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Advancing science, technology and innovation policies on emerging technologies for economic growth in the post-coronavirus disease era

I. Introduction

1. The work on technology and innovation undertaken by the Economic Commission for Africa (ECA) is led by the Innovations and Technologies Section of the Technology, Climate Change and Natural Resources Management Division. The overall objective is to support member states harness frontier technologies to meet their development goals. This is achieved by undertaking rigorous policy analysis research, pilot projects, advocacy and consensus-building activities, and contributing original data and frameworks to inform policymaking.

2. The present thematic report discusses the ongoing work undertaken by ECA regarding the promotion of emerging technologies in Africa. Chapters II and III provide the background and objective of the report, respectively. Chapter IV contains an overview of emerging technologies, and chapter V presents the current state of development of the participation of Africa in emerging technologies. Chapter VI explores the potential of emerging technologies for economic growth. Chapter VII outlines the conclusions and ongoing work of ECA, and chapter VIII proposes some issues for discussion.

II. Background

3. The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes the coronavirus disease (COVID-19), has reinforced the importance of science, technology and innovation, both as an enabler and critical sectors in its own right. The world has relied on science, technology and innovation to find treatments, track the evolution of the virus and the disease, keep the world at work, and keep families and friends in touch during the pandemic. For instance, scientists and technology firms in

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various disciplines have provided knowledge that has informed strategies and decisions to contain and mitigate the COVID-19 crisis.[1]

4. The COVID-19 pandemic has pushed African countries to embrace the digital revolution in a big way. Despite the progress made in mobile money transfers (primarily between individuals), digital and electronic banking are still poorly developed in automation, personalization and real-time transactions. In a digital world, individuals expect to have online access to a wide range of financial services and to be able to conduct transactions instantaneously. Nonetheless, Africa has a long way to go to fully capture the benefits of digital technologies to drive innovation, business development, and public service delivery and empower communities to improve their well-being.

5. Africa is lagging in energy accessibility. Almost half of its population does not have access to electricity. People who have access to electricity also pay twice as much as others in the rest of the world. Blackouts, brownouts and other power supply failures cost Africa between 2 and 4 per cent of gross domestic product ($52 billion–$104 billion) a year.[2] This is particularly problematic during the COVID-19 pandemic when a stable power supply is needed for laboratories, hospital wards and intensive care units; telecommuting workers; and information and communications technology infrastructure, which connects people to their workplaces, friends and relatives. Africa faces significant challenges in attaining the goals of increasing access to electricity while simultaneously reducing reliance on traditional sources of electricity (such as coal and petroleum) and increasing energy efficiency.

6. From a technology perspective, Africa has the opportunity to deploy emerging advanced energy technologies to meet its energy needs and participate in the development, production and trade in advanced energy solutions. It could seek to develop energy solutions that can be used in electric vehicles, drones, mobile devices, bioelectronics and nanodevices, among others. Africa has an abundance of the necessary resources (such as the copper, cobalt and lithium needed in solar systems and batteries) and a vast access to sun, wind and water resources almost all year round. With suitable investments in people, institutions and technologies, Africa can move from being a net exporter of petroleum and minerals to a key player in renewable and green energy production and exports.

III. Objective

7. The overall objective of the present report is to highlight the potential economic contributions of emerging technologies in Africa in the post-COVID-19 era and how countries can design policies and strategies that harness emerging technologies to meet their development aspirations. It is also intended to stimulate dialogues on the key attributes and benefits of emerging technologies, on whether existing policy and governance arrangements are “fit for purpose” in a rapidly changing world, and how regional integration can help to bring about investment in crucial infrastructure and the competencies that are required to unlock the full potential of emerging technologies. The outcomes of those dialogues will inform the work of ECA and member States.

[1] Benjamin Roche and others, “Was the COVID-19 pandemic avoidable? A call for a ‘solution-oriented’ approach in pathogen evolutionary ecology to prevent future outbreaks”, *Ecol Lett.*, vol. 23, No. 11 (31 August), pp. 1557–1560.

