Introduction of resource efficient, cleaner production (RECP) methods in industry

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Abstract. This article focuses on the implementation of Resource Efficient and Clean Production (RTTI) methods in industrial enterprises located in the Fergana Valley of Uzbekistan. Its main goal is to improve energy efficiency, reduce CO2 emissions, and ensure optimal use of resources. Currently, the low efficiency of resources in many enterprises increases the energy demand of production and damages the environment. Within this article, it is envisaged to solve the problems by training local specialists and introducing technological innovations. Preliminary results show a 10-15% reduction in energy consumption and a 10% increase in resource efficiency. Local experts trained through trainings are trained to optimize production processes in enterprises and are directed to apply this approach to wider industrial sectors. This paper will allow for the development of sustainable industrial practices and widespread adoption of green technologies in the Fergana Valley, which will bring long-term economic and environmental benefits.

1 Introduction

Uzbekistan is one of the major industrial centers in Central Asia, and its economic development largely depends on various industries [1]. In the country, industries such as chemistry, oil and gas, energy, construction materials and textiles consume a large amount of energy. At the moment, the issues of stability of economic development and minimization of the impact on the environment are becoming more and more urgent. However, these sectors are not efficient enough in terms of efficient use of energy and the need for modern energy efficient technologies is felt. This problem is especially noticeable in the regions of Uzbekistan where industrial clusters are located, including the Fergana Valley.

Energy consumption and problems of the industrial sector. The industrial sector of Uzbekistan accounts for a large part of the country's total energy consumption. Many of the country's plants and factories were built, especially at the end of the 20th century, and they do not meet modern requirements in terms of energy saving. Since modern technologies are not introduced, most of these enterprises waste large amounts of electricity and natural resources in their production processes. As a result, not only production efficiency remains

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low, but also the negative impact on the environment is increasing, CO_2 emissions, which cause climate change, are significantly increasing.

In particular, Fergana Valley is the industrial center of Uzbekistan. The chemical, oil and gas and construction industries occupy an important place in this region. However, along with industrial development, low energy efficiency in these plants and factories is emerging as a significant problem. Although several efforts have been made to reduce energy consumption in the country, widespread adoption of modern Resource Efficient and Clean Manufacturing (RTTI) methods is still lagging. These methods provide great opportunities for increasing energy efficiency and reducing resource consumption.

Importance of Resource Efficient and Clean Manufacturing (RTTI) approach. The RTTI approach mainly focuses on the efficient use of energy and resources in the industrial sector. This approach combines economic and environmental goals at the same time. Looking at world experience, RTTI methods have been implemented in many developed countries and have significantly increased energy efficiency. These methods allow not only to reduce energy consumption, but also to reduce waste and rational use of resources. In many countries, the use of RTTI methods is an important factor in ensuring stability in industrial development [2-7].

In addition, RTTI methods ensure stable production and increase the competitiveness of enterprises. By reducing energy consumption, production costs are reduced, which causes businesses to benefit economically. Also, reducing the amount of waste reduces the impact on the environment and helps prevent climate change.

The introduction of RTTI methods in Uzbekistan's industry is of great economic and environmental importance. Since many industries in the country have a low level of efficient use of energy resources and raw materials, this approach can bring significant gains for industrial enterprises. Therefore, within the framework of this project, the goal is to increase the energy efficiency of industrial enterprises and reduce the impact on the environment by introducing RTTI methods at enterprises in the Fergana Valley.

The need to improve energy efficiency in the Fergana Valley. Fergana Valley is one of the most densely populated and industrially developed regions of Uzbekistan. The chemical and building materials industry located in this region places great demand on energy resources. At the same time, energy efficiency is low due to the fact that most of the industrial enterprises operate on the basis of outdated technologies, which leads to the waste of large amounts of resources and energy [8]. Therefore, the need to introduce energy-saving technologies in industrial enterprises in the region is increasing significantly.

Reducing energy consumption in industrial enterprises in the Fergana Valley is not only economically beneficial, but also of great importance in solving environmental problems. By increasing energy efficiency in the region, not only increase the efficiency of production processes, but also contribute to the protection of the environment. It is especially important to reduce CO_2 emissions and reduce other harmful emissions. Solving these problems will ensure the ecological stability of Uzbekistan and prevent climate change on a global scale.

