# Engineering the Future of Ghana: The Role of Emerging Technologies and Digital Transformation

## Abstract

Emerging technologies continue to reshape the global marketplace, providing new opportunities for businesses and societies to adopt emerging digital technologies. These technologies offer innovative and business executives a chance to leverage the technology in creating and transforming their organizations in the digital world (Atiso & Adkins, 2015). Like many emerging economies, Ghana recognizes the crucial role that adopting new digital technologies plays in a country's competitiveness and growth. The importance of digital transformation in Ghana's development has been acknowledged in various policy and development frameworks. The broadband policy states that enhancing the national broadband ecosystem is necessary for developing and deploying broadband networks and services in all sectors of the economy. In addition, the digital innovation and entrepreneurship centre at the Institute of Technical Training and Innovation aims to provide a turnkey facility for training and up-skilling inspiration and facilitate technology transfer and knowledge sharing with local industry and operators. The government’s policy direction is aimed at demonstrating leadership in embracing innovation, entrepreneurship, and digital adoption. Historically, the role of infrastructure, skills, and software in digital transformation has been examined based on secondary information from sources. This study identifies the key dimensions of digital transformation and prepares a question for face-to-face interviews with industry and government stakeholders in Ghana. In doing so, an in-depth and original analysis of the role and prospects of digital transformation in Ghana is provided. This industry is nascent, and there is no similar research on adopting new and emerging digital technologies in Ghana.

## 1. Introduction

The mission of the Ghana Academy of Arts and Sciences since its founding has been to encourage the creation, acquisition, dissemination and utilization of knowledge through the promotion of excellence in the sciences, humanities and the arts for national development and the overall welfare of mankind. It is, therefore, heart-warming that this symposium is focusing on the role of Engineering in the development of Ghana. The question to ask is whether this noble goal for Ghana is being realized. This writer is of the contention that, in spite of the availability of emerging technologies, the desired pace of development in Ghana is not being achieved, largely due to the lack of an appropriate national strategy and infrastructure for digital transformation (Atiso & Adkins, 2015).

The rapid developments over the last thirty years in Information and Communication Technologies (ICTs) in general and the INTERNET in particular, has no doubts, enhanced the further enrichment of scientific knowledge through the speedier flow, storage, manipulation, sharing and retrieval of digital data. Coupled with this is that the private sector activities in terms of initiation of research and development projects in diverse areas of ICT applications have accelerated the transformation of national economies mechanized into digital economies. Paradoxically, whilst the economically and technically advanced nations of this world are making tangible efforts in the introduction of sophisticated technologies for digital transformation, the less well-endowed of these have either non-existent or most inappropriate strategies for this purpose.

## 2. Historical Overview of Engineering in Ghana

While speaking to an automotive engineer from Ghana in 2021, he indicated that during the automotive boom in Ghana, there was always one car in the yard waiting for repairs to start on the other one. This cycle would continue, and he explained that due to ineffective production or maintenance procedures, Ghanaians keep their vehicles for twice as long as the recommended period. Engineering has always been for making life easier, although defining life and progress is still debatable. Engineering has evolved based on the needs of the people. There was a time when in times of drought, it was a miracle to rely on a vast network of water boreholes and wells. Every good road did not lead to Rome but to a functioning water source. There was a time when the quality of education could be mentioned to describe life in times past. It was enough to be a teacher to earn respect. There was a time where the possession of a fixed telephone landline was a symbol of success.

Biomedical engineering contributes significantly to health care delivery. Despite this, the full potential of Biomedical engineering is not fully comprehended in Ghana. Started in the late 1990s, Biomedical engineering in Ghana, as of November, 2011, is described here. In the late 1990s, the Biomedical Engineering Department was started at Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. In training biomedical engineers, the Biomedical Engineering Department received help from Linkoping University, Sweden, and Dalarna University, Sweden (Quansah Amissah et al., 2013). Ghana has since seen an increase in institutions employing and educating biomedical engineers. With the growth of the profession, institutions such as the Ghana Society of Biomedical Engineers, Engineering Council, and the Food and Drugs Board Medical Device Department have joined stakeholders. From a simple camera repair technician to electrical engineering students, the career has attracted a wide variety of people. Bioinstrumentation is the dominant subspecialty in Ghana.

## 3. Current State of Engineering Education and Research

Most developed countries attach significant technological development, especially in the areas of emerging technologies, and leadership to the growth and progression of both their economy and industrial sector(s). To this effect, emerging technologies in Ghana as an example in this study cannot be handled or taken for granted as secondary to other aspects of human-life development. It is in view of this benchmark that governments in Sub-Saharan Africa, including Ghana, have come to terms with issues affecting technological development.

There is a growing numeracy of trained engineers in countries across the continents of the world including Ghana (Quansah Amissah et al., 2013). The rate of educated or trained engineers is sky-rocketing than it had been in the previous years and in the near future that developed countries will greatly depend on. The training of engineers in Ghana however, is open to transformation and reengineering leading to unforeseen future. Build on that, a new perspective is engineered into the changing trends and transformation of likely engineering training and research in Ghana and the future as well. Engaging in this new field of education and research is still immature in many countries where Ghana is no exception. On a global scale, developing countries are far behind the curve in discovering the discipline to the extent that the economic competitiveness is under severe threat.

## 4. Digital Transformation: Concepts and Implications

In recent years, digital transformation has reshaped how we think about, share, and use knowledge and information. Webs of networked relationships have become widespread, often mediated by platform companies. In a relatively short time, digital transformation has impacted economies worldwide, providing many challenges for existing regulatory models in the process (B. Arewa, 2022).

While not a new concept, digital transformation frequently shifts in evolution’s boundaries. Over the past couple of decades, stark trends reflecting automation and digitization have been evident in a wide range of new technologies and applications. These have often brought in development that highlights a deeper understanding of the problems and opportunities associated with digital transformation. A core aspect of digital transformation relates to data and information. In the information age it is said that we are living in, technologies have facilitated widespread dissemination of information and rapid communication to billions of people. These processes, driven by telecom and internet technology, have had widespread social, economic and political effects.

From a business lens, digital transformation has involved a core set of principles. These include, but are not limited to, flexibility of behavior and dynamic reconfiguration of the production system, decreased execution time of production processes, independent or nearly so of the production quantity and resource intensity, necessity of customization or personalization for production processes, increased efficiency of processes and services and, as a derived principle, more efficient and effective scheduling and management of communication and transactions within and between production systems and the external environment, increased effectiveness of manufacturing systems utilizing different technologies for physical and digital objects and processes and more adaptable organization structures compared. At the broader level, there is enormous potential for technology, including the 4th industrial revolution, to lead to long-term gains in efficiency and productivity.

