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Technology foresight and technology assessment for sustainable development

Report of the Secretary-General

Summary

Technology foresight and technology assessment can guide sustainable development policies, as highlighted in this report. While distinct, the two practices complement each other in helping countries strengthen anticipatory governance capacities and proactively adjust technological trajectories. Together, they help foster resilience by enhancing adaptability to unforeseen technological changes, creating shared goals that unite diverse stakeholders and challenging existing policy narratives by helping to reveal blind spots, debunk biases and identify missed opportunities and risks. Technology foresight and technology assessment can act as honest brokers, as underscored in the report, expanding the range of policy options rather than promoting a single course of action. Building local capacities and institutional frameworks to implement technology foresight and technology assessment is critical in developing countries, although it is neither easy nor inexpensive, as shown in the report, which draws on international case studies, panel discussions and national experiences. Recommendations are provided on institutionalizing technology foresight and technology assessment, ensuring the independence and inclusivity of such activities and strengthening global support and knowledge-sharing networks, to ultimately embed them more firmly into sustainable development policies.

Introduction

1. At its twenty-seventh session, in April 2024, the Commission on Science and Technology for Development selected “Technology foresight and technology assessment for sustainable development” as one of its priority themes for the 2024–2025 intersessional period.

2. The secretariat of the Commission convened an intersessional panel meeting on 21 and 22 October 2024 to deepen understanding of this theme and to support the Commission in its deliberations at its twenty-eighth session. This report is based on the issues paper prepared by the secretariat, the findings and recommendations of the panel, country case studies contributed by Commission members and contributions from United Nations entities.[1]

3. Effective, evidence-based and proactive strategic planning is critical in anticipating and reacting to current and future technological changes. The General Assembly, in its resolution on science, technology and innovation for sustainable development, encouraged all stakeholders “to explore ways and means of conducting inclusive national, regional and international technology assessment and foresight exercises on existing, new and emerging technologies to help to evaluate their development potential and mitigate possible negative effects and risks”.[2] The Economic and Social Council, in its resolution on science, technology and innovation for development, encouraged countries to consider conducting “technology assessment and foresight exercises as a process to encourage structured debate among all stakeholders towards creating a shared understanding of the implications of rapid technological change”.[3] However, many developing countries have not yet undertaken such exercises and have minimal capacity to do so due to limited experience to date. Developing countries may face challenges in adopting such practices and, in this regard, there is considerable scope for learning from the experiences of countries that have developed and institutionalized them, to ensure ongoing use in national contexts.

I. The development of technology assessment and technology foresight

4. Technology assessment and technology foresight are systematic methodologies designed to help understand and shape the implications of technologies in socioeconomic systems. Both follow explicit methodological steps and rely on interdisciplinary approaches, to evaluate technologies and outline policy implications.

5. Technology assessment involves the systematic evaluation of the consequences of technological development and adoption, focusing on immediate social, economic and environmental impacts. At its core, technology assessment is aimed at supporting and enhancing capacity for sound reasoning and informed decision-making in shaping scientific and technological advances and utilizing outcomes towards sustainable development.

6. Technology foresight is a forward-looking methodology for systematically exploring emerging technologies, potential applications and long-term societal impacts. A key

[1] Contributions from the Governments of Austria, Belize, Brazil, Cuba, Ecuador, Germany, India, Indonesia, the Islamic Republic of Iran, Japan, Oman, Peru, the Philippines, Poland, Portugal, South Africa, Türkiye, the United Republic of Tanzania, the United States of America and Zambia, as well as the Economic and Social Commission for Asia and the Pacific, the Economic and Social Commission for Western Asia, the International Telecommunication Union, the Organisation for Economic Cooperation and Development, the Technology Bank for the Least Developed Countries, the United Nations Environment Programme and the United Nations Industrial Development Organization are gratefully acknowledged. For all documentation from the intersessional panel meeting, see https://unctad.org/meeting/commission-science-and-technology-development-2024-2025-inter-sessional-panel.
Notes: All websites referred to in this report were accessed in January 2025. Mention of any firm or licenced process does not imply the endorsement of the United Nations.