2 Method

Strategies aimed at reducing CO_2 emissions by improving energy efficiency and implementing Resource Efficient and Clean Production (RECP) methods in local industries have been implemented. The approach presented in the article is based on the training of local specialists, conducting energy audits in enterprises and introducing modern technologies. The main methodological steps used in the article are detailed below.

Educational programs. One of the most important steps highlighted in the article is the establishment of special training programs for local specialists on RECP methods. These trainings are energy aimed at the development of practical knowledge and skills for

specialists working in enterprises, with the aim of increasing efficiency and efficient use of resources. The trainings were held with the participation of international experts, who shared best practices and technologies in the field of energy saving. During the training, the participants studied the theoretical and practical aspects of RECP methods, as well as evaluated the possibilities of developing specific measures to improve energy efficiency in industrial enterprises.

These training programs focused on mastering modern approaches to energy and resource conservation and provided the necessary knowledge for effective implementation of energy efficiency strategies in target enterprises (Table 1).

Table 1. The project's action plan.

Activities	2025											
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
Training of trainers												
Kick-off meeting												
Preparation for training (Design, content, ...)												
Educational materials												
Venue												
Travel and Accommodation												
Training of trainers												
Initial assessment												
Mobilization												
First data collection												
First assessment visit												
Second assessment visit												
Evaluation report												
Presentation of IRT and priority list												
Company interaction												
Movement development												
Implementation guide												
Documentation, data collection and monitoring												
Evaluation of implementation												
Training for employees												
Sustainability												
Guidelines for Effective Use of Resources for Development												
Knowledge dissemination activities												
The final event												

Table 1 shows the project's action plan for 2025 and it includes different phases. Each activity represents a sequence of activities that must be performed at a scheduled time. Below is a breakdown of the main sections of the table:

Training of trainers. This section describes the process of training trainers at the initial stage of the project. Training preparation (Design, content) activities will continue from December 2024 to January 2025. After that, educational materials are prepared. In February-March, the issues of place and accommodation will be decided. The process of training trainers is carried out in March-April.

Initial assessment. This section describes the initial assessment processes that will be carried out in enterprises during the project. Mobilization will begin in January; the first data collection will be carried out in January-February. The first assessment visit will be held in February and the second assessment visit will be held in March-April. Evaluation reports will be prepared in May, IRT presentation and priority list will be done in June. Company interaction. This section covers the development of actions in enterprises, implementation guidelines and monitoring processes. These processes are planned for June-September. Documentation and data collection will take place in July-August, and implementation evaluation and staff training will take place in July-October.

Sustainability. In this section, activities are planned to ensure the sustainability of the project. Guidelines for effective use of resources for development will be developed in September. Knowledge dissemination events will be held in September-October and the final project event will be held in October.

Evaluation of enterprises. Another key aspect of the methodology was a detailed energy audit of enterprises, which focused on enterprises in the construction materials and textile industries. During the energy audit, each enterprise's energy consumption, level of resource use, and volume of waste were studied in detail. Based on this, individual energy saving plans were developed for enterprises.

Based on the evaluation results, optimized energy saving measures and technical solutions were recommended for each enterprise. In these plans, specific ways to reduce energy consumption and efficient use of resources were shown. Strategies aimed at reducing energy costs were developed and implemented as an important part of enterprise evaluation. Also, during the assessment, technical capabilities and the state of existing facilities were studied, and the acceptability of introducing technological innovations was analyzed within the framework of the Sustainability and Industrial Innovation Program (SIIP), funded by GIZ.

Table 2. Recommendations for evaluating companies and saving energy.

COMPANY NAME	REDUCTION IN ENERGY CONSUMPTION (%)	INCREASE IN RESOURCE UTILIZATION EFFICIENCY (%)	REDUCTION IN WASTE VOLUME (%)	EFFECTIVENESS OF TECHNICAL MEASURES (%)
COMPANY 1	15	10	12	85
COMPANY 2	12	8	10	78
COMPANY 3	20	15	18	90
COMPANY 4	17	12	14	88
COMPANY 5	13	9	11	80

Energy consumption reduction (%): This column shows the percentage reduction in energy consumption as a result of energy saving measures implemented according to the results of the energy audit for each enterprise (Table 2).

Increase in efficiency of resource use (%): In this column, the indicators of percentage growth as a result of efficient use of resources (raw materials, water and other resources) in enterprises are given.

