THE POTENTIAL OF "GREEN NANOTECHNOLOGY" FOR A BETTER SUSTAINABLE ECONOMY: A PRELIMINARY ANALYSIS

Lucia Martiniello *, Talita Rossi *, Marco Sorrentino *

* Pegaso Digital University, Naples, Italy

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Abstract

The care for the environment, as an instrumental value to the free development of the human being, requires a modification of economic systems and the need to seek new ways of doing business, abandoning the logic of mere profit in favor of choices that pursue the protection of both the individual and the ecosystem (consider, for example, the need to progressively eliminate the use of the most polluting energy sources in favor of other sources with lower environmental impact) (Ellabban et al., 2014; Farghali et al., 2023).

The challenges we are nowadays facing are linked to the concept of sustainable development, capable of combining economic efficiency with the protection of human beings and the environment (Barbier, 1987).

There is a particularly urgent need to revise development models and reconsider the relationship with nature and the use and consumption of natural resources; the underlying scenario is represented by the possible depletion of some environmental goods, as well as the alteration of the ecosystem, with all the consequences this may have on current human lifestyles and the sustainability of economic and productive activities.

The ecological transition, along with the digital transition and social inclusion, represents one of the three pillars, shared at the European

level, around which the model of sustainable development revolves. This leads to a new way of doing business where the logic of profit gives way to growth that must be qualitative as well as quantitative. This pillar, along with digitalization and innovation, constitutes a response to contribute to the European Green Deal and, in particular, to the goal of making the European Union the first continent with net-zero climate impact by 2050.

The objective, as also highlighted in the 2020 Commission Communication along with the 2018 package of Directives, should be the construction of a sustainable economic model that creates widespread and equal prosperity. This aims to prevent the development of practices incompatible with the idea of a market where the reasons for efficiency and production can be reconciled with those of social, human, and civic solidarity.

Accordingly, the recent Corporate Sustainability Reporting Directive (CSRD) — EU Directive No. 2464/2022 — aims to promote transparency and disclosure of information by companies regarding the environmental, social, and governance (ESG) impacts of their activities. This Directive, which effectively replaces the previous No. 95/2014 (NFRD), must be implemented by the Member States of the Union by July 2024 and will lead to a significant strengthening of sustainability reporting obligations, involving nearly 50,000 companies at the European level (in Italy, instead, the number of companies bound to sustainability reporting will increase from about 200 today to about 4–5.000 by 2027).

Corporate social responsibility (CSR) has given rise to a new entrepreneurial model based on an ethical substrate in which the care of social and environmental interests becomes crucial, with the aim of gaining social consensus (Dean & McMullen, 2007; Chenavaz et al., 2023).

Within this context, the logic of the so-called "green economy" is also encouraging the valorization of technologies, products, and production processes that are more environmentally sustainable from the perspective of atmospheric and climate protection. More specifically, it is possible to observe an ever-greater development of "green nanotechnology" (Jones, 2004; Iavicoli et al., 2014; Khan, 2020; Pokrajac et al., 2021), which emerges as a fundamental resource for addressing the challenges of a sustainable economy, offering a wide range of opportunities and solutions in various key sectors such as sustainable agriculture (Singh, 2021; Muraisi et al., 2022; Bhandari, 2023), climate change (Chausali, 2023), renewable energies (Zang, 2011; Hussein, 2015; Ahmadi et al., 2019), water purification (Qu et al., 2013; Mishraet et al., 2020; Punta et al., 2022; Dhanda & Kumar, 2023), eco-friendly materials (Aithal & Aithal, 2022), and healthcare (Anjum et al., 2021; Haleem et al., 2023; Malik et al., 2023).

To this effect, the development of eco-friendly materials is essential for reducing the impact of human activities and negative environmental

externalities; furthermore, the creation of lightweight, durable, and biodegradable materials is useful for the production of ecological and biodegradable packaging, thus reducing the use of plastic and waste. Additionally, nanotechnology can contribute to the development of more efficient and durable building materials, reducing the energy required for the production and maintenance of buildings.

In other words, "green nanotechnology" fits perfectly into the perspective of sustainability, allowing the exploitation of nano-innovations in materials science and engineering to generate products and processes that are energy-efficient, as well as economically and environmentally sustainable. This fosters the circular economy, ensures better resource allocation, and reduces emissions, pollution, biodiversity loss, and environmental degradation for a company.

Therefore, it is fundamental to analyze the opportunities that this technology offers for the transition towards a sustainable economy, without neglecting its risks, especially in the absence of adequate regulation. These risks are not only related to environmental, health, and safety issues but also to ethical and social reasons that impose a uniform regulation of the phenomenon across all territories.

The first example is the agricultural sector. Food security and the need to reduce environmental impacts associated with intensive fertilizer and pesticide use are unavoidable goals to which green nanotechnology can offer valid responses to improve the efficiency and sustainability of agriculture. This is achieved through the use of nanomaterials such as carbon nanotubes and silicon nanoparticles to enhance nutrient absorption by plants, increase crop yields, and reduce fertilizer usage.

However, concerns regarding the use of such materials and their potentially harmful effects on humans cannot be ignored due to their hazardous properties, which are not yet fully understood.

It is therefore essential to identify effective rules to ensure responsible and safe use of nanomaterials while respecting people and the environment.

Another relevant usage of nanotechnology is for water purification, using nanomaterials for the removal of organic and inorganic contaminants. Materials such as graphene oxides and cellulose nanofibers can be used to create advanced filters capable of efficiently and sustainably removing pollutants. However, even in this different context, it is important to carefully assess the side effects and risks associated with the use of these materials and their potential environmental impact. It is necessary to balance the need to protect water quality, essential for human health and ecosystem preservation, with the corresponding need to regulate the matter through preventive precautionary measures, including employee training, the use of collective and personal protective equipment, and health surveillance programs to protect workers' health and safety.

The importance of technology in the process aimed at achieving a sustainable economy is also evident in the renewable energy sector, another pillar of a sustainable economy. Also, in this field, green nanotechnology plays a central role: the potential of nanomaterials, such as perovskite nanoparticles, to improve the efficiency of solar cells is evident, making solar energy more accessible and efficient. Additionally, nanotechnology can contribute to the development of more performant and durable batteries for energy storage, reducing dependence on fossil fuels and lowering greenhouse gas emissions.

Lastly, it is also valuable to the enormous potential of nanotechnology in the healthcare field for early diagnosis and treatment of diseases, enabling timely and personalized therapeutic interventions, thus improving the effectiveness of treatments. However, it is crucial to carefully evaluate the safety and efficacy of these tools before their clinical application and, therefore, not to underestimate the risks, even for human health, associated with their indiscriminate and unregulated use.

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