

# **Entrepreneurship and Innovation in the Energy Sector**

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## **Abstract**

Entrepreneurship and innovation are widely recognised as vital for economic growth, social progress and sustainability, especially in the energy sector. Innovation is a key driver of development and sustainable economies. Adopting policies that catalyse innovation and entrepreneurship can greatly contribute to a sustainable society and energy sustainability. This paper examines the role played by innovation and entrepreneurship in a sustainable society and in sustainable energy use. Key best practices in countries that are frontrunners in innovation are explored. As the world becomes increasingly globalised it is evident that successfully nurturing entrepreneurial ecosystems and fostering innovation is key. This paper explores the dynamic relationship between entrepreneurship, innovation and sustainable development with a focus on the energy sector. It provides insights into effective policy approaches and strategic innovation that promote entrepreneurship and innovation effectively in the energy sector. As the importance of sustainability takes centre stage across all industries a focus on innovation and entrepreneurship is vital. This paper seeks to draw attention to the pivotal importance of innovation and entrepreneurship to drive success in the energy sector particular as the world grapples with the need to transition to a low carbon and cleaner energy focus.

## **Keywords**

Energy, Entrepreneurship, Innovation, Sustainability, Sustainable Development

## **1. Introduction**

Entrepreneurship and innovation are fundamental to success in a competitive world. In a fast-paced and increasingly globalised world the ability to innovate is critical. An entrepreneurial approach is also vital in every industry to drive innovation and long-term competitiveness. The energy sector is critically important and underpins economic and social development. A thriving energy sector drives economies, regions, and communities. The extent of innovation in the energy sector is increasingly apparent, especially with the drive to a cleaner and more sustainable energy sector. As global warming and climate change take centre stage global energy innovations are moving towards the renewable energy sector (Pandey et al. 2023). The role that innovation and entrepreneurship can play in a more sustainable energy sector is quickly unfolding as new approaches, innovations and technologies are emerging to drive sustainability.

Entrepreneurship and innovation are key to driving energy solutions. Renewable energy innovation is of vital importance to promoting sustainable development objectives across diverse industries (Dogan et al. 2025). For instance, technological innovation is vital to the energy sector. Technologies driven by innovation have brought a crucial edge to the energy sector. Energy technology plays a vital role in innovative and sustainable solutions in the evolving energy sector (Alka et al. 2025). Similarly, entrepreneurship in the energy sector helps grow the sector and drives the move to lower carbon technologies in the industry.

### **1.1 Objectives**

Research on energy innovation and entrepreneurship is gaining momentum globally against the background of a growing focus on the green transition and climate change. Entrepreneurship and innovation work synergistically to drive growth and sustainability in the energy industry. Governments and organisations are focusing on energy

innovations such as clean energy technologies like solar, wind and hydrogen as well as groundbreaking policies and interventions that foster innovation and entrepreneurship. The energy sector is a pivotal sector that drives economic growth and development as well as impacts social development. There is need to understand how this sector is being shaped by entrepreneurship and innovation. To unpack key trends in energy innovation and entrepreneurship this exploratory paper seeks to accomplish the following objectives.

- To explore the role of innovation and entrepreneurship in the energy sector
- To determine the factors influencing innovation and entrepreneurship in the energy sector
- To determine best practices in innovation and entrepreneurship in the energy sector

## **2. Methodology**

Innovation and entrepreneurship have become increasingly important in the energy sector particularly as the need to transition to more sustainable energy sources increases. The paper presents the emerging role of innovation and entrepreneurship in the energy sector. There is a paucity of research that focuses directly on the intersection of innovation and entrepreneurship in the energy sector. For instance, despite the importance and impact of entrepreneurship in the renewable energy sector interdisciplinary research in the field is still scarce (Bendig et al. 2025). This paper seeks to contribute to research in this area and help address this gap by providing an exploratory review of a selection of recent literature identifying key trends in energy entrepreneurship and innovation. The review is a narrative review aimed at documenting emerging developments in entrepreneurship and innovation in the energy sector.