## 5. Emerging Technologies in Engineering

Engineering the future of Ghana involves the innovative design, testing, and prototyping of a plurality of assets for the country, including buildings, infrastructure, transportation, production tools, machines and devices, vehicles, aircraft and spacecraft, etc. Engineering processes involve not only physical products such as energy materials, parts, structures, or machines and devices, but also digital artifacts, such as models, drawings, simulations, programs, etc. that provide the basis for the physical products; and all sorts of enterprise services, data, digitalized equipment and facilities, workers, etc. required for making and operating the products.

Engineering is digitizing fast. Digital engineering is recently defined as engineering that is undertaken through the medium of digital tools, techniques, and technologies, focusing on the development and use of digitalized products, services, and enterprises together with suitably re-skilled and upskilled workforce. Emerging disruptive digital technologies, such as AI, machine learning, 5G, digital twins, are transforming engineering to a digital paradigm that blurs the borders between the physical and digital worlds. With the digital transformation of engineering, more and more engineering artifacts, processes, and enterprise activities are now digitalized, impacting energy, 1st and 2nd materials, components, 3D and 4D structures and parts, as well as physical and virtual models, datasets, simulations, and standards. Model creation is a process that leverages digital artifacts and relevant data collected throughout the engineering stages. Emerging and rapidly evolving technologies allow AI and machine learning to be successfully applied for building models using the massive and rapidly growing data generated from or associated with the engineering stages. As a result, model use and exploitation have boomed in a wide range of applications exploiting and taking advantage of models coming from different sources, representing the physical and behavioral information of a product, process, or system across various environments and systems.

## 6. Case Studies of Technological Innovations in Ghana

This section includes the cases of the private sector at the level of an individual enterprise and the cases of the ICT empowerment of individuals as technologies to encompass a wider set of activities beyond just the traditional scope of manufacturing; these encompass private entrepreneurs and also cases where the public sector agriculture and the social sectors. The cases are selected to be varied as possible, including cases that are great majority of studies in Africa of the informal non-farming sector that dominates the society and addresses the cases that have engaged Ghana, the country where there is a field site of the research project. Inclusive capitalism will take a clear boost if such individually profitable production transformation of manufacturing would also reshape the sphere in agriculture. While it is not manufactures, it does discuss productive private entrepreneurs in Ghana. Emerging just a few years ago in the nascent stage of Ghana, the “water-tank-phone” (WTP) special value-added service (VAS) is a living example of successful launch of product innovation through a mobile operator and innovation vendor partnership (Sabri Nawar, 2019). The VAS caters to a community of local water suppliers that have been thriving all across the country, when more and more urban Ghanaians are put off by the notorious tap water shortfall, coerced to procure this essential liquid substance from other than the Ghana Water Company – ie. natural unsanitary sources most of the time. Recycling and distributing these supplies from door to door are local operators, who offer their service at exorbitant price compared to the GWC water. Split into two launch phases, WTP was an instant hit in the Greater Accra Region, whereas the launching in Kumasi (the second largest city) was delayed and withheld as the northern regime of the water tanker price was being finalized.

## 7. Challenges and Opportunities in Adopting Emerging Technologies

As emerging technologies and digital transformation have begun to reshape industrial operations, the role of emerging technologies in socio-economic development will be evinced, especially in infrastructure projects. The construction industry is internationally known to be a major player in socioeconomic development due to infrastructure provision. The construction industry constitutes a significant proportion of the GDP of a country and hence, plays a key role in internal economic development. A lot of critical establishments such as new roads, housing, and water supply systems that acts as a catalyst to trigger other sectors, such as hospitality, transportation, logistics network, and job creation, fall under infrastructural development (Atiso & Adkins, 2015).

The impacts of emerging technologies in developing countries will be discussed with reference to Ghana. Due to predominant exposure of academic studies and experience, the perspective of academia in Ghana on the role of emerging technologies in national development will be evaluated. Engineering education to meet the dynamic skill demand of the construction industry due to emerging technologies will be analyzed. The challenges will be revealed. Opportunities for embracing emerging technologies to benefit from the social and economic development and possible strategies to encounter the impediments will be unfolded. It is envisaged that this narrative will open the eyes of concerned authorities in academics and industry to meet the rapidly evolving technological transformations in the construction industry and socioeconomic development of the country at large. The challenge to adopt and take advantage of emerging technologies such as AI, Social media, Big Data, IOT, VR, drone technology in Ghana is certainly enormous for both government and industry stakeholders. The penetration of advanced technologies in the industrial and private sector in Ghana is very limited. Inadequacies of relevant infrastructure, outdated technology, and lack of skilled manpower, and huge power constraints wider the gap. Mutual awareness of emerging technologies, its potential impacts, including handling associated risks or mishaps, is considerably sclerosis. On the other hand, fast urban migration, climate change challenges and the need for more sophisticated engineering constructions, also necessitate the optimal exploitation of emerging technologies and best possible practices.

## 8. Policy and Regulatory Frameworks for Technological Advancement

Over the years, Ghana has put in substantial efforts to overcome a complex web of challenges that have seen investment in technology and human capital undermined. Investments in science technology and research for development collapsed which in turn created a widening gap between the developed countries and developing LDCs with regard to technological advancements. The Government has developed a range of programmes/Measures including giving a therapeutic input to small-scale enterprises/firms to stay afloat in a competitive market. This is already in place and, the construction of modern science and technology (S&T) parks to improve the production of local enterprises and industry. This also encompasses the need to establish efficient finance, follow-up, consultancy, engineering services, technological information and skill trainings.

There is a necessity to formulate a policy which will address the bottlenecks facing the transfer of technology and its peripheral issue, such as human capital, efficiency and eliminating the gap. In addressing these issues, several programmes have been set up in place. It is also expected that a new innovation-driven national development strategy encourage to track record of Ghana and create a better business environment not jeopardize technological advancement (Kwame Affum & Wang, 2019). Further the strategy endeavors to enhance the public service and science & technology system related to advanced technology, and develop modern technology R&D capabilities. Hence, the impending national strategy endeavours to foster effective mechanisms that engage the co-operation of domestic, overseas and multi-various sectors with the purpose of learning from interested entities so as to eradicate technological bottlenecks (N. Jobodwana, 2009). To encourage innovation and technological advancement, it is planned to establish frameworks and organisational change. An example of such innovative measures will be the establishment of a fund to foster innovation.

