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SUSTAINABLE INNOVATIONS IN QUALITY 5.0 MANAGEMENT TO STRENGTHEN GLOBAL DIGITAL COMPETITIVENESS AND DEVELOP EXPORT POTENTIAL

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A B S T R A C T

The digital intellectual economy has evolved into a distinct form of digital economy. The mechanism of its functioning is based on the principles of Quality 5.0 management. Digital technologies, which have been used for technological modernisation acquire in the age of Quality 5.0 management new qualities and advantages which contribute, apart from the achievement of high consumer qualities of products, to the achievement of the Sustainable Development Goals. These technologies are based on sustainable innovations, which gradually penetrate various sectors. In this research, we show the necessity to create partnerships at the business-R&D level, which would allow ensuring the high viability of sustainable innovations to develop export potential and strengthen global digital competitiveness.

This research proves that sustainable innovations are created and implemented primarily by companies that are committed to the achievement of the Sustainable Development Goals, which are declared in their social corporate policy. These goals are agreed with the global and national goals of the category. The modern state of the market of innovations does not allow for their mass implementation by companies of small, medium, and micro businesses due to high financing costs. This problem requires the search for ways of organisational integration of this category's companies with other subjects of business and R&D.

In this research, we identify the types of sustainable innovations that are connected with the concept of Quality 5.0 management and that are used for the growth of high-tech exports and positions in the sphere of global digital competitiveness. We provide theoretical support and practical justification of the specifics of integrating digital intellectual innovations into the management of Quality 5.0, as a precondition for the achievement of high competitive positions in the conditions of digital intellectual economy.

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1. INTRODUCTION

Effective integration of countries and companies into foreign economic markets involves a high level of export potential and global digital competitiveness. Achievement of results within the course towards the implementation of the Sustainable Development Goals is possible due to the use of sustainable innovations, which are based on digital intellectual technologies. The application of these technologies and innovative solutions is connected with the digital economy's transition to its new form – the digital intellectual economy. The digital intellectual economy is based on Quality 5.0 management, presented by a well-balanced interaction of digital technologies and human intellect. Also, this type of economy becomes attractive for investors, because it ensures reforms and intellectual digitalization of traditional sectors' productions, which do not have high competitiveness and export potential (Wan & Wu, 2025). At the current stage, there are sectors and large production companies with a potential for reforms and modernisation. Investors could be attracted to these spheres by the government and institutions interested in support and/or increase in the number of jobs and growth tax revenues from the economic activities of large taxpayers.

Also, sustainable innovations are the basis for progress for high-tech sectors and start-ups, which are flagships of the digital intellectual economy. This is true for the production sectors which have modern equipment with intellectual technologies and the service sector, which satisfies increasing demands of consumers and contributes to the growth of the quality of life.

In this research, our goal is to identify the types of sustainable innovations, connected with the concept of Quality 5.0 management, which are used for the growth of high-tech exports and positions in the sphere of global digital competitiveness. This requires solving a range of tasks: presenting a list of countries with the leading positions in the sphere of high-tech export and global digital competitiveness and assessing companies that contribute to achievements in these directions and sustainable technologies in Quality 5.0 management, which are used to ensure effectiveness.

2. METHODOLOGY AND LITERATURE REVIEW

The methodological framework, used in this research, is comprised of the optimal set of methods and scientific and analytical materials devoted to the assessment of sustainable innovations in the conditions of of Quality 5.0 management and their influence on the positions in the sphere of global digital competitiveness and growth of high-tech exports.

We used the trend method to reveal the main types of sustainable innovations used by manufacturing companies (including companies active in international markets) within the course towards the management of Quality 5.0. The structural approach enabled us to determine the structure of high-tech exports of the leading countries in the sphere of high-tech production. We utilised the ranking approach to establish countries and companies with key positions in the sphere of global digital competitiveness.

For this research, we analysed a number of scholarly works devoted to the influence of sustainable innovations in Quality 5.0 management on the development of export potential and the growth of global digital competitiveness of high-tech companies and entire countries.