Waste volume reduction (%): Here, the percentage reduction of waste volume as a result of waste reduction recommendations implemented in enterprises is reflected.

Effectiveness of technical measures (%): The total results obtained through technological innovations and technical measures are shown in percentage. These results

show the effectiveness of the optimizations made for enterprises. Implementation of practices and technologies. practical measures aimed at introducing modern energy-saving technologies and best practices are described in detail. High-efficiency technologies have been introduced to reduce energy consumption in enterprises, including energy-efficient equipment and software to optimize production processes.

As new technologies were integrated into the production system of enterprises, it helped not only to significantly reduce energy consumption, but also to make the use of resources more efficient. Also, technological innovations have made it possible to reduce operating costs for enterprises and reduce environmentally harmful waste

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In the methodology presented in the article, regular monitoring was carried out in the process of improving energy efficiency. This made it possible to evaluate the effectiveness of the process and, if necessary, implement additional technological measures. Based on the results of the monitoring, additional recommendations were made to further optimize production processes and expand resource saving strategies in enterprises.

3 Results and discussions

As a result of detailed energy audits and technological innovations, a significant reduction in energy consumption was achieved in the evaluated enterprises. The initial results of the project showed the following:

On average, energy consumption was reduced by 10-15% in the assessed enterprises.

This reduction was achieved through energy efficiency technologies and optimization processes. These results have brought not only economic savings for enterprises, but also significant progress in reducing the harmful impact on the environment. Activities and recommendations on effective use of resources have led to significant changes for enterprises. The work carried out to improve the efficiency of resource use showed the following:

- In many enterprises, the efficiency of resource use has been increased by an average of 10%. These changes were made by reducing waste in production processes, using resources more efficiently and recycling waste.

By saving resources, enterprises were able to reduce their production costs and achieve sustainability.

3.1. Energy saving algorithm

In order to develop a scientific algorithm for the results of energy saving, we need to carry out calculations, analyzes and optimization processes based on the results of energy audits in a step-by-step manner. Below is the process of developing a scientific algorithm for saving energy.

We use audit data to analyze and optimize energy consumption step by step to develop a scientific algorithm for energy saving results. Below is a scientific algorithm for saving energy.

3.1.2. Initial data collection

Collect initial data:

Current electricity consumption (E_"current"),

Consumption of natural fuel or other sources (gas, coal, etc.) (F_"current"),

Efficiency (η) of each fuel and available emissions.

3.1.3. Subsub section 1

- To determine the total energy consumption of the enterprise, the consumption of electricity and fuel is calculated:
- $E_{total} = E_{current} + F_{current} \cdot \eta$
- Here:
- E_{total} — total energy consumption (electricity and other fuels),
- $E_{current}$ — electricity consumption,
- $F_{current}$ — consumption of fuels (gas, coal, etc.),
- η is the efficiency coefficient of energy sources.
- Analyze the energy saving possibilities and calculate the available efficiency level:
- $E_{potential} = E_{total} - (E_{current} \cdot (1-r))$
- Here:
- $E_{potential}$ is a potential opportunity to save energy,
- r is the percentage of energy saving (for example, if 10% energy saving is planned, r=0.10).
- Formulation of energy saving algorithm
- Follow these steps to save energy:
- Login information:$E_{current}$ — current energy consumption (kWh),
- $F_{current}$ — fuel consumption.(m^3, tons and etc.),
- r — energy saving percentage.

I**dentifying energy waste:**

$$E_{waste} = E_{total} \cdot r$$

Energy waste is determined here.

Technological optimization:

$$E_{new} = E_{total} - E_{waste}$$

In this formula, the optimized energy consumption is calculated.

Waste reduction:

$$F_{new} = F_{current} \cdot (1 - r)$$

Consumption of fuels and other resources will decrease.

Final energy consumption:

$$E_{\text{final}} = E_{\text{new}} + F_{\text{new}} \cdot \eta$$

Energy consumption is based on optimized technologies.

Analysis of results

The results calculated by the algorithm are evaluated by the following indicators:

Energy saving level:

$$T_{\text{energy}} = \frac{E_{\text{total}} - E_{\text{final}}}{E_{\text{total}}} \times 100$$

Here the energy saving percentage is determined.

