Onsite RES and Carbon Credit Rate as a Smart Solution to Fully Decarbonize the Textile Sector in Albania. A Case Study

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Abstract: - Albania can explore several strategies to implement CO_2 credit rates in the textile and leather sector, leveraging tools like RETScreen Expert for energy modeling and long-term energy planning. Incentivizing carbon credit rates, as a smooth pathway for textile companies to adopt sustainable practices and improved energy efficiency is analyzed. This mechanism assists in lowering operational costs, and as a result, cheaper products for consumers are assured creating a beneficial cycle for both the environment and the economy. In this regard, our approach intends to give an answer to the question of how Albania can explore specific strategies or practices in implementing CO_2 credit rates in the textile and leather sector. The overall performance of production, increased availability, low costs, and socio-economic effects by applying carbon trading schemes in the textile and leather sub-branch such as CO_2 credit rate as a way toward mitigation is analyzed. By investing in onsite renewable energy sources, and clean technologies and exploiting circular economy, textile and leather companies contribute to creating additional revenue streams and encouraging investment. The simulations are performed using a highly sophisticated energy modeling tool, RETScreen Expert widely used by academia and for diverse feasibility studies, including industry processes. In conclusion investing in onsite renewable energy sources (RES) within the textile and leather sub-branch, by setting a carbon price of €50/tonne and using a debt rate of 70% over 15 years, textile factories can achieve better returns on their investments. The approach we have used helps meet the National Energy and Climate Plan targets by 2030, aligning with the 1.5 ºC pathway and SDGs to combat climate change and poverty as well.

Key-Words: - Textile, Carbon Credit Rate, RETScreen Expert, Energy modeling tool, Onsite RES, GHGs, ZET, RECP and SDGs.

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1 Introduction

Globally the industry sector is responsible for releasing around 9.0 Gt of CO_2, accounting for a quarter of global CO_2 emissions based on the 2022 report. A lot of efforts are done on an annual basis showing that has slightly declined in the period between 2020 and 2022, far away from the Net Zero Emissions Scenario (NZE) by 2050 , in which industrial emissions fall to about 7 Gt CO_2 by 2030, [1]. The textile industry accounts for approximately 7% of emissions within the light industry sub-branch. In Albania, the industrial sector consumes about a quarter of the total energy, significantly impacting the environment. As a result, the industrial sector, including textiles, is the second largest contributor to environmental impact in Albania, following the transportation sector, [2]. Industrial energy consumption is historically dominated and still relies on fossil fuels, in particular coal, and other fossil sources and accounts for about a quarter of energy-related CO_2 emissions. Industry is one of the most difficult sectors to decarbonize, as historically the sector has relied heavily on fossil fuels, especially coal and other fossil sources. With the rapid decrease in the cost of solar PV, wind power, and battery storage, electrifying industries with renewable energy sources offers a highly promising route to achieving decarbonization, [3], [4]. As the global economy and population grow, the demand for materials and goods rises. This increasing activity level (AL) calls for technologies and strategies that promote sustainable production of commodities and GHG emissions, waste reduction, and circularity, [5]. Adopting innovative and effective carbon reduction strategies within the textiles sub-branch, can not only significantly lessen the environmental impact, preserve the planet and contribute to a more sustainable and eco-friendly future, [6]. The textile sub-branch contributes to a significant portion of global greenhouse gas (GHG) emissions, estimated at 5-10%, [7]. Moreover, resource-efficient and cleaner production (RECP) practices are part of the solution that optimizes resource management and promotes circular business models. In Albania, the sub-branch faces some challenges with waste management, as a large portion of textiles end up in landfills or uncontrolled burning. A roadmap to net-zero emission for apparel by increasing productivity while minimizing waste and energy consumption is given, [8]. To close the gap and stay on pace with the 1.5ºC pathway, the apparel sector should significantly direct its efforts to reduce GHG emissions through mechanisms that support energy efficiency [9] measures, onsite RES, and minimization of wastes. The study conducted by authors [10] examine the impact of the textile on the Pakistan Stock Exchange (PSX), as the sector holds a very significant position being one of the country's largest and most vital sectors.

In the study of [11] new applications for End-of-Life Household Materials (EoLHM), with a focus on textile wastes are explored step by step. In the study of [12] the possibility of converting EoLHM, multiple issues such as waste reduction, energy efficiency, and support for vulnerable households are carefully presented. Furthermore, an approach for End of LifeTextile Recovery Based on Short Wave Infrared Spectroscopy is evaluated by authors in the study [13], with the aim to reuse and recycling textiles as a strategy to reduce the environmental impact.

In this work we are trying to prioritize sustainability and influenced by economic growth and will contribute to Albania's emission reduction targets through carbon credit rates applied in a concrete textile factory located in Tirana to achieve 2030 emission reduction goals by 18.7% as required in [14], [15], [16] following the European Green Deal [17], to reduce greenhouse gas emissions at a level of55% by 2030. Albania's favorable geographic position makes it an ideal location for developing renewable energy sources (RES) for electricity generation. Numerous studies have highlighted the potential for fostering environmentally friendly energy types, such as solar and wind power, in the region [18], [19] and [20]. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions. The cost of manufacturing PV and other RES technologies has plummeted dramatically in the last decade [21], making them not only affordable but often the cheapest form to be replaced and integrated into existing power systems. PV power plants have a lifespan of roughly 20-25 years [22] so optional GHG reduction credit, per equivalent tonne of CO_2 (tCO_2) in conjunction with the net GHG reduction can be used to calculate the annual GHG reduction revenue. Prices for GHG reduction credits, per equivalent tonne of CO_2 (tCO_2), vary widely depending on how the credit is generated and how it will be delivered to achieve the most feasible option in RES projects. The variation of the energy consumption by fuel type is given in the graph in Figure 1 (Appendix). In addition, Albania's textile and leather energy consumption based on the official energy report is around (16-20) ktoe.