Wan and Wu (2025) evaluated three directions of the influence of the digital intellectual economy on the level of regions' development (based on the statistical data from 30 provinces of China for the last 14 years). The authors proved that the distinguished directions (stimulation of entrepreneurial activities, improvement of the quality and scales of innovations implemented by the business environment, and growth of investments in the development and implementation of sustainable innovations) foster the sustainable development of regions' economy and can be adapted by developing countries.

Senna et al. (2023) presented a systematisation of the barriers faced by the EU member states in the context of the transition to digitalisation of industrial production. The scholars identified sub-barriers within the sectors of EU countries' economies and in the context of measures undertaken to overcome them.

Ergasheva et al. (2024) studied scientific approaches to the issues of knowledge management in the conditions of digitalisation and disclosed the list of models of digital organisation of this process. Attention should be paid to the classification of tools and stages of the models in different conditions of companies' activities.

Sergi et al. (2025) presented an example of the creation of sustainable innovations in the form of information systems for forecasting of socioeconomic state of countries and territories with the help of systematised information and tools for its transformation. Value-added of information increased in the age of Quality 5.0 management, compared to the period of Quality 4.0 management when the forecasting benchmark was connected only with traditional methods and facts.

Prerna and Singh (2024) presented a systemic analysis of evolutional transformations of AI technologies and assessed their application in chatbots. The importance of this work for the presented paper is that the authors demonstrated the possibility of human intellect's influence on the set algorithms of chat bots' activities to ensure the sustainability of the functioning of subjects using them and the persons they interact with. This

research is an example of the transition from a digital economy to a digital intellectual economy, based on commitment to the achievement of the Sustainable Development Goals.

Tadevosyan (2023) elaborated on the influence of innovations on international competitiveness and tried to reveal whether innovations raise international competitiveness and how they influence exports. Amangeldiev et al. (2025) dwelt on the types and features of sustainable innovations, developed in the context of implementing the concept of Quality 5.0 management at the level of infrastructure, business, and public authorities. Provisions and conclusions of this work allow for a comprehensive assessment of the specifics and necessity for developing and implementing sustainable innovations in the conditions of Quality 5.0 management.

There is a comprehensive body of scholarly research devoted to the influence of sustainable innovations on export potential and global digital competitiveness in the conditions of Quality 5.0 management. This paper supplements the previous works and allows improving the theoretical and practical framework of substantiating the selected problems in the context of systematisation of the types and assessment of the features of sustainable innovations.

3. RESULTS

Unique sustainable innovative technological solutions (digital products and digital services) are traditionally created and manufactured by high-tech companies from countries with developed or quickly developing economies. The list of the countries that are leaders in high-tech exports and global digital competitiveness is as follows.

Based on the analysis of materials of international rankings (Digital Switzerland, 2020; International Institute for Management Development, 2019; International Institute for Management Development, 2024; Invest Chile, 2022; Invest Chile, 2024; Poder360, 2022), the top countries have the following positions by global digital competitiveness:

1) Norway: 2024 – 10th position; 2023 – 14th; 2022 – 12th; 2021 – 9th; 2020 – 9th; 2019 – 9th;
2) Taiwan: 2024 – 9th; 2023 – 9th; 2022 – 11th; 2021 – 8th; 2020 – 11th; 2019 – 13th;
3) Netherlands: 2024 – 8th; 2023 – 2nd; 2022 – 6th; 2021 – 7th; 2020 – 7th; 2019 – 6th;
4) Hong Kong SAR: 2024 – 7th; 2023 – 10th; 2022 – 9th; 2021 – 2nd; 2020 – 5th; 2019 – 8th;
5) 5) South Korea: 2024 – 6th; 2023 – 6th; 2022 – 8th; 2021 – 12th; 2020 – 8th; 2019 – 10th;
6) Sweden: 2024 – 5th; 2023 – 7th; 2022 – 3rd; 2021 – 3rd; 2020 – 4th; 2019 – 3rd;
7) USA: 2024 – 4th; 2023 – 1st; 2022 – 2nd; 2021 – 1st; 2020 – 1st; 2019 – 1st;
8) Denmark: 2024 – 3rd; 2023 – 4th; 2022 – 1st; 2021 – 4th; 2020 – 3rd; 2019 – 4th;
9) Switzerland: 2024 – 2nd; 2023 – 5th; 2022 – 5th; 2021 – 6th; 2020 – 6th; 2019 – 5th;
10) Singapore: 2024 – 1st; 2023 – 3rd; 2022 – 4th; 2021 – 5th; 2020 – 2nd; 2019 – 2nd.