There is a paucity of research that is directly focused on entrepreneurship and innovation in the energy sector. This research is narrowly focused on a selection of recent articles but provides a glimpse into the emerging role of entrepreneurship and innovation in the energy sector. A targeted selection of peer reviewed journal articles directly focusing on entrepreneurship, innovation and the energy sector were included in the study. While the literature reviewed is limited it provides insight into an area where research is limited and in a sector that plays a key role in social and economic development. The review is a mini review and a total of 32 articles were reviewed which represents a curated collection of relevant studies.

The literature search was conducted using databases such as Google Scholar, Scopus and ScienceDirect. Specific keywords were used to search for and identify articles to be included in the review. Keywords used include “innovation in the energy sector”, “entrepreneurship in the energy sector”, “innovation” as well as “entrepreneurship”. After initial searches article titles and abstracts were screened for relevance. Relevant articles focused directly on innovation and entrepreneurship in the sector as well as articles that focused on innovation and entrepreneurship more broadly. The aim of this exploratory review is to present a concise overview of the role that innovation and entrepreneurship can play in the energy sector. The following inclusion and exclusion criteria were used for the study.

### Inclusion Criteria

- Relevance – Articles must focus directly on innovation, entrepreneurship or the intersection of both within the energy sector.
- Recency – A focus on recent studies and particularly those published within the last ten years. Many of the publications were very recent articles published in 2025.
- Peer-reviewed – Priority was placed on peer-reviewed journals to ensure academic rigour.
- Language – Articles published in English

### Exclusion Criteria

- Studies that discuss innovation or entrepreneurship in sectors unrelated to energy.
- Outdated studies which are older than 10 – 15 years and not related to current trends in energy innovation and entrepreneurship.
- Non-English studies.

## **3. Research Contribution and Scope**

This research aims to provide a concise, succinct and informative overview of the growing significance of entrepreneurship and innovation in the energy sector, highlighting how transformative and breakthrough developments are reshaping the industry. This paper provides an integrated and sector-specific perspective of

entrepreneurship and innovation. Energy drives development and underpins sustainable economies. Through an examination of emerging trends, technologies and innovative business models the research focuses on a sector that is fundamental to economic growth and the transition towards sustainable economies. Case examples also provide practical examples and progress towards a more sustainable energy sector driven by innovation and entrepreneurship. There is limited research directly focusing on entrepreneurship and innovation in the energy sector specifically so this research seeks to contribute to an emerging area.

#### **4. Conceptual Framework**

Innovation and entrepreneurship interact to drive sustainability in the energy sector. Although there are fundamentally different concepts, both focus on creating and implementing new ideas. In the energy sector innovation and entrepreneurship have the potential to transform the industry.

##### **4.1 Understanding Innovation**

Innovation has become an increasingly pervasive term and according to Kahn (2018) who delves into the meaning of innovation it is identified as three different things. As seen below innovation is identified as an outcome, innovation is identified as a process and also as a mindset highlighting the multifaceted nature of innovation (Figure 1).

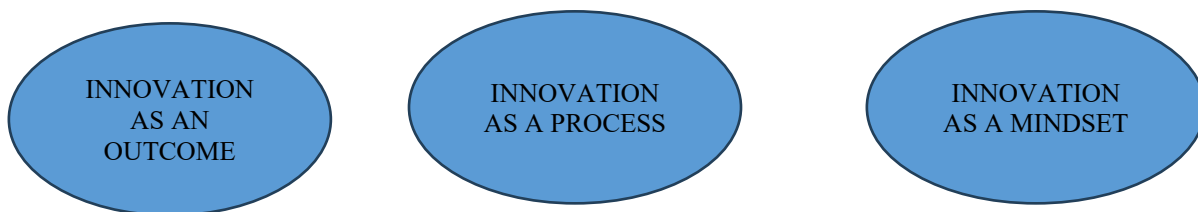


Figure 1. Understanding Innovation

##### **4.1.1 Innovation as an Outcome**

Kahn (2018) further breaks down the key components of innovation as an outcome. Innovation as an outcome emphasises output. Typically, the output associated with innovation is new products and services. Innovation as an outcome has several different focus areas. These are product innovation, process innovation, marketing innovation, business model innovation, supply chain innovation and organisational innovation. Each focus area of innovation or component can be defined further. Product innovation for instance focuses on market offerings such as new products or services.