[2] A/RES/78/160.

[3] E/RES/2023/4.

characteristic is the embrace of the non-linearity inherent in technological development, recognizing that scientific and technological advancements often follow unpredictable and complex paths due to interactions in sociotechnical systems. Technology foresight involves a diverse range of qualitative and quantitative methods, along with participatory processes, to envision possible futures. In addition to enhancing policy coherence and improving long-term planning, technology foresight practices can foster resilience by helping to build adaptability to unforeseen technological changes, contribute to creating shared goals that unify diverse stakeholders with regard to desired technological futures and challenge existing policy narratives by uncovering blind spots, debunking implicit biases and identifying missed opportunities and risks.

7. Classic technology assessment and technology foresight practices operate along different timelines but are complementary tools in addressing technological and societal challenges. Technology assessment is used to evaluate current technologies and mostly immediate impacts, offering actionable insights for short-term policy decisions, and to ensure that technologies are implemented responsibly, considering the environmental, social and economic dimensions. Technology foresight is used to anticipate future trends and innovations, guiding long-term strategic planning and investments in research and development. Together, the practices help provide a comprehensive framework for decision-making, addressing both present needs and future opportunities.

A. Roles and functions of technology assessment and technology foresight

8. Technology assessment emerged in response to the unintended consequences of technological advancements, such as environmental pollution and public health hazards. As a challenge-driven and problem-oriented field, technology assessment combines scientific exploration with practical applications.[4] It is used to examine the potential benefits of technological progress while addressing unintended side effects that often result from interactions between technologies, human behaviour, regulatory frameworks and socioeconomic conditions. Technology assessment originated in the United States of America; the Office of Technology Assessment, established in 1972 to assist Congress in evaluating the impacts of scientific and technological advancements, has issued over 750 assessments, influencing policy decisions in diverse fields, and technology assessment is now undertaken by the science, technology assessment and analytics team under the Government Accountability Office. In Europe, countries began to adopt technology assessment in the 1980s, creating parliamentary units to provide technology-related insights. In Germany, for example, the Office of Technology Assessment, established in 1990, offers scientific advice on issues such as teleworking, deepfake technologies and offshore wind farms.

9. Technology assessment is aimed at the following three main goals: providing policy advice; fostering public dialogue; and shaping technology development. Historically, its core purpose was to offer evidence-informed recommendations that could inform policy decisions, as demonstrated by the early use of parliamentary technology assessments. Over time, the field has expanded; the scope now encourages public dialogue, engaging stakeholders beyond the immediate policy community. This shift has helped to address ethical considerations, foster participatory decision-making and ensure that a wider range of perspectives contributes to shaping technological pathways. Approaches such as constructive technology assessment and value-sensitive design further extend the mission by integrating societal expectations and values into technology design, thereby helping to ensure that technological progress aligns with the needs and aspirations of the communities it serves. Technology assessment can be applied to particular technologies, evaluating short-term consequences, typically within a horizon of three to five years, to generate actionable policy options that respond to immediate challenges. Beyond this focus, technology assessment is also used to examine the broader sociotechnical context, recognizing that technologies evolve within complex ecosystems of regulatory frameworks, economic structures and cultural norms. Through this perspective, technology is understood as part of an interconnected value chain, in which changes at one point can create ripple effects throughout the system.

[4] Grunwald A, 2018, *Technology Assessment in Practice and Theory* (Routledge, London).

Thoroughly analysing interdependencies requires a comprehensive approach that encompasses both immediate needs and future scenarios. Incorporating foresight methods into technology assessment is therefore critical in order to ensure that assessments of technological implications not only address present concerns but also consider long-term outcomes and consequences.