The structure of the indicator of global digital competitiveness is assessed through the elements of knowledge, technologies, and future readiness.

In 2024, Switzerland was ranked 1st by the indicator of knowledge; Singapore was ranked 1st by technologies and future readiness. In 2024, Denmark was ranked 2nd by future readiness, 6th by technologies, and 7th by knowledge.

Let us determine whether these countries' positions in the ranking of global digital competitiveness conform to their positions in the high-tech exports ranking.

According to the 2024 global innovations ranking (WIPO, 2024), the leaders in high-tech export share in the total structure of trade were the following countries:

- USA – 20th position;
- Panama – 19th;
- France – 18th;
- Israel – 17th;
- Netherlands – 16th;
- Japan – 15th;
- Belgium – 14th;
- Germany – 13th;
- Hungary – 12th;
- Mexico – 11th;
- Switzerland – 10th;
- Ireland – 9th;
- Thailand – 8th;
- Czech Republic – 7th;
- South Korea – 6th;
- China, Malaysia, Singapore, and Vietnam – 1st.

Given the above results, it is relevant to study the use of sustainable innovations in Quality 5.0 management in Singapore and Switzerland. These countries are present in both considered rankings as of 2024. Since we analyse the influence of the practices of Quality 5.0 management on the two selected indicators (development of export potential and global digital competitiveness it is necessary to establish countries with the best results in the sphere of sustainable development.

According to the Sustainable Development Report 2024 (Sachs et al., 2024), 10th position belonged to Poland, while the UK was ranked 9th, Croatia – 8th, Norway – 7th, Austria – 6th, France – 5th, Germany – 4th, Denmark – 3rd, Sweden – 2nd, and Finland – 1st. Thus, neither of these ten countries is among the top 10 countries by high-tech exports in the structure of trade. France is ranked 20th in the 2024 IMD World Digital Competitiveness Ranking

(International Institute for Management Development, 2024), 18th in the high-tech exports ranking (WIPO, 2024), and 5th in the sustainable development ranking (Sachs et al., 2024). We shall also analyse Germany, which is ranked 23rd in the 2024 IMD World Digital Competitiveness Ranking (International Institute for Management (International Institute for Management Development, 2024), 13th in the high-tech exports ranking (WIPO, 2024), and 4th in the sustainable development ranking (Sachs et al., 2024).

The three analysed indicators (global digital competitiveness, development of export potential, and sustainable development, which are the basis of sustainable technologies) are not sufficiently interconnected. The reason for this is that there is a problem of adapting sustainable digital intellectual technologies to production requirements. This is a multifaceted problem, which includes the following aspects:
- Absence of finished information solutions (digital information systems of production management). This problem was peculiar to the digital economy and digital intellectual economy, which determines the insufficient efforts of all interested parties in Quality 5.0 management;
- Availability of necessary infrastructure and regulatory framework for digital modernisation;
- Measures of support from the government, aimed at digital modernisation;
- Other barriers of organisational, socioeconomic, and technical character (Senna et al., 2023).

Further on, we shall assess the types and features of sustainable innovations employed by companies in the countries that are leaders in the above rankings in the context of Quality 5.0 management. We shall not consider the activities of companies that create IT products; instead, we shall elaborate on the results of companies in the sphere of high-tech production in other sectors of the economy. We're interested in their approach to dealing with technological barriers to modernisation of production lines.

As of early 2025, French company Soitec SA was ranked 4th in the list of French high-tech companies (the top 3 positions are occupied by companies that work in the sphere of IT products and services) (Disfold, 2025a).

The company utilises sustainable innovations that help it excel in the sphere of digital competitiveness in the world markets and ensure the growth of high-tech exports (semiconductor materials and equipment) (Soitec SA, 2025b).

