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ADVANCING THE GREEN ECONOMY THROUGH DIGITAL INNOVATION AND ENTREPRENEURIAL PATHWAYS: AN INTERNATIONAL BUSINESS PERSPECTIVE

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1. Introduction and Methodological Approach

The industrial revolution through its inventions, discoveries and entrepreneurship brought disruptive transformation which positively impacted our civilization as never before. But it had similar negative consequences as production processes, unsustainable consumption and depletion of natural resources created ecological imbalances and threats to environment which needed redressal. By the 1970s, the adverse effects of industrial age were pronounced and entered public consciousness. Research from leading universities while raising public awareness highlighted the problems of pollution, resource depletion, and waste management. By the late 1980s, environmental issues gained traction with governments and media, amplified by activist groups amid global socio-political challenges. Globalization of 1990s' lead to worldwide concern for environmental problems, impacting industries ranging from agriculture, power, transportation, to space.

By the new millennium, population growth, production methods, and waste management became focal points for addressing industrialization's environmental toll. All stakeholders globally agreed that a sustainable green economy is essential for humanity's future, with entrepreneurs and researchers as key drivers. Since then, Globalization, fueled by increasing digitization and wide spread use of internet, mobile telephony, and IT-enabled services, has created virtually connected, green-conscious society. Digitalization is now a powerful tool to address problems that arose from industrialization. According to author, digitized green economy reduces negative environmental impact by minimizing resource use and promoting: a) eco-friendly production and consumption, b) sustainable raw materials, c) recycling, and d) digitized business processes for efficiency and sustainability.

This paper explores how digitization enables innovation and entrepreneurship to drive the global transition to a green economy across diverse socio-economic and cultural contexts. It adopts a conceptual and comparative approach, synthesizing insights from business practices, academic literature, and policy frameworks, rather than empirical fieldwork. It highlights companies, governments, universities, and multilateral agencies advancing the green economy through digital innovation. Drawing on the author's experience in ASEAN, the Far East, South Asia, Europe, and CIS countries, the study offers insights into regional progress.

This approach is justified for two reasons: The global nature of the green economy, shaped by varied regulatory and economic contexts, requires comparative analysis to understand its dynamics. Additionally, integrating academic, corporate, and policy perspectives enables practical recommendations and a conceptual model to guide future research, resource planning, and the accelerated growth of the green economy.

2. Entrepreneurship and the Green Transition

The green business models currently around the world mostly exist as MSMEs (Micro, Small, and Medium Enterprises), primarily because economies are still in transition. Also MSMEs, unlike the big corporations and the startups, have the agility to adopt disruptive models because of their size. Governments and developmental agencies across the world are targeting most of their efforts on building up the green economy through the use of digitization at the MSME level¹. Also globally in innovation & digitization universities are playing important role as resource pivot for Research and Business Incubation collaborating with big corporations. It is pertinent then for gaining international business perspective into dynamics of green economy environment we undertake comparative study of a) prominent green economy business models in world and b) collaborative researches for commercialization being carried in universities around world. These are discussed below.

1) Circular Economy Ventures: These are companies that use digital tools to manage recycling, refurbish products, and share resources. Many of these are supported by the EU Green Deal Project, UNEP, ADB, and national governments. Through digitization, they are able to reduce pressure on resources, reduce carbon emissions, create green jobs, and bring in impact investments.

- a. Europe:** Ventures like Renewcell (Sweden) Loop (UK/EU), Umicore (Belgium), Vigga (Denmark), and Fairphone (Netherlands) use digital platforms to manage textile recycling and modular electronics³. They use digital platforms for material tracking and to create product passports, which provide data on a product's origin, materials, and recyclability. Strong EU regulations like the Circular Economy Action Plan, along with early adoption of green consumerism, are key strengths. However, scaling up beyond the EU and high operating costs remain challenges.