Resource efficiency:

$$S_{\text{resources}} = \frac{F_{\text{current}} - F_{\text{new}}}{F_{\text{current}}} \times 100$$

This formula shows the efficiency of using resources.

Using the above scientific algorithm, it is possible to calculate and optimize energy saving strategies in enterprises. As a result of the analysis, this algorithm is aimed at determining how to improve technological processes and reduce energy waste.

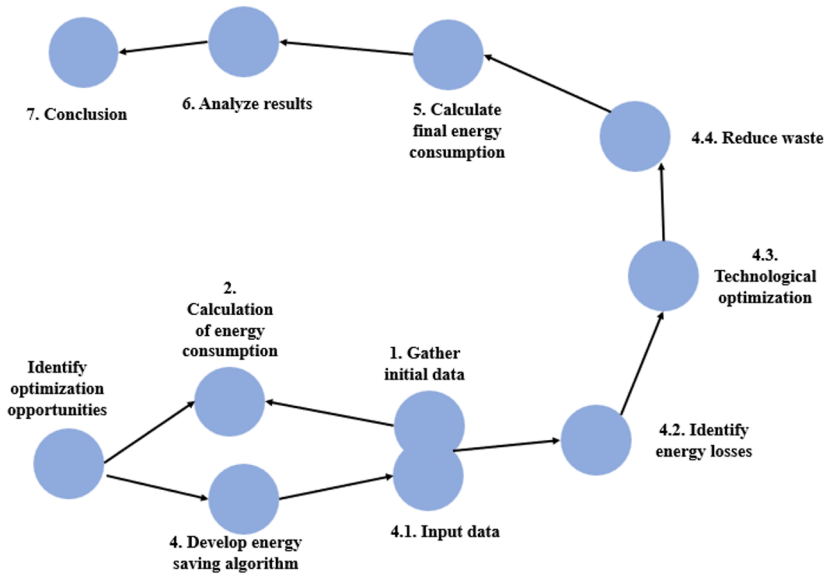

Fig. 1. Energy saving algorithm.

Above, the algorithm (Figure 1) shows the steps of the scientific algorithm for saving energy. The algorithm step by step includes the following steps:

- Initial data collection.
-Energy consumption calculation.
- Determination of optimization opportunities.

- Formation of an energy saving algorithm, at this stage input data is analyzed, energy wastage, technological optimization and waste reduction are carried out.
- Calculation of final energy consumption.
- Analysis of the results.
- Conclusion.
- Discussion

Improving energy efficiency and reducing CO_2 emissions in industrial enterprises of Uzbekistan is considered an important environmental and economic task. To achieve these goals, the introduction of Resource Efficient and Clean Manufacturing (RTTI) methods will bring significant advances in industrial development. The results of this analysis create opportunities that can be widely applied not only to target enterprises, but also to other industries in the region.

Energy efficiency programs can provide long-term benefits to regional economies. These measures not only help to significantly reduce the consumption of energy resources, but also allow economical use of resources used in production processes. For example, the results of energy saving in the field of textiles and building materials create new opportunities for economic development based on stability for the industry of Uzbekistan.

The possibilities of reducing energy consumption by 10-15% and increasing the efficiency of resources by 10% in the assessed enterprises show that optimization processes aimed at energy saving of industrial enterprises are being successfully implemented. Such processes require an individual approach for each enterprise, which is planned taking into account the technological processes and the general operation strategy of enterprises. Comparative analysis. Compared to other industries in the region, RTTI methods for improving energy efficiency have been effective in the textile and building materials sectors, but they still need to be widely implemented in the chemical industry and heavy industries. In the chemical industry, it is important to optimize reactive power and improve energy efficiency in waste treatment processes, as these industries are characterized by high energy consumption and are one of the main sources of CO_2 emissions.

There are also opportunities for energy efficiency in the food industry. Significant progress can be made in this area by introducing technologies to optimize the efficient use of resources and energy-efficient technologies. In order to ensure the sustainable development of production processes in industrial enterprises, the applied energy saving technologies can play an exemplary role for other sectors in the region.