[2] Gregor Schwerhoff and Mouhamadou Sy, “Where the sun shines: renewable energy sources, especially solar, are ideal for meeting Africa’s electrical power needs”, *Finance and Development*, vol. 57, No. 1 (March 2020), p. 54.

IV. Overview of emerging technologies

8. Emerging technologies are also known as “transformative technologies” or “frontier technologies” because they often “encompass an array of new materials, products, applications, processes and business models, [that] are interdependent, interconnected and mutually reinforcing”.[3] Emerging technologies share several attributes that transform or disrupt current industries; reallocate economic, social and environmental value; and alter how people live and work.

9. Emerging technologies generally build on existing technologies. Thus, countries with the basic infrastructure, skills, knowledge and support industries could easily upgrade to newer technology solutions. The current discussion on 5G is a case in point. Many countries, including developed ones, could deploy 5G technology over 4G infrastructure and network faster and even cheaper. COVID-19 vaccines are also built on existing technologies. Africa needs to move out of its comfort zone of overly focusing on regulations and invest its resources and efforts to build and stimulate the development of national innovation systems that foster and encourage countries to adopt new technologies as they emerge.

10. To this end, the Conference of African Ministers of Finance, Planning and Economic Development, in the report on the work of its fifty-second session (E/ECA/CM/52/2), called upon ECA to “help member States to replicate good practices in the digital economy” and upon member States to “build their human and technological capacity” and “formulate integrated plans for the development of the digital and green economy”.[4] The present report looks at two emerging technologies: advanced energy and digital technologies.

V. African participation in emerging energy and digital technologies

11. There is significant interest in the role of emerging technologies in spearheading the continent’s transformation and in achieving the Sustainable Development Goals of the 2030 Agenda for Sustainable Development. The following sections discuss two broad categories of emerging technologies – digital technologies and advanced materials focusing on nanotechnology.

A. Emerging energy technologies

12. Very few African countries have an energy supply that is stable, reliable, accessible and affordable, and most are heavily reliant on biomass. Africa needs to step up efforts to reduce dependence on biomass – one of the drivers of deforestation. Emerging energy technologies enable renewable sources to offer a more affordable, accessible, and environmentally friendly energy supply. The present section looks at a few emerging energy technologies that Africa should seriously consider and pursue – noting that renewable energy has lower life cycle greenhouse gas emissions than conventional fossil fuels. For example, life cycle greenhouse gas emissions from solar photovoltaic and wind energy are 4 and 1.5 per cent, respectively.[5] Such technologies play an essential role in reducing greenhouse gas emissions and mitigating climate change.

[3] E/2018/50/Rev.1. ST/ESA/370 (Executive summary).

[4] Fifty-second session of the Conference of African Ministers of Finance, Planning and Economic Development, Marrakech, Morocco, 25 and 26 March 2019.

[5] Thomas Bruckner and others, “Energy systems”, in *Climate Change 2014: Mitigation of Climate Change – Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (Cambridge, United Kingdom and New York, Cambridge University Press, 2014).

13. While each technology may be studied and discussed independently to highlight its specificity, in practice, these technologies could generate better outcomes if they were used in combination. In particular, hybrid systems that utilize multiple energy sources are needed to guarantee reliable supply in all-weather conditions. Various emerging technologies for energy capture, conversion, storage and use are discussed below.

Technologies for energy capture and generation

14. The rapid uptake of solar photovoltaic systems has been driven by improvements in solar technology, a reduction in manufacturing costs, increased funding for renewable energy and the adoption of enabling renewable energy policies.[6] Photovoltaic technologies (such as crystalline silicon and cadmium telluride) are now produced at an industrial scale, and many more technologies are in development.[7] As a result, the price of photovoltaic systems has decreased significantly since 2010. As of 2019, the average levelized cost of generation of solar photovoltaic electricity was $51/MWh – making it a cheaper source of electricity than coal, easier to install and cheaper to operate (i.e. low maintenance).