- b. South Asia (India):** Companies like GEM Enviro, Hasiru Dala, Attero Recycling, Saahas Zero Waste, Banyan Nation use digital solutions for PET recycling, e-waste, and plastics. Their digitization efforts include developing apps for waste collection scheduling, using block chain for supply chain transparency, and leveraging data analytics to optimize sorting and processing. The strengths here include rapidly growing waste streams, a large workforce, and policy push from Extended Producer Responsibility (EPR). Challenges include integrating the informal waste sector and infrastructure bottlenecks.
- c. CIS:** Companies like Eurasia, Kazakhstan Waste Recycling LLP, BelVTI (Belarus), Tetra Pak CIS are emerging with digital-driven solutions for plastic and carton recycling. They are using digital systems to track collected waste, manage inventory, and connect with businesses that can reuse recycled materials. They benefit from emerging policy support and a growing need for urban waste management. However, a lack of circular economy culture and limited investor interest are significant challenges.
- d. APAC:** ePac Asia (Singapore), Terracycle (Japan/Korea), Hyundai Motor (Korea), NTT Facilities (Japan), Circular Economy Asia (Malaysia) leverage technology for packaging and recycling^{1-b}. They use digital printing for on-demand, sustainable packaging to reduce waste and utilize AI and IoT for real-time tracking of recyclable materials. The region's strengths lie in strong corporate backing, regional collaborations, and innovation hubs. Challenges include market fragmentation and consumer awareness gaps.

2) Renewable Energy Startups: These are ventures mostly supported by developmental agencies, governments, and private equity funds with deep financial commitments due to the stakes involved in weaning economies away from fossil fuels. Digital innovation has allowed entrepreneurs to deploy microgrids of solar energy in rural communities.

- a. Europe:** Northvolt (Sweden), Sono Motors (Germany), Oxford PV (UK), Skeleton Tech (Estonia), Enapter (Italy/Germany) are leading in solar, EV, battery, and hydrogen technology³. They leverage digital twins for R&D, use AI for optimizing battery production, and employ IoT sensors to monitor and predict the performance of renewable energy assets. Advanced R&D and strong EU funding from the Green Deal and Horizon Europe are major strengths. However, high costs and long approval cycles pose challenges.
- b. South Asia(India):** Renew Power, Organ, Sunroofs, Husk Power, Infecund utilize digital platforms for solar rooftops, wind energy, and rural micro grids. These platforms use mobile applications for real-time energy monitoring, smart meters for billing and usage tracking, and cloud-based software to manage distributed power generation. The large market, government subsidies (MNRE), and rural electrification demand are significant strengths. Challenges include financing gaps and land acquisition issues.
- c. CIS:** Hevel Solar (Russia/Kazakhstan), SolarStrand (Ukraine), EcoEnergy (Belarus), Samruk-Energy Green Ventures (Kazakhstan) are focused on

solar, biomass, and waste-to-energy projects. They use digital tools for remote asset management, predictive maintenance, and optimizing grid connections. They benefit from abundant natural resources and state-driven projects. Political instability and dependency on fossil fuels are major challenges.

- d. **APAC:** Gogoro (Taiwan), Sunseap (Singapore), Genex Power (Australia/APAC), Ping An Energy Tech (China), VFlowTech (Singapore) are pioneers in battery swapping, floating solar, and pumped hydro technology^{1-b}. Gogoro's model is based entirely on a digital network that tracks battery usage and manages the swapping stations, while Ping An uses block chain technology for energy trading and transparent carbon accounting. The region benefits from tech leadership in China, Singapore, and Taiwan, along with strong regional investment flows. Challenges include inconsistent policy and grid integration issues.

3) Green Logistics & Land Mobility: Digitalization is central to the greening of logistics. Green electric-powered personal vehicles, both two and four-wheelers, are increasingly being supported by governments through registration discounts and subsidized charging points. E-commerce companies in countries like India started to use digital platforms to manage last-mile deliveries through e-vehicle drivers.