##### **4.1.2 Innovation as a Process**

As outlined by Kahn (2018) innovation is defined as a process shining a spotlight on the step-by-step nature of innovation. It involves a series of stages that turn an idea into a product. To achieve a particular innovation outcome there are steps or activities that are followed. Innovation is not a singular event but has stages that are followed. One innovation cycle proposes that there are three stages in innovation namely **discover**, **develop** and **deliver**. In the discover stage opportunities are found and delineated. In the develop stage the opportunities are developed and specifications are defined. Finally, in the deliver stage the opportunity is turned into a final offering.

##### **4.1.3 Innovation as a Mindset**

This focuses on how individual members of an organisation internalize innovation (Kahn, 2018) The right mindset can catalyse innovation and foster a culture or environment that encourages innovation. It is important that innovation is nurtured in the right environment. In organisations that are successful at innovation the right culture exists that promotes innovation. Employees are encouraged to take risks and to present new ideas. The right mindset can catalyse innovation.

##### **4.1.4 The Importance of Innovation in the Energy sector**

While the definitions of innovation may differ the importance of innovation in the energy sector is clear. Fostering innovation as an outcome, process and mindset in the energy sector can help create an innovative and entrepreneurial

environment that promotes new products and new ways of operating especially in the drive to promote cleaner and more renewable energy. In the energy sector innovation has become more visible with the focus on green innovation and the growing moving to low carbon technologies.

According to the International Renewable Energy Agency (IRENA), ‘innovation is at the heart of a successful, sustainable and just energy transformation, essential in mitigating the impacts of climate change while improving energy security’ (IRENA, 2025). Innovations that address climate change impacts and reduce adverse environmental impacts are key and, in the energy sector promote sustainability. Innovation in the energy sector is imperative as the realities of climate change and environmental degradation shine a spotlight on all industries to adopt low carbon technologies and cleaner energy.

## **5. Defining Entrepreneurship in the Energy Context**

Entrepreneurship is a term that has become something of a buzzword and has garnered many definitions. Prince et al (2021) define entrepreneurship as the act of generating and developing an idea for validation. There are many other definitions of entrepreneurship and these definitions continue to evolve. Atici et al (2023) in their book focusing on energy entrepreneurship defined energy entrepreneurship as follows:

Energy entrepreneurship is the process of identifying, developing and commercializing new energy technologies or business models that contribute to solving the energy challenges today

They further explain that energy entrepreneurship differs from conventional entrepreneurship as it is specifically focused on the energy sector and issues that are energy related like energy generation, storage, distribution and consumption. Energy entrepreneurs are not focused only on profit but have other goals such as sustainability and environmental stewardship.

## **6. Global Trends in Energy Innovation and Entrepreneurship**

This section presents emerging trends in innovation and entrepreneurship in the energy sector. Innovation and entrepreneurship are closely related. A focus on innovation has driven sustainability in the energy industry and innovation can help address the substantial challenges in the energy industry (Costa-Campi et al. 2014). Similarly, entrepreneurship has been a catalyst of innovation in the energy sector and has also been beneficial to sustainability in the industry.

### **6.1 Innovation and Entrepreneurship for Sustainable Energy Transitions**

SDG 7 focuses on the need for sustainable energy to drive economic and social development and to drive environmental sustainability (United Nations, 2025). Environmental sustainability has emerged as a critical consideration and driver for a resilient future (Dhayal et al. 2024). Innovation and entrepreneurship in the energy sector have played a growing role in driving sustainability in the industry. Bendig et al (2025) conducted a literature review on entrepreneurship in the renewable energy sector which revealed that new businesses play a crucial role in driving sustainability through ground-breaking decarbonisation initiatives and innovative solutions for energy access.