In the graph in Figure 1 (Appendix) the historical annual energy consumption (ktoe) by fuel type from 2010 up to 2023 is given. As depicted in Figure 1 (Appendix), electricity serves as the primary fuel carrier, accounting for approximately 80% of the total energy demand within the sub-branch. Diesel contributes to roughly 10% of the energy demand, while gasoline fulfills the remaining portion. The total energy demand within the sub-branch has varied from 0.145 TWh in 2010 to 0.185 TWh. The aim is to reduce the reliance on traditional fuels to zero, replacing them with cleaner energy options. The total activity level for the textile industry in 2023 results in approximately 25 thousand tons of textile products, which constitutes roughly 4% of the average industry sector demand for the chosen time frame. In the textile sub-branch, the contribution of electricity generated from onsite renewable energy sources (RES) is almost negligible. The focus of our study is to implement strategies for self-supply and to reduce the environmental impact of the textile sub-branch, [23].

2 The Case Study

In this research work a textile factory that operates in the district of Tirana, geographically located at latitude and longitude 41.32°N 19.81°E is selected as a case study. The chosen factory is a private enterprise performing its processes in a total building area of 7200 m² fractioned into floors. The tested enterprise utilizes advanced technology across various stages of the operational environment within the facility processes, including thermal transfer printing, cutting, condensing, and sewing machines as depicted in Figure 2.

The selected textile factory employs approximately 600 workers, who operate a single shift per day. These workers are engaged in various processes related to textile production, including yarn spinning, weaving, dyeing, and finishing. The factory has undergone significant modernization, incorporating advanced machinery and technology to enhance efficiency and product quality.

Fig. 1: Photograph captured at the factory workstations, illustrating key stages of the textile production process

Each process requires specialized skills and state-of-the-art equipment to ensure high-quality textile products. The factory adheres to strict quality control measures to maintain product standards and fully comply with industry and safety regulations. The estimated annual electricity consumption of the textile factory is approximately 660 MWh. This study compares energy consumption based on the number of employees and the quantity of textiles handled per year, while also integrating the carbon credit rate to evaluate environmental impact and potential cost savings. The distribution of energy consumption for the tested factory, shown in Figure 3, is split based on data obtained through a direct survey. This considers the capacities of electrical appliances (kW) and their daily operational hours.

3 Materials and Methods

Various models exist for conducting analyses of environmental impacts and benefits. RETScreen Expert is a widely used tool in the clean-energy sector, applicable to multiple industries, including textiles, [24], [25]. This model aids planners in estimating the yearly decrease in greenhouse gas emissions achieved by transitioning to cleaner technologies. By accurately assessing these reductions, planners can make more informed decisions regarding the implementation of sustainable practices. Additionally, the model helps identify key areas where clean technologies can have the most significant impact, ultimately contributing to a greener and more sustainable future.

The The energy model uses a computerized system with mathematical algorithms and a top-down approach to overcome barriers to clean energy technology at the preliminary feasibility stage, [24].

Fig. 2: Workflow of the RETScreen Expert Energy Modelling Tool, [25]

The RETScreen Expert energy modeling tool is a comprehensive software designed to analyze and optimize energy projects. It is particularly useful for renewable energy system (RES) projects, providing a range of analytical capabilities to support informed decision-making. The workflow and capabilities of the RETScreen Expert tool, pursue the structured workflow presented in Figure 3. The first step in the RETScreen Expert workflow involves gathering historical climate data and facility-specific energy consumption data. Once the data is collected, the next step is to establish an energy baseline scenario which should be validated. The baseline scenario serves as a reference against proposed scenarios. The third step is the feasibility study that includes, [24]: energy, cost, GHG reduction, financial and risk analyses, by choosing one of three available methodologies. In our case study to carry out our analysis, methodology 2 is selected including a set of influencing variables and parameters.

4 Scenario Conceptualization

In this section, the conceptual framework and proposed scenarios enabling carbon reduction efforts in the textile sub-sector, specifically in the clothing sub-branch through the application of CO_2 credit rate are introduced.

4.1 Base Case Scenario

The base case scenario is developed using energy bills provided by the factory owner and direct surveys conducted by authors through site visits. The graphical representation depicted in Figure 4

(Appendix) presents the detailed breakdown of energy consumption by end-user type, assuming the factory operates without onsite RES technologies, and considering electricity is produced from oil (the case when electricity is imported from the regional market).

Energy consumption patterns vary significantly across different end-users, and understanding these patterns is crucial for effective energy management and optimization. In the base case scenario, the energy balance analysis provides insightful data on how electricity is consumed across various end-users. Processing electricity emerges as the dominant end-user, representing a substantial 46% of the total electricity consumption. The energy balance analysis for the baseline scenario (base case) reveals that processing electricity and space cooling are the primary consumers of electricity, accounting for 46% and 26% of the total annual energy consumption, respectively. These insights emphasize the need for targeted energy management strategies to optimize industrial processes and HVAC systems. From the factory energy bills, it is evident that approximately 66,000 kWh per year is attributed to all uses, as shown in the graph in Figure 4 (Appendix). This data provides a comprehensive overview of the factory's energy consumption and helps identify key areas where energy efficiency measures can be implemented.