- a. **Europe:** Companies like DHL GoGreen, Maersk ECO Delivery, DB Schenker, Havi Logistics use digital tools to manage electric/hydrogen fleets and carbon-neutral shipping³. These platforms use IoT for real-time fleet tracking⁶, AI for dynamic route optimization to reduce fuel consumption, and blockchain for transparent carbon emissions reporting. The EU Green Logistics Directive and advanced supply-chain digitalization are key strengths. Challenges include higher logistics costs and fragmented standards.
- b. **South Asia (India):** Delhivery Green, Blue Dart (EV pilot), Mahindra Logistics, Ecom Express use digital platforms for EV cargo fleets and solar-powered warehouses. They use mobile applications to coordinate last-mile deliveries, leverage data analytics to optimize delivery routes, and deploy smart warehouse management systems to increase energy efficiency. The government's FAME-II subsidies, rapid e-commerce growth, and startup agility are major strengths. Challenges include charging infrastructure gaps and a cost-sensitive market.
- c. **CIS:** Russian Post Green Pilot, Nova Poshta (Ukraine), Kazpost Sustainability Drive (Kazakhstan) are leveraging digital solutions for hybrid delivery vehicles and route optimization⁴. Their digital efforts focus on using GPS for efficient route planning, telematics to monitor vehicle performance, and software to manage fuel consumption. Their strengths include intermodal potential due to a large landmass and state-run logistics support. Limited private innovation and fossil fuel reliance are challenges.
- d. **APAC:** JD Logistics (China), Nippon Express (Japan), SingPost (Singapore), Grab Logistics Green (SEA) integrate technology like AI and block chain

into their operations. JD Logistics employs AI for warehouse automation and drone delivery, while Nippon Express uses data analytics for predictive logistics to minimize empty runs and improve delivery efficiency ⁴. The region benefits from strong state support in countries like China and Japan. However, uneven policy adoption across ASEAN and high capital expenditure are hurdles.

4) University–Business Collaborations in Green and Digital Innovation: Universities and businesses are collaborating leveraging their research and corporate resources to drive green and digital transformation. Business incubators, science parks and technology transfer offices are the crucial elements of this ecosystem and has transformed universities to become research, knowledge & entrepreneurship resource center of society⁵. Some of these collaborations are below:

- a. **Europe:** Partnerships like **TU Delft & Shell** (renewable fuels, carbon capture), **Oxford University & BMW/Mini** (EV batteries, recycling), and **Fraunhofer & Siemens** (smart cities, digital twins) showcase Europe's leadership ⁵. These collaborations are supported by strong EU funding frameworks like **Horizon Europe** and benefit from advanced labs and close academic–industry ties. However, challenges such as bureaucratic hurdles and disputes over intellectual property ownership slow down commercialization ⁷.
- b. **South Asia (India):** Collaborations include **IIT Madras & Ashok Leyland** (EV buses, hydrogen tech), **IIM Ahmedabad & ISB & NITI Aayog** (digital entrepreneurship, green policy), and **TERI & Reliance** (solar, bioenergy). India's strengths lie in a vibrant young talent pool, rapid digital adoption, and government schemes like **Startup India** and **FAME-II**. Key challenges include scaling research into commercially viable solutions and bridging funding gaps⁷.
- c. **CIS: Skolkovo & Rosnano** (nanotech for renewables), **Nazarbayev University & Chevron** (clean energy labs), reflect the region's state-led innovation drive. With strong government–industry support and new innovation hubs, CIS countries are moving towards cleaner technologies. Yet, overdependence on fossil fuels and limited global integration remain structural barriers ⁷.
- d. **APAC: Tsinghua & Huawei/Alibaba** (AI for smart grids), **University of Tokyo & Toyota** (hydrogen mobility, batteries), and **NUS & Grab** (smart city logistics)⁵. APAC benefits from strong corporate R&D, heavy state investment, and innovation hubs in **China, Japan, and Singapore**. However, issues with IP protection (especially in China) and fragmented ASEAN frameworks challenge regional integration ⁷.