## 9. Ethical Considerations in Engineering and Technology

Introduction

Ghana has enjoyed a relatively stable political climate since the beginning of the Fourth Republic in 1992. Continued efforts to consolidate its democracy, steadily growing economy, and improving economic prospects promise bright future for the country. As the future of Ghana is being formed, it is important to consider how emerging technologies and digital techniques and applications offer both opportunities and challenges. The engineering profession is at the forefront of the national development process in nations like Ghana with a remarkable potential for growth in the future. To maximize the benefits and minimize the downsides of the engineering worlds, several ethical considerations ought to be taken into account (Vladimirovna Fell et al., 2017).

Ethical considerations in engineering and technology

Scientific discoveries and technological advances are key drivers of economic growth and are often considered essential for development. The wealth of nations has been linked to their technological and scientific advancements and the capacity of governments and populations to develop, adopt, and exploit new technologies. The advances of emerging technologies will significantly shape the world we will live in tomorrow and those who will need to engineer those technologies will bear much responsibility in what will be brought about. This is an ethical responsibility.

Robotics, artificial intelligence, and automation are expected to lead to significant transformations, creating substantial opportunities as well as challenges. In the foreseeable future, technological revolutions driven by advances in “Four Specific Technologies (4ST)”, namely the robotization of production, automation of information processing, breakthroughs in bioscience, and advances in materials science, are expected to compete due to their transformative power. Similarly, the enormous potential of nanotechnologies offers extraordinary improvements in the development of cleaner and more efficient energy sources, new modes of treatment for a range of diseases, and the emergence of new substances, improved materials, and a vision for elevated manufacturing standards with profound transformative power.

## 10. Socio-Economic Impact of Technological Advancements

Technological advancement and digital transformation have had a significant influence on both the economic fabric and the way of life of communities worldwide over the past few decades. The resultant changes have brought about the rapid displacement of old jobs, the creation of new jobs, the widening of the economic divide in society, and alterations to educational paradigms to teach and learn in the digital era. With technology evolving at breakneck speed, many jobs as they are known today may cease to exist within a decade while emerging digital jobs, still largely nascent, are expected to gain prominence. What-eyed researchers forecast that 6 out of every 10 Ghanaian children entering basic school today will likely work in professions that do not currently exist, and predictions such as these, which are predominant in the developed world, are no less portentous for developing nations. To ensure Ghana’s ability to compete with the rest of the world, significant effort needs to be placed on ensuring that its work force is prepared for such fluidity and versatility (Atiso & Adkins, 2015). A notable gap exists in the socio-economic impact of technological advancement, particularly in Ghana. As a result, the ambition for this study is fourfold: primarily, it seeks to analyze the available information and databases; subsequently, it will examine both the known and potential socio-economic implications of digital advance and dwell on how these may have an impact on local life in the foreseeable future; thirdly, it will scrutinize current and anticipated key changes in the employment and education sectors, with a gander towards proposing recommendations for the reconfiguration of current educational paradigms in Ghana, as these will likely affect, and be most influenced by, emerging technologies.

## 11. Gender and Diversity in Engineering and Technology

The 2030 Vision of the Engineering Council (UK) is ‘to have a professionally and sustainably developed engineering workforce in which any individual can participate and choose their role, can develop to their full potential and fulfil that potential under the auspices of a diverse range of representative employers’ (Strachan et al., 2018). In the UK, the STEM field, particularly Engineering, suffers from a lack of diversity. Women, for example, professoriately make up 50% of the population, but in Engineering, their numbers are often around 10-25%. This underrepresentation is mirrored by the lack of BAME (Black, Asian, and Minority Ethnic) individuals and those from socially deprived backgrounds. The underrepresentation of women in Engineering is a global issue. Moreover, the 4th United Nations Sustainable Development Goal is to ‘ensure inclusive and equitable quality education and promote life-long learning opportunities for all’. Countries worldwide must help ensure this kind of education is available in the STEM disciplines. This will be more challenging if the perception that STEM is not an appropriate career for women continues.

## 12. Skills Development and Capacity Building

With an increasing desire for technology-driven economies globally, Ghana is taking huge strides to position itself as a significant player among the league of technology-driven economies. These strides come in the form of policies that stimulate innovation, accelerating the adoption of emerging technologies, and creating conducive environments for the growth of innovative enterprises. Although the country is heavily dependent on raw material production and a handful of agricultural products, awareness has finally surfaced regarding the need to diversify its economy through technology and innovation. There is an encouraging wave of innovative start-ups and young entrepreneurs in the Accra-Tema region who are exploiting niche markets and the digital space. Moreover, academia and industry collaboration is gaining momentum with numerous hackathons, digital fairs, coding programs, workshops, and Makeathons (Ayarebilla Ali & Akayuure, 2016). Digital mindset and transformation-focused conferences are making giant strides in the West African economy. Consequently, it's imperative that this digital atmosphere extends throughout the country and that academia and industry alike are involved in this modern transformation.

Digital Transformation is a type of Social Transformation, not Digital Communication. Much as the capability to effectively communicate if you print a photo on film or send a photo by text contribution to the societal connection and transformation of nature interpretation, the potential to digitally store and disseminate distributed ledgers, using blockchain technologies to certificate, keep, and track the quality of supply chain activities, can completely revolutionize the field. It is therefore not the transactional change to digital technologies that the journey is slowed down by a misunderstanding or reductionism but the systemic societal change caused by the ability to use a number of convergent digital technologies to penetrate, harness, and replace technological and other societal systems in order to make them suddenly more adaptive, integrated, effective, and innovative. Just like the development or invention of the book, the bank, the automobile, the computer, or the digital photo, the digital transformation may be of various degrees, depths, and scopes, from slightly influencing local outcomes to enormously influencing the connection, You cannot cross a mountain in a jump or food by swallowing but through a series of small changes made more gradually, persistently, and uniformly (Palmer, 2010).