15. Geothermal steam can be used to generate electricity. KenGen in Kenya is the leader in geothermal electricity in Africa. Other countries in the African Rift Valley could deploy geothermal power plants that utilize this resource. Research and expertise from KenGen and geologists[8] could reduce the risk for investors. In addition to finding a suitable site, it is crucial to evaluate the long-term hydrology and hydrogeology of the area. Even though the Earth will supply heat for millions of years, the underground water for steam production can be depleted if the water is not recharged.

B. Energy storage technologies

16. There are several emerging energy storage technologies, but the most advanced include lithium-ion (Li-ion), lead-acid; redox flow; sodium-sulfur; sodium metal halide; zinc-hybrid, cathode batteries, and storage types such as hydropower pumped, flywheels, compressed air energy and ultracapacitors. Each of these has its advantages and disadvantages. The lithium battery is perhaps most commonly used in laptops, mobile phones and electric mobility (e.g. electric vehicles, scooters and bikes). Rapid technological advancement has driven prices per kilowatt-hour down from $1,160 to $176 between 2010 and 2018, and the price is expected to drop further.[9] Lithium-ion batteries hold more charge per volume, require less maintenance, if any, and have a long life span of up to 15 years. Although these batteries can be used in small devices (e.g. mobile phones) and large-scale installations (e.g. power utilities), they are still relatively expensive.

17. Lead-acid batteries are the cheaper energy storage solution for home solar systems and use in automobiles to start and run accessories. They are easily disposable but require maintenance (i.e. they may leak), have a shorter life span (about five years) and are bulkier. Similarly, flow batteries contain water-based electrolytes that store chemical energy; they are bulky and expensive. Unlike other batteries, they can be discharged fully, have a lifespan of up to 30 years, and do not require maintenance.

18. A fuel cell is an electrochemical cell that converts the chemical energy stored in fuel and an oxidizing agent into electricity through a pair of redox reactions. The

[6] G.M. Wilson and others, “The 2020 photovoltaic technologies roadmap”, *Journal of Physics D: Applied Physics*, No. 53 (2020).

[7] Benjamin Mow, “STAT FAQs part 2: lifetime of PV panels”, National Renewable Energy Laboratory, 23 April 2018.

[8] Elizabeth de Oliveira, “What can geothermal power do for East Africa?” Stanford Earth Online News, 16 April 2018.

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

fuel in a fuel cell can serve as an energy storage medium for vehicles or appliances that use electricity. In a hydrogen fuel cell, the fuel is hydrogen[10], and the oxidizing agent is oxygen, with water as the molecular product. The complete process for the typical production method – starting from the splitting of water to produce hydrogen, then the storage of hydrogen, and completed by the oxidation of the hydrogen and electricity production – has an overall efficiency of approximately 30 per cent.

19. Morocco seeks to produce 133,000 tons of ammonia from 13,000 tons of green hydrogen. At the same time, Sasol – the South African chemical and energy company– has announced two major hydrogen projects that will lead to the installation of hydrogen cells in heavy-duty and long-haul vehicles of Imperial Logistics. Sasol has also conducted a feasibility study to develop a hydrogen hub at the port in partnership with the Northern Cape Development Agency.[11] In addition, Namibia and Germany have signed a cooperative agreement to develop the hydrogen economy.

C. Distributed energy generation

20. Africa is a large continent with a widely dispersed population in small, rural and often isolated communities that may be hard to reach. Even in countries with higher population density, geography may pose a challenge to the extension of national electricity grids. As renewable energy technologies such as solar-powered microgrids become affordable, a $100,000 investment could power a community of several thousand people.[12] Such microgrids are simpler and faster to build and could be maintained by the local community. In a way, it makes Africa the perfect place for distributed or decentralized energy systems and microgrids.