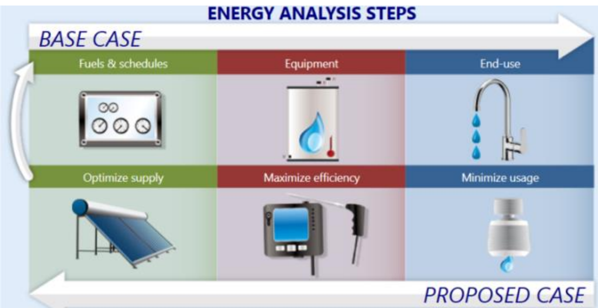

Fig. 3: RETScreen Expert energy analysis steps, [25]

Once the base case scenario is constructed in the RETScreen energy model, then the model uses optimization to cleaner options are introduced considering only PV for electricity generation and solar panel installation to meet hot water requirements with a solar fraction of 100%. The optimization function can be executed directly within the RETScreen energy modeling tool through an optimization tool that considers installing onsite RES, a roof photovoltaic system, and solar water heating system) installed on the roof of the factory building as it is depicted in Figure 5.

4.2 Proposed Case Scenarios

The clothing sub-sector is a significant contributor to global greenhouse gas (GHG) emissions, and it faces substantial challenges in reducing its carbon footprint while maintaining economic viability. This scenario conceptualization explores the potential impact of CO_2 credit rates on the sector, aligning with the 2030 climate and energy framework. Implementing energy efficiency measures in buildings and electrical appliances is crucial for reducing energy consumption, lowering utility bills, and minimizing the environmental impact. Energy efficiency measures such as Insulation, air sealing, High-Efficiency HVAC systems, smart thermostats, LED lighting, and Energy-Efficient appliances (VSD) sewing machines are included in the model merged with onsite RES installation. In Table 1 (Appendix), the key scenarios are explored, focusing on different strategies to improve energy efficiency and reduce greenhouse gas emissions.

In scenario 1 installation of onsite RES technologies is assumed to be implemented in the second part of the year. the scenario 2 considers the implementation of CO_2 credit rates to incentivize emission reductions and foster faster onsite RES. The proposed factory earns credits for reducing emissions, which can be traded or used to offset enterprise costs, [24].

The cost of the given clean systems varies depending on several factors, including the size of the system, the efficiency of the solar collectors, and the thermal storage capacity. In our case study, a total expenditure for a PV plant is assumed around €650/kWp, while maintenance and operational cost can be given in terms of DC capacity or electricity generation. Investing in a solar water heating system with a 100% solar fraction is another way to benefit from clean energy systems, a lot of savings on energy bills and carbon footprint can be achieved. The adoption of CO_2 credit rates provides a financial incentive for companies to invest in sustainable practices, ultimately benefiting the economy and the environment, too. The photovoltaic system is aimed to fill up at least 25% of the tested factory roof area, while the SWH system will occupy a minimum of 85% of the daily energy demand mainly used for de-sizing (9-28) l/min; scouring (13-35) l/min; bleaching with (15-39) l/min; dyeing with a quantity flow rate of (25-55) l/min and finishing with10-20 l/min. In our case study, a mean value of 30 l/min for all actual and future services that may be added in the tested factory is assumed.

The hot water flow rates are approximate values, but they can vary based on the type of fabric, machinery, and specific process parameters. By adopting water-efficient technologies and practices, textile manufacturers can significantly reduce their water consumption, leading to substantial cost savings and environmental benefits.

4.3 Emission Reduction Analysis and Simulation Results

In this research work the model allows to perform a GHG emission reduction by considering that electricity demand can be covered by the proposed systems. The transmission and distribution losses, incurred only by photovoltaic systems are accepted in the range of 7%. The chosen loss values are necessary to assess the level of carbon dioxide reduction of (Δ_{GHG}). Emission factors are referring to diesel fuel type. For the chosen fuel type diesel 2 with 95%, and the remainder gasoline with 5% making 100% fuel mix, while emission in (kg/GJ) for the electricity generation system is given in Table 2.

In the baseline scenario the diesel 2 shares 95%, and gasoline shares the remainder of 5%. This fuel balance with support the yearly energy balance as given in the graph in Figure 1 (Appendix). Assuming that a typical power plant system has an overall efficiency of 30% and CO_2 emission factor of the electricity mis results 251.2 kg/GJ. Furthermore, the specific emission factor for the suggested energy system based on fuel shares given in Table 2 leads to a specific N_2O and CH_4 emission of 0.0023 (kg/GJ) and 0.0120 (kg/GJ). The system GHG emission factor per each kWh produced results in 0.908 $kgCO_2/kWh$ considering 7% transmission and distribution losses.

5 Simulation Results and Discussion

The simulation conducted in the energy modeling tool, it is shown the base case electricity system and base case system GHG summary and a description of the emission profile of the baseline system compared to the proposed case system. The simulation results are expressed in terms of equivalent tonnes of CO_2 avoided per year.

Extended analyses will be performed in the time horizon of 20 years reflecting the lifetime of the proposed energy system implemented on onsite RES.

In Table 3 (Appendix) the GHG emission carried out from the base case system by multiplying the fuel consumption with the GHG emission factor including 7% losses of transmission and distribution lines. From the simulation, the GHG emission refers to the base case system by multiplying the annual system losses by the global warming potential is carried out. The annual GHG released into the environment results in around 679 tCO_2. As a result, the gross annual reduction in GHG emissions for the proposed results is around 674 tCO_2.