3. Regional Comparative Insights

In EU **European Green Deal, European Smart City initiatives** are part of EU's strategy for transition to a green economy, and it involves all the models covered above. The EU and the European Investment Bank are behind the schemes in which they have initiated host of private-public partnerships with multi-stakeholder's involvement including universities. So whole gamut of stakeholders are helping in transition to green economy through digitization (*universities participate in individual projects in their respective EU countries)⁶. These flagship projects showcase strategic direction backed by a strong regulatory framework and financial muscle. Entrepreneurs in these project benefit from subsidies, grants, and supportive innovation ecosystems already in existence. Most of the green startups and MSMEs in Europe are in Fintech, renewable energy, and building smart infrastructure ⁴.

In comparison to Europe, the green initiative programs in Asia have a different story. Most of them barring Japan & China face the common problem of limiting infrastructure and an uneven regulatory environment. However, despite constraints, dynamism of entrepreneurs has led to remarkable ventures in digitization of economy. Digital India program is one such globally acclaimed program Digital entrepreneurship to solve host of problems while addressing environmental problems. UPI (United Payments Interface) platform in India system of payment that has revolutionized the way business payments are made and has created both micro & macro-economic value. Amongst all countries Indian digital startup scene is booming and is second only to China in the number of unicorns that have mushroomed there. In APAC and S Asia young people in age group of 25-35 years comprise of largest group of participants ⁴,secondly one of the important platforms for launch of these initiatives is universities like IIT, IISc (both India), NUS (Singapore), Tsinghua (China) ⁵. In Kazakhstan, the government is backing business incubators and startups as part of its 2050 Digitization & Green Economy Strategy⁴. The broader contours of comparison show that while Asian green innovation is based more on the entrepreneurial dynamism of its citizens, the European scene is mostly thriving based on institutional support.

From the discussion we can say that any conceptual model for advancing the transition to a green economy would be dependent on four pillars:

- **Pillar 1: Digital innovation** to provide solutions to problems.
- **Pillar 2: Green Entrepreneurship** for translating the solutions to problems into sustainable business models.
- **Pillar 3: Policy and Regulatory Framework** that is an enabler and nurtures creative, solutions-based entrepreneurship.
- **Pillar 4: Higher education** which nurtures research, an entrepreneurial mindset, and also provides for the necessary skills.

The implications of discussion above are:

1. Entrepreneurs must use digital tools for leveraging innovation and automating processes, and leverage IT-enabled technologies and AI for real-time efficiency in business processes.
2. Universities must play their role as social incubators and resource centers for the transition and become entrepreneurial universities from being just classical and research universities.
3. Policymakers must frame regulations that make digitization a pivot as an enabler for green transitioning, consolidation, and expansion.

On the other side, the biggest challenges that all countries have are to include marginalized groups in the digitization drive, to provide equal access to funding avenues to all entrepreneurs, and lastly, the adoption of a similar regulatory framework across as many countries as possible to bring in certainty, encourage global green practices, exchange knowledge, and expedite international expansion of successful green enterprises.

4. Conclusion and Future Directions

Digital innovations and entrepreneurship are sine qua non for the advancement of a green economy. The regions we visited during our discussions, show how businesses are contributing to building a green economy through digitization. The primary focus of all governments at this time is on MSMEs as vehicles and involving individual and institutional stakeholders for the greening of economies.

This brings us to where future research should be focusing for accelerating a sustainable growth of the greening of the economy. These focus areas according to the author are:

- Impact metrics need to be built for measuring digital green entrepreneurship.
- A longitudinal multinational study on how startups shape up in green ecosystems must be conducted.
- The role of universities as resource enablers for entrepreneurs to commercialize solutions to problems needs to be explored across the world.

In conclusion, it is the author's considered opinion that the mindset of people needs a contextual change. It is imperative that people start looking at the green economy not only as a responsibility but also predominantly as an opportunity. For entrepreneurs, the message is clear: the green economy represents not only a responsibility but also a vast opportunity. For academics and policymakers, fostering digital literacy, regulatory alignment, and cross-sector collaboration will be key to ensuring a sustainable, inclusive, and digitally-empowered future.

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