21. Renewable energy microgrids are rapidly expanding in Africa, with homegrown companies such as PowerGen (with operations in Kenya, Nigeria, Sierra Leone and the United Republic of Tanzania) attracting international investments and partners.[13] Microgrids have also been shown to provide power to small businesses in Africa – for example, small businesses that need to refrigerate their food, or those involved in carpentry, water treatment and sales, or milling maize, cassava and sorghum.[14]

22. Africa has not been entirely left out of pursuing a low-carbon growth path. Between 2011 and 2020, the installed capacity for solar energy in Africa has increased from 331 MW to 10,687 MW (a 32-fold increase), while that of wind has risen from 995 MW to 6,496 MW (a 6.5-fold increase). Over the same period, installed geothermal energy capacity has risen fourfold, and that of bioenergy 1.1 fold because of the rapidly falling costs of solar and wind energy systems.

23. Regarding research and development investment, in 2019 alone, about $6.7 billion was spent on solar systems, $2.7 billion on the wind, $1.8 billion on biofuels, $1 billion on biomass, $0.7 billion on small hydropower, and $0.2 billion each on geothermal and marine energy. Similarly, the top 20 automobile manufacturers spent $97.5 billion on battery research and development in 2019 and 2020.[15] Both cases highlight intensive research investment, focusing on the technology value chain (materials, production, integration and recycling), with the

[10] Hydrogen could be produced through electrolysis, use of microbes to split water or ferment biomass, solar- and metal oxide to split water, as well as by reforming hydrocarbons with steam and hight temperature to produce hydrogen.

[11] For details, visit www.h2-view.com/news/africa/.

[12] Rajesh Kumar Singh, “Tata, Rockefeller Foundation plan 10,000 India microgrids”, Bloomberg, 4 November 2019.

[13] PowerGen, “Microgrids”, available at www.powergen-renewable-energy.com/microgrids/.

[14] Booth et al., *Productive Use of Energy in African Micro-Grids: Technical and Business Considerations*. Golden, Colorado, 2018). National Renewable Energy Laboratory and Energy 4 Impact.

[15] BDO United Kingdom, “Top 20 global carmakers spend £71.7 billion on R&D”, 26 July 2021.

desire to optimize performance, costs and durability to meet environmental and economic growth ambitions.

D. Digital technologies

24. The digital economy in Africa has been proliferating, as is evident in increased Internet and mobile technologies and innovations. Estimates suggest that Africa is now home to 11.5 per cent of the world's total Internet users (lower than the 12.5 per cent of 2019). In absolute terms, Africa was home to 590 million Internet subscribers in 2020.[16,17] The COVID-19 pandemic has fast-tracked the development of digital services in Africa. Examples of this include deploying robots in Rwanda and Tunisia during the lockdowns, drones in Ghana and Rwanda to deliver healthcare services to remote areas (e.g. collecting samples), and an electronic platform in Sierra Leone for self-assessment COVID-19 symptoms. Various African entities developed platforms and tools for collecting and publishing national, regional and global data on COVID-19 trends.

25. ECA and its partners launched the Africa Medical Supplies Platform to facilitate the transparent procurement of high-quality medical supplies at competitive prices, including medicines and medical technologies.[18] ECA and its partners also launched the Africa Communication and Information Platform and the Africa United Nations Knowledge Hub for COVID-19. All United Nations agencies share information on COVID-19-related activities such as publications, research, experiences and country responses. COVID-19 has shown that all African countries can easily collect and share up-to-date data by leveraging digital technologies supported by appropriate mechanisms and policies.

26. That said, growing the number of Internet users to attain universal access remains a priority for Africa and could profoundly impact economic and social prosperity. Specifically, the Internet economy of Africa was worth $115 billion in 2020 and may hit $250 billion by 2030.[19] The African Internet economy supports the growth of e-commerce, financial technology, cloud computing services and the digitalization of traditional sectors such as banking, utilities, agriculture, health and education.

27. Similarly, the number of mobile phone subscribers in Africa has grown from around 87 million in 2005 to roughly 882 million in 2020.[20] The mobile economy employs over 700,000 people and provides 1.5 million informal jobs in Africa. Mobile technologies have transformed the financial sector and expanded access to financial services, especially for the poor, young people, women, and rural areas.

