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Background report on emerging technologies for advancing shared prosperity in Africa

I. Introduction

1. The aim of the present background report is to highlight some of the key issues and conditions that enable new and emerging technologies to advance inclusive and shared prosperity, with a view to fulfilling the 2030 Agenda for Sustainable Development and Agenda 2063: The Africa We Want, of the African Union. In the report, four emerging technologies are highlighted that could help Africa to achieve its aspirations.

2. Between 1990 and 2018, the number of people living in poverty globally declined from 1.9 billion to 689 million, while the number of people living in poverty in Africa increased from 283 million to 433 million.[1] The Economic Commission for Africa (ECA) estimates that 546 million people in Africa were poor in 2022.[2] Similarly, one in five people (about 278 million) in Africa were undernourished in 2022, and that number increased to about 283 million in 2023.[3] Africa is unlikely to meet the commitment made in the Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods to end all forms of hunger by 2025, and neither is it likely to achieve the targets of Sustainable Development Goals 1 and 2 by 2030[4] and the pledge made under the 2030 Agenda to ensure that all human beings can enjoy prosperous and fulfilling lives. Those suffering from poverty and hunger experience more than just a lack of economic resources; they also experience powerlessness, helplessness, hopelessness, worthlessness and voicelessness.[5]

3. Solutions from the fields of science, technology and innovation can provide the poor with the means to help themselves, to speak out, to be heard and to be engaged. As the former Secretary-General, Kofi Annan, underlined, “in this age of unprecedented wealth and technical prowess, we have the power to save humanity

[1] United Nations, Statistics Division, “The Sustainable Development Goals report 2021: extended report – Goal 1: end poverty in all its forms everywhere”, 2021.

[2] ECA, “Fostering recovery and transformation in Africa to reduce inequalities and vulnerabilities”, press release for the fifty-fifth session of the ECA Conference of African Ministers of Finance, Planning and Economic Development, 2 February 2023.

[3] Oxfam International, “Over 20 million more people hungry in Africa’s ‘year of nutrition’”, 17 February 2023.

[4] Food and Agriculture Organization of the United Nations (FAO), African Union Commission, ECA and World Food Programme, *Africa: Regional Overview of Food Security and Nutrition 2023 – Statistics and Trends* (Accra, FAO, 2023).

[5] Deepa Narayan and others, *Voices of the Poor: Can Anyone Hear Us?* (New York, Oxford University Press, 2000).

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from this shameful scourge".[6] Countries must acquire or develop the scientific, technological and industrial capacity that is necessary to lift themselves out of poverty and eliminate hunger.

II. Revisiting the notion of a prosperous Africa

4. There is no single agreed definition of what constitutes a prosperous Africa that is backed by detailed figures. However, in the context of Agenda 2063, Africa could be defined as prosperous once it has met the following conditions: a per capita income above $18,000; an urban population that exceeds 60 per cent of the total population; a highly skilled population of which young people constitute at least 70 per cent; at least 60 per cent of graduates of tertiary institutions major in science, technology, engineering and mathematics; at least 90 per cent of all agricultural exports are processed locally; at least 50 per cent of gross domestic product (GDP) comes from manufacturing; and technology-driven products comprise half of all manufactured products. Other conditions are: at least 25 per cent of firms originate from technological breakthroughs and innovative products commercialized by Africans; and renewable energy exceeds 50 per cent of total energy production.

