

Digitalization and the Green Economy: From Presumed Synergy to Potential Paradox: A Critical Reading of the International and National Literature, with Reference to the Algerian Experience

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Abstract

This study examines the relationship between digitalization and the green economy from a critical standpoint that goes beyond the prevailing assumption that digital technology is a neutral instrument that serves sustainability merely by virtue of its adoption. We adopt a descriptive-analytical method grounded in a targeted review of studies published in Scopus-indexed international journals and in Algerian journals hosted on the Algerian Scientific Journal Platform (ASJP), together with a reading of recent official Algerian documents concerning the National Digital Transformation Strategy 2025–2030 and the National Renewable Energy Programme. The study arrives at three principal findings. First, digitalization opens genuine channels toward the green transition, most notably by raising energy-use efficiency and stimulating green innovation. Second, this effect is conditional and non-automatic: international studies show that the carbon footprint of the digital sector and the rebound effect may cancel out part of the anticipated gains. Third, Algeria possesses two parallel tracks — digital and energy — that have yet to converge within an explicit institutional framework. The study concludes by proposing a four-condition analytical framework for achieving a “twin transition” in the Algerian context.

Keywords: green economy; digitalization; twin transition; rebound effect; renewable energy; Algeria.

JEL Classification: Q01; Q42; Q56; O33.

Introduction

Discourse on the green economy is no longer merely an intellectual luxury confined to international conferences. Since the United Nations Environment Programme issued its landmark 2011 report, the concept has become a framework through which governments formulate their investment policies, and a yardstick by which researchers gauge economies' capacity to grow without depleting their natural capital (UNEP, 2011). In parallel, digitalization has permeated every facet of economic activity — from public administration to agriculture and electricity grids — until it has become, in the official discourse of most developing countries, a precondition for development rather than merely one option among others.

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At first glance the two trajectories appear complementary: digitalization promises precision, coordination, and reduced waste, and the green economy needs precisely these qualities. Yet the recent literature does not move in a single direction. Some studies demonstrate that the digital economy supports green innovation and raises energy efficiency (Wang et al., 2024; Pu, 2025), while others warn that digital technologies are themselves energy-intensive, and that their gains may be eroded by what is known as the rebound effect (Freitag et al., 2021; Muñoz de Bustillo Llorente, 2024). Indeed, an empirical study at the level of European regions found that the local development of digital technologies was associated with higher industrial greenhouse-gas emissions, whereas environmental technologies were associated with lower emissions (Bianchini et al., 2022).

In Algeria the question takes on a pressing practical character. In August 2024 the Presidency of the Republic approved the National Digital Transformation Strategy 2025–2030, whose content was officially unveiled in May 2025 under the slogan “For a Digital Algeria 2030,” while the National Renewable Energy Programme proceeds along a trajectory targeting 15,000 megawatts by 2035. Two tracks — digital and energy — are advancing simultaneously, without it being clear from the published documents how one is meant to serve the other.

Research Problem

On this basis, we pose the following research problem: to what extent can digitalization serve as a lever for the transition toward a green economy, and what conditions render its net environmental effect positive in the Algerian context? The following sub-questions follow from it:

First, through which channels does digitalization positively affect green-economy indicators according to the published literature?

Second, what are the limits and risks of this effect, and how do empirical studies account for them?

Third, where does the digital track intersect with the energy track in the Algerian experience, and what institutional gaps obstruct this intersection?

Research Hypotheses

Hypothesis One: Digitalization contributes to the green transition through two principal channels — efficiency and innovation.

Hypothesis Two: The net environmental effect of digitalization is conditional on the energy source powering the digital infrastructure and on the capacity of public policy to contain the rebound effect.

Hypothesis Three: The intersection between the digital strategy and the energy programme in Algeria exists in potential rather than in practice, owing to the absence of an explicit coordinating framework linking the two tracks.

Significance and Objectives of the Study

The significance of the topic stems from the fact that most of what has been written in Algeria on digitalization and sustainable development treats the two tracks separately, generally confining itself to a survey of potential and challenges. The present study, by contrast, sets the two tracks against one another and interrogates the implicit assumption that digitalization is environmentally benign by nature. Our objectives are accordingly threefold: to synthesize recent international evidence on the effect of digitalization on sustainability indicators; to clarify the conditions and limits of this effect; and to read the Algerian case in this light, proposing an analytical framework that can be tested in subsequent studies.