### **6.2 Addressing Energy Poverty through Entrepreneurship**

According to Beyene et al (2025) energy poverty has an adverse impact on entrepreneurship. It inhibits entrepreneurship, especially in rural areas where energy infrastructure is lacking. The authors note that reducing energy poverty drives new business creation. They conclude that reducing energy poverty enhances entrepreneurship. Cheng et al (2021) proffer a different viewpoint arguing that being energy poor increases the likelihood of being an entrepreneur. In their study that used 2012-2018 China Family Panel Studies they examined the relationship between household energy poverty and entrepreneurship and they concluded that energy poverty increases the probability of being an entrepreneur in China.

### **6.3 Low carbon and Renewable Energy technologies**

Low carbon technologies driven by innovation are playing an important role in the energy sector. According to Bouattour et al (2025) robust green technological innovation promotes circularity and fosters green growth as demonstrated by the authors research focused on the EU. According to the International Renewable Energy Agency (IRENA) there is need for an acceleration in the pace and speed of renewable energy deployment and that innovations

that go beyond technology are needed (IRENA. 2025). Holistic enablers such as policy and regulation, physical and digital infrastructure as well as stakeholder engagement and international collaboration are crucial (IRENA, 2025).

#### **6.4 Digital Transformation in the Energy Sector**

The digital age has been transformative across industries ushering in innovative approaches and initiatives that are changing the way things are done. In the energy sector the digital age is emerging as key to growth and catalysing change. Digital technologies are increasingly deployed in the energy sector (Lyu &Liu, 2021). Digital technologies and green innovation have had a transformative impact on the energy sector in recent years and green innovation is increasingly intertwined with digitalisation (Zwyiolek et al. 2025). Innovations such as artificial intelligence, big data analytics as well as blockchain are impacting the energy sector. The rise of Industry 4.0 is increasing efficiency in the renewable energy sector (Pandey et al. 2023). Digital technology is set to usher in a more innovative and entrepreneurial dynamic in the energy sector.

#### **6.5 Policies, Regulation and Green Innovation**

Policies play a key role in the propensity of enterprises to adopt green innovation.(Chi et al. 2025).Policies play a crucial role in catalysing and stimulating green innovation. Polices also play a role in driving entrepreneurship.+ Research conducted by Zhang et al (2022) revealed that stringent environmental policy encourages green innovation in renewable energy technologies. Their research further shows that a stringent environmental policy stimulated green innovation for diverse types of energy such as geothermal energy, hydro energy and marine energy but did not for wind and solsr energy.

In South Africa for instance various policies have been developed that have sought to stimulate green innovation and entrepreneurship in the energy sector. Policies focused on renewable energy such as the White Paper on Renewable Energy (2003) and the Integrated Resource Plan (IRP) have been the driver of an increased focus on renewable energy (DMRE, 2025). Similarly in the SADC region energy innovation focused policies have led to the adoption of green energy. The SADC Protocol on Energy for instance recognises the critical importance of energy in the attainment of the vision for the region (SADC. 2025). The protocol on energy is focused on cooperative energy development within the region and also aims at aligning policies, strategies, and procedures. One of the key goals of the protocol is cooperation in transferring low-cost technologies. Various other strategic plans focused on the energy sector have also been developed that drive entrepreneurship and innovation in the energy sector.

#### **6.6 Circularity and Innovation and Entrepreneurship in the Energy Sector**

The circular economy can play a key role in sustainable entrepreneurship and innovation in the energy sector. The circular economy is driving change across a range of industries driven by a growing concern regarding the impact of anthropogenic activities on the climate and on the environment. Key issues such as waste disposal have become a focus area where innovation and entrepreneurship incorporating circular economy principles are key. Green technological innovation facilitates circularity (Bouattour et al. 2025). The circular economy is an alternative to the linear system and is focused on minimising waste and maximising the use of resources (Ellen McArthur Foundation, 2025). Transitioning to a circular economy means that companies must engage in more sustainable practices in the energy industry adopting green innovations and dynamic entrepreneurship.