5. While these are ambitious goals that should be realized, Africa is far from achieving any of them. The continent's GDP per capita at current prices rose from about $900 in 2000 to about $2,370 in 2014, then declined to an average of $2,000 between 2016 and 2023.[7] High-technology exports comprise close to 0.6 per cent of total manufactured exports (nearly 0.3 per cent of the world's high-technology exports), and intra-African trade in agriculture makes up less than 20 per cent of total trade.[8] Moreover, less than 25 per cent of students in tertiary institutions in Africa are pursuing subjects in science, technology, engineering and mathematics, which foster collaboration, problem-solving, communication, critical thinking and digital literacy skills.[9]

III. Emerging technologies as drivers of growth and shared prosperity

A. Definition of emerging technologies

6. Emerging technologies "encompass an array of new materials, products, applications, processes and business models … [that] are interdependent, interconnected and mutually reinforcing".[10] The five common attributes of emerging technologies are: (a) radical novelty (radically different from existing technology); (b) relatively fast growth; (c) coherence (distinct from their original discipline or technology); (d) prominent impact (visible impact in various fields, industries and communities); and (e) uncertainty and ambiguity (the full impact on development will be fully realized some distance in the future).[11]

[6] United Nations, "Secretary-General calls for concerted action in message marking international day for eradication of poverty", press release, 11 October 2002.

[7] International Monetary Fund, "GDP per capita, current prices", DataMapper. Available at www.imf.org/external/datamapper/NGDPDPC@WEO/AFQ (accessed on 1 February 2024).

[8] FAO and African Union Commission, *Framework for Boosting Intra-African Trade in Agricultural Commodities and Services* (Addis Ababa, 2021).

[9] Ruth Kagia, "STEM education in Africa: risk and opportunity", Brookings Institution, 10 February 2023.

[10] *World Economic and Social Survey 2018: Frontier Technologies for Sustainable Development* (United Nations publication, 2018).

[11] Daniele Rotolo, Diana Hicks and Ben R. Martin, "What is an emerging technology?", *Research Policy*, vol. 44, No. 10 (December 2015).

7. Emerging technologies create numerous new innovative solutions and applications that less technologically advanced countries or less sophisticated businesses can exploit to meet their own needs. In Africa, wireless technology connected 132 million phone numbers in one decade, whereas it took 100 years to accumulate 28 million fixed-line phones by 2005.[12] Similarly, there are more people with mobile phone accounts than there are people with bank accounts.

8. Emerging technologies create technological niches that serve as safe spaces for radical innovations to be developed with minimal competition from larger players in the field and limited regulatory oversight (because rules are still being formed). For instance, most early entrants into the mobile phone industry were African start-ups that were initially ignored by large telecommunication firms at the time. Similarly, early Internet service providers were start-ups and spin-offs, as were mobile services for money transfers. In all these cases, the products were tailored for African clients, filled gaps in services and were not initially viewed as threats by bigger telecommunication companies or financial institutions, which gave their creators time to learn and grow.

9. Such niches can also be found in today's world, where, for example, the metaverse, generative artificial intelligence, flexible batteries, wearable sensors for humans and plants, spatial omics and flexible neural electronics are only just beginning to attract the attention of large firms and regulators. Therefore, investing early in emerging technologies can help countries to find technological niches that they can exploit to enhance productivity and service delivery and create jobs and wealth.

B. Emerging technologies with high potential impact in Africa

1. Biotechnology

10. The global market for biotechnology was estimated at about $1.55 trillion in 2023 and is expected to reach $3.88 trillion by 2030, driven largely by genetic sequencing, personalized medicine and the rise in chronic and orphan diseases.[13] Biotechnology is empowering firms and researchers to improve health care and advance industrial processes that may be cheaper, safer and more environmentally friendly. Africa has a growing number of biotechnology hubs and centres. For instance, 5 per cent of all the medical catheters sold globally are produced by major firms that have established manufacturing facilities in a dedicated biopark located in Mauritius. In 2021, the Government of Mauritius provided $25 million to set up the Mauritius Institute of Biotechnology to produce coronavirus disease (COVID-19) vaccines and other pharmaceutical products.[14]

11. The opportunities for creating wealth and jobs are immense. For instance, the share price of Novo Nordisk surged 50 per cent in 2023, making it the company with the highest valuation in Europe, worth about $500 billion,[15] driven largely by high demand for its drugs for weight loss and diabetes. With appropriate investment in biotechnology research and development, Africa could use such items from its indigenous flora as hoodia[16] to develop similar weight-loss drugs.