28. The impact of extending mobile services to the poor has been a subject of significant research interest. One study found that the introduction of mobile money "led to cost-savings for remittance transactions… doubled non-farm self-employment rate, and reduced the fraction of households with very low food security from 62.9 to 47.2 per cent, in areas far from a bank branch", but did not affect savings, agricultural outcomes or poverty.[21] Others have shown that the increased use of digital financial

[16] Data based on Internet World Stats, available at www.internetworldstats.com/stats1.htm (accessed 20 October 2021).

[17] Data for 2019 were available for Cabo Verde, Côte d'Ivoire, Kenya and Mauritius; data for 2018 were available for Guinea, the Niger and Zambia. For all other countries, the latest available data were for 2017 (except for Nigeria, where the most recent year was 2016).

[18] Available at https://amsp.africa/.

[19] Google and International Finance Corporation, "e-Conomy Africa 2020", IFC, World Bank Group, n.d.

[20] GSMA, "618 active tech hubs: the backbone of Africa's tech ecosystem", 10 July 2019.

[21] Christina Wieser, Miriam Bruhn, Johannes Kinzinger, Christian Ruckteschler and Soren Heitmann, "The impact of mobile money on poor rural households: experimental evidence from Uganda", Policy Research Working Paper No. 8913 (Washington, D.C., World Bank, 2019).

services has been linked to informal, micro and small enterprises.[22,23] This anecdotal evidence highlights the role digital technology can play in reducing inequalities and ensuring inclusive and shared prosperity for all.

29. Africa is doing well in digitalization from a digital economy perspective, but not in the core digital and information technology sectors. M-Pesa is an excellent example in this regard. M-Pesa was hosted in Germany until 2015, following which the migration of the technology to Kenya started. It was owned by Vodafone (United Kingdom) until 2020, at which point Safaricom and Vodacom South Africa acquired the brand and its technologies for about $13 million. From a development perspective, such an arrangement denied the continent both a more profound technological learning opportunity and foreign exchange (in royalty payments at 2 per cent of its revenues). M-Pesa is not the only example. With minimal investment in cloud computing, technical expertise and support infrastructure and services, many African technology platforms are hosted abroad. African firms, such as Liquid Intelligent Technologies, have data centres in Johannesburg, Cape Town, Nairobi, Harare and Kigali. They partnered with Microsoft's Azure and demonstrated that Africa could compete in core digital services with the right incentives and investments to build digital skills and infrastructure.

30. In terms of the generation and use of digital technologies, the continent's capabilities are also emerging. For example, the United Nations Conference on Trade and Development estimated in its 2021 report that the African share of global Internet traffic is minimal, and usage remains low: about 9.8 per cent of Internet users use Internet banking, and 3.5 per cent sell goods and services online.[24] Africa and Latin America account for a combined share of 1 per cent of the world's 70 most influential digital platforms[25], suggesting limited digital innovation and limited commercialization capacity. A similar trend is observed in blockchain-related patents, global spending on the Internet of Things, and the global market of commercial cloud computing.[26]

31. While Africa is doing well in terms of the growth rates in Internet and mobile phone users, the continent seems to perform poorly regarding the key technologies that underpin the digital economy. Cloud computing is one of those critical technologies where Africa remains behind. Still, it is essential for individuals, firms, and institutions to store, process, and use the vast volumes of data generated every day. The global cloud computing market is currently worth $371.4 billion and is expected to reach $832.1 billion by 2025.[27] Some of the top firms (such as Amazon, Google, and Microsoft) are making massive investments in cloud services, covering applications, infrastructure management, security, and business processes.

32. Another area of concern is the digital gender divide. The mobile Internet gender gap in Africa[28] grew from 20.7 per cent in 2013 to 33 per cent in 2019.[29] Africa

[22] Yee Kwan Tang and Victor Konde, "Differences in ICT use by entrepreneurial micro-firms: evidence from Zambia", Information Technology for Development, vol. 26, No. 2 (April 2020), pp. 268–291.

[23] Kenneth Miriti Nyaga and B.M. Okonga, "Does mobile money services have any impact on SMEs performance in Naivasha?" *International Journal of Current Research*, vol. 6, No. 10 (October 2014), pp. 9394–9398.