6 GHG Reduction Credit Rate

Prices for GHG reduction credits attributed to each equivalent tonne of CO_2 (tCO_2), vary widely depending on how the credit is generated and how it will be delivered in each project. In our case study the optional GHG reduction credit rate of €50/tCO_2, is suggested. This parameter is used in conjunction with the net GHG reduction in order to calculate the annual GHG reduction revenue [24], and [25]. Are applied between \$1 to \$168 per ton of CO_2 [25], while according to [27] it can be around €150/tCO_2. The model that adjusts the Greenhouse Gas (GHG) reduction credit rate each year is based on an escalation rate, starting from the first year and continuing throughout the entire GHG reduction credit duration outlined in Table 4.

Table 1. Revenue projections and assumptions for Greenhouse Gas (GHG) emission reductions

	Unit	Value
GHG reduction credit rate	€/tCO_2	50
GHG reduction credit duration	yrs	20
GHG reduction credit escalation rate	%	3.0
GHG credit transaction fee	%	2.0

Table 5 shows the simulation results providing insight into how these variables influence the outcomes based on the input parameters listed in Table 4.

Table 2. GHG Reduction revenue and assumptions for the tested energy system

	Unit	Value
Gross annual GHG emission reduction	tCO_2	674
Net annual GHG emission reduction	tCO_2	660
GHG reduction revenue	€	33,019

The percentage of credits that should be paid annually at a transaction fee is considered. To obtain credits for the tested GHG project, a portion of the credits is subtracted at a transaction fee of 2% which should be paid on a yearly basis to the crediting agency. As a result, the model reduces the gross annual GHG emission reductions by the assumed percentage value and calculates the net annual GHG emission reduction. From the simulation around 660 tCO_2 is calculated as it is given in Table 5. The GHG reduction credits are applied for the entire lifetime of the proposed onsite renewable energy system (RES). Each year, the rate of GHG reduction credits increases by 2.0%. In conclusion, the net annual GHG results in around 660 tCO_2 benefiting around €33,013 of GHG reduction revenue.

6.1 Financial Simulation Output

The financial parameters in Table 6 (Appendix) highlight the key benefits of using the RETScreen energy modeling tool. This tool helps decision-makers evaluate energy projects efficiently, making the whole process smoother and more informed including (e.g. discount rate, debt ratio, etc.), and its calculated financial viability output quantities (e.g. IRR, simple payback, NPV, etc.) allows the project decision-maker to consider various financial parameters in the same energy model sheet.

From Table 6 (Appendix), the fuel escalation rate is assumed 2%, a discount rate of 11%, an inflation rate of 3%, and a reinvestment rate %. The debt structure involves 70% financing with a 5.5% interest rate, repaid over 15 years, based on the actual feasibility studies and Albanian contexts.

After determining the income effective tax rate of 15% based on the Albanian context and applying straight-line depreciation over 15 years, a simple payback period analysis is conducted for each scenario developed in the RETScreen energy modeling tool. This analysis enables us to evaluate the time required to recover the initial investment in each scenario, considering the income tax and depreciation. The depreciation is following a straight line, assuming that the capitalized costs of the project are depreciated at a constant rate on a period of 25 years. The initial costs that are not capitalized (i.e., not recorded as an asset on the balance sheet) are expensed in the period they are incurred, which in this case is during the year of construction/investment (Year 0).

From the graph in Figure 6 simulations are performed to carry out the base case scenario the simple payback period results and the equity payback value. The SPP and equity time were around 7.7 years of 4.8 years respectively. In this scenario, only energy efficiency measures (EEM) that consider envelope heat transfer values are used, based on the values provided in reference [28] or walls and windows. Improvements in lighting systems, variable speed drive (VSD) machines, and heat pump systems follow the requirements outlined in the EU recommendation, [29]. The onsite RES and GHG in the base case scenario are not considered.

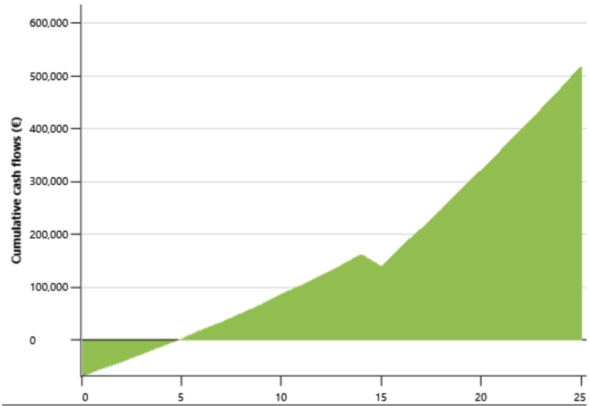

Fig. 4: Equity Payback period for the base case scenario. Simulation results for the base case scenario without onsite RES application

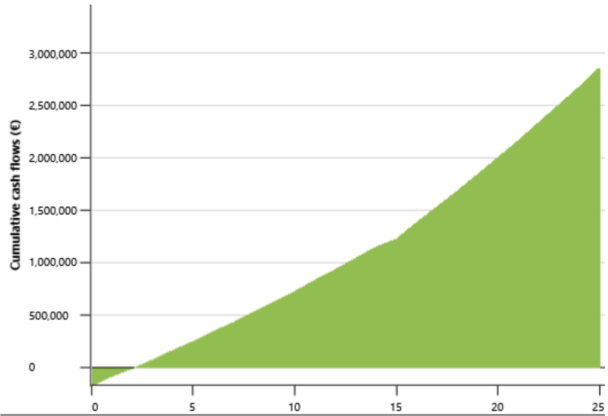

Fig. 5: Payback period for scenario 1 implying onsite RES without GHG credit rate