[12] Tim Kelly and Phillipa Biggs, "Mobile phones as the missing link in bridging the digital divide in Africa", *African Technology Development Forum,* vol. 4, No. 1 (April 2007).

[13] See www.grandviewresearch.com/industry-analysis/biotechnology-market.

[14] United States of America, International Trade Administration, "Mauritius: country commercial guide – biotechnology", 10 April 2023.

[15] Elliot Smith, "Novo Nordisk hits $500 billion in market value as it flags soaring demand for Wegovy, Ozempic", CNBC, 31 January 2024.

[16] Hoodia is a cactus-type plant found in the Kalahari Desert that allegedly suppresses hunger and thus helps in weight loss.

12. The continent's share of the global biotechnology market is about 1.8 per cent,[17] which is lower than its share of the global population (about 15 per cent) and of the global population working in research and development (2.4 per cent).[18] Steps must be taken to ensure that Africa is not left out of this rapidly growing sector. Biotechnology is also one of the few sectors that employs highly qualified people. From a development perspective, Africa needs biotechnology to develop its own treatments, diagnostic tools, and food and industrial processing platforms, to increase food production and to reduce pollution, especially in areas of little interest to the rest of the world.

2. Digital technology

13. The continent's digital economy has been growing rapidly, evidence of which can be seen in the increased uptake of innovative Internet and mobile technologies. The Internet economy in Africa was worth $115 billion in 2020 and may reach $250 billion by 2030.[19] However, about 42 per cent of those covered by a mobile Internet network are not using it, suggesting that a large segment of the population is being left behind. In sub-Saharan Africa, the number of mobile phone connections stood at roughly 980 million and the mobile economy employed over 1.4 million people and contributed $170 billion to the economy in 2022.[20] With 489 million unique mobile subscribers and 590 million Internet users, Africa is far from achieving universal access to telephone and Internet technologies.[21]

14. While those numbers sound impressive, the global market for the metaverse alone is expected to grow from $92 billion in 2023 to $1.3 trillion in 2030 (and $3.1 trillion by 2032),[22] that of artificial intelligence is expected to grow from $538 billion to $1.8 trillion (and $2.6 trillion by 2032)[23] and that of the Internet of things is estimated to grow from $374 billion to $1.13 trillion between 2023 and 2030.[24] These significant industries are being driven by various factors, such as the gaming industry in the case of the metaverse; generative artificial intelligence in the case of artificial intelligence; and health care, manufacturing and infrastructure services in the case of the Internet of things. These markets have significant overlaps, as do the skills and systems that underpin the technologies. For instance, many artificial intelligence applications are used in the metaverse and in the Internet of things. As digital technology transforms every aspect of the economy, governance and society, African countries should invest in education and research with the aim of generating innovative solutions to the continent's challenges and establishing firms that can compete globally. Such programmes as the African Girls Can Code initiative organized by ECA can significantly contribute to stimulating interest and building the digital capacity of girls. Other initiatives include the generic curriculum on artificial intelligence and robotics that ECA makes available to universities to adapt and quickly deploy as part of an undergraduate or graduate programme, and the centre of excellence on artificial intelligence established in the Congo.[25]

[17] See www.verifiedmarketresearch.com/product/africa-pharmaceutical-biotechnology-market.

[18] United Nations Educational, Scientific and Cultural Organization, *UNESCO Science Report: Towards 2030* (Paris, 2015).

[19] Google and International Finance Corporation, *e-Conomy Africa 2020: Africa's $180 Billion Internet Economy Future*, 10 November 2020.

[20] GSMA, "The mobile economy 2023: sub-Saharan Africa", 2023.

[21] Miniwatts Marketing Group, "Internet users statistics for Africa", Internet World Stats. Available at www.internetworldstats.com/stats1.htm (accessed on 1 February 2024).

[22] See www.precedenceresearch.com/metaverse-market.

[23] See www.precedenceresearch.com/artificial-intelligence-market.