10. Technology foresight is used to systematically examine future technological possibilities, emphasizing long-term opportunities and challenges.[5] Unlike more traditional, expert-driven advisory processes, technology foresight exercises actively engage a wide range of stakeholders, from domain experts and policymakers to industry representatives and civic groups, thereby broadening the pool of perspectives and enhancing political legitimacy. Diverse methods are employed to explore and shape potential futures. The following approaches may be used: Delphi method surveys, to systematically gather expert insights on emerging technologies and trends; scenario planning, to construct plausible futures in order to guide policy and strategy; horizon scanning, to identify weak signals and drivers of change; and visioning, to create aspirational scenarios in order to prioritize strategic actions. For example, Japan has conducted large-scale science and technology foresight surveys approximately every five years since 1971, with the National Institute of Science and Technology Policy overseeing efforts since the fifth survey in 1992. The application of Delphi and other technology foresight methods in Japan has inspired similar practices worldwide, for example, in Peru, the establishment of the National Foresight Observatory, which integrates foresight into strategic planning at the national level; and the conduct of large-scale foresight exercises in the European Union, used to inform multi-year research agendas, such as those under Horizon Europe.

11. One of the principal reasons for employing technology foresight is the ability to enhance preparedness in the face of future uncertainties.[6] By encouraging policymakers to consider the complex dimensions of emerging issues, envision various potential scenarios and evaluate the opportunities and costs associated with alternative outcomes, technology foresight enables a more holistic approach to strategic planning. Through the systematic exploration of multiple future possibilities and their interactions, the use of technology foresight not only illuminates what might lie ahead, but also challenges existing visions of the future and entrenched assumptions. In doing so, it broadens the scope of decision-making and invites a more flexible, inclusive and forward-thinking perspective on shaping the future. The use of technology foresight also helps to foster coordination among multiple government departments and stakeholders, enabling holistic policymaking, to address cross-cutting issues such as climate change, health and sustainable infrastructure. For example, in the United Kingdom of Great Britain and Northern Ireland, a technology foresight exercise addressed flooding by involving housing, transportation, river management and emergency services stakeholders; and an exercise on obesity engaged the food, education and health sectors. Such exercises can not only inform policymakers but also establish lasting networks between experts and decision makers, ensuring a sustained exchange of knowledge and resources.

B. Comparing technology assessment and technology foresight

12. Technology assessment and technology foresight share a focus on understanding and shaping the impacts of technology but differ in key aspects; technology assessment is often used to address immediate concerns related to the implications of adopting or developing a technology and the use of technology foresight offers a broader vision of future possibilities, helping to shape innovation strategies (table 1).

[5] Miles I, Saritas O and Sokolov A, 2016, *Foresight for Science, Technology and Innovation* (Springer, Berlin).

[6] Weber CL, Sailer K and Katzy BR, 2015, Real-time foresight: Preparedness for dynamic networks, *Technological Forecasting and Social Change*, 101:299–313.

Table 1
Comparison of technology assessment and technology foresight

Typical characteristics	*Technology assessment*	*Technology foresight*
Focus	Consequences of technology development and adoption	Opportunities for technology development and adoption
Time horizon	Often short to medium term (years)	Longer-term vision (decades), but related to policies in immediate future
Thematic orientation	Focuses on particular technologies or applications; may consider issues in major emerging fields	Examines broader technology fields, potentially covering entire science, technology and innovation landscape relevant to a country or particular challenge; often focuses on innovation systems, with activities aimed at reshaping such systems
Fields of expertise often employed	Multidisciplinary, including science and technology studies, policy analysis and sociology	Multidisciplinary, including innovation studies, design and management studies
Methods employed	Workshops, public surveys, stakeholder interviews, technology trend and impact analyses and design tools; may involve a wide range of stakeholders, including affected communities and employees	Workshops (including scenario analysis), Delphi analysis and strengths, weaknesses, opportunities, and threats analysis; wide participation from industry experts, academics and policymakers and some representation of stakeholder groups
Use of technology forecasting data and models	Focuses on diffusion and implications of widespread technology adoption and sometimes on reinvention (unanticipated uses of new products)	Focuses on product development, including gaps and obstacles in commercialization, product cycle issues, etc; Delphi method often used to gather expert insights on potential technological developments
Organizations commissioning work	Main clients often include Governments or national parliaments; in areas of public concern, work may be commissioned by professional bodies, learned societies or membership organizations (e.g. trade unions, environmental groups)	Main clients often include ministries or government agencies involved in science, technology and innovation, such as those responsible for research and development funding
Policy outputs	Informs near-term policies related to introduction, use and regulation of new technologies	Informs strategic planning in science, technology and innovation policy and technology development in various policy areas