[24] United Nations Conference of Trade and Development, *Digital Economy Report 2021. Cross-border data flows and development: For whom the data flow* (United Nations publication, Sales No. E.21.II.D.18). 2021.

[25] United Nations Conference of Trade and Development, *Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries* (United Nations publication, Sales No. E.19.II.D.17). 2019.

[26] Ibid.

[27] Available at www.marketsandmarkets.com/Market-Reports/cloud-computing-market-234.html.

[28] Measured as the difference in Internet penetration rates for males and females as a proportion of Internet penetration rates for males multiplied by 100 (per cent).

[29] International Telecommunication Union, "Measuring digital development: facts and figures 2019", 5 November 2019.

was second only to South Asia, where the mobile Internet penetration gender gap was higher, at 51 per cent, in 2019. Indeed, in Africa, a boy is 1.5 times more likely than a girl to own a mobile phone. However, the gender gap in mobile phone ownership was much lower – about 13 per cent – in 2019.[30] Given that most users access the Internet through their mobile devices, the above observation may mean that the percentage of female mobile phone users not accessing the Internet on their devices is higher than that of males who own mobile phones.

33. Digital technologies can transform every aspect of the economy, governance and society. African countries should address barriers and ensure gender equality in science, technology, engineering, and mathematics, which can provide career paths and business opportunities. Countries should upscale digital skills training in formal and informal education, improve security online, drive down costs, and improve the quality of infrastructure and regulatory frameworks.

34. Bootcamps and events such as the African Girls Can Code Initiative – organized by the International Telecommunication Union, the United Nations Entity for Gender Equality and the Empowerment of Women (UN-Women), the African Union Commission and ECA – can go a long way in stimulating interest and building the digital capacity of girls. Municipalities could also be encouraged to build shared and safe digital access centres for women and young people, especially in rural and poorer communities. For instance, the City of Tshwane in South Africa offers up to 1GB of free Internet access per day per user at public institutions, informal settlements and partner public places (such as restaurants with ample bandwidth). It has partnered with the IBM Digital-Nation Africa programme to enable its residents to access the knowledge, skills and tools needed to design, develop and launch digital solutions.[31] Such actions to address some of the factors that perpetuate digital divides along gender, wealth, and community could help drive inclusive development.

VI. Advancing science, technology and innovation policies for emerging technologies

35. Policies are generally seen as tools that enable Governments to achieve clearly defined objectives when private incentives provided by free markets systematically perform poorly.[32] For developing countries, the incentives for the private sector to engage in emerging technologies are even lower for a range of reasons.

36. While most countries have different procedures and mechanisms for developing policies, there are several vital pillars that countries may wish to consider when designing science, technology and innovation policies, especially for advancing emerging technologies. First, emerging technologies are disruptive, interdisciplinary and intersectoral and thus require an integrated approach and some flexibility to adapt quickly to changes. For instance, expertise in computer science, neuroscience, mathematics, physics, engineering, chemistry, design, art and economics, among others, may help inform the design and development of technologies such as artificial intelligence, big data, recycling of information technology devices, design of applications, as well as in the design of solar systems, wind turbines or electric cars. Even countries with limited resources can attempt to develop shared facilities, centres and platforms.

37. The second pillar is strengthening institutional arrangements that are consistent, stable and inclusive in designing policies and strategies. For instance, the Human Sciences Research Council in South Africa has dedicated units for research

[30] GSMA, “The mobile gender gap report 2020”, 2020.

[31] City of Tshwane, “Welcome to free TshWi-Fi powered by the City of Tshwane”, available at www.tshwane.gov.za/Pages/WIFI.aspx.

[32] D.L. Weimer and A.R. Vining, *Policy Analysis: Concepts and Practice* (Englewood Cliffs, New Jersey, Prentice-Hall, 1989).

and development and innovation monitoring, while the National Advisory Council on Innovation undertakes research to advise the Minister of Science and Technology and the Government. However, countries such as the Republic of Korea and Singapore have institutions to monitor performance and make changes to ensure success. African countries may wish to develop equivalent institutional arrangements to ensure success.