[24] See www.precedenceresearch.com/industrial-iot-market.

[25] ECA, "ECA set to launch Africa's first AI Research Centre in Brazzaville Congo, with focus on technology and innovation", press release, 23 February 2022.

3. Nanotechnology

15. The nanotechnology industry comprises two major categories: companies that make the tools and devices needed to operate at nanoscale and companies that integrate nanotechnology into their products. The second category offers greater opportunities for firms and institutions to participate in nanotechnology product development and commercialization.

16. The global market for nanotechnology is expected to grow from $79.14 billion in 2023 to $248.56 billion by 2030. North America accounts for 33.8 per cent of the global market share, while that of Africa is estimated at about 1 per cent.[26] Nanotechnology is fuelling developments in other emerging technologies, such as digital technology (for example, the design of powerful, smaller, faster and smarter chips), energy technology (for example, batteries that have high energy density but are lighter) and biotechnology (such as nanomedicines).

17. Not all nanotechnology applications involve high technology. For instance, Gongali Model Company Limited, based in the United Republic of Tanzania, has developed water purification systems of various sizes for homes and communities in rural areas using nanotechnology-based filters that operate without electricity. Gongali Model has won awards from the World Health Organization for reducing water-borne diseases in rural areas without access to safe water. This demonstrates that nanotechnology can play a significant role in meeting development goals.

4. Energy technology

18. Energy technology is evolving rapidly and is empowering the energy transition and offering the hope that the world can cut the use of fossil fuels and the associated carbon emissions. For instance, emerging solar systems are cheaper, more reliable and have longer lifespans, making them more accessible, especially in Africa, where about half of the population lacks access to electricity. The size of the global market for solar cells was estimated at $26 billion in 2021 and may reach $37 billion by 2028,[27] while that of solar panels was valued at $180.4 billion in 2020 and may rise to $641.1 billion by 2030.[28]

19. Another area of interest is the rapidly evolving battery technology that is powering the mobile industry. The global market for electric vehicle batteries alone is expected to grow from $132 billion in 2023 to $508 billion by 2030.[29] Rapid technological advancement drove down battery prices from $1,160 per kWh to $176 per kWh between 2010 and 2018, and the price is expected to drop further.[30]

20. The use of hydrogen as a source of renewable energy is a compelling proposition, with multiple applications in a range of sectors in which other types of renewable energy may fail (for example, for mining furnaces and refineries). The global market for hydrogen generation is expected to grow from about $129 billion in 2022 to about $255 billion by 2030. As the world seeks to decarbonize, the market for electrolysers needed to convert water into hydrogen and oxygen is expected to rise from about $6 billion in 2021 to about $69 billion by 2030, while the market for hydrogen storage is expected to almost double and that of fuel cells may increase sixtyfold.[31]

[26] See www.fortunebusinessinsights.com/nanotechnology-market-108466.

[27] See www.gminsights.com/industry-analysis/solar-cells-market.

[28] See www.alliedmarketresearch.com/solar-photovoltaic-panel-market.

[29] See www.marketsandmarkets.com/Market-Reports/electric-vehicle-battery-market-100188347.html.

[30] Bloomberg, “Gasoline prices around the world: the real cost of filling up”, 4 August 2020.

[31] ECA, “Emerging technologies in advancing Africa’s energy security sustainably”, draft background note for the fifth African Science, Technology and Innovation Forum, held in Niamey on 26 and 27 February 2023.

21. Several African countries are taking advantage of the opportunities arising from green hydrogen. For example, a green hydrogen project in Namibia, with an estimated annual output of 300,000 tons of green hydrogen,[32] is a partnership involving the Government, technology owners, investment partners and stakeholders involved in trade promotion.[33] Many current hydrogen projects are in developing countries (for example, Chile, Morocco and South Africa) and involve partnerships with developed countries.