Methodology and Scope of the Study

We adopt a descriptive-analytical method combined with a targeted literature review. The study's corpus comprises three categories: (a) studies published in Scopus-indexed international journals, selected on the criterion of direct relevance to the relationship between digitalization or the digital economy and environmental or energy outcomes; (b) Algerian articles published in journals hosted on the Algerian Scientific Journal Platform (ASJP); and (c) official Algerian documents and data pertaining to the digital

strategy and the energy programme. It should be stressed that the study offers no new econometric estimate; its findings are inferential, drawn from a synthesis of published evidence, and that some official data are sourced from officials' press statements rather than detailed technical reports — limitations to which we return in the conclusion.

The study is organized into five sections: the first presents the conceptual framework of the green economy; the second addresses the channels through which digitalization exerts a positive influence; the third discusses what we term the digital–environmental paradox; the fourth is devoted to the Algerian case; and the fifth proposes an analytical framework for the twin transition.

Section One: The Conceptual Framework of the Green Economy

1.1. The Green Economy: A Multi-Stranded Concept

The UNEP report presents the green economy as one that improves human well-being and social equity while simultaneously reducing environmental risks and ecological scarcities. The report argued that directing the equivalent of 2% of global GDP toward greening ten central sectors would shift the trajectory of development toward a low-carbon, resource-efficient model, and that greening economies is not a drag on growth but a new engine for it and a net generator of decent employment (UNEP, 2011).

The concept, however, has not settled on a single definition. Loiseau and colleagues (2016) observed that the green economy intersects with a wide array of neighbouring concepts, and that its relationship to sustainability is not always clear, prompting them to compare and evaluate the definitions in circulation. This ambiguity carries a practical import no less significant than its theoretical one. Whoever understands the green economy through the logic of “weak sustainability” accepts the substitution of manufactured capital for natural capital, whereas an adherent of “strong sustainability” rejects such substitution (Neumayer, 2010). In light of this distinction, one might argue that digitalization admits of two divergent readings: for proponents of weak sustainability it is a legitimate substitute compensating for depleted resources, whereas for proponents of strong sustainability it constitutes additional capital that does not exempt one from safeguarding natural assets. This reading is our own inference in linking the two bodies of literature, and not a conclusion stated by the authors cited.

1.2. The Green Economy in the Algerian Literature

The topic has attracted considerable attention in Algerian journals since the mid-2010s, approached from multiple angles, including green jobs, which Kheirdja (2015) regards as the fruit of major investment in energy efficiency, renewable energy, green infrastructure, and waste management, and green technologies and the carbon footprint, as addressed by Khetouf (2025). It may be observed, within the limits of what we have reviewed, that a substantial portion of this work adopts the descriptive-analytical method and stops short at surveying potential and challenges. Khetouf's (2025) study epitomizes this tendency: Algeria, in the author's assessment, possesses considerable potential for developing a green economy, yet financing constraints and technology-transfer challenges remain an obstacle to doing so.

Section Two: Digitalization as a Lever for the Green Transition — Channels and Evidence

2.1. The Efficiency Channel

The first and most widely invoked argument holds that digitalization raises the efficiency of resource use. The review prepared by the European Commission's Joint Research Centre summarizes the potential positive effects in terms of improved production efficiency and coordination among its stages, and in the “dematerialization” of goods and services (Muñoz de Bustillo Llorente, 2024). This argument resonates with the theoretical framework of Wang and colleagues' (2024) study of the circulation sector within Chinese industry. The authors distinguish between two opposing effects of the digital economy: a scale effect that expands activity and thereby raises energy consumption and emissions in an initial phase, and an efficiency effect that grows as the application of digital technologies deepens and energy use improves.

2.2. The Green Innovation Channel

The second channel is less visible but arguably more consequential in the long run. Wang and colleagues' (2024) study treats the encouragement of green technological innovation as one mechanism through which the effect is transmitted, and Pu's (2025) study proceeds in the same direction, examining the relationship between digitalization and green innovation efficiency across several sub-dimensions. Its findings reveal a notable disparity among technologies: components such as cloud computing and digital-technology applications emerge as pivotal in raising green innovation efficiency, whereas technologies such as artificial intelligence, blockchain, and big data encounter implementation difficulties. The study further reports that the speed of digitalization amplifies these gains. Liu and colleagues (2024), for their part, examine how scientific and technological innovation can drive the digital economy toward sustainable development within the framework of the green economy, balancing growth against environmental protection and resource efficiency.

2.3. The Financing and Economic-Resilience Channel

The literature extends as well to the financial dimension. Zhang's (2025) study examines the relationship between the digital economy, green finance, and economic resilience across Chinese regions; Ozturk and Ullah (2022) investigate the role of digital financial inclusion in growth and environmental sustainability within Belt and Road Initiative economies; and Razzaq and colleagues (2023) study the effect of digital finance and renewable-energy-technology innovation on green growth in China. Closer to our own region, Alrifadi and colleagues (2026) examine the relationship between green finance, the digital economy, and energy consumption in the countries of the Middle East and North Africa, and, in their cross-country comparison, place Algeria among the countries lagging in digital-economy indicators.