## 13. Collaborations and Partnerships in Technology Innovation

No country can economically develop when the vast majority of its population is illiterate and numerate. Next to reading, writing, and arithmetic, the future will require new skills such as the ability to acquire, organize and analyze information and to use it to make well-reasoned decisions quickly; the ability to understand complex systems and derive lessons from models and simulations that predict how the system will behave over time; managing multidisciplinary teams; completing projects on time, to specification and within budget; synthesizing and presenting information in writing and orally, and admitting what one does not know. Furthermore, the countries that last in the global economy will be those that can turn out, in quantity, engineers with these skills (L. Clifford & H. Zaman, 2016). Developing countries, including Ghana, often have tertiary education systems that are far from satisfying any of these needs. Rigorous analysis demonstrates the relationship between the low number of students receiving high-quality education and training in very specific fields for tracking into high-income modern sectors of low-income countries and the latter’s inability to compete in the global economy.

The growth of most sectors of the economy is ultimately constrained by the rate of expansion of the pool of engineers, scientists and technicians which can be trained not only because these skills are directly useful but, equally important, because these people are essential for the operation of advanced technologies. Advanced technologies play a crucial role in activities that are central to economic development, like steel making and pharmaceuticals that are being transformed by biotechnology. There is reason to believe the importance of advanced technologies will become even greater in the coming decades as commercial applications of molecular biology, information theory, material science, robotics, and lasers permeate all industrial sectors and lead to transformations that are as dramatic as that following the development of the steam engine and the factory system. In engineering, the advanced technologies can be useful for the analysis and design of systems so complex and intricate that they defy intuition. However, advanced technology is used in engineering in a much broader sense. For example, automated water treatment plants are easily maintained without an engineer, automotive vehicles are designed by engineers, and telecommunications networks are engineered. The future will require automated transportation networks, such as Intelligent Vehicle/Highway Systems and computer-controlled factories.

## 14. Infrastructure Development for Technological Integration

For developing countries like Ghana, participating in the digital economy has both promise and pitfalls. For example, there are the opportunities and risks of establishing digital supply chains to ensure that cash crops like cocoa are sustainably sourced and delivered to the ultimate buyer wherever that may be. Given forecast technology, what kind of future should Ghana anticipate? One plausible option may be futures where Ghana functions more as an assembler than producer of AI tech, smart phones, laptops, or robotics for example.

The extractive industries of gold, bauxite, and oil, important as they are in current times, have little forward linkages in terms of technology transfer and few possibilities for other sectors to learn or develop through extractive-led growth. So which sectors might have the best prospects of engineering the economy of the future? For now, because of the current reality of where Ghana is positioned in these globalize supply chains, it is not expected to emerge as a producer of cutting-edge technology at any stage.

## 15. Entrepreneurship and Start-ups in the Tech Sector

The rate of technological advancement over the last couple of years is growing at an exponential rate. Information is more readily available, and technologies have increased efficiency in various industries. Much innovation and improvement is happening in emerging and developing countries that have leapfrogged the industrialized western world in certain areas (Essuman, 2018). Some analysts believe that advanced technologies and materials science will overcome many of the challenges to space research. In the short run, space technology can be employed in addressing some practical needs such as monitoring of activities on earth, forecasting weather, and global positioning satellite services. The technology sector has seen a massive growth, attracting many start-ups in Ghana. Below are three interesting examples related to engineering, tech and digital transformation.

The Accra Digital Center spotted the vacuum in the IT industry in Ghana, plan to employ 10,000 young Ghanaians by 2020, 5,000 of them IT graduates. The accelerator and incubator programs have so far provided support for 60 start-ups. It provides IT firms with facilities, workshops, office space, mentors, and potentially even a platform for IT firms looking to collaborate. The government of Ghana Data Center’s aims to move voice calls onto satellite links thus freeing up mobile phone masts for 3G data coverage. Ghana has a whopping army of 11,200 ATM machines and even 3 extra in the headquarters of the International Telecommunication Union in Geneva. App developers have sensed the opportunity and Socharo provides an easy way of cashless veenerer purchasing. The Apperance of elastic banks suits incambertions and eliminates the otherwise bulky bag packed with a few stacks of cedi notes. Tracking of the veenerer vendor is easy as he / she is located check in on the App using GPS. With Over 700 transactions and 10,000 GHC processed through Kyebi, Obo and Kumasi so far, Socharo has proved popular amongst customers. Ofting manufactures backpacks and duffle bags that recharde mobile devices as they are carried. These are becoming increasingly popular among the digital crowd with power cuts at sickly accurate tims. Ofting bags can provide up to 20 additional hours of battery life.

## 16. Funding and Investment in Technological Projects

Recently, the Director General of the National Communications Authority (NCA), Mr Joe Anokye, asserted that the role of technology and its observational application play a fundamental role in the development of every nation. To support these views, it is recommended that the government invest in technology to generate revenue. It is also argued that this would help in reducing the high rate of unemployment among the Ghanaian youth. He emphasized that Ghana's young, fast growing population and its sizeable tech-savvy/tech-enthusiast demographics will be major accelerants.

A report indicated that Total Spending on IT Infrastructure Products in Ghana was forecast to more than double over the 5 years to 2023. The huge number of IT infrastructure development projects coupled with a growing mobile telephone subscription base will create many ecosystem opportunities. According to the report, annual spending in this area will reach $234.4m within the year under consideration. In a related development, the National Communications Authority disclosed that the telecom sector has become one of the largest contributors to the Ghana Revenue Authority's tax revenue basket. Further details were revealed in the Authority's first-quarter Industry Performance report where the National Communications Authority (NCA) revealed that the telecom industry had contributed GHȼ912,305,404.07 in taxes during the year under review. The report also showed that the telecom industry’s contribution to corporate taxes has steadily increased over the last five years, rising by sixfold – from 2.8% to 16.8%.

## 17. Environmental Sustainability and Green Technologies

Increasing mercury, arsenic, iron, and chromium contamination in water during 2017 and 2019 has become a major environmental issue for Ghana. Water-related diseases have caused a significant death toll. This has resulted in the Government of Ghana to develop policy frameworks to ensure the sustainability of water quality and its contamination. The quality of water produced and used has to be ensured through technological advances to achieve sustainability (Kwame Nti et al., 2023). While the rest of the contamination stabilization programs are going well in Ghana, combating water contamination has become a difficult task.