22. Africa has the minerals and energy resources required to compete, provided that it builds the capacity to design, manufacture, install, maintain, upgrade and safely decommission such energy technologies.[34] For instance, the few incentives for renewable energy, such as duty-free imports of renewable energy products, have sparked the growth of firms that supply, install and maintain solar energy products, which, in turn, is creating employment and generating wealth while bringing clean energy to people who had none.

23. Viet Nam is a good example of a developing country that is exploiting emerging energy technologies for prosperity. The country boasts seven firms that manufacture solar panels and batteries for local use and export. As a result, about 11 per cent of the electricity demand was met by solar power in 2022, saving Viet Nam about $1.7 billion in potential fossil fuel imports and creating over 8,000 jobs.[35] Similarly, the electric vehicle manufacturer VinFast has grown rapidly in the past five years to become the automaker with the third highest valuation in the world in terms of market capitalization (behind Tesla and Toyota) in 2023 (at about $191 billion),[36] and has ambitious plans to build manufacturing plants in India and the United States of America.

24. The first challenge is to reduce the cost of green hydrogen production. For example, the Department of Energy of the United States is supporting research on ways to reduce the overall cost of producing hydrogen from $5 per kg to $1 per kg of hydrogen in one decade. Such a development could potentially curb 16 per cent of carbon dioxide emissions by 2050 and generate 700,000 jobs and $140 billion in revenue by 2030 in the United States alone.[37] Besides the relatively high investment cost, Africa may need new facilities or alternative means to build competitive hydrogen markets.

IV. Why Africa needs emerging technologies to fulfil its aspirations

25. As technologies penetrate every aspect of life, the market sizes of emerging technologies are becoming larger than those of traditional industries. For example, the global market for coffee is expected to grow at a rate of about 5.0 per cent a year, from $129 billion to $210 billion between 2023 and 2030, and that of fish is expected to grow at a rate of 2.6 per cent, from $1.07 trillion to $1.20 trillion over the same

[32] Hyphen Hydrogen Energy Ltd., “Namibia announces progress with Hyphen Hydrogen Energy to unlock US$10bn investment for first green hydrogen project to help power the energy transition”, 1 June 2022.

[33] European Commission, “COP27: European Union concludes a strategic partnership with Namibia on sustainable raw materials and renewable hydrogen”, press release, 8 November 2022.

[34] AusIndustry, Government of Australia; and South Metropolitan TAFE, Government of Western Australia, “Vocational skills gap assessment and workforce development plan”, prepared for Future Battery Industries Cooperative Research Centre, August 2021.

[35] Rapid Transition Alliance, “Viet Nam’s rapid rise to becoming a solar powered state”, 25 January 2023.

[36] Takafumi Hotta, “Vietnam’s VinFast now world’s No. 3 automaker as market cap surges”, Nikkei Asia, 29 August 2023.

[37] United States, Office of Energy Efficiency and Renewable Energy, “Hydrogen Shot: overview”. Available at www.energy.gov/eere/fuelcells/hydrogen-shot.

period.[38] Similarly, the global market for copper is predicted to grow from $318 billion in 2023 to $447 billion in 2030 (growing at a rate of 5.1 per cent a year).[39] In contrast, and as noted earlier, the biotechnology market will be over $3 trillion by 2030 and the artificial intelligence market will surpass the $2 trillion mark by 2032. If Africa is to realize the aspirations of Agenda 2063, it must participate in the development of emerging technologies, as they will generate large markets with the potential to create wealth, improve lives and save the environment.

26. Furthermore, emerging technologies are giving undue advantages to those who own and use them. For instance, those employing biotechnology to develop high-yielding and drought-resistant seeds for their famers can outcompete those without such technology. Likewise, those using biological systems to process leather can more easily overcome environmental regulations and reduce the number of processing steps than their peers using harmful chemicals. As seen during the COVID-19 pandemic, those with more sophisticated technology were able to more easily produce their own vaccines, which left Africa stranded as vaccination became a requirement for travel.