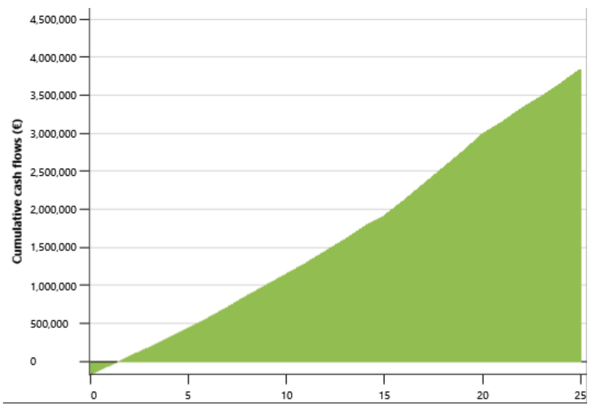

Fig. 6: Equity Payback period for scenario 2 implying onsite RES with GHG credit rate (50€/tCO_2)

From the simulation results in the case of Scenario 1, that apply the installation of a 0.5MWp DC photovoltaic system and a solar panel for hot water heating that covers at least 85 % of the daily demand is assumed. In that scenario, the equity payback time is reduced to 2.1 years and SPP results to 4.5 years as shown in the graph in Figure 7.

In this case, the equity payback and SPP are reduced to 1.5 years and 3.4 years as can be seen in the graph in Figure 8. The reduction in equity payback period is very significant reducing by a factor of 3.2.

On the other hand, the variation of the other outputs such as benefit-cost ratio and debt service coverage is increased. The simulation results are given in the graph in Figure 9.

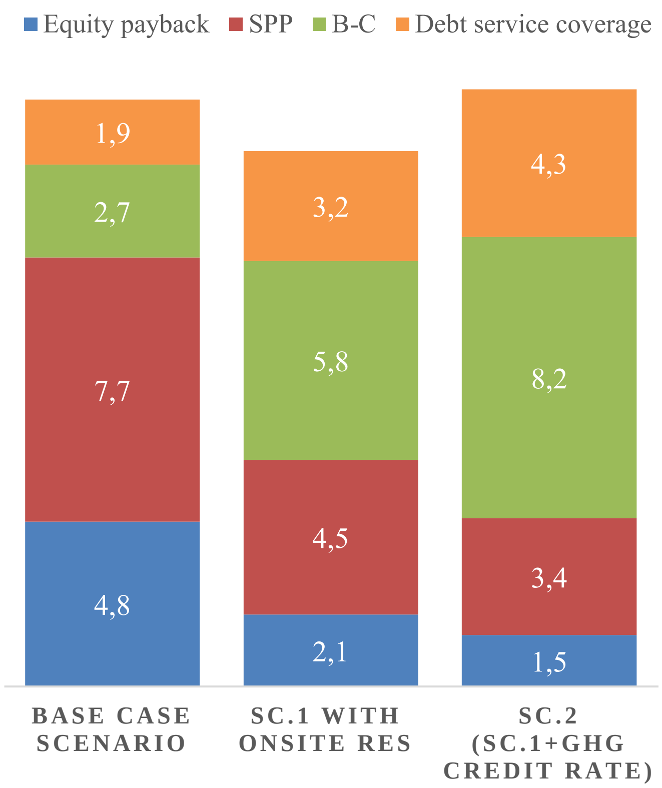

Fig. 7: Payback period, equity payback, B-C, and debt service coverage per each scenario

As can be seen from the graph in Figure 9 the debt service coverage and B-C ratio is increased from 1.9, 3.2, and 4.3, while B-C ratio is increased from 2.7, 5.8 to 8.2.

In the model the sensitivity analyses of equity payback value assessed as a function of GHG credit rate and debt rate at a range of ±25% is realized as it is depited in the graph in Figure 10 (Appendix). In this context the simulation including onsite RES and GHG credit rate applications are assumed for the case of scenario 2.

Higher the debt rate, lower the equity payback results. The correlation of GHG credit rate and debt rate can be given by the mathematical expression in. Equation 1.

$$y = -0.0214 \cdot x^2 - 0.2214 \cdot x + 2.34 \quad \textbf{(1)}$$

The coefficient of determination R^2 results 0.99, a very strong correlation between variables is defined. In more detail, an R^2 of 0.99 implies that 99% of the variance observed in the dependent variable can be explained by the variance in the independent variables chosen for conducting the sensitivity analyses. From our simulation, it is observed that as the debt rate moves toward 0%, the burden of financing shifts more heavily onto equity. With less debt, the company relies more on equity, which typically has a higher cost of capital.

The implementation of carbon-pricing policies, such as carbon taxes and emissions-trading systems (ETSs), aims to put a financial cost on carbon emissions, thereby incentivizing reductions. These policies' effectiveness can vary widely, influenced by design specifics, market conditions, and socio-economic factors.

Our case study, which employs a carbon price of €50/tCO_2, signals a significant pricing level. This substantial carbon price serves as a powerful economic lever, that drives considerable reductions in carbon emissions. Such a carbon price can lead to widespread changes, including increased investment in renewable energy, accelerated adoption of energy-efficient technologies, and a broader shift toward sustainable practices in the textile and leather sub-branch in Albania.

The empirical evidence on carbon-pricing policies' effectiveness is mixed, hence our scenario underscores the importance of context-specific application and robust policy design in achieving desired environmental outcomes using a powerful energy modeling tool, RETScreen Expert software.