### **7. Case Studies**

#### **7.1: Poland**

According to the International Energy Agency (IEA) Poland has made noteworthy progress to transition to reliable sources of energy (IEA, 2025). In 2022, renewables share of power generation was 17.1% (IEA, 2025). There are some encouraging developments in adopting low carbon technologies in the energy sector. Poland has a fast-growing solar PV market and one of the fastest in the European Union. Poland is also aiming to be a major player in offshore wind aiming for at least 3.4 GW of capacity by 2030 (IEA, 2025). Dzikuc et al. (2021) analysed trends in innovation in the energy sector in Poland and note that while Poland is implementing innovative solutions that are reducing the negative environmental impact of coal-based energy not enough is being done to develop a low carbon economy and Poland's dependence on coal is unsustainable.

While there has been some progress in adopting innovative practices in the energy sector in Poland significant backlogs related to implementation of innovation in the operation of enterprises exist particularly the development of

renewable energy (Dzikuc et al. 2021). Some of the reasons for these backlogs include a lack of state support, low GDP per capita and insufficient involvement of the R&D sector. As shown in Table 1 the International Energy Agency (IEA) has put forward a number of recommendations that can drive the transformation of the energy sector in Poland enabling an environment that drives innovation and entrepreneurship in the energy sector (IEA, 2022). These recommendations can provide best practice approaches to enable entrepreneurship and innovation in the energy sector (Table 1).

Table 1. Recommendations to drive a more sustainable energy sector in Poland

Update the energy policy for Poland until 2040 as well as the National Energy and Climate Plan with measurable targets and measures.
Review and reconsider the timeline for closing all coal fired generation
Enable and boost private investments along the entire energy value chain.
Revise and review the regulatory framework to increase energy market competition.
Adjust taxes, market regulations and financial support measures
Develop a transition plan for the entire coal value chain that reflects the need for a more rapid energy transition by 2030

Source: IEA, 2022

## 7.2 Gujarat, India

India is a country embracing the renewable energy sector and entrepreneurship and innovation are helping to grow this sector. India is increasingly seen as a major player in the global renewable energy sector. Electricity demand in India has been increasing sharply and there has been a surge in investment in renewables led by solar PV (IEA, 2025). In 2024 83% of power sector investment went to clean energy (IEA, 2025). India has enabled the growth of the clean energy sector by introducing a number of measures to facilitate and support growth in the renewable energy sector.

Gujarat, a city in India is one of the top Indian states in terms of renewable energy. Halder (2021) studied sustainable entrepreneurship development in the renewable energy sector in Gujarat and noted that there were a range of enablers for RE entrepreneurship including the following.

- Institutional Support in the form of skill development programs
- Subsidies and the reduction of entry level barriers
- Technology Expertise

They also identify barriers facing entrepreneurs such as inadequate financing, bureaucratic challenges as well as a host of other barriers. The authors further note that sustainable entrepreneurs can take up the role of innovators. The Gujarat Integrated Renewable Energy Policy 2025 aims to provide a unified investor-friendly framework for the expansion of renewable energy across Gujarat through 2030 (Renewable Energy Gujarat Policy, 2025). This policy supersedes the 2023 policy. The policy aims to boost Gujarat's status as a renewable energy leader. The policy has a number of key targets or goals to drive growth in the renewable energy sector. The policy aims to achieve more than 100 GW of renewable energy capacity by 2030 contributing significantly to India's broader goal of 500 GW of non-fossil energy by the same year. The policy further aims to achieve 150 GW by 2035 and 300 GW by 2047. A significant aspect of this policy is the promotion of Battery Energy Storage Systems (BESS). Battery energy storage systems are identified as key enablers for grid stability and higher renewable penetration. Gujarat's growth is crucial to India's national renewable energy targets.