2.4. Digitalization in the Renewable Energy Sector

The energy sector represents the clearest area of intersection. El Zein and Gebresenbet (2024) reviewed the literature on digitalization in renewable energy and concluded that further effort is still required, particularly with respect to making data Findable, Accessible, Interoperable, and Reusable (FAIR) and to addressing cybersecurity concerns. In an Algerian context, Bergougui and Meziane (2026) invoke Tunisia's experience with smart metering and blockchain in energy trading and the resulting improvement in grid resilience, arguing that capitalizing on Algeria's solar and wind potential requires investment in research and development and technological partnerships.

Table 1. A Sample of the Studies Reviewed and Their Reported Findings

Study	Context and Period	Digital Variable	Green Variable	Reported Conclusion
Wang et al. (2024)	China, circulation sector	Digital economy	Carbon emissions	A scale effect raises consumption, offset by a growing efficiency effect; green innovation is the transmission channel
Pu (2025)	Firms (per study context)	Dimensions and speed of digitalization	Green innovation efficiency	Cloud computing and digital applications improve efficiency; AI, blockchain and big data face implementation difficulties

Study	Context and Period	Digital Variable	Green Variable	Reported Conclusion
Bianchini et al. (2022)	EU regions and the UK, 2007–2016	Digital patents	Industrial emissions GHG	Environmental technologies reduce emissions while digital technologies raise them; big data and computing infrastructure the most harmful
Bergougui & Meziane (2026)	Algeria, 1995–2022 (quarterly)	Green technologies, institutional quality	Energy diversification	Positive shocks to institutional quality and green technology enhance diversification; negative shocks weaken it
Allouit et al. (2026)	Algeria, 2018–2024	AI adoption	Green innovation and entrepreneurship	Progress in renewable-energy projects and a relative decline in emission intensity; AI facilitates resource management and innovation

Source: prepared by the author based on the studies cited. Note: conclusions are reported as stated by their respective authors and are not directly compared, given differences in context and methodology.

Section Three: The Digital–Environmental Paradox

3.1. The Carbon Footprint of the Digital Sector

Freitag and colleagues' (2021) paper critiques certain optimistic estimates of digital technology's climate impact. It concludes that analysts agree ICT-sector emissions will not decline absent broad, concerted political and industrial effort, and it advances three reasons for expecting them to rise without intervention, noting that not all of the sector's carbon pledges are ambitious enough to meet climate targets. This implies that the claim that “digitalization reduces emissions” holds only when accompanied by an explicit policy to decarbonize the digital infrastructure itself.

3.2. The Regional Empirical Evidence

The strongest evidence for this paradox is perhaps Bianchini and colleagues' (2022) study of the “twin transition” across European regions. The authors combined data on environmental and digital patents with emissions data from highly polluting industrial plants at the level of major metropolitan regions between 2007 and 2016. They found that the local development of environmental technologies reduces emissions, while the local development of digital technologies raises them — effects that vary across technologies, with big data and computing infrastructure the most harmful. In fairness, these findings pertain to specific European regions over a specific period and should not be mechanically generalized to Algeria; they nonetheless suffice to refute the proposition that digitalization's effect is invariably positive.

3.3. The Rebound Effect and the Divergent Drivers of the Two Transitions

The Joint Research Centre's critical review (Muñoz de Bustillo Llorente, 2024) acknowledges digitalization's potential benefits in combating climate change but warns of the risk that a rebound effect may absorb a substantial share of them, and of digitalization's negative environmental effects more broadly, including intensive energy consumption, the generation of e-waste, and the environmental footprint of cryptocurrencies and artificial intelligence. The author adds an observation worth pausing over: the digital transition is driven principally by firms, consumers and markets, and preceded the green transition in time, whereas governments originally led the green transition. That is, the two concurrent processes differ in their objectives, drivers and actors — hence the difficulty of reconciling them through a single policy decision.

3.4. An Illustrative Formulation of the Net Effect

To render the idea more concrete, the net environmental effect of a digital project may be expressed through the following relation — an illustrative formulation of our own devising, not an econometrically estimated equation:

$$\text{Net Effect} = (\text{Efficiency and Innovation Gains}) - (\text{Direct Footprint of Digital Infrastructure} + \text{Rebound Effect})$$

When the gains exceed the sum of the other two terms, the project is genuinely green; when the reverse holds, we are faced with digitalization that is “greened” in discourse rather than in the balance sheet. This perhaps explains the divergence among empirical studies: they disagree less about the underlying mechanisms than about the relative weight of each of the three terms in a given context.