7 Conclusion

As a result, our research work is focused on GHG credit rate aspects which in turn highlights the transformative potential of sustainable practices within the textile and leather sub-branch section in Albania. Our study has shown an excellent example of how targeted strategies can drive both economic and environmental benefits, too. By implementing these strategies, the textile sector in Albania can significantly reduce its carbon footprint, achieve substantial cost savings, and contribute to a more sustainable and flexible energy system. The present paper addresses various aspects related to onsite RES and GHG credit rate application in the textile industry in Albania. Nowadays, benefits coming from onsite RES systems are becoming extremely interesting from both, techno-economic and environmental points of view. Positioning onsite RES technology in the textile and leather sub-branch

as a crucial solution for deep decarbonization and improved financial viability outputs as given in the graph in Figure 9 (B-C, IRR, debt coverage, SPP, etc.) of the textile and leather sub-sector, while advocating for a minimum carbon credit rate of €50/tCO_2 is more than a need toward deep decarbonization and a fully decarbonized society.
Discussing the promising results of sensitivity analyses on equity payback, it is clearly shown that the minimum debt rate should be at least 70% with a debt interest rate of not more than 5.5% extended over the period of 15 years.

In a conclusion, applying a GHG credit rate of€50/tCO_2 impacts the specific energy consumption, and textile and leather enterprises can be converted to positive textile factories (ZET) and fully decarbonized.

8 Suggestions for Future Research

In the future, more variables of influence such as economic growth rate, activity level, and other key independent variables that impact energy consumption within the textile and leather sub-sector will be included. The way toward zero-emission textile and leather sub-branch referred as (ZET) will be the focus of our future research, employing advanced statistical methods and long-term energy modelling planning tools.

List of abbreviations

AI:	Artificial Intelligence
AL:	Activity Level
DC:	Direct Current
DHW:	Domestic Hot Water
EEM:	Energy Efficiency Measures
ETSs:	Emissions-Trading Systems
EoLHM:	End-of-Life Household Materials
EI:	Energy Intensity
IEA:	The International Energy Agency
IRENA:	The International Renewable Energy Agency
EU:	European Union
GDP:	Gross domestic product
GWP:	Global Warming Potential
GHG:	Greenhouse gases
IRR:	Internal Rate of Return
ML:	Machine Learning
MLR:	Multi Linear Regression
NECP:	National Energy and Climate Plan
NZE:	Net Zero Emissions
NPV:	Net Positive Value
O&M	Operations and Maintenance
PV:	Photovoltaic
PEF:	Positive Energy Factory
RES	Renewable Energy Sources
RECP	Resource-Efficient and Cleaner Production
SDG:	Sustainable Development Goals
SPP	Simple Payback Period
SWH:	Solar Water Heater
T&D:	Transmission and Distribution losses
tCO_2:	tons of Dioxide Carbon
TotCapEx:	Total Expenditures
TFEC:	Total Final Energy Consumption
TPES	Total primary energy supply
VFD:	Variable Frequency Drive
VSD:	Variable Speed Drive
UNFCCC:	United Nations Framework Convention on Climate Change
HVAC:	Heating, ventilation, and air conditioning
ZET:	Zero Emission Textile

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Declaration of Generative AI and AI-assisted Technologies in the Writing Process
The authors wrote, reviewed and edited the content as needed and they have not utilised artificial intelligence (AI) tools. The authors take full responsibility for the content of the publication.

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APPENDIX

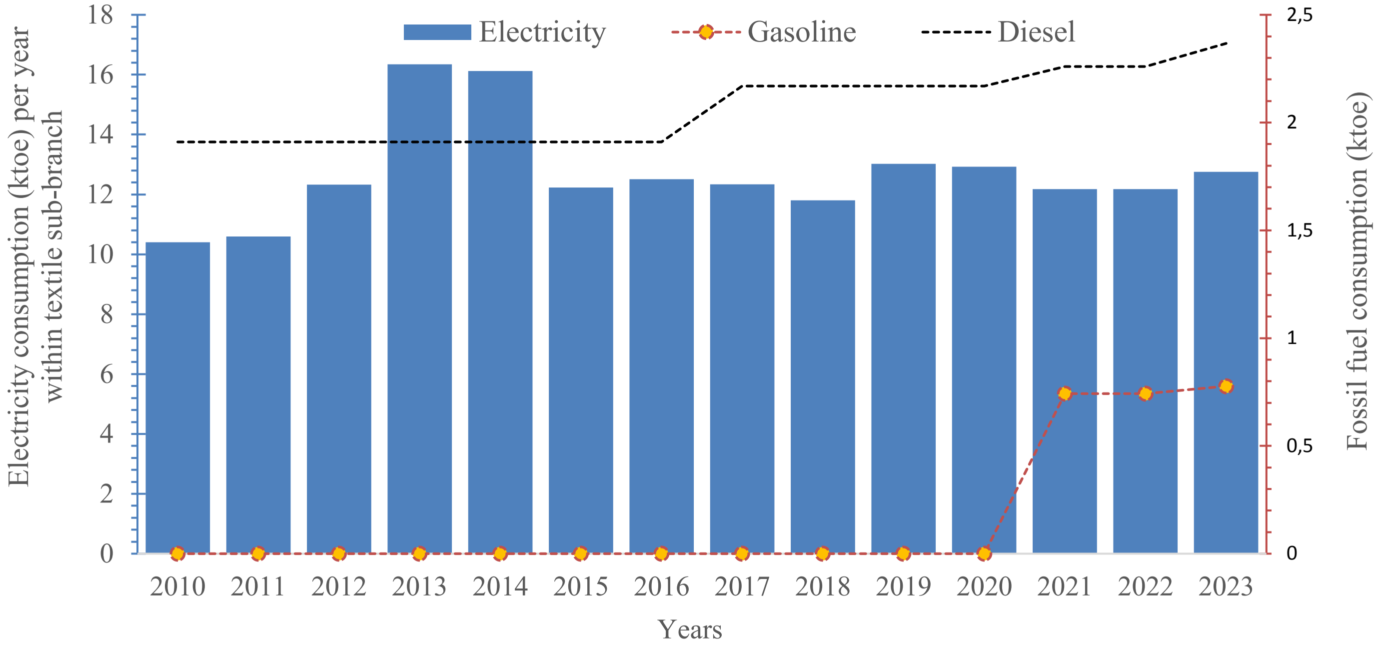

Fig. 8: Historical energy consumption by fuel type in textile sub-branch in Albania, 2010-2023