## 7.3 Germany

The Germany Energiewende (green transition) has made progress. Germany has made significant strides in the transition to renewable energy. Germany has committed itself to drastically reducing greenhouse gas emissions and the energy transition ranks high on the policy agenda. The country has set ambitious targets for reaching net zero

emissions by 2045 (IEA, 2025). Germany is targeting a 65% reduction in greenhouse gas emissions by 2030 (IEA, 2025). Khan et al. (2022) explored whether technological innovation is a driver of renewable energy in Germany. Their study revealed that progress in renewable energy leads to increased spending on technology innovation. Germany is progressing in the transition to renewable energy. Germany has prioritised technological innovation and green energy and is a frontrunner in the renewable energy sector (IRENA 2015). Germany is emerging as a global leader in solar PV and offshore wind and nuclear power was phased out in 2023 (IEA, 2025).

Favourable policies have played a role in the progress seen in Germany and the energy transition represents an immense opportunity. Germany's Climate Law outlines the framework for reaching net zero emissions by 2045 and in order to reach this significant milestone 80% of electricity supply must come from renewable energy (IEA, 2025). Feed in tariffs (FiTs) have played a key role in the growth of the renewable energy sector in Germany and these tariffs boosted the solar energy sector and led to the growth of the solar energy sector to 42.39 GW installed capacity in 2017 (World Bank, 2025). Germany represents a country that is embracing innovation in the energy sector and achieving tangible sustainability outcomes. As a leader in technology and industrial leader Germany has immense potential to transform its energy sector with groundbreaking innovation and entrepreneurship, Solar and Wind energy in particular have immense potential.

## **8. Discussion**

The energy sector is a key global sector underpinning the development and growth of economies. The importance of entrepreneurship and innovation in the energy sector is increasingly clear. Innovation has brought new ideas, products or services that are transforming the energy sector. Entrepreneurship has turned these ideas into new ventures.

While entrepreneurship and innovation in the energy sector is being driven by the growing focus on the green transition and the need to address climate change there is still a lot that can be done to further catalyse and grow this sector. One of the key drivers of innovation and entrepreneurship in the energy sector is a favourable policy environment focused on green innovation. As seen by developments in the SADC region as well as other regions in Europe and worldwide, policies that are enablers for entrepreneurship and innovation are key. Another key enabler of entrepreneurship and innovation in the energy sector is adequate financing which drives investment in this sector. Technology also plays a key role and is in many ways the engine of energy innovation. Collaboration and sharing of best practices are also key in driving an entrepreneurial and innovative energy sector as seen in the SADC region.

There is need for more research into the role of entrepreneurship and innovation in the energy sector particularly in the developing regions of the world where there is still need for a faster pace in adopting green technologies. With the critical need to address the impacts of climate change and steer away from fossil fuels new innovations and an entrepreneurial drive is necessary in the energy sector, While there have been promising developments in the adoption of green innovation and low carbon technologies more still needs to be done. Green innovation can play a key role in driving the energy sector to a more sustainable future.

## **9. Conclusion**

Entrepreneurship and innovation in the energy sector is playing a crucial role in transforming the energy sector, especially against the background of growing energy demands and the need to reduce environmental impact. Through innovative solutions in the energy sector low carbon technologies are being adopted that drive sustainability. Groundbreaking entrepreneurship is unveiling innovative initiatives and products in the energy sector. Fostering innovation and entrepreneurship in the energy sector is key to sustainability in the energy sector.

Encouragingly there is progress to adopting groundbreaking innovations and entrepreneurial initiatives in the energy sector globally. The need to foster a culture and environment where innovation and entrepreneurship can thrive in the energy sector is crucial. There is need for a policy environment where innovation and entrepreneurship can thrive and where new ideas are promoted and fostered.