Section Four: The Algerian Case

4.1. The Digitalization Track: An Ambitious Strategy from a Relatively Lagging Position

The High Commission for Digitalization announced that the Presidency of the Republic had approved the National Digital Transformation Strategy 2025–2030, presenting it as the first national reference framework of its kind to structure the digital-transformation process (Al-Ghad Al-Djazairi, 2024). According to the official statement, the strategy rests on five pillars — core ICT infrastructure; human resources, training, research and development; digital governance; the digital economy; and digital society (Algeria Press Service, 2025) — and comprises 25 strategic objectives to be realized over the period 2025–2030 (Radio Algérienne, 2025).

This ambition, it must be said, is being pursued from a position that remains relatively lagging. According to Snoussi's (2024) reading of the 2022 Arab Digital Economy Index report, Algeria ranked twelfth among twenty-two Arab countries across most indicators, notwithstanding the significant steps it has taken. This intersects with Alrifadi and colleagues' (2026) finding of Algeria's lag in digital-economy indicators at the regional level. The Algerian literature, for its part, largely concurs on the anticipated benefits: Neghmouchi and Meïzi (2021) hold that digitalizing economic, social, environmental and institutional domains enhances performance and reduces time, effort and cost while eliminating queues and bureaucracy; Benguerrache (2024) regards digital governance as among the most important tools through which Algeria has accelerated its pursuit of sustainable-development goals by strengthening digital transformation across sectors. Brahimi and colleagues (2025), meanwhile, note the absence of prior studies addressing the digital master plan for higher education in Algeria — one example of how many areas remain unstudied.

4.2. The Energy-Transition Track: Quantitative Targets and International Partnerships

On the energy side, the Ministry of Energy and Mines states that the National Renewable Energy Programme targets a total capacity of 15,000 megawatts of photovoltaic power by 2035, with Sonelgaz having begun implementing 3,200 megawatts as a first phase (Ministry of Energy and Mines, 2024). To this is added a partnership with the European Union and Germany, through the German Agency for International Cooperation (GIZ), under the “TaqatHy+” programme, funded at roughly €28 million and aimed at expanding renewable-energy use, developing green hydrogen, and improving energy efficiency (Al-Araby Al-Jadeed, 2025). Green hydrogen is likewise presented as an export option via the MedLink electricity-interconnection project and the SouthH2 Corridor hydrogen pipeline (Attaqa, 2025).

These projects are not without acknowledged technical challenges. Africa News Algeria quoted Sonatrach's chief executive as stating that Algeria plans to produce green hydrogen at a cost ranging between \$1.2 and \$2 per kilogram, while noting the difficulty of guaranteeing a “pure” supply based entirely on renewable energy, since the national grid is interconnected and combines conventional and renewable power (Africa News Algeria, 2026). This is precisely the kind of gap that digital tools — metering, tracing, and certificates of origin — could help address, though this inference is our own and not stated in the source.

4.3. What the Algerian Studies Say About the Intersection

Few studies have explicitly linked the two tracks. Among those that come closest is Allouit and colleagues' (2026) study, which examines the role of AI adoption in green innovation and green entrepreneurship in Algeria over 2018–2024. Its findings point to notable progress in renewable-energy projects — solar and wind in particular — and a relative decline in emission intensity, and indicate that artificial intelligence has become a facilitating factor in resource management and the acceleration of innovation. Bergougui and Meziane (2026), for their part, employed a Fourier nonlinear autoregressive distributed-lag model on quarterly data for 1995–2022, finding that positive shocks to institutional quality substantially raise energy diversification, that negative shocks reduce it, and that the same holds for green technology. The key inference here is that governance and institutions are a decisive factor — consistent with Khettoouf's (2025) linkage of progress to addressing financing and technology-transfer obstacles.

4.4. The Framing Gap

Examining the five declared pillars of the digital strategy, we find no explicit environmental pillar among them, so far as the published summaries we have reviewed reveal; sustainability appears as a general value within the strategy's aims (Algeria Press Service, 2025) rather than as a measurable commitment. Conversely, the renewable-energy programme is defined by capacity indicators (megawatts) rather than digital ones. The two tracks thus run in parallel without a declared institutional point of convergence — a finding that supports our third hypothesis at the level of available documentation. We naturally qualify this conclusion: unpublished executive or sectoral documents may address the matter, a possibility that would require subsequent field research to establish.

