GHG emission levels. The Rodale Institute states that regenerative organic agriculture and its managing practice is a potentially important tool for distributing more than the current global annual emissions and for changing the greenhouse effect (‘Regenerative Organic Agriculture and Climate Change A Down-to-Earth Solution to Global Warming,’ n.d.). The current diversion of soils and pastures to regenerative organic farming is expected to lead to 111% of annual carbon emissions, leading to annual negative emissions (‘Regenerative Organic Agriculture and Climate Change A Down-to-Earth Solution to Global Warming,’ n.d.). Scientific research is devoted to traditional farming methods by introducing crop and many plant species rotation to preserve land fertility and natural growth conditions and supply residents with local food in an innovative area (Niu et al., 2019). There are many recommendations for controlling weeds and other pests, ensuring plant nutrients, and reducing energy consumption (Saldukaitė et al., 2022). Plant rotation, correctly and well-defined soil purity, respected ecosystems, and natural plant growth conditions are the main principles of successful plant cultivation in an organic agricultural system (Morugán-Coronado et al., 2022; Saldukaitė et al., 2022). Farm experience shows that suitable results may be achieved in the long term and strictly follow organic farming principles (Verburg et al., 2022).

This study is carried out to develop knowledge on achieving a higher reduction of GHG emissions by looking at two levels - sector and company. The study results in a decrease in GHG emissions, therefore helping to achieve EU targets to reduce GHG emissions in the agricultural sector. This research aims to measure the potential energy and emission savings from the implementation of energy management actions and to propose the framework for an energy management system in the agricultural sector on a company level. All segments of agricultural activity have management options that can reduce their environmental impact. Therefore, awareness of the basic principles of energy management in agricultural companies should be promoted, and informative measures on energy management and reduction of GHG potential should be implemented.

METHODOLOGY

The methodology was based on the IPCC guidelines, written in 2017–2018. The year 2005 was compared to 2015 to see the increase in emissions in the agricultural sector. In analysing the agricultural sector, the bottom-up approach for evaluating impacts can be helpful; for example, Adewale et al. (2019) used an agricultural carbon footprint to examine the impact of two farms. Blancard and Marti (Blancard & Martin, 2014) used Data Envelopment Analysis to analyze farm energy efficiency, and Hosseinzadeh-Bandbafha et al. (2017) to evaluate fattening farms. Alonso and Guzman (Alonso & Guzmán, 2010) used the energy balance method to analyze energy efficiency in producing energy crops. Meul et al. (2007) used process analysis methodology for the calculation of energy balance in farms.

Thus, the following methods, guidelines, and manuals will be used in this publication: IPCC Guidelines, Latvian Inventory Report on GHG Emissions, and manual 'Guide for Farmers to calculate GHG at farm level and measures to reduce it'. Analysis of indicators and comparison of agricultural enterprises will be carried out, and a methodology that can be applied at a certain level will be developed.

Two specific companies were chosen because they are relevant to the research's needs, and it is appropriate to compare them. One of these companies did not apply energy management principles, which increased annual emissions, while the other involved half of these principles, and the emissions were reduced. The study demonstrated that if the basic principles of energy management in agriculture are used, emissions will be reduced several times.

To achieve the goal of this research, an algorithm of methodology has been developed (Fig. 1). It is divided into eight stages, showing the advisable actions on each level – (1) evaluation of data on GHG emissions, (2) analysis of data on the national, (3) sectoral, or (4) company level, (5) analysis of the data on energy consumption, (6) comparison of the companies, (7) improvement measures are proposed, and (8) energy efficiency measures are defined. The algorithm's first part is oriented toward identifying and analyzing the current situation. Still, the second part is identifying future perspectives, searching for possibilities, and implementing practical solutions to promote development.

As it is seen on the scheme, the methodology includes eight modules, of which three are the main ones: state level (2), sectoral level (3), and company level (4). From stages 1 to 5, data collection and publicly available data are analyzed using data analysis methods. Data are compared in stages 6 to 8, and GHG emissions and energy reduction measures are proposed. These measures are also called energy efficiency measures.

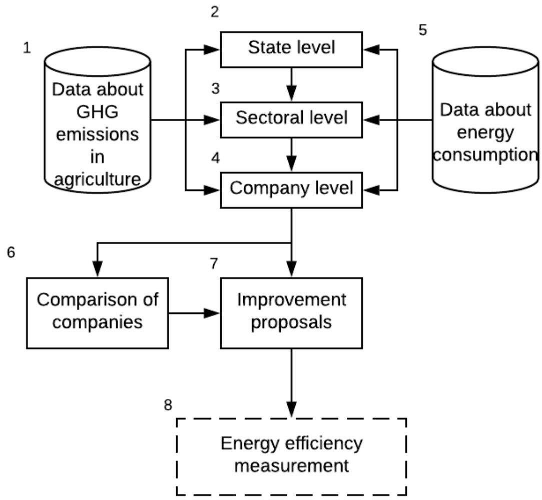

Figure 1. Scheme of the methodology.