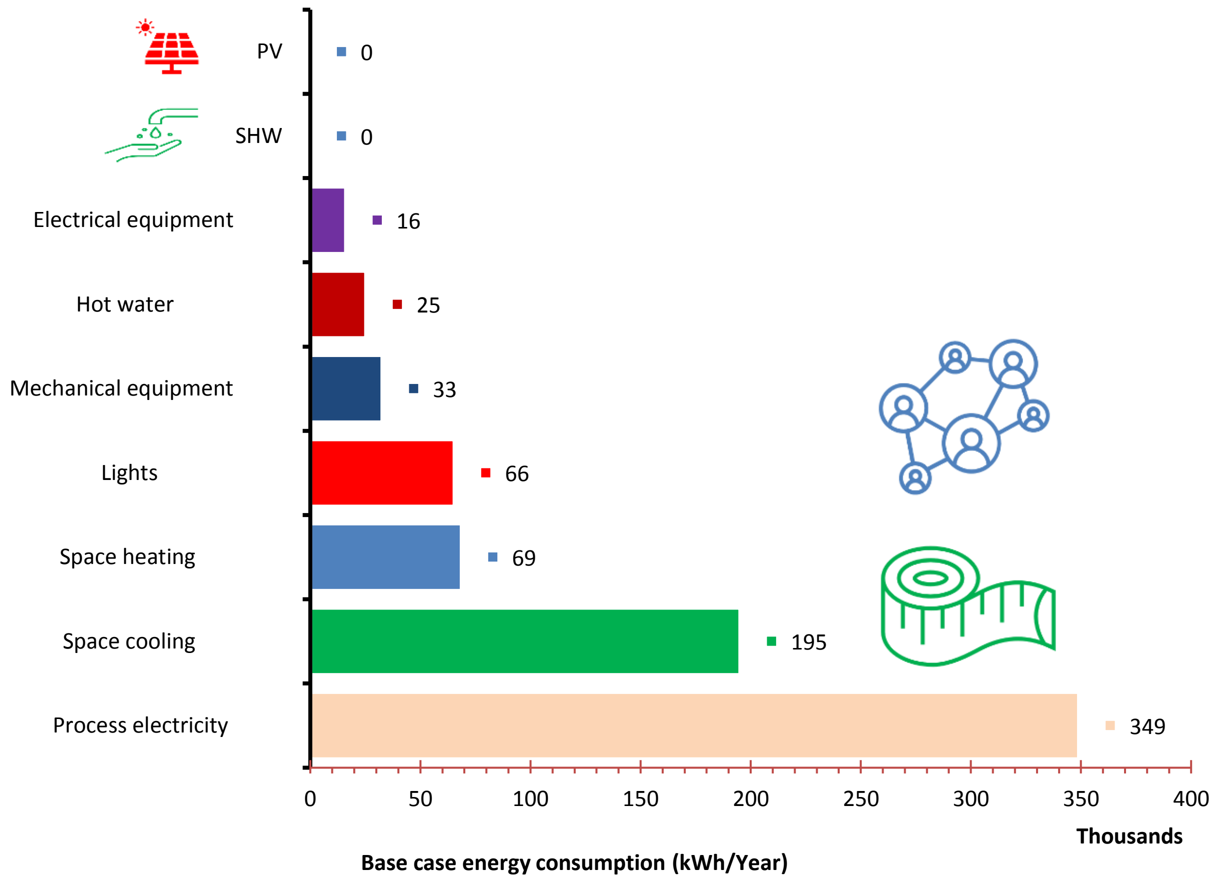

Fig. 9: Detailed breakdown of energy consumption by end-user type, [26]