Due to the growth of competition in the global market of semiconductors, used in various sectors of the economy, at the end of 2020, Soitec SA partnered with the research institute CEA-Leti and created a digital intellectual technology of production of semiconductor materials and equipment, which was called Smart Cut™. This technology has the following qualities (Soitec SA, 2025c):

- Possibility to use thin layers of consumables utilised during the production of semiconductor materials and equipment (reduction of material intensity). Saving materials equals 100-150 %, which leads to the growth of economic effectiveness and competitive and pricing advantages of products, as well as reduction of CO2 emissions during product recycling. Due to the reduction of the thickness of monocrystal layers of semiconductors, the Smart Cut™ technology allowed for the expansion of the application of semiconductor materials in new types of products that meet consumer demands (companies of high-tech sectors of industry). The following digital intellectual technologies are used: machine learning for precise operations according to the set algorithms; digital twins for the creation of a digital analogue of a product sample, which contributes to high quality and adherence to precise production parameters;
- Quality and homogeneity of the monocrystal layers of semiconductors, which could not be achieved with previous production technologies;
- Limited production capacities on assembly of monocrystal layers of semiconductors. Possibility to use one substrate, which is unique for such type of production. This allows saving area and energy and material resources;
- Expansion of the type of materials that can be used within the Smart Cut™ technology for the production and assembly of monocrystal layers of semiconductors. Other materials apart from traditional silicon, can be used.

The Smart Cut™technology led to the growth of consolidated revenue during the change in the product life-cycle at Soitec SA (Figure 1). According to the data of financial reports, the company's consolidated revenue demonstrated growth with an increase in product life cycle (2021-2023). A decrease in 2024 may be connected to the fact that the company did not create a sufficient number of sustainable technologies that could support the company's positions in the sphere of global digital competitiveness and export potential.

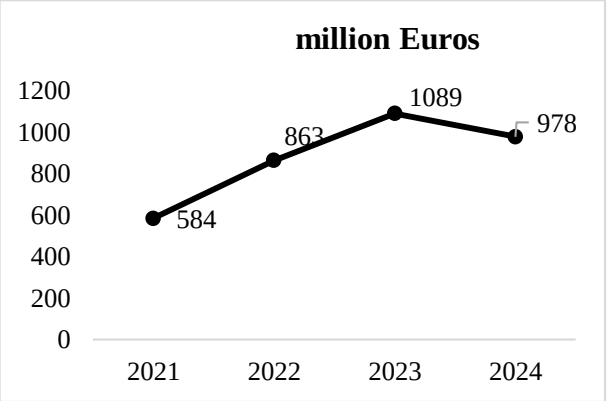

Figure 1. Dynamics of the indicator "consolidated revenue" of Soitec SA in 2021-2024
Source: Created by the authors based on Soitec SA (2025b)

To create sustainable innovations, Soitec SA partnered with a company that deals with R&D in the sphere of microelectronics. Thus, for a certain period, which showed the growth of product sales, Soitec SA overcame the barrier of the absence of finished digital intellectual solutions. However, after that, being unable to ensure – independently or with a partner – the development of finished digital intellectual solutions for manufacturing unique products with innovative qualities – the company faced a decrease in sales and competitive positions. Following the successful case of the Smart Cut™ technology, Soitec SA worked on similar partnerships at the business-R&D level in 2024. At the initial stage of new technology creation, Soitec SA makes capital investments. This led to the development of a new technology SmartSiC™, which is utilised for transferring monocrystal layers of semiconductors (used in car electronics). The main advantages of these sustainable technologies are as follows (Soitec SA, 2025a):

- Reduction of material intensity through unique features of the management of the transfer of monocrystal layers of semiconductors (100-150 %). This also contributed to reduced CO2 emissions during recycling of used semiconductors;
- Transfer is conducted in low-temperature conditions, which ensures the reduction of the negative effect on the environment;
- Possibility of 10x use of substrate for semiconductors;
- Increase in the range of electric vehicles which use semiconductors based on the SmartSiC™ technology. A full charge of an electric car that utilises this technology is around 500 km, while traditional technologies allow only 350 km. The volume of consumed energy for charging car batteries is also reduced.

General indicators of using sustainable technologies for Quality 5.0 management in Soitec SA are presented in Table 1.