38. The third aspect is prioritization regarding specific goals, technologies, industries, skills, research and development infrastructure, and the future development trajectory. For instance, a Government with $20 million for solar energy can prioritize building a solar power plant to light 100,000 homes in a rural community or invest in 500 startups in the solar energy industry value chain. If just ten startups grew to medium-sized firms in 10 years, the solar energy industry would have grown. It may even provide superior services to a larger community, drive exports and create decent and sustainable jobs and wealth. Countries like the Republic of Korea and Singapore made hard choices to build their private sectors by exploiting emerging technologies beyond learning to operate or use the technology.

39. The fourth aspect has a decent implementation plan with clear roles and responsibilities. For instance, the continental digital strategy set the following as its second objective: "By 2030, all our people should be digitally empowered and able to access safely and securely to at least [six megabits per second] all the time… at an affordable price of no more than $0.01 per megabit through a smart device manufactured in the continent at no more than $100 to benefit from all basic e-services and content hosted in Africa."[33] It is unclear which stakeholders agreed to meet those targets by that time. Like many national science, technology and innovation policies, the strategy does not have an implementation plan. It does not specify the roles, tasks, task owners, a realistic timeline, or the support required for the tasks.

40. Fifth, it is necessary to establish continuous monitoring and evaluation mechanisms before, during, and after the policy is implemented. Thinking through how the programme will be evaluated requires planning and analysis. It incorporates scenario planning and helps prepare those responsible for the policy to adapt to any eventuality, be it delayed construction of infrastructure, a major new disruptive technology, a change of government philosophy, or an international disaster, such as the 2008 financial crisis or the COVID-19 pandemic. Planning, monitoring and evaluation enable policy managers to be flexible and adaptable to change.

41. Sixth, stakeholder engagement and buy-in at every stage of the policy development process are critical to developing a sound policy and ensuring its acceptance, uptake and implementation. For the development of a science, technology and innovation policy, it is especially critical that stakeholder engagement be well planned and thought through, given the diverse nature of sectors, disciplines and actors involved in emerging technologies, noting that they span Government, the private sector, academia and, increasingly, civil society. However, different stakeholders hold varying sizes of the "stake". Thus, some policies may require more private-sector engagement (e.g. e-banking), while others may require more community engagement (e.g. land for a solar farm).

42. Finally, national policies are, by nature, political constructs. Politics is sometimes defined as "the art of the possible". An appropriate, politically attuned governance structure – combined with an emphasis on evidence-informed decisions, planning, evaluation and broad stakeholder engagement – can extend the realm of what science, technology and innovation policy can deliver when it comes to emerging technologies, especially when contentious issues such as land, security, privacy and risk are involved. Appropriately developed and implemented science, technology, and innovation policies can profoundly impact national development and

[33] African Union, "The Digital Transformation Strategy for Africa (2020-2030)", 2020. African Union Commission.

well-being. Good policies could drive the successful adoption, development and deployment of emerging technologies that deliver development gains.

VII. Conclusion

43. In recent years, ECA has undertaken rigorous policy research and has provided policy advice to member States on several emerging technologies, such as blockchain, artificial intelligence and nanotechnology. Emerging technologies offer Africa the opportunity to build back better and enable countries to meet their various global and regional commitments. With the appropriate policies for advancing emerging technologies in energy and digitalization, Africa can build strong, resilient, inclusive and environmentally friendly economies.

Follow-up on recommendations of the first session of the Committee

44. The first session of the Committee on Private Sector Development, Regional Integration, Trade, Infrastructure, Industry and Technology made several recommendations to ECA regarding its work on emerging technologies,[34] in response to which ECA implemented various initiatives, as detailed below.