Each year, every country in the European Union must submit an inventory report on GHG emissions developed by the IPCC guidelines related to the UN Framework Convention on Climate Change.

The inventory report includes direct and indirect GHG emissions from all sectors in the country, which are expressed in CO_2 equivalent. In the report submitted in 2017, GHG emissions were calculated for the timeframe starting with 1990 until 2015, considering the global warming potential coefficients for a one-hundred-year period.

In the Convention reporting guidelines, GHG emissions were compiled for such areas or sectors as energetics, industry and product manufacture, agriculture, land cultivation, land-use change method and forestry, and waste management.

The following subsection compares GHG emissions in CO_2 equivalent for 2005 and 2015. In the case study, data were taken from Latvia's inventory report about GHG emissions in the agricultural sector.

As the Inventory report divides the agricultural sector into several areas, this division will be further explained. On the bottom of the energy sector stands the category 'Other', in which emissions from fuel (both - for heating and transport purposes) combustion are located. These emissions are produced in all sectors - agriculture, forestry, and fishery. Unfortunately, there were no data available regarding fuel consumption in the agricultural sector, and because of that, the total amount was used and analyzed.

In agriculture, forestry and fishery usually utilize:

Stationary combustion appliances – liquid, solid-type fuel, and biomass;

District transport and other mechanic systems – gasoline and diesel fuel;

Fishery – gas and diesel fuel.

The agricultural sector is analyzed as a separate sector, and emissions are calculated in the following categories:

Agricultural lands;

Intestinal fermentation;

Manure;

Land liming;

Urea utilisation (‘National Inventory Submissions 2022 | UNFCCC,’ n.d.).

In Fig. 2, the division of emissions in the agricultural sector, the type of produced emissions and in what area of the sector is explicitly shown.

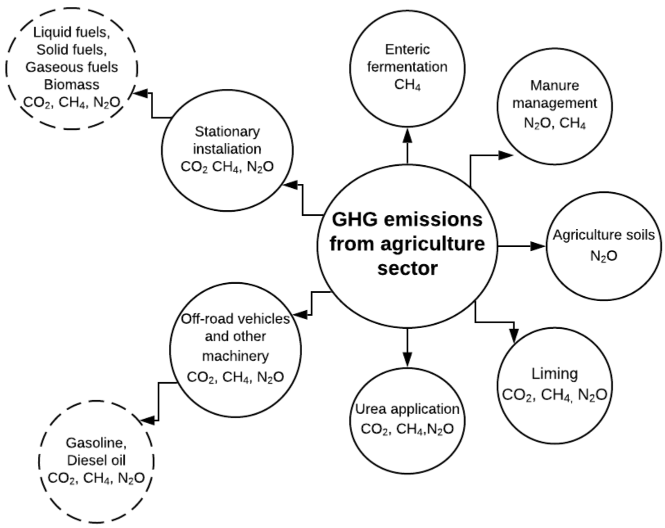

Figure 2. Breakdown of emissions from the agricultural sector.

This research aimed to measure the potential energy and emission savings from implementing energy management actions and propose a framework for the energy management system in the agricultural sector on a company level.

RESULTS AND DISCUSSION

A significant part of GHG emissions in Latvia comes from agricultural lands and cattle’s intestinal fermentation, which is why, in this work, measures of GHG reduction are explicitly proposed in these areas. GHG reduction measures are described in the ‘Guide for Farmers to calculate GHG at farm level and measures to reduce it.’ This guidebook is based on the IPCC guidelines, and this advice can be implemented in the case of Latvia. Some of the measures are introduced in the surveyed companies.

As the literature survey shows, a significant amount of emissions comes from land cultivation. The division of produced GHG emissions in both areas is as follows:

Agricultural land:

Implementation of precise fertilization system - plan development and required technique purchase - perform soil analysis;

Use of practical techniques and technologies - combined field processing machines, zero or minimal tillage technique implementation;

Land reclamation or improvement;

Trenches around the cultivated land to avoid water pollution by fertilizers.

Intestinal fermentation:

Nutrient dosage management (plan developed and introduced);

Nutrient additive utilization to improve digestion;

Purchasing cattle that produce less methane (CH_4) in their metabolic processes.