27. Finally, the ability of Africans to learn about and participate in technology-intensive value chains may also be undermined. If Africa had captured just 10 per cent of the global $1.6 trillion electronics market by learning how to make products with underlying technologies similar to those produced in other parts of the world, it could have created 1.7 million decent jobs and added $160 billion to the continent's GDP.[40] Africa could also have increased its share of the electronics that are supplied to traditional sectors that currently depend on imports. For example, the United Nations Conference on Trade and Development estimates that local vendors supply a mere 1 per cent of products to the mines in Zambia,[41] forgoing opportunities for technological learning and wealth and employment creation.

V. A future for Africa in emerging technologies

28. The market for emerging technologies is growing rapidly both in terms of its value and impact on society. For example, between 2000 and 2019, total energy supply in Africa grew by 75 per cent, while the supply of renewable energy grew by 1,740 per cent. Therefore, the question is not whether there is appetite for renewable energy in Africa[42] but rather whether the current approaches and business models[43] are likely to help Africa to reduce its dependence on traditional fossil fuels and biomass, build the industries capable of designing, manufacturing, installing and exporting renewable energy products, and continuously innovate and grow to create the skills, wealth and services that Africa desperately needs. The same can be said about biotechnology, nanotechnology and digital technology.

29. In order to carve out a decent portion of the future global market for emerging technologies, Africa needs to move as fast or faster than its peers to catch up. While generative artificial intelligence has gained global attention only recently, research

[38] See www.verifiedmarketresearch.com/product/coffee-market/ and www.mordorintelligence.com/industry-reports/fish-market.

[39] See www.precedenceresearch.com/copper-market.

[40] See www.ibisworld.com/global/market-research-reports/global-consumer-electronics-manufacturing-industry/#IndustryStatisticsAndTrends.

[41] *Economic Development in Africa Report 2023: The Potential of Africa to Capture Technology-Intensive Global Supply Chains* (United Nations publication, 2023).

[42] See, for example, Anders Ellegård and others, "Rural people pay for solar: experiences from the Zambia PV-ESCO project", *Renewable Energy*, vol. 29, No. 8 (July 2004).

[43] See Velma Mukoro, Maria Sharmina and Alejandro Gallego-Schmid, "A review of business models for access to affordable and clean energy in Africa: do they deliver social, economic, and environmental value?", *Energy Research and Social Science*, vol. 88 (June 2022).

on systems that can draft scientific papers, answer complicated questions, process images and videos and solve puzzles has been ongoing for decades. Despite this, in Africa there are few universities, experts and industries with knowledge of current developments and likely trends in the field. The section below highlights a few approaches to speeding up the development of emerging technologies, which may not be applicable in all cases or to all technologies.

A. Holistic approach to human capital development

30. The development of new and emerging technologies requires a range of skills, knowledge sets and tools drawn from various disciplines and sectors, making it relatively hard to determine entry points. One option is for countries to encourage relevant institutions to set up interdisciplinary training and research centres in collaboration with existing technology firms and undertake research and develop products for and with stakeholders in relevant industries. It would also be practical to focus only on one area of national interest.

31. There are plenty of programmes and courses that countries can integrate into their formal education system – from the primary to the tertiary level. This is already being done with regard to digital technology in some countries. In Zambia, information and communications technology (ICT) courses have been introduced in primary and secondary schools and teacher training colleges, while most universities and colleges have specialized computer science or information technology programmes.[44] This is an important step in producing the skills required to operationalize ICT in society. However, ICT research and development for the production of devices and software and the delivery of services has yet to be undertaken. Similarly, collaboration among representatives of industry, academia and government geared towards developing an ICT industry is missing in most countries.

32. In other words, a holistic approach to skills development should cut across all of society – from young people to the elderly, from formal to informal education and from industry to the public sector. Skills can also be tailored around existing knowledge centres and industries, existing training centres, special economic zones and technology parks or any combination that may fit the national context. For example, industry can provide the entrepreneurial talent and resources, academia can bring detailed subject understanding from diverse angles and government can provide resources, orchestrate development and enable a conducive environment around a specific technology field or in a special economic zone or technology park.