45. In response to the recommendation that ECA support research that focused on the critical drivers of innovation in informal firms and how those firms used digital technologies to expand their businesses and compete in the marketplace, the Commission, in partnership with ACS and Alibaba, has supported several countries (such as Ethiopia and Rwanda) to identify firms and products of interest that could be introduced to the Chinese market on the Alibaba platform. Furthermore, in collaboration with the New Partnership for Africa's Development (NEPAD), ECA surveyed informal and small and medium-sized firms using digital technologies. The main concerns include costs and reliability of networks for micro and small firms, while security and lack of skills are essential concerns for medium-sized and large firms.

46. In response to the request that ECA undertakes in-depth research to improve understanding of the African market for startups, the institutions that support them, their levels of support, and the policies that target startups, the Commission is completing the first study on advancing entrepreneurial universities in Africa, focusing on people and incentives, pathways for entrepreneurs, partnerships with the external/private sector, entrepreneurship education and international partnerships, and the government policies that support startups and entrepreneurs, especially in universities. ECA also organized the first Africa Innovation and Investment Forum in 2020, which brought together potential innovators, entrepreneurs, investors and Governments to address policies and ways of building dynamic innovation ecosystems in Africa that support startups. Several startups and innovators showcased their products and highlighted some of the challenges in the African market. Efforts to narrow the gap between the needs of innovators and investors are required.

47. In response to the recommendation that ECA provides information on the methods used by member States to build their research and development systems and to increase both the number of researchers and the expenditure on research and development, to enable countries to draw lessons, the Commission participated in the African Science, Technology and Innovation Indicators initiative, as part of which the Organisation for Economic Co-operation and Development issued manuals to support 25 countries in undertaking research and development surveys and community innovation surveys. The results of this work are partly set out in *African Innovation Outlook III*, published by the African Union Development Agency, and a test survey

[34] See the report of the first session of the Committee on Private Sector Development, Regional Integration, Trade, Infrastructure, Industry and Technology (E/ECA/CPRTIIT/1/9).

of community innovation surveys adapted for informal firms was piloted in Cameroon, Zambia and Zimbabwe, with positive results;

48. In response to the request that ECA develops a virtual platform that would enable African research and development institutions to collaborate with African researchers in the diaspora and other researchers worldwide, the Commission implemented several initiatives. First, the ECA-inspired African Biomedical Engineering Consortium developed Africa-European Union e-infrastructure for promoting innovation through education. The platform enables innovators from Africa and worldwide to share designs, be mentored and assess the global standards for which their designs may qualify. This initiative and the Innovation Bridge of South Africa – another comprehensive platform for sharing information on research, funding, projects and their contributions to the Sustainable Development Goals – were featured at the second Africa Regional Science, Technology and Innovation Forum, held in Victoria Falls, Zimbabwe, in 2020. Both served as anchor platforms for the Africa Innovation and Investment Forum 2020.

VIII. Issues for discussion

49. Issues for discussion include the following:

(a) What policy measures and incentives should African countries enact to reduce private investment risks and enhance the business environment to encourage businesses to invest in emerging technologies and realize productivity gains?

(b) What steps should countries take to strengthen their science, technology and innovation institutional arrangements to support emerging digital and energy technology policies in terms of design, implementation and general oversight to ensure success in meeting set national objectives?

(c) In the face of competing for national demands and given the wide range of emerging digital and energy technologies and their multiple applications and benefits, what measures should countries use to set ambitious but achievable priorities for research and industrial and national development?

(d) While countries have different approaches to science, technology and innovation policies, the absence of specific, measurable, actionable, realistic and time-bound targets and monitoring and evaluation mechanisms seems common. What measures and support are needed to encourage countries to develop implementation plans and monitoring and evaluation frameworks to accelerate the development of emerging technologies?

(e) Resources remain a significant challenge. What are the appropriate policy instruments and mechanisms that countries can use to leverage regional research networks, industrial alliances and common markets to combine resources, share risks and become competitive?

(f) Emerging technologies are not necessarily neutral or inclusive. How can countries ensure that emerging technologies deliver development gains that are inclusive and equitable, considering the needs of small and medium-sized firms, women and young people, and rural and urban dwellers?

(g) What are the critical social and regulatory challenges emerging technologies present in Africa? What needs to be done to minimize their impacts?