Source: UNCTAD.

13. Technology assessment and technology foresight increasingly overlap in practice, since both are aimed at addressing systemic challenges posed by technology. The potential of each to address both immediate and long-term issues is highlighted in energy systems, whereby a technology assessment is used to examine current technologies, such as renewable energy production and storage systems, to inform decisions about infrastructure investments and to assess the socioeconomic impacts of such technologies on communities and industries; and technology foresight is used to project future advancements in energy technology, such as breakthroughs in battery efficiency and the integration of decentralized energy grids. Technology foresight can complement technology assessment by helping to explore long-term trajectories, identify technologies that could disrupt existing systems and foster international cooperation. Both practices have an emphasis on capacity-building and inclusive decision-making, enabling countries to adapt technologies to local needs while addressing global challenges. The integration of methodologies helps ensure a more comprehensive approach to technology governance, balancing short-term impacts with long-term opportunities.

14. The two practices have significant differences in processes and purpose but are highly complementary and on a path towards some degree of convergence. The institutionalization of technology assessment and technology foresight reflects this convergence. Many organizations incorporate elements of both methodologies, using tools such as scenario planning and the Delphi method to inform policy and strategic decisions. This hybrid approach enhances the capacity of Governments and stakeholders to navigate the complexities of technological change effectively.

15. In India, for example, technology assessment and technology foresight are integrated in the Technology Information Forecasting and Assessment Council, which conducts technology-oriented studies of electric vehicles, telemedicine and climate-smart agriculture. Participatory practices, such as consultations on genetically modified crops, have incorporated public concerns while shaping national policies.

16. Both technology assessment and technology foresight can be conducted as one-time stand-alone exercises or integrated into ongoing programmes overseen by dedicated institutions. A number of approaches are commonly adopted; the stages may appear linear, but in practice often involve iterative cycles, revisiting earlier analyses and adjusting proposals as new information and insights emerge (table 2).

Table 2
Comparison of technology assessment and technology foresight processes

Process stage	*Technology assessment*	*Technology foresight*
Scoping ↓	Determine objectives of assessment Which technologies or applications are the focus? Which criteria are critical? What is the need for the new technology?	Determine focus topics for foresight (usually in consultation with client) What is the span of the technologies or issues? What is the time horizon? Which stakeholders should be involved?
Initial intelligence ↓	Map key features of the technology or application; identify current state of development and diffusion, leading and lagging uses and scope for stabilization of designs and platforms	Scanning phase: Examine drivers and trends, apply horizon-scanning methods, consider weak signals and use tools such as the Delphi method to gather expert opinions