B. Investing in research and development

33. Globally, about $88.6 billion was invested in research and development by the biotechnology sector in 2022,[45] and about $13 billion was spent on research and development in the field of emerging energy technology.[46] These are massive investments that are driving knowledge discovery, product development and commercialization. The African continent's share of global research and development in general is estimated at about 2 per cent, while research and development in some emerging fields is even lower. Africa cannot compete if it simply relies on copying what has already been developed and marketed by others.

34. In the past three decades, there has been no shortage of announcements of African teams that have invented or built a tablet, phone, computer or an application

[44] Policy Monitoring and Research Centre, "Implementation status and challenges of ICTs in Zambian schools", January 2020.

[45] Ernst & Young LLP, *Beyond Borders: EY Biotechnology Report 2022 – How Do Biotechs Stay the Course in Uncharted Waters?* (June 2022).

[46] ECA, "Emerging technologies in advancing Africa's energy security sustainably".

for farmers; however, very few, if any, have survived, even when supported by government. What has often been overlooked is that producers of devices released on the market today are already working on new versions to be released in the coming years. This is what research and development needs to be focused on to ensure that firms remain competitive. For instance, the top 20 automobile manufacturers spent $97.5 billion on battery research and development between 2019 and 2020.[47] These investments are being directed towards the technology value chain (materials, production, integration and recycling), with a view to optimizing performance, costs and durability to meet environmental requirements and fulfil economic growth ambitions.

35. Evidence suggests that investment in renewable energy has been limited in Africa. There is no African country among the top biotechnology, digital technology, nanotechnology or renewable energy patenting countries or leading industry players. In order to change this, the first step is for African countries to create research and product development centres in universities and research and development institutions with a focus on at least one emerging technology.

36. Expanding research and development instantly creates jobs for some of the brightest and creative minds that Africa may otherwise lose to the rest of the world. It gives Africa a stake in generating knowledge that will drive the future of technology industries and helps Africa to develop the skills and industries needed to build smart cities and infrastructure. Expanding research and development also provides opportunities for top research teams and industry players to work closely together, which has been observed to speed up the growth of industries in emerging technologies.[48]

37. Emerging digital technologies are also becoming important tools for advancing and accelerating research and development. Artificial intelligence in particular can help to quickly analyse data, process massive amounts of biological information to identify leads and improve the efficiency of research and development initiatives. Similarly, the metaverse can promote collaboration in research and enhance the experience of partners in pilot and field studies.[49]

C. Actively seeking strategic alliances and collaboration

38. African countries should prioritize identifying areas where strategic alliances may be of greater value. It should be underlined that research alliances will be important in acquiring or developing national capacity for research in emerging technologies. This may include bringing together relevant training, teaching and research institutions, exchanging and hosting top researchers and students, and running joint research facilities at home and in partner countries. Such alliances must have a clear goal to help countries to move up the technological ladder to avoid perpetual dependency.

39. Industrial alliances are formed between firms for a range of reasons, including sharing unique knowledge, intellectual assets and experiences in research and development, manufacturing or production, distribution, marketing and sales. Africa may have to incentivize its largely vertically integrated energy utilities and private

[47] Alan Feldberg, “EV investment nears peak”, Bodyshop Magazine, 26 July 2021. Available at www.bodyshopmag.com/2021/news/ev-investment-nears-peak/.

[48] See Lynne Zucker, Michael Darby and Marilynn Brewer, “Intellectual human capital and the birth of U.S. biotechnology enterprises”, *American Economic Review*, vol. 88, No. 1 (March 1998); and Reddi Kotha and Gerard George, “Academic entrepreneurs: the role of star scientists in commercialization of radical science”, *Frontiers of Entrepreneurship Research: Proceedings of the 30th Annual Entrepreneurship Research Conference* (2010).