The use of various advanced technologies for sustainable water quality has been proposed. Many researchers have worked on the revitalization of natural water using agricultural waste as an absorption bed material. With increased agriculture and industrialization, sustainable water quality is essential for quality life. Agricultural wastes such as snail, grass, rice bran, and sugarcane have also been effectively used for zinc absorption. Foranthracites made from coal are placed between gravel over sand or an optional membrane. After some time spent in pure water, this natural biological growth breaks down into energy-forming colonies. Organic substances and pollutants from water are absorbed by the granules. Adsorption characteristics can also be influenced by the water pH value. Used granules in both acidic and basic water conditions exhibit minimum adsorption efficiency. Advanced technologies for sustainable water purity have been developed and proposed for Ghana. Wastewater and water reuse have been effectively cleaned with various advanced technologies. These technologies play an important role in the sustainability of water purity. As the population of Ghana increased, the demands of water also increased.

## 18. Cybersecurity in the Digital Age

Cyber civilization began on 29th October 1969 with ARPANET, the first computer network, which connected computers at Stanford University and the University of California, Los Angeles. Over the years more computers were connected by both universities, and ARPANET grew into a network. Almost each country eventually had a network of their own which they used to connect with other networks thus creating the Internet. Around August 1991 the General Public was made aware of the Internet essentially opening the gates of a new, wondrous world.

Up until now, the Internet was a realm of freedom where people could share ideas without censorship; where every idea was heard without classification, a democratic place if you will. But it was short lived; as the new millennium approached, governments and corporations understood the value of the Internet and sought to control it. This is where Cybersecurity plays a crucial part: It allows the user or group of users to protect the principles of Democracy and Freedom of Speech on the Internet by protecting the data one uploads; it prevents unwanted access to personal data (Alam, 2022).

In the next decades, Cybersecurity will increasingly be dependent on the advancement of technologies that are necessary to foresee developing computer, smart device, IoT network, Cloud Computing systems and networks to avoid future threats. The future of Cybersecurity Technologies heavily leans on strong encryption and the struggle between encryption and quantum computation as well as the implementation of Zero-Trust Architecture across Autonomous Adaptable Networks. In addition, international government and corporate cooperation will vastly increase for intelligence sharing with regards to potential and preexisting attacks (Bahalul Haque, 2019).

## 19. Data Privacy and Protection

The term ‘personal data’ is defined in strict terms in the Ghanaian data protection law. Personal data includes information which can be disclosed to the public and which is related to the private or family life of a person (Ewuresi Amowi Hammond, 2014). Mobile telephony has progressed at an exponential rate, offering a wide range of services. Ghanaians are benefiting greatly from this technology. However, the use of mobile telecommunications has also attracted its share of attention and concern.

19.1. INTRODUCTION The Electronic Communications Act is Ghanaian legislation that establishes the National Communications Authority (NCA) and its functions. The NCA is Ghana's National Regulatory Authority for Telecommunications. The Act empowers the NCA to grant authorization to a person who establishes a facility for the provision of public electronic communication services, provides postal services, provides public electronic communication services or grants its infrastructure to others for the provision of services. The NCA can impose special requirements to collect, store, process, and deliver traffic data for the purpose of providing customer billing services. The NCA sanctions the unauthorized interception of messages or data. Furthermore, customer information can only be used by service providers or operators for the provision of services to customers and includes the information relating to services provided to or by a customer, all the data necessary to deal with that person. service provided or data that is generated by using the service. Any value-added service provider who processes personal data must register. Value-added service providers need to disclose the criteria used to collect and process personal data. Every donation considered as a value-added service must comply with the data protection principles enshrined in the Act and with any guidelines issued by the NCA.

19.2. Personal Data Processing De-identification is the removal or reduction of the association of information with an identified or identifiable natural person in order to prevent the subsequent association of the information with a data subject. Personal data privacy tends to weaken user data sharing with researchers. To solve this problem, a clustering-based method is proposed to group similar data sharing preferences together and make global decisions regarding whether or not to share information with researchers. Six experienced researchers were interviewed to determine the potential use of the proposed utility-based data sharing strategy in real-world settings. The privacy requirements of people with regard to data collection and data processing need to be observed. A platform for data governance will be presented, which will enable the implementation of a data control by the Career Center. The Model will facilitate documentation of the data processing by generating and storing a set of corresponding documents necessary to provide the information to the people. Thus, it is possible to satisfy the information provision obligations. By embedding legislative provisions, the platform will recommend how the Career Center should maintain the records of the data processing in accordance with the GDPR.

## 20. The Role of Artificial Intelligence in Engineering Applications

Discuss AI model, trustworthiness of AI interactions, and AI-based methodologies in dissimilar engineering problems. With the fusion of human knowledge and technological capabilities, sustainable engineering comes along with the innovation of emerging technologies. Modeling as forecasting the past and future of processes, devices, and systems is one of the oldest engineering fields, though recent advances in machine learning, internet of things (IoT), low-cost sensors and actuators, digital twin, and cloud computing have stimulated revolutionary changes to engineering analyses, systems, designs, and operations. Large increase in big data together with powerful computing capabilities is another sparking point for the recent deployment of the deep neural networks and artificial intelligence (AI) in different interdisciplinary areas. AI applies in model building from big data coming from upstream and downstream engineering stages and environment. Interaction between digital models occurs for both system components and external systems. Uncertainties asked for a report on the trustworthiness of AI systems are analyzed. From a consumer durability or business point of view, AI models should be vouched for truthful and painless use (Huang, 2023). A paradigm shift due to AI-based engineering activities for field professionals and scholars is described with protective actions against malicious operators. Pathfinding global optimization algorithms relies on what is the target of searching. The local or gradient-based methods assume a single deterministic solution at a fixed neighborhood. As for learning enhancements, AI-based methodologies can efficiently resolve quite different engineering problems.

## 21. Blockchain Technology and its Applications

A blockchain is a decentralized digital ledger that is constantly growing as completed blocks and is recorded and added in chronological order, allowing participants to keep track of transactions and is considered tamper-proof and fraud resistant as these completed blocks are linked and security measures are in place. Several industries could benefit, amongst others, from this technology. It could be the beginning of the democratization of the global financial system. Software application(s) that use blockchain technology have started to spread in the agrifood sector. Looking from an innovation systems perspective, it seems that start-ups and small businesses are more actively involved in such projects as they can be developed fast and cheap if combined with open data and shared knowledge. This is a smart move for better understanding the potentials of the tech and its sector-wide implications (Muntean, 2019). Finally, the H2020 initiative and their development of a blockchain technology-based platform for management and verification of tendering processes and contracts might come as a disruptor of the public sector by increasing transparency and efficiency, thus reducing misuse of money.