Process stage	*Technology assessment*	*Technology foresight*
Exploring and modelling interconnections ↓	Outline potential and probable implications in various fields beyond key criteria and how they might interrelate; consider reactions to change, unanticipated consequences and unintended impacts	Develop models of change using soft systems or similar methods; develop alternative scenarios, to outline plausible futures for technology development and use
Analysis and visioning ↓	Use multicriteria analysis or trend impact analysis to quantify and contrast impacts across different areas	Outline aspirational scenario and key features of stretch target for desired outcomes
Appraisal ↓	Compare costs, benefits and risks of different actions, including inaction; consider implications for risk management	Create a road map for development and action in future years; prioritize areas for policy action or dedicated interventions in near term
Recommendations ↓	Identify main policy recommendations for action based on assessment; document and justify recommendations using materials developed in earlier stages	Identify main policy recommendations for action based on foresight
Dissemination ↓	Prepare suitable range of outputs, summarizing results for key stakeholders; develop detailed report for main client and execute follow-up activities	Disseminate outputs for policymakers and stakeholders, ensuring clarity of results and necessary follow-up
Reflection	Reflect on extent to which assessment generated useful results; assess effectiveness in informing policy, raising stakeholder awareness and driving action; draw lessons for scoping, designing and managing future exercises	Consider how well foresight informed policy and stakeholders; reflect on lessons learned, to improve future exercises

Source: UNCTAD.

II. Roles of technology assessment and technology foresight in science, technology and innovation policies and sustainable development

17. Technology assessment and technology foresight are critical in aligning technological innovations with sustainable development objectives. Both practices have evolved from a predominantly technology-centric focus to a more problem-oriented approach characterized by an increasing emphasis on proactively designing solutions for global grand challenges. These challenges require multidimensional solutions that account for social, economic and environmental factors. For example, ensuring global food security goes beyond simply increasing agricultural output and requires addressing inefficiencies in food distribution, curbing food-related speculation, promoting sustainable farming practices and considering the effects of climate change on crop yields. The complexities of modern challenges require holistic and system-oriented solutions.

18. The shift in technology assessment and foresight practices and broader science, technology and innovation policies towards addressing global challenges and providing targeted solutions aligns with sustainable development, yet this emerging challenge-solution

framework can also have unintended consequences. Framing innovation solely around predefined challenges risks generating short-term, technocratic solutions that focus on immediate symptoms rather than addressing underlying systemic issues. One of the main concerns with regard to the new paradigm in science, technology and innovation policies, and the role of technology assessment and technology foresight within, is that it could promote innovation within the constraints of existing socioeconomic and political systems. This could perpetuate unsustainable practices by failing to consider the broader structural transformations required to achieve long-term sustainability. For example, a focus on incremental technological improvements, such as developing cleaner technologies, might overlook the more significant need to restructure the global energy system, including changes in consumption patterns, governance and equity. Innovating within the boundaries of existing systems may lead to the continued replication of unsustainable dynamics, leaving deeper systemic challenges unaddressed.

19. Recognizing these limitations, recent attention has turned to transformative innovation policies that target underlying sociotechnical systems.[7] Such policies endeavour to catalyse more significant changes necessary for long-term sustainability. In this setting, technology assessment and technology foresight can serve as "honest brokers", expanding the array of policy options rather than championing a single technocratic route.[8] The use of technology assessment and technology foresight can also help ensure that science, technology and innovation policies do not intensify political and cultural divides, but instead foster inclusive dialogue and governance that can support sustainable transformations. Both practices encourage a culture of experimentation and continuous learning, which is critical in the success of transformative innovation policies. By embedding evaluation and learning mechanisms into the policy process, both practices allow for real-time adjustments based on feedback and changing circumstances. For example, policies can be adapted as new technologies emerge or as the social and environmental impacts of current innovations become clearer. In the context of transformative innovation policies that aim to rectify systemic failures, such as market inefficiencies or governance gaps, the use of technology assessment and technology foresight can provide the analytical tools necessary to identify failures and propose out-of-the-box solutions to fix them. Technology assessment, used to examine how technologies interact with existing regulatory frameworks, markets and institutions, can serve to highlight governance gaps that need to be addressed in order to facilitate systemic transformation. The use of technology foresight can aid in exploring new governance models that can better support innovation ecosystems geared towards global grand challenges. The use of both technology assessment and technology foresight can help ensure that innovation policies are aligned with broader societal missions and stay on course. Assessment is used to determine whether particular technological innovations contribute to or detract from missions; the use of foresight can help set long-term strategic directions that align with grand challenges.