Sustainability in the energy sector is not only a buzzword but is becoming a pivotal pillar in every industry, In the energy sector sustainability has come to the fore and innovation and entrepreneurship are critical to drive sustainability in the sector. This paper has presented key developments in innovation and entrepreneurship in the energy sector, bringing to light the need for the sector to embrace new technologies, innovations and initiatives that can drive sustainability in the sector. Countries that have embraced innovation and entrepreneurship are leading in the renewable

energy sector like Germany. Different countries have made progress to varying extents in the adoption of low carbon and renewable technologies and countries in Africa and other countries in the Global South can learn from countries that are ahead of them in the green transition. There is immense potential for catalytic entrepreneurship and innovation to drive sustainability in the energy sector.

## References

- Alka, T.A, Raman, R., Suresh, M., Critical success factors for successful technology innovation development in sustainable energy enterprises, *Scientific Reports*, Vol 15. 2025
- An enabling framework to decarbonize the hard-to-abate sectors with renewables, Available: <https://www.irena.org/>, 12 November 2025
- Atici, K.B., Semerci, A.B, Kabaksi, S., Shrestha, P., *Energy Entrepreneurship, Sustainability, Innovation and Financing : Practical Applications and Future Directions*, 1<sup>st</sup> Edition, Springer Cham, Switzerland, 2023
- Bendig, D., Bruss, L., Degen, F., Entrepreneurship in the renewable energy sector: A systematic literature review of types, characteristics and sustainability impacts, *Renewable and Sustainable Energy Reviews*, Vol 212, 2025
- Beyene, B.O., Eloundou, G.N., Nyamou, J.C.M, Gallouj, C., Energy poverty and entrepreneurship: evidence from Sub-Saharan Africa, *The Bottom Line*, Vol 38, No 2, 2025.
- Bouattour, A., Gharbi, S., Kalai. M., Helali, K., Relationships between green technological innovation, renewable energy, circular economy and green growth, *Journal of Innovation and Knowledge*, Vol 10, No 4, 2025
- Cheng, Z., Tani, M., Wang, H., Energy poverty and entrepreneurship, *Energy Economics*, Vol 102. 2021
- Chi, G., Liu., Y., Fang, H., Wen, W., Urban energy planning, policy orientation and green innovation incentives: evidence from Chinese listed companies, *Sustainability Accounting, Management and Policy Journal*, Vol 16, No 6, pp 1397 – 1425. 2025
- Costa-Campi, M.T., Duch-Brown, N., Garcia- Quevado, J., R&D drivers and obstacles to innovation in the energy industry, *Energy Economics*, Vol 46, pp 20 -30. 2014
- Dhayal, K.S., Agrawal, S., Agrawal, R., Kumar, A., Giri, A.K., Green energy innovation initiatives for environmental sustainability; current state and future directions, *Environmental Science and Pollution Research*, Vol 31, pp 31752 – 31770. 2024
- Dogan, B., Nketiah, E., Ghosh, S., Nassani, A.A, The impact of the green technology on the renewable energy innovation, Fresh pieces of evidence under the role of research and development and digital economy, *Renewable and Sustainable Energy Reviews*, Vol 210, 2025
- Dzikuc, M., Goraczowska, J., Piwowar, A., Dzikuc, M., Smolenski, R., Kulyk, P., The analysis of the innovative potential of the energy sector and low carbon development: A case study for Poland, *Energy Strategy Reviews*, Vol 38, 2021
- Energy System of Germany, Available: <https://www.iea.org/>, 14 November 2025
- Energy System of Poland, Available: <https://www.iea.org/>, 14 November 2025
- Halder, S., Sustainable Entrepreneurship development in the renewable energy sector: Insights from Gujarat, India, *African Journal of Science, Technology, Innovation and Development*, Vol 13, No 7, pp 873 – 885. 2021
- India, Available: <https://www.iea.org/>, 19 January 2026
- Innovation: Available <https://www.irena.org/>, 12 November, 2025
- Integrated Resource Plan, Available at <https://www.dmre.gov.za/mining-minerals-energy-policy-development/integrated-resource-plan/irp-2023>, 13 November 1025
- Kahn, K.B. Understanding Innovation, *Business Horizons*, Vol 61, No 3, pp 453 – 460. 2018
- Khan, K., Su, C.W., Rehman, A.U., Ullah, R., Is technological innovation a driver of renewable energy, *Technology in Society*, Vol 70, 2022
- Lyu, W., Liu, J., Artificial Intelligence and emerging digital technologies in the energy sector, *Applied Energy*, Vol 303, 2021
- Pandey, V., Sircar, A., Bist, N., Solanki, K., Yadav, K., Accelerating the renewable energy sector through industry 4.0: Optimisation opportunities in the digital revolution, *International Journal of Innovation Studies*, Vol 7, pp 171 -188. 2023
- Poland 2022, Available: <https://www.iea.org/>, 13 November 2025