Broad Application of RTTI Methods: The broad application of RTTI methods not only ensures energy efficiency but also contributes significantly to ecological sustainability in Uzbekistan's industrial sector. By widely implementing these methods in other regional sectors, it is possible to modernize industry and enhance production efficiency. For instance, by introducing energy-saving methods in energy networks, the overall electricity consumption can be optimized, thereby ensuring energy security. Furthermore, advanced international experiences in energy efficiency and ecological sustainability can be adapted to Uzbekistan's industrial development strategy. This process aligns with the implementation of sustainable industrial practices, combating global climate change, and reducing waste in accordance with global best practices.

4 Conclusion

The article highlights selected enterprises such as "Chortoq Temir Beton" LLC in Namangan, "Xo‘jaobod Trans Lider" in Andijan, as well as "Bursa House", "Faxrli Qurilish", "Ark Osiyo Savdo", "T.E.T-2001", "Xarakat Oltiariq Fayz", "Margilon Nodi

Qurilish", "Besh Bola Beton" LLC, and "Global Textile" in Fergana. These enterprises were chosen due to their clear goals and firm commitments to enhancing energy efficiency. Their necessary infrastructures and readiness to implement energy-saving technologies ensure the successful realization of the project.

During the selection process, existing collaborations with the companies, their dedication to improving energy efficiency, and their readiness to adopt innovations quickly were taken into account. These enterprises demonstrated their capability to adopt energy-saving measures while proving alignment with the project's goals and objectives. Early involvement of these companies has led to comprehensive outcomes of the measures within the project framework.

The selection process was conducted based on open and fair principles. We focused on ensuring balance among the industrial sectors and regions in the area. The seminars and communication events organized during the project served to explain the benefits of energy efficiency to the beneficiary companies and ensured their effective participation.

References

1. Y. Wang et al., Appl. Soft Comput. J. **92**, 106333 (2020) DOI: http://dx.doi.org/10.1016/j.asoc.2020.106333
2. C. Wang, Y. Feng, S. He, Energy Convers. Manag. **196**, 1021–1034 (2019) DOI: http://dx.doi.org/10.1016/j.enconman.2019.06.033
3. J. Li, H. Zhao, Y. Zhang, J. Clean. Prod. **189**, 234–250 (2018) DOI: http://dx.doi.org/10.1016/j.jclepro.2018.04.049
4. Z. Liu, X. Chen, Q. Zhu, J. Clean. Prod. **166**, 89–100 (2017) DOI: http://dx.doi.org/10.1016/j.jclepro.2017.08.014
5. R. Smith, X. Zhang, J. Kim, Chem. Eng. Sci. 228, 115938 (2020) DOI: http://dx.doi.org/10.1016/j.ces.2020.115938
6. P. Gupta, K. Singh, A. Yadav, Energy Sustain. Dev. **61**, 32–45 (2021) DOI: http://dx.doi.org/10.1016/j.esd.2021.02.012
7. M. Patel, P. Kumar, S. Roy, J. Ind. Ecol. 23, 987–1003 (2019) DOI: http://dx.doi.org/10.1111/jiec.12891
8. S. Kumar, A. Singh, G. Reddy, J. Clean. Prod. **245**, 118876 (2020) DOI: http://dx.doi.org/10.1016/j.jclepro.2019.118876
9. H. Zhao, Y. Li, M. Xu, J. Manuf. Syst. **56**, 185–199 (2020) DOI: http://dx.doi.org/10.1016/j.jmsy.2020.03.001
10. J. Chen, L. Wang, Q. Zhou, J. Manuf. Process. **62**, 88–104 (2021) DOI: http://dx.doi.org/10.1016/j.jmapro.2020.11.003
11. Sh. Yulbarsovich, R. Sultonov, et al., International Journal of Power Electronics and Drive Systems (IJPEDS) **15(2)**, 704–714 (2024) DOI: https://doi.org/10.11591/ijpeds.v15.i2.pp704-714
12. Sh. Usmonov, A. Iqbal, A. Saleem, et al., International Journal of Power Electronics and Drive Systems (IJPEDS) **15(1)**, 412-421 (2024) DOI: 10.11591/ijpeds.v15.i1 .pp412-421
13. M. A. Samad et al., Indonesian Journal of Electrical Engineering and Computer Science **36(3)**, 1421-1429 (2024) DOI: 10.11591/ijeecs.v36.i3.pp1421-1429
14. M. Madaliev, M. Usmonov, Z. Umirzakov, et al., E3S Web of Conferences **538**, 01013 (2024) DOI: https://doi.org/10.1051/e3sconf/202453801013