20. The accelerating pace of innovation in many technologies has expanded the scope of technology assessment and technology foresight. Both practices need to address not only the technologies themselves but also their intersections with societal systems and values. For example, advancements in artificial intelligence, quantum computing, neurotechnology and biotechnology require assessments of ethical implications, regulatory issues and long-term societal impacts, including the economic, social and environmental dimensions of sustainable development. Digital tools are also starting to transform technology assessment and technology foresight practices, enabling real-time data collection, scenario modelling and stakeholder engagement. Such advancements can enhance the efficiency and scope of assessment and foresight exercises, allowing for more nuanced analyses of complex sociotechnical systems.

[7] Diercks G, Larsen H and Steward F, 2019, Transformative innovation policy: Addressing variety in an emerging policy paradigm, *Research Policy*, 48(4):880–894.

[8] Pielke RA, 2007, *The Honest Broker: Making Sense of Science in Policy and Politics* (Cambridge University Press, United Kingdom).

III. Technology assessment and technology foresight practices across countries

A. Institutional models at the national level

21. Countries employ diverse institutional approaches to technology assessment and technology foresight, reflecting variations in national priorities, political systems, resources and cultures. Models range from centralized government systems to decentralized networks involving public–private partnerships, research institutions and parliamentary bodies.

22. Austria has a decentralized model whereby multiple institutions, including the Institute of Technology and the Institute of Technology Assessment, collaborate on initiatives. Federal ministries also have in-house capacities that contribute to the process.

23. Brazil has developed a technology assessment and technology foresight ecosystem with multiple agencies working across sectors. The Centre for Management and Strategic Studies in science, technology and innovation supports the national science, technology and innovation strategy and the Agricultural Research Corporation conducts strategic agricultural foresight. Participatory approaches, such as through the Framework for Participatory Impact Assessment, engage local stakeholders, to assess the sustainability impacts of policies.

24. Chile has a parliamentary model, through the Parliamentary Technical Advisory Unit, which consults experts and conducts foresight studies, to inform legislative decision-making. This approach strengthens the connection between scientific evidence and public policy.

25. Malaysia uses public–private partnerships, including the Industry–Government Group for High Technology, which hosts the foresight institute My Foresight.

26. The Philippines is considering establishing a dedicated technology foresight institute under the Department of Science and Technology, to provide ongoing support in strategic intelligence and anticipatory governance to policymakers and civil servants. The Department has conducted a technology foresight exercise.

27. The Russian Federation has a technology foresight hub model, through the International Research and Educational Foresight Centre of the Higher School of Economics, which serves as a central hub for developing foresight methodologies and conducting futures studies. The Centre collaborates with international organizations and research centres, contributing to the global foresight community. Its work includes producing long-term foresight studies and road maps for various sectors; assisting in the formulation and revision of the government strategy on priority science and technology areas and critical technologies; and supporting the foresight activities of the business sector. Beyond these contributions, the Centre offers foresight training, fostering a new generation of foresight practitioners.

28. Singapore has a centralized approach through the Centre for Strategic Futures, located in the Prime Minister’s Office. By linking technology foresight expertise directly with the Government, the Centre helps ensure that foresight activities have a direct impact on strategic decision-making at the highest levels.

29. In the United States, large-scale technology foresight programmes common in other industrial countries have not been conducted, but there is a technology assessment and technology foresight ecosystem. Many academic groups and consultancies perform work that resembles technology foresight; organizations such as the Rand Corporation have led the development of relevant techniques and, for example, the Future Today Institute, an advisory firm, conducts strategic foresight, enabling public and private organizations to plan for the future using its methodology, scenario planning, strategy advice and capacity-building. In addition to formalized approaches, there are also grass-roots initiatives, with networks such as the Expert and Citizen Assessment of Science and Technology and the Public Interest Technology University Network.