Prince, S., Chapman, S., Cassey, P., The definition of entrepreneurship: is it less complex than we think, *International Journal of Entrepreneurial Behaviour and Research*, Vol 27, No 9, pp 26 -47. 2021

Protocol on Energy. Available: <https://www.sadc.int/document/protocol-energy>. 12 November 2025

Renewable Energy Gujarat Policy. Available: <https://www.eqmagpro.com/>, 19 January 2026

Renewable Energy Prospects:Germany. Available: <https://www.irena.org/>, 19 January 2026

The 17 Goals, Available: <https://sdgs.un.org/goals>, 12 November 2025

The power of sunlight: incentivising private investment in solar PV. Available: <https://ppp.worldbank.org/>, 19 January 2026

What is the meaning of a circular economy and what are the main principles?, Available at <https://www.ellenmcarthurfoundation.org>, 11 November 2025

Zhang, D., Zheng, M., Feng, G, Chang, C., Does an environmental policy bring to green innovation in renewable energy? *Renewable Energy*, Vol 195, pp 1113 - 1124

Zwyiolek, J., Wolniak, R., Grebski, W., From traditional to digital: The paradigm shift in the energy sector through green innovation, *Energy Reports*, Vol 14, pp 1 -16, 2025

## **Biographies**

**Professor Charles Mbohwa** is a Distinguished Professor of sustainability engineering and future technologies at the College of Science, Engineering and Technology, at the University of South Africa, Florida Campus. He was, previously the University of Zimbabwe Pro-Vice Chancellor responsible for Strategic Partnerships and Industrialisation. Before that he was a professor and a visiting professor of sustainability engineering in the Faculty of Engineering and the Built Environment at the University of Johannesburg and a Professor Extraordinaire at the Tshwane University of Technology in South Africa. He was a mechanical engineer in the National Railways of Zimbabwe from 1986 to 1991, and lecturer and senior lecturer at the University of Zimbabwe from 1991 to 2007. He was Senior Lecturer, Associate Professor and Full Professor at the University of Johannesburg from 2007 to 2019. He was Chairman and Head of Department of Mechanical Engineering at the University of Zimbabwe from 1994 to 1997. He was Vice-Dean of Postgraduate Studies Research and Innovation in the Faculty of Engineering and the Built Environment at the University of Johannesburg from July 2014 to June 2017 and Acting Executive Dean in the Faculty of Engineering and the Built Environment from November 2017 to July 2018. He was a Special Advisor to the Dean after that until the end of 2018. He has published very widely and holds a BSc Honours in Mechanical Engineering from the University of Zimbabwe in 1986; Master of Science in Operations Management and Manufacturing Systems from University of Nottingham 1992; and a Doctor of Engineering from the Tokyo Metropolitan Institute of Technology 2004.

**Nyasha Grace Gatawa** is a postdoctoral fellow at the College of Science, Engineering and Technology at the University of South Africa, Florida Campus. She was previously a research fellow at UN-Aligned. She has a PhD in Geography from the University of the Witwatersrand, Johannesburg, a Masters degree in Tourism Studies from the University of the Witwatersrand, a Postgraduate Diploma from the University of Cape Town and a Bachelor of Science Degree from the University of Zimbabwe. She has worked in a range of different roles focusing on research and strategy.