Section Five: Toward an Analytical Framework for the Twin Transition in Algeria

On the basis of the literature reviewed, we propose a framework of four conditions under which digitalization becomes a lever for, rather than a burden on, the green economy. This is a hypothetical framework whose elements are drawn from the concepts of the “twin transition” and the rebound effect (Bianchini et al., 2022; Muñoz de Bustillo Llorente, 2024); its proposed indicators are our own construction, intended for subsequent empirical testing.

Table 2. Conditions for the Twin Transition and Proposed Indicators in the Algerian Context

Condition	Content	Proposed Indicator	Basis in the Literature
1. Clean energy for digital infrastructure	Progressively powering data centres and communication networks with renewable energy	Share of renewable energy in the digital sector's consumption	Freitag et al. (2021)
2. Environmental-impact measurement	Ex-ante and ex-post environmental assessment of major digital projects	Emissions avoided versus emissions generated per project	Muñoz de Bustillo Llorente (2024)
3. Shared governance	A standing coordination mechanism linking digitalization, energy and the environment	Existence of a declared institutional framework and unified indicators	Bergougui & Meziane (2026); Benguerrache (2024)
4. Human capital and financing	Training competencies in green digitalization and financing innovation	Number and funding volume of green digital start-ups	Khettoouf (2025); Pu (2025)

Source: prepared by the author.

The first condition is the most pressing. If international estimates suggest that digital-sector emissions are likely to rise absent countervailing measures (Freitag et al., 2021), then building new data centres and networks in a country whose electricity generation still relies chiefly on conventional sources risks producing the opposite of the intended effect. Given its solar and wind potential, as noted in its own literature (Bergougui & Meziane, 2026), Algeria is in principle well positioned to power its digitalization

with clean energy and thereby secure an advantage that eludes many other countries.

Discussion of the Hypotheses

Hypothesis One (the efficiency and innovation channels) finds support in several international studies (Wang et al., 2024; Pu, 2025; Muñoz de Bustillo Llorente, 2024), subject to one important qualification: digitalization's effect varies by technology, and not all of its components appear to yield the same gains. We therefore regard it as partially confirmed.

Hypothesis Two (the effect is conditional on the energy source and on containing the rebound effect) is the most strongly supported, converging as it does with Freitag and colleagues' (2021) review, Bianchini and colleagues' (2022) study, and the Joint Research Centre's report (2024). We accept it, while noting that the available empirical evidence is drawn predominantly from European and Chinese contexts, and that its extension to Algeria requires local testing.

Hypothesis Three (the intersection exists in potential rather than in practice) is supported by the documentary reading of the digital strategy and the renewable-energy programme as published, though we accept it only at the level of published documentation, since the absence of a declared coordinating framework does not prove its absence in practice.

Conclusion and Recommendations

This study has sought to shift the discussion from the question “is digitalization green?” to the more precise question of under what conditions it is so. The available evidence shows that digitalization opens genuine positive channels through efficiency and innovation, but also carries a direct environmental cost and a rebound effect that may cancel out part of these gains, and that the line between the two outcomes is drawn by the energy source, the quality of governance, and the capacity to measure. In Algeria, two major tracks — the Digital Strategy 2025–2030 and the Renewable Energy Programme — are advancing simultaneously and require an institutional point of convergence to transform simultaneity into complementarity.

In light of this, we offer the following recommendations, which are exploratory in nature, grounded in the foregoing analysis, and would require a feasibility study before adoption:

First, incorporate an environmental dimension with measurable indicators into the National Digital Transformation Strategy or its implementing instruments.

Second, establish a standing coordination mechanism between the authority responsible for digitalization and the sectors responsible for energy and the environment.

Third, link the expansion of digital infrastructure — data centres in particular — to renewable-energy sources, and publish data on their consumption.

Fourth, adopt ex-ante and ex-post environmental assessment of major digital projects, measuring both avoided and generated emissions.

Fifth, direct digitalization toward the domains where the efficiency effect is most pronounced, such as electricity-grid management and smart metering, through pilot projects evaluated before wider rollout.

Sixth, support training in green digital competencies and finance start-ups in this field, so as to address the financing and technology-transfer obstacles identified by the Algerian literature.

Limitations and Avenues for Future Research

This study is confined to synthesizing published evidence and does not offer a new econometric estimate. A portion of the official Algerian data, moreover, is drawn from officials' press statements rather than detailed technical reports, and the international empirical studies relied upon were conducted in contexts different from the Algerian one. Future research could test the proposed framework through econometric modelling linking a national digital indicator to emission and energy indicators, or through field case studies of digitalization in the electricity sector and energy-sector institutions.

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