30. Whether through decentralized models involving multiple actors, centralized hubs, public–private partnerships, governmental agencies or parliamentary bodies, each country tailors approaches to unique needs and contexts, reflecting different national circumstances

in both resources and ambitions. Not all Governments are able to institutionalize technology assessment and technology foresight in such ways and many require external expertise, while developing national capabilities.

B. Regional initiatives and international collaboration

31. Regional and international collaborations enhance national capacity to implement technology assessment and technology foresight. Such initiatives foster resource-sharing, capacity-building and knowledge exchange, particularly benefiting developing countries.

32. At the regional level, several networks support futures literacy and foresight. The Asia Pacific Futures Network promotes futures thinking in the region, supported by the Asia-Pacific Economic Cooperation Centre for Technology Foresight. The Association of Southeast Asian Nations Foresight Alliance facilitates evidence-based planning within member countries, with a focus on environmental sustainability. Regional cooperation in Europe is conducted through the European Parliamentary Technology Assessment Network, providing policymakers with shared methodologies for evaluating the socioeconomic and environmental impacts of technologies, supporting comparative studies and fostering harmonized approaches among countries. The Ibero-American Futurists Network connects countries in Latin America, Portugal and Spain, to share methodologies. In addition, there are transnational collaborations within BRICS [Brazil, Russian Federation, India, China and South Africa]; for example, the Russian Federation and South Africa have partnered on technology assessment and technology foresight projects, with the National Research and Technology Foresight project in South Africa working with scholars in the Russian Federation to conduct big data analyses, to support technology foresight efforts in South Africa.

33. The United Nations supports global foresight initiatives through specialized agencies. For example, the International Maritime Organization and the International Telecommunication Union focus on addressing technological and environmental issues pertinent to their respective fields; the United Nations Development Programme works with developing countries to support foresight capacities and futures literature; the Chairs in Futures Studies and the Global Futures Literacy Network of the United Nations Educational, Scientific and Cultural Organization promote futures thinking; and the United Nations Industrial Development Organization implements regional and global technology foresight initiatives, to build capabilities in the anticipatory governance of emerging and critical technologies. An UNCTAD pilot project on technology assessment in Africa focuses on renewable energy technologies in three pilot countries, adapting methodologies from developed countries, with a seven-step approach that emphasizes stakeholder participation and considers the particular impacts of technology adoption on women, youth and marginalized groups.

34. Technology assessment and technology foresight are increasingly recognized as critical tools in addressing global grand challenges, such as climate change and public health crises. By integrating sustainability considerations into science, technology and innovation policies, the use of technology assessment and technology foresight practices helps ensure that technological advancements are aligned with environmental, social and economic priorities. The diversity in practices underscores the adaptability of these methodologies. Centralized, decentralized and hybrid models each offer advantages, from fostering inclusivity to ensuring coherence among national strategies. Regional collaborations, such as the Association of Southeast Asian Nations Foresight Alliance and the European Parliamentary Technology Assessment Network, illustrate the value of aligning foresight approaches in order to address cross-border challenges.

IV. Overcoming constraints in technology assessment and technology foresight

A. Challenges in implementation

35. Many countries face significant obstacles in implementing effective technology assessment and technology foresight activities. Key challenges include limited human and financial resources, insufficient institutional capacity and the lack of integration between exercise results and policymaking processes.

36. Constraints from human and financial resource limitations are among the most fundamental barriers to conducting comprehensive exercises. This affects all stages, from data collection to analysis and scenario development. As a result, decision makers often work with incomplete information, which undermines the strategic value of technology assessment and technology foresight in shaping policies. Many countries lack trained personnel skilled in related methodologies. This issue is exacerbated by weak institutional frameworks, making it difficult to sustain long-term initiatives. Inadequate futures literacy in the public and private sectors further hinders understanding of and engagement in technology assessment and technology foresight processes. There is often a disconnect between science and policy. The weak science and policy interface in many countries often results in missed opportunities to translate strategic insights gained from technology assessment and technology foresight exercises into actionable strategies and policies. In addition, if activities are successfully conducted and generate valuable recommendations, there is no guarantee that such insights will be used in policymaking processes. The disconnect can reduce impacts in shaping long-term national development plans and hinder the ability of Governments to respond proactively to future challenges and opportunities.