It is worth noting that the emission division in the agricultural sector emissions does not include the emissions from transport utilization and maintenance. In the Latvian agricultural sector's emissions, fuel produces only 11% of the total GHG emissions (Center of Environment, 2022). This percentage would decrease if the proposed agricultural land and intestinal fermentation management measures were implemented.

In the case study, comparing two agricultural companies, where the main working areas are connected to livestock, has been performed and evaluated as to how much electricity each consumes and what GHG emissions are produced. Besides, for both these criteria – electricity and GHG emissions, individual reduction measures have been developed for each company.

Company 'A' acquires 1,120 ha of agricultural land, on which a biogas plant, cattle sheds, cow milking carousel machine, refrigerator premises, personnel rooms, offices, and warehouses are located. The company's 'B' inventory shows that this company owns an agricultural land area of 1,080 ha, a workshop for technical repairs, personnel premises, an office heated by using wood chips and firewood, a grain dryer, and cattle sheds.

After acquiring all the information regarding energy consumption and overall operation, several energy efficiency measures have been developed for each company. These measures include electricity and GHG emission reduction actions (Table 1).

Table 1. Inventory data

Company	'A'	'B'
Land area (ha)	1,120	1,080
Business directions	Livestock (milk), field crop production	Livestock breeding, field crop production
Livestock	948	740
Electricity consumption (GJ)	3,895.2	1,065.6
Produced GHG emissions (tCO_2eq)	3,282	2,525

The more data, the more precise and better improvements can be made. These data allow analysing which part of the company consumes more electricity and what measures could be introduced. Fig. 3 shows that, unfortunately, company 'A' has data only regarding energy consumption on the farm (cattle breeding) and the warehouse when company 'B' acquires information about all its compartments.

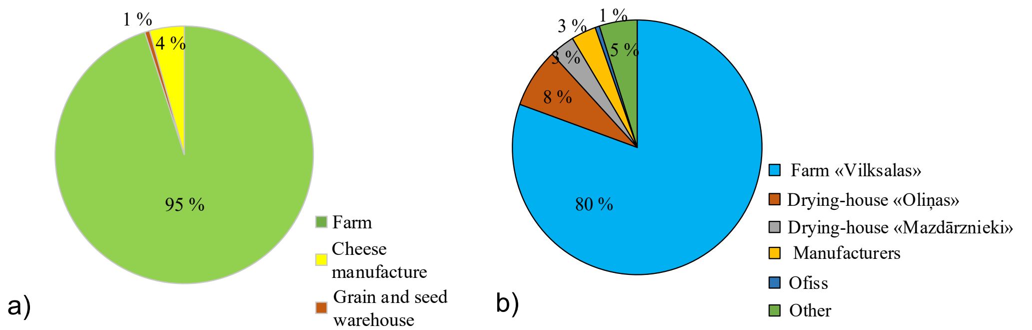

Figure 3. Share of electricity consumption by sectors in 2016: a) company 'A'; b) company 'B'.

Although the two situations are very different, depending on the information obtained, easy-to-implement proposals that do not require significant investments to increase energy efficiency and reduce GHG emissions were individually developed.

- For energy savings company ‘A’ was offered to start with such solutions as:
- Replacing inefficient lighting systems with new efficient ones;
- Use of fuel-efficient tires (if replaced by ten vehicles);
- Use of engine lubricants (if used in 10 vehicles);
- While company ‘B’ had such solutions as:
- Use of fuel-efficient tires (if replaced by ten vehicles)
- Pump replacement.

These recommendations resulted in 14% and 20% energy savings, respectively, where a suggestion for company ‘A’ is a transport use with a hybrid-type energy system, while for company ‘B’:

- Manure and agricultural residues transferred to bioenergy production facilities
- Use transport with a hybrid-type energy system
- Use of control systems for fuel economy.

If the agricultural companies implemented the GHG emission reduction measures, the emission level would decrease by about 43%. However, it is possible to conclude that there is not one specific recipe that all companies should follow because each, depending on the company’s level of development, operational specifics, and applied practices, needs to individually develop a plan for reducing emissions and increasing energy and resource efficiency to achieve maximum productivity at the lowest costs and emissions.

Table 2. The Indicators for Farm Comparison

Indicator	Unit
Direct and indirect energy consumption	GJ ha^{-1}
Direct and indirect energy input per tonne of crops	GJ ha^{-1}
Direct and indirect energy input per tonne of product (livestock)	GJ ha^{-1}

During the research, the indicators for farm comparison, which can be used as benchmarking, were identified and compiled in Table 3.