[49] Ernst & Young LLP, *Beyond Borders: EY Biotechnology Report 2023*. Available at www.ey.com/en_us/life-sciences/beyond-borders.

firms to seek partnerships that may lead to the formation of joint ventures or to form start-ups in a given technology field, which would facilitate greater access to skills and experience, joint research and development projects and the co-creation of manufacturing and production platforms for renewable energy technologies or products.

D. Capitalizing on interdependencies for high performance

40. None of the emerging technologies discussed in the present background report can be developed in isolation. Almost all the technologies will need input from life scientists, physical and material scientists, computer and engineering experts and mathematicians, as well as experts in art, design and media, among other areas.

41. More specifically, anyone developing renewable energy systems will have to be familiar with the digital technologies that may be needed to optimize the operation of such systems and the advanced materials that may improve the performance, weight, size and durability of those systems. Most digital technologies may require specialized energy sources and advanced materials and may be integrated into a biological environment. Countries can form highly performing teams by ensuring that they are diverse, inclusive, open and engaged – across disciplines, gender, age, ethnicity and experiences.

E. Developing road maps

42. Several issues discussed in the present section could inform national and regional road maps for the development of emerging technologies. A detailed plan may address how countries will transition towards a clean, accessible, competitive, secure, safe and affordable energy supply for all or build a competitive nanotechnology industry. Policymakers and emerging industrial entities in Africa need to develop clearer strategic plans that guide the behaviour of all stakeholders and inspire a better future. For example, plans may include information on the number of jobs that will be created, the number of communities that will be served, the affordability of the services provided, the benefits that will result and how they will be shared, and the key players that will be needed. While plans do not always work out as intended, they can inspire academia, industry, government agencies and society at large to work towards a common future.

43. While each country may employ different tools and approaches, they may want to consider existing technological, industrial, trade, employment and investment requirements and emerging regulations and practices, as well as to identify the costs and benefits, those who stand to benefit and those who stand to lose, among other issues. For instance, 75 per cent of the jobs created through the development of photovoltaic systems for communities and utilities are in manufacturing and 25 per cent are in construction and installation,[50] while 60 per cent of employment in green hydrogen is in renewable energy production (for example, the solar farms that power the green hydrogen plants) and 30 per cent in hydrogen production, transmission and storage.[51] While large biotechnology and digital technology firms typically employ fewer people than large firms in mature industries, they may have a greater impact on the direction of a society's development. Clearer road maps could help to guide national policies, investment and human capital development, minimize damage and optimize the benefits, and encourage healthy competition and collaboration at the

[50] Sandra Müller and others, *Achieving Inclusive Competitiveness in the Emerging Solar Energy Sector in Morocco*, report No. 79 (Bonn, German Institute of Development and Sustainability, 2013).

[51] Sonja van Renssen, "Hydrogen tests climate policymakers with its job potential", Energy Monitor, 6 May 2021.

national, regional and global levels. The road maps should also include clear implementation and investment plans.

VI. Conclusion

44. The main purpose of the present background report is to highlight several emerging technologies and the opportunities that they present to Africa, to illustrate some of the trends in the field and to pinpoint areas where Africa could fully participate in the emerging technology industries. The aim is also to stimulate research, debate, policy development, collaboration and partnerships among countries to advance the development and manufacture of products in Africa that can enable the continent to sustainably build a prosperous society.

45. As demonstrated earlier in the report, such traditional and mature sectors as mining and agriculture are estimated to grow much slower and thus offer minimal space for rapid development to meet the aspiration in Africa for shared prosperity. In contrast, emerging technology industries are growing by over 10 per cent a year and thus offer greater opportunities for learning, creating wealth and achieving sustainable development.

46. To make the most of those opportunities, Governments may have to choose sectors of interest, invest in skills development and research and development, and support emerging entrepreneurs, especially women. Governments, academia and industry need to set clear goals, priorities and timelines and to include them in their road maps for emerging technologies. Clearer policies can help to stimulate development, mitigate risk and encourage collaboration.