## 22. Internet of Things (IoT) and Smart Cities

The 22nd century era would be characterized by a lot of development in the social, economic, and political spheres of the people of Republic of Ghana. An upsurge in the development of emerging technologies would lead to a changed and challenging world. With the emergence of such technologies, citizens in Ghana would play their roles in adapting and utilizing them to help sustain their development. Hence, this discussion focuses on how citizens in Ghana can be proactive and benefit from the emerging technologies and digital transformation.

The object of the discussion is to focus on the physiological, affective, and behaviors of domestic citizens in their social environment, ranging from their political ambitions to industrial orientations and desires. Such attempts are analyzed and directions for merely improvement proposed. Control serious levels of undevelopment and mismanagement of domestic industries and infrastructure, as well as alienation of foreign industries, would demand the development of a new breed and the competences of citizens.

To boost the development of ICT, government, industries, and education networks would be expected to work. Furthermore, a more efficient and eco-friendly utilization of energy resources could sustain development-induced climate changes. There may forever be a huge gap between the sunbelt and the underdeveloped nations. This is because the immediate and adequate solutions to the low productivity of the citizens and industries are unpractical. It is advisable to have in place powerful and concerted strategies with forward-looking, multi-dimensional, and well-planned objectives, which could lead to the development of comprehensive abilities and competences in dealing with the future challenges of emerging technologies and digital transformation.

## 23. Robotics and Automation in Industry

The digitization and advancement of manufacturing is ongoing, and robotics and related technologies are central to that. This discussion elaborates on emerging applications and technologies, identifying several pertinent challenges, and delineating key, promising directions for future research (Sanneman et al., 2020). Broadly, present-day robotics can be seen as evolving from ‘traditional’ industrial robots to diverse leveraged technologies—each beneficial in different ways but each also involving noteworthy challenges. The section articulate five prominently identified challenges, brainstorming possible research directions for addressing each. Finally, there are technologies that are not themselves robotic per se—data processing & utilization and user-interface design & engineering—but are critically linked to robotics utilization across manufacturing systems, and are often focal to ongoing robotics deployment and its effectiveness.

## 24. Biotechnology and its Impact on Engineering

Biotechnology has evolved as a versatile and innovative means of producing chemicals, foods, beverages, materials, biopharmaceuticals, and bioenergy. The successful implementation of biotechnology depends on the unification of complex, multidisciplinary tasks in engineering, basic life sciences, and computer annotation systems. However, biotechnological research and application are growing rapidly and are not internationally homogeneous, which may lead to ambiguities or abuses in biotechnological research and industrial applications (Wintle et al., 2017). Modifying and synthesizing genetic information is becoming simpler and more widely accessible. From a transatlantic perspective, 20 emerging issues in biological engineering are identified that could have societal impact and are of concern or interest to both the North American and European communities.

Bioengineering of life involves technology that works at the atomic, molecular, and cellular levels, where specific activities of mechanistic systems emerge from the algorithmic execution of defined and designed tasks on informational substrates. Bio-engineering will enable lock-and-key, size-weight-shape, and evolutionary selection mechanisms. At the atomic scale, the sequencing and printing of DNA are well understood and performed. The rational computation and engineering of molecular processes are emerging, and functioning synthetic molecular devices were first designed and constructed. These devices exhibit logic computation, amplification, clocked cycle, and have been composed into basic registers and implemented in microfluidic and PCR technologies. Bioengineering has resulted in the development of a new generation of chips that can measure a large number of nucleic acids in a single single. The new platforms are reliable and economically feasible, making multiple measurement of gene expression levels or genomic states part of the routine genetic analysis that might facilitate improved patient treatment. Only a few common diseases that illustrate the complexity of genetic traits are discussed. The first level of complexity results from genetic variation. At a second level, the penetrance, onset and progression of common genetic traits are influenced by age and environmental factors that interact among themselves. On top of these analyses at the single-gene level, effects and interactions of multiple genes need to be understood. However, the available techniques for large-scale measurement of gene expression and other genomic features have been maturing rapidly. Therefore, information-based medicine has the promise of taking a more holistic approach on board these various levels of complexity.

## 25. Renewable Energy Technologies and Sustainable Development

The last two decades have witnessed an increase in the availability of renewable energy technologies that are capable of addressing energy challenges by providing clean, cost-competitive, environment-friendly, and decentralized energy services, making them particularly appropriate for sustainable and localized energy supply in a developing country. The huge potential to harness renewable energy resources in Ghana to address the issues in sustainable energy provision and utilization is yet to be developed. Among these, the harnessing of solar energy through solar photovoltaic (SPV) power conversion offers a significant opportunity in this endeavor (Adjei, 2018).

There is a push for renewable sources of energy as demand on the national grid continues to outstrip supply. While advocacy grows for more sources of renewable energy to be introduced into the supply mix of the country, the use of solar panels has the potential to help meet the demand – need for central power generation sources focusing on hydro, gas, and nuclear. ORDER OF HEADINGS AND SUB-HEADINGS IN THIS CHAPTER: Renewable Energy Technologies and Sustainable Development; Emerging Technologies and Industries Worldwide; Economic Development of Emerging Industries: Some Sector-Specific Strategies and Policies; Conventional Wisdom About Skills, Education, and Job Creation.

## 26. Healthcare Technologies and Biomedical Engineering

Healthcare has always been a primary concern of society. Recent times have seen health care delivery optimised by the involvement of many professionals; either managing health care facilities or inventing and demonstrating new technologies for healthcare delivery. These emerging technologists include biomedical engineers, who apply the theories and principles of engineering to the clinical settings. Biomedical engineers develop sophisticated designs of medical equipments, devices, and software, as well as work with the industries that produce it. In addition nical support for medical equipment. In most health facilities, the role of the biomedical engineer is to install, maintain, inspect and repair biomedical equipment. By using their multidisciplinary background, they bridge the gap between the engineering and medical sectors hence enhance healthcare delivery (Quansah Amissah et al., 2013). The practice of biomedical engineering can be summarised as that of designing, building, maintaining and troubleshooting medical equipment for the diagnosis, monitoring and treatment of patients. This equipment can range from simple stethoscopes to more complex items like X-ray machines. Likewise, the technology that falls under the Biomedical category can vary from biomechanics and bioinstrumentation, to tissue engineering and genetic engineering. The discipline is rapidly expanding, as such there are always new technological innovations that are used to improve healthcare delivery.