Table 1. Effectiveness of using sustainable technologies by the example of Soitec

	Direction of effectiveness	Description
1	Digital intellectual capital	
1.1	Number of registered patents for prototypes of semiconductor materials and equipment	2024 – 377 patents
1.2	Share of income used for R&D, %	2024 – 14 %
1.3	Number of tests of prototypes of each type of product	2024 – 6 times (except for the creation of the product's digital twin). This contributes to the objectivity and validity of technical and technological qualities of products created with the help of sustainable technologies
2	Environment	
2.1	Reduction of water resources consumption for production, %	2024 – 32.44 % Plan for 2029-2030 – 50 %
2.2	Reduction of chemical emissions (including CO2), %	2020-2030 – 30 % (1st and 2nd categories of emissions) 2020-2030 – 50.9 % (3rd category of emissions)
3	Social sector	
3.1	New employees	2023-2024 – 130
3.2	Career growth of personnel, % of employees	2024 – 17.3 %
3.3	Females in the total structure of the company's personnel, %	2024 – 34.6 % Plan for 2029-2030 ≥ 40 %
3.4	Females in the total structure of the company's executive committee, %	2024 – 26 % Plan for 2025-2026 ≥ 20 % Plan for 2029-2030 ≥ 30 %

Source: Created by the authors based on Soitec SA (2025d)

SES-imagotag SA is a French high-tech company that functions in the market of electronic price labels for retail trade (in 2024, it was renamed VusionGroup due to corporate mergers). Advantages that facilitate the international integration of the company are innovative products, presented by the company in 2024. These are electronic price labels of the V-TAG series, which have five categories. They can be used on products without shelves and on the shelves of various modifications. The features of these electronic price labels are as follows (Vision Group, 2025a):

- Multivariancy of sizes. Information about the product is presented without the change in text quality, which is due to the high level of graphic design, based on the use of AI technologies (machine learning, used for the establishment of the set size of the label, and digital twins, which allow modelling consumers' perception of the label). Saving resources on the production of electronic price labels allows for cost savings and reduction of CO2 emissions;
- Full-colour capabilities, which ensure a vibrant spectrum of colours and visualization of products. They are also achieved due to the use of the above AI technologies;
- Environmental friendliness of electronic price labels (they can be recycled several times). The circularity of electronic price labels was approbated with the application of digital twin technology, followed by mass production.

V-TAG electronic price labels were created by VusionGroup in partnership with research companies in

the sphere of intellectual graphic design and individual specialists.

The creation and realisation of sustainable electronic products led to environmental and economic effects. The introduction of these products in the national and international markets led to an increase in revenue: from EUR 805.6 million in 2023 to EUR 1,010.5 million in 2024. The company's exports also grew (with the key countries of export being countries of North and South America and Asia-Pacific): an increase of 200 % in 2024 compared to 2023 (Vision Group, 2025b).

A German company Jenoptik AG is ranked 13th among German high-tech companies and 1st among German companies dealing with the production of electronic components for optics (Disfold, 2025b). The company develops and employs many sustainable innovations to manufacture products with high quality for the development of export potential and global digital competitiveness. One of the key sustainable digital intellectual innovations, used in the recent three years, is JENvelt (Jenoptik vision enhanced laser tool). JENvelt is an optimal module that ensures laser treatment of various materials. The key difference between JENvelt and traditional laser technologies is that JENvelt uses AI technologies (Jenoptik AG, 2025b). JENvelt could be used for smart laser treatment of metals, plastic, and other materials. Its software allows the management of all processes of laser treatment; also, it is adaptive to various productions and materials. High sensitivity and computer vision with the top level of image recognition allow for a reduction of production waste down to 0 % and a 100 % reduction of CO2 emissions from their processing.

This technology was created to raise the external integration of the company's products into international markets, which was successful due to advertising the technology's features and unique qualities. It was developed together with research organisations in the sphere of photonics. Effectiveness of Quality 5.0 management, based on the indicators of innovations' sustainability, consists in the following:

1) Economic efficiency. The company's revenue has positive dynamics: 616 million Euros in 2020, 751 million Euros in 2021, 981 million Euros in 20222, 1,066 million Euros in 2023, and 1,116 million Euros in 2024 (Jenoptik AG, 2025a). The year 2024 demonstrated positive dynamics of product exports: export to the USA grew by 2.8 %, EU countries – 0.8 %, China – 4.8 %, India – 6.5 %, and Switzerland – 6.8 %. This is a sign of sustainable innovations' contribution to the growth of global digital competitiveness.