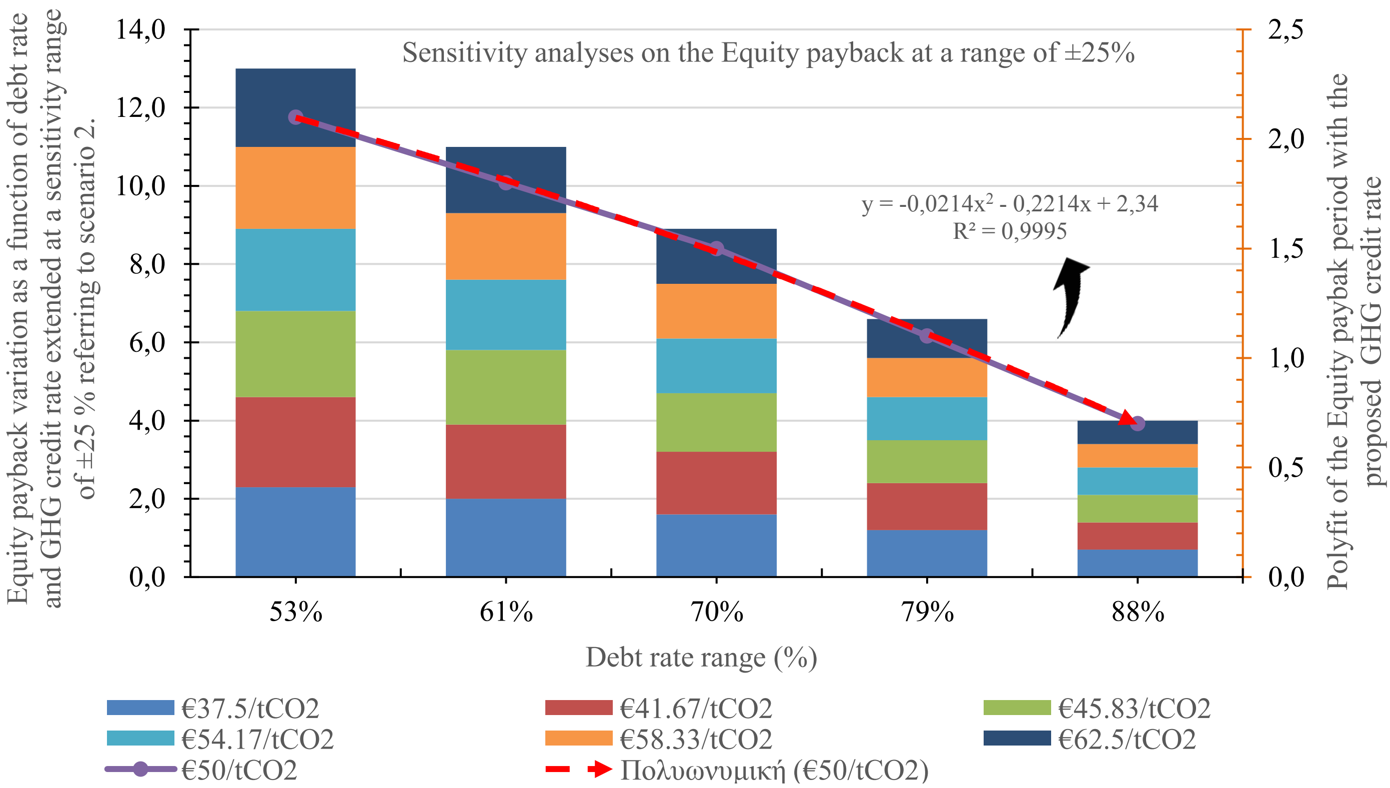

Fig. 10: Equity payback variation as a function of debt rate, and different GHG credit rates for the case of scenario

Table 3. Scenario conceptualization for the tested textile factory

	Scenario 1	Scenario 2
Scenario conceptualization	Installing a photovoltaic (PV) system with a capacity of 0.5 MWp (€650/kWp), O&M €15/kWp plus inverter replacement after 11 years. - Installing a Solar Water Heating System to achieve a 100% Solar Fraction. TotCAPEX (€650/m² aperture including thermal storage option).	- Measures applied in Scenario 1 plus GHG carbon credit rate (50€/tCO_2)

Table 4. Base case electricity system

Fuel Type (Base case)	Fuel Mix	CO_2 emission factor (kg/GJ)	CH4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Electricity Generation efficiency (%)	T&D losses (%)	GHG emission factor ($kgCO_2$/kWh)
Diesel 2	97.5%	70.0	0.0020	0.0006	30	7	0.906
Gasoline	2.5%	71.8	0.0285	0.0019	30	7	0.943
Electricity Mix	100%	251.2	0.0120	0.0023		7	0.908

Table 5. Base case and proposed scenario GHG summary

BASE CASE SCENARIO							
Fuel type (Diesel # 2+Gasoline)	Fuel	CO_2 emission factor	CH_4 emission factor	N_2O emission factor	Fuel consumption	GHG emission factor	GHG emissions
97.5/2.5%	%	kg/GJ	kg/GJ	kg/GJ	kWh	kg CO_2/kWh	tCO_2
Electricity	100	251.2	0.0120	0.0023	747814	0.908	679
Total	100	251.2	0.0120	0.0023	747814	0.908	679
PROPOSED CASE SYSTEM GHG SUMMARY							
	Fuel	CO_2 emission factor	CH_4 emission factor	N_2O emission factor	Fuel consumption	GHG emission factor	GHG emissions
	%	kg/GJ	kg/GJ	kg/GJ	kWh	kg CO_2/kWh	tCO_2
Solar	2.5	0	0	0	18842	0	0
Solar	97.5	0	0	0	728814	0	0
Total	100	0	0	0	7474130	0	0
			T&D losses				
			7%		5506	0908	5.0
						Total	5.0

Table 6. Financial input parameters for viability analysis in a textile and leather manufacturing context

Income tax analyses	*Unit*	Value
Effective tax rate	%	15
Loss carries forward?		Yes
Depreciation method		Straight line
Depreciation tax basis	%	100
Depreciation period	yrs.	25
Is a tax holiday available?		No
Financial parameters		
General		
Fuel cost escalation cost	%	2
Inflation rate	%	2
Discount rate	%	9
Reinvestment rate	%	2-5
Project life	Yrs.	25
Finance		
Debt ratio	%	70
Debt interest rate	%	5.5
Debt term	Yrs.	15

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Ilda Kola: Conceptualization of the published work, writing, formulation, and evolution of overarching research goals and aims. Data curation and scrubbing data and maintaining research data including proofing and validation.
- Blerina Kolgjini: Conceptualization of the published work, formulation, writing, and evolution of overarching research goals and aims. Data curation and scrubbing data and maintaining research data including proofing and validation.

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Conflict of Interest

The authors have no conflicts of interest to declare.