## 27. Agricultural Technologies and Food Security

Rapid advances in artificial intelligence, robotics, energy, ICT and biotechnology are providing powerful tools for agriculture. New technologies range from smartphones linked to sensors and satellite imaging of fields and livestock to data analysis of crop and animal growth, yield and health, and prognoses of a range of risks, including pests, diseases, nutritional deficits, and extreme weather events. Technologies include wind, solar, and advanced bioenergy, centralized and decentralized grid power solutions, and smart-grid systems to provide highly reliable power with less vulnerability to cyber threats or EM pulses. Application of technologies are complemented by “soft” components of planning, regulations, economic instruments, training, gender empowerment, greater employment, and public-private partnerships. The increasing penetration of mobile phones, especially in developing countries, is revolutionizing a range of activities, with a direct effect on food production. New technologies range from smartphones linked to sensors, either on the phones or in the clouds, to satellite imaging of fields, livestock and fisheries. Their monitoring of crop and animal growth, yield and health, along with data analysis and prognoses of a range of risks, notably crop and animal pests and diseases, and also nutritional deficits. Improved weather forecasting is becoming ever more precise. Snow cover is also being measured. Far more detailed maps of yields are being produced throughout the major producing countries.

## 28. Transportation and Infrastructure Innovations

As part of a comprehensive effort in the area of innovations and infrastructure, the focus on ultra-modern infrastructure such as high-speed rail network investment could lead to potential gains for areas in Ghana, which includes potential trade opportunities. This would make it possible to connect industries and big markets to the port and allow for their export. Ghana is facing significant challenges with its existing transport infrastructure, including congestion and capacity constraints, resulting in very high cost on the mobility of Goods and People.

Currently, it takes more than 2 hours to make the 200 kilometer journey from the seaport at Tema to the factory belt north of Accra. In the future, this problem will be magnified by economic and population growth, which are placing increasing strains on existing systems. The transport sector must also cater for the needs of population and freight growth, social, and economic development.

With a population growing by around 1 million people per year, there are significant opportunities for public and private sectors in the construction and operation of transport systems. It is reported that a 10% increase in digitalization in the transport sector could improve system performance by 1-2 per cent in additional countries. Development of available resources, capacities and strong collaboration at a continuing dialogue can contribute to monitoring and evaluation. Cross-sector collaboration and communication are needed, a national and global partnership can support emerging countries in the adoption and effective implementation of connected and digital systems (FEIKIE et al., 2017).

## 29. Water and Sanitation Technologies

About 70% of Earth’s surface is covered by water, but an estimated 780 million people around the world still lack access to clean drinking water. Worldwide, 2.5 billion individuals do not have adequate sanitation facilities, and sewage contaminates 70% of all bodies of water. In Africa, most health problems stem from the same water used for personal hygiene, preparing food, and washing dishes, contaminating drinking water and causing the exercise of water-related activities in polluted areas. This contamination often occurs downstream of communities with waste overflowing from septic tanks, open defecation, or latrines too close to the water table, where containment can easily percolate into water used by downstream communities. Common water-related diseases include diarrhea, cholera, typhoid fever, Guinea worm, Schistosomiasis (bilharzia), and trachoma. The first U.N. Millennium Development Goal is to reduce by half, by 2015, the number of people without access to safe drinking water. Ghana is trying to meet this and other goals, and to do so, attention must also be focused on rural and peri-urban communities, where the population has a much lower access to safe drinking water than those in urban areas, even when piped systems are functioning ((Claire Eliane H. Y.) Mattelet, 2006). The greatest concern is for the rapidly developing peri-urban areas. In these regions, pollution follows the rapid expansion. Very little research has been done concerning this issue, but those who have looked into it found that in peri-urban areas, there is more diffuse pollution due to disposal of agriculture pesticides, fertilizers or chemicals. Polluted surface water bodies are used for drinking purposes and there is a general disregard for the environmental hazards of improved sanitation systems. In peri-urban areas, there is a compressing environmental and public health risk due to poor disposal of sewage, effluent discharge, and solid waste.

## 30. Mining and Extractive Industry Technologies

Africa’s richest mineral endowment is the mining sector that includes copper, cobalt, nickel, and gold. It has 32 operations in 9 countries, generating 11 thousand jobs. In 2019, it contributed USD 2 billion to the GDP of the African country. The productive sector is centralized in the extraction of goods under the economic concept of a mining enclave, causing few micro-enterprises to interact with them (Clausen & Sörensen, 2022). From this, the digital solutions are usually made up of large suppliers offering specific innovations. The existing local automotive industry is unproductive, centralizing the borrowing of special vehicles for transport or materials transport and maintenance work.

In Guinea Bissau, there are no commercial deposits, having the dependence on the port of Bissau in the neighboring country, services that are central to the extraction and export processes. Mining operations rely on the availability of fixed machines, which schedules maintenance services for possible replacements, which causes changes in the extraction of minerals until they are replaced. This situation requires the use of IIoT for monitoring of mechanical conditions. Dust and contact with various ores causes premature wear of parts by heavy equipment in various sectors (mining, construction, logging), including pinion teeth, crowns, hydraulic cylinders, and inspection within the engine. Diesel analysis for the monitoring of the microbial flora within the fuel tank can be carried out using chemo sensors.

## 31. Educational Technologies and E-Learning Platforms

Educational technologies and e-learning platforms are becoming increasingly prevalent given the chance that traditional face-to-face education will not be possible in many settings for some time. The closing down of schools and educational institutes during the pandemic brought about an unprecedented disruption of the education systems across the globe. This has created a dilemma for education providers who have had to act fast to find ways to continue providing education using tools and facilities. During the time of the schools and universities’ closure, both locally and internationally, there has been an increased sudden and unexpected demand on e-learning platforms.

In Africa, it is anticipated that the primary short-term impact would be that students currently enrolled in residential universities, colleges and schools will have to shift to online teaching learning while enforced stay home to slow down the spread of the virus. There are arguments held among educators, ed-tech practitioners who design digital systems, and digital vendors who implement them, that represent a key human aspect that is missed in the technical language: namely, the benefits of face-to-face contact and of the physical nurturing of communities. Although digital communication tools can be used effectively at a distance, many feel that in these areas they couldn’t replace physicality and intimacy for women and men. Teachers and educators worry that traditional class-based learning will be put under pressure or will be badly replicated in on-screen forms, since teaching is essentially about the cultivation of the person; encouraging and cajoling; supporting and embodying; and tailoring activities and excitements to co-present and constantly evolving group dynamics.