2) Environmental effectiveness, Transition to green energy, which is promoted during implementation of the analysed innovation (JENvelt), is conducted within corporate commitments and shows the company's adherence to the Sustainable Development Goals. JENvelt allows saving energy due to higher precision (10 % and more), and the company supports the necessity to use renewable energy. As of year-end 2024, the company's energy transition was at the level of 95.8 % (in 2023 – 93 %) (Jenoptik AG, 2025c);

3) Social responsibility. The company's activities on development, implementation and sales of analysed sustainable innovations are conducted in the context of support of labour resources' quality of life. Jenoptik AG is committed to the improvement of the quality of knowledge and skills of personnel, which contributes to satisfaction with labour and future readiness. This policy is based on the conceptual framework of quality management of knowledge as the basis for companies' competitiveness companies (including in international markets) (Ergasheva et al., 2024). Also, Jenoptik AG practises the methods of improvement of gender equality. All these social measures are promoted by Jenoptik AG when advertising its brand, products, and sustainable innovations.

4. DISCUSSION

iven the importance of reducing the considered barriers during Quality 5.0 management for companies that are aimed at foreign economic integration (growth of export potential) and global digital competitiveness, it is expedient to identify the ways of improvement in this direction.

The first barrier is the absence of finished digital intellectual solutions (sustainable innovations which are ready for use in the sectorial activities or can be easily adapted to the company's activities). As shown by the example of a French company, stable partnership at the business-R&D level allows creating sustainable technologies which contribute to the improvement of Quality 5.0 management and the growth of export potential and global digital competitiveness. Insufficient interaction between business subjects and R&D leads to a reduction of the considered indicators. R&D subjects create digital intellectual solutions that meet the demands and expectations of business (production sector). Digital intellectual solutions cannot be adapted to all productions, and high-tech is no exception. Though the focus on the subject character of digital intellectual innovations involves higher costs, but allows achieving better effects. This approach to the management of Quality 5.0 requires more R&D expenditures, which can be covered by large production companies. Micro-, small, and medium businesses can solve the problem of new technologies through network partnerships with R&D subjects and investors.

The second important barrier is the absence of financing for production companies (including by the government) for the achievement of digital modernisation in traditional sectors. Companies and sectors that do not employ digital intellectual technologies cannot ensure their digital global competitiveness and integrate into international markets. Financing of digital intellectualisation of production processes could become the object of business plans submitted by companies to stakeholders (including the government). The main

investment advantages here could be the implementation of the Sustainable Development Goals (change of traditional technologies for digital intellectual; preservation and/or improvement of employment and an increase in the quality of life; reduction of climate impact as a result of production activities); improvement of product quality and growth of products' value-added (factors ensuring the improvement of global digital competitiveness and disclosure of export potential).

5. CONCLUSION

Summing up the conducted research, it is possible to draw the following conclusions regarding the perspectives of using sustainable innovations in the context of improvement of export potential and growth of global digital competitiveness.

First, in the conditions of Quality 5.0 management, the business environment cannot independently create sustainable innovations with a long life cycle. To ensure success in development, approbation, and realisation of sustainable innovations it is necessary to take into account their resilience. Its growth is possible if the company convinces the consumer that the given innovation is unique and the consumer needs it. The key basis of the effectiveness and resilience of such innovations is the consideration of the needs of interested parties (consumers) in the short term and the attraction of specialists for joint innovative activities. Second, micro-businesses and small and medium companies need incentives for participation in the digital modernisation of economic activities. This is especially relevant in economies where companies of this scale dominate. This will allow ensuring digital intellectual growth and raising the level of the population's employment. Third, sustainable innovations, which are aimed at the growth of high-tech exports, could foster the global digital competitiveness of consumer companies, which provides new opportunities for their attraction as investors. Here it is necessary to create technical tasks and substantiate the resilience of sustainable innovations for specific categories of consumers.

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