Table 3. Comparison of Indicators in Companies

Company	GJ ha^{-1}	GJ/unit
‘A’	3.30	4.1
‘B’	0.98	1.4

These indicators have been developed by analyzing the literature on this topic and summarizing other researchers’ assessments. Two indicators were retrieved from limited access to information on company consumption data and considering Table 3 - direct and indirect energy consumption per ton of crops and direct and indirect energy input per livestock. Table 5 gives a comparison of indicators in both companies.

These indicators allow us to compare different companies and analyze the benefits of energy efficiency measures and can be used in benchmarking similar size and profile farms.

Five company-level measures were identified by reviewing scientific articles and examining practices in this field of research. The most effective energy efficiency measures for the company level were determined:

Optimized fertilizer production;

Energy-saving cultivation practices;

Improved water management;

Better livestock feeding;

Use of renewable energy sources.

All found information was summarised and applied in companies, thus proving the efficiency of the developed measures. By introducing these measures, the emission level, the consumed energy and resources, also expenses can be reduced. During the research, an energy management system (Fig. 4) for the agricultural sector at the company level was developed, which can be adapted to evaluate and compare different agricultural companies.

The results have shown that using proposed indicators and benchmarking for farm comparisons is beneficial for improving the agricultural sector and reducing greenhouse gas emissions and energy consumption, leading to efficient, sustainable, and competitive farming.

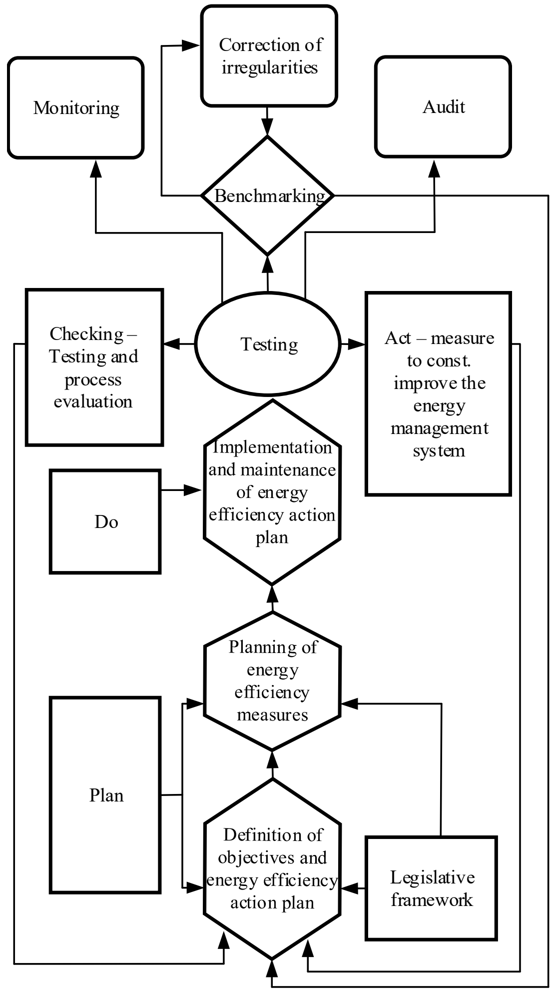

Figure 4. Energy management framework for the agricultural sector on the company level.

CONCLUSIONS

The energy management system can and should be implemented by agricultural companies. It would reduce energy consumption, optimise costs, and reduce GHG emissions. However, informative measures are required to implement these basic energy management principles in companies.

The surveyed companies should follow the initial monitoring of energy consumption data to understand where electricity and heat are consumed the most and the potential for reducing this amount. It would be advisable for agricultural companies to install an intelligent energy system. It is a sustainable energy supply system that contains information on energy consumption and options for reducing it based on monitoring the system's performance.

The energy management system can be combined with greenhouse gas reduction measures, such as organic farming and other methods and guidelines already introduced in Latvia. However, not all companies follow these guidelines. It is necessary to develop a specific policy and support program for companies to implement energy management, as implementing the basic principles of energy management or the energy system requires investment.

By implementing the energy system in an agricultural company, energy consumption in this company can be assessed, and measures can be taken to reduce energy consumption. Policy and agricultural guidelines should focus on optimizing farming and manure management.

Results show that energy efficiency improvement measures are a more effective way to reduce CO_2 emissions. If measures are applied to reduce GHG emissions from agricultural companies, the average emissions would be reduced by 43%. By implementing the basic principles of energy management, it would be possible to reduce the average energy consumption by 17%. However, it depends on the specifics of the company and what measures it can implement.

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