Yet the potential benefits of new technologies and global systems for transporting knowledge and ideas are also some of the highest profile examples of what technology can offer. The rapidly changing progress in blockchain and distributed ledger technology offers a step change in the potential for solidarity in professional communities and the sharing of best practices. The new systems being developed by government, professional bodies and NGOs are amongst the more striking; including a blockchain-based system, and an early proponent of using blockchain in academic and professional credentialing.

## 32. Telecommunications and Connectivity Solutions

The AE Group, headquartered in Accra, Ghana, took over the country’s Telecommunications Company Ghana in 1987. The group decided to build the country into a role model for the provision of telecommunications and connectivity solutions in the West African region. This has been achieved through the establishment of cellular telephone systems and a high-speed digital network. “Communities could optimize the benefits of the AE Group progress through digital empowerment centers, based in premises the company granted for free. Parliament passed legislation that allowed the Western-style liberalization of the telecommunications sector in 1996. There were large foreign investments as a result of the telecom liberalization. In 2003, the draft law established an independent regulator for the telecom sector, and this caused a huge increase in mobile penetration (N. Jobodwana, 2009). The government also played a role in imposing a reduction in the payment of termination rates among operators. The companies associated with all outstanding bills carried out these under the supervision of the NCA. However, with the amendment of the regulations by the NCA, the introduction of content regulation, tax stamps were expected to be placed on imported and locally distributed fixed and mobile phones”.

“Telecommunication is the base for the nations’ success and its progress is essential for the future of each country, and as part of various applications, such as business organizations, government service, and social services, the service needs to improve. Alongside this, because of the economic growth, telecommunication networks and the number of subscriptions have to be continuously developed. Every person in the world wishes to be connected regardless of where he or she resides, lives, or works. Because of this, a variety of systems have to be developed and utilized to guarantee the quality of service. Such improvements presume a modernization and an increased variety of the equipment used which might be established only at high additional cost. To ensure the progress of the service that’s then one of the best possible solutions is to establish an intelligent network (IN)”.

## 33. Space Technology and Satellite Applications

Despite its broader economic development challenges Ghana has made substantial progress in the space technology domain by having a space policy that clearly articulates the county’s developmental priorities. The policy recognizes the importance of space technology as a key driver industry in the ongoing technical transformation to wealth creation, development and enhancement of society’s quality of life, as well as providing direct support to various sectors of the economy. For instance, an earth observation facilities to be among the first to be established. The facility will be used for providing meteorological satellite information to the meteorological services and in particular to provide agriculture, water resources and disaster management with reliable and affordable satellite information. Currently, Ghana depends on external institutions and providers mainly on meteorological satellite products (C Navulur, 2017). Similarly, an educational-research satellite, microgravity research and communication/cable TV satellite service are also envisioned in the policy.

The role of the internet and especially the social media have become crucial in Ghana’s current socio-political and socio-economic development. In the modern context it is unacceptable for any government to completely severe the internet and other media platforms. Efforts to do so always invite powder keg situations, labelling the country undemocratic. Consequently, African States are moving towards internet democracy. Indeed, the internet and the social media have the power to change a government, either good or bad. In Ghana the internet and social media have become very powerful tools in the fight against corruption, political accountability, social injustice and protecting fundamental rights. Nevertheless, the same tools could be used to spread hate messages, commit crimes, strife or riots if they are left unchecked. Ultimately, the presence of social media platforms during elections have now forced political parties to change their old modus operandi. The younger generation is now using the social media to understand, interrogate and make informed voting decisions. This might accelerate the political power from the control of a selected few to the youth.

## 34. Future Trends and Predictions in Engineering and Technology

The trend in completely digital engineering is facing the coming profound technological changes as a result of the ongoing fourth industrial revolution (4IR). Already in progress is a global campaign initiated by the European Union (EU), which is the Horizon 2020 or Horizon Europe programme of the European Green Deal with the theme “Industry and Energy Transition” that appears geared towards the next industrial revolution for renewable natural resources, particularly renewable energy, reusable materials, and eco-environmental sound economies to achieve harmony between human activities and nature (Huang, 2023). The campaign includes but is not limited to the clean energy transition, future food systems, energy intensive processing sectors, power to act, materials for sustainable energy, advanced connected transport, and sustainable water borne transport. In the context of this campaign, the European Commission is committed to European leadership in sustainable renewable hydrogen and approves in principle some large pilot projects on green hydrogen technologies for sustainable development from renewable electricity generated from renewable energy sources using wind and solar, such as a renewable hydrogen production facility with a production capacity five times larger than the DEMO prototype of a famous international manufacturer of energy, power, renewable energy systems and automation company.

Efforts to achieve the sustainable development of human society have been placed in the context of the rise of Industry 4.0 or its equivalents, which also took place following the technological development of industry marked by the first Industrial Revolution in Britain, which then spread to all countries in Europe, America and other countries of the world. More than two hundred years have passed since the first industrial revolution up until now. The industrial revolution that has taken place in the world is undoubtedly followed by changes in technology and society that will foster sustainable convergence. Engineering is one of the most tangible manifestations of the changing face of technology. Engineering will bring the world of scientific knowledge into the real world by developing practical technologies and designing innovative solutions. With these solutions, industry will be more efficient, and the industrial impact on the environment can be minimized. At least in principle, it can be achieved if all requirements are fulfilled that will bring the prosperity, and population growth will be balanced. But in practice, realizing this is a very big challenge. It is because sustainability itself is a highly complex problem.

## 35. Conclusion and Recommendations

The challenges of economic development are still a major scurrilous issue in Africa. Since gaining independence in the 1950s and 1960s, many countries struggled with various strategies aimed at uplifting socio-economic hardship but with little success. Nonetheless, there are some success stories like China, Malaysia, and South Korea who have managed to escape the jaws of poverty and transform their economy to a middle- and high-income average within a generation or two. Despite the success stories, African countries still face daunting tasks on their path towards development (Amankwah-Amoah et al., 2018). In Africa, countries and firms are often endowed with superior resources and capabilities to be harnessed to meet ‘the catching-up’ challenges. For countries, this is the availability of vast natural resources which has attracted considerable foreign investment in a resource seeking manner. Paradoxically, this comes with disadvantages since foreign investors are often mere resource extracting rather than technologically intensive. Hence, there is a need of proactively fostering the export base towards an increased sophistication level. Nevertheless, an important condition is the accumulation of human capital which in part is related to technology transfer. Without those aspects, the high revenue from the extraction of resources is often re-invested in white elephants projects with limited technological spillover.

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