37. Access to research outputs and bibliographic databases presents a critical challenge in many developing countries. The high costs associated with accessing such essential resources limit the ability to conduct thorough and effective technology assessment and technology foresight exercises. This lack of access to research articles is particularly problematic in developing countries, where financial constraints already pose a significant barrier.[9] Without reliable access to research outputs, many countries are at a disadvantage in making informed decisions about future technological developments.

38. In addition, a sectoral approach to technology assessment and technology foresight activities, whereby the focus is on particular industries or technologies, can also limit the broader applicability of results. This approach can prevent the identification of cross-sectoral issues and opportunities that could be critical in ensuring a more holistic understanding of future trends and challenges. By focusing too narrowly, countries may miss out on important insights that could benefit multiple sectors, thereby limiting the strategic value of technology assessment and technology foresight activities. In addition, the documentation of related efforts in developing countries is often sparse, particularly in assessing tangible impacts on policy and planning. Recommendations from technology assessment and technology foresight exercises frequently form only one component of a broader group of proposals emerging simultaneously. An exception in this regard is the Technology Foresight Programme in Colombia, which incorporates a systematic evaluation of technology foresight activities, a practice not common in similar efforts. In many cases, the priorities of technology assessment and technology foresight initiatives in developing countries are driven more by prevailing trends and external agendas than by locally grounded needs assessments. Without systematic follow-up to measure the actual influence of initiatives, valuable opportunities to capture lessons learned and improve future efforts may be lost. The political culture in many countries may lead to a greater focus on the short to medium term, with governance organized in national development planning periods of five years; in such cases, there may be less of a tradition of longer-term planning. Longer time horizons are often adopted in technology foresight exercises. Introducing technology foresight methodologies in such contexts could

[9] UNCTAD, 2024, *Data for Development* (United Nations publication, sales No. E.24.II.D.17, Geneva).

encourage policymakers to adopt a broader, long-term perspective, fostering a cultural shift toward extended planning horizons.

39. Another challenge involves managing the expectations of clients and customers. Ensuring that the outcomes of technology assessment and technology foresight activities align with the needs and constraints of stakeholders, such as government agencies or private sector clients, is critical in the success of initiatives. If expectations are not managed effectively, there is a risk of misalignment between the technology assessment and technology foresight results and the practical needs of those who rely on the insights for decision-making.

40. Finally, the early identification and management of obsolete technologies with negative environmental and socioeconomic externalities is a critical yet complex and resource-intensive task. Maintaining technological relevance and sustainability requires significant technology assessment and technology foresight capacity, which may not always be available. This challenge is exacerbated by the need to continuously monitor technological developments and assess long-term viability, a process that demands both financial resources and specialized expertise. Without the ability to identify and phase out obsolete technologies, countries risk falling behind in the rapidly evolving global technological landscape, which can have significant economic and social implications.

B. Learning from national experiences

41. In countries with greater experience in technology assessment and technology foresight, typically middle-income and high-income countries, a dedicated organization is often established to undertake related activities that feed into the policymaking process. Ideally, such an organization operates with a clear legal mandate, to enhance authority and effectiveness. Both practices are frequently, but not always, conducted by the same body. Activities are typically carried out using a range of complementary methods and techniques, which requires skilled individuals who can effectively apply such techniques and assess the quality of work undertaken by others. Typically, such capabilities are fostered in the first instance by sending staff members for training abroad; learning-by-doing with the support of external consultants is also conducted. Once skills have been established, methods may be adapted to local environments, and practitioners may also remain in contact with peers in other countries, for example by participating in international conferences.

42. If there is less familiarity with the purposes and practices of technology assessment and technology foresight, it may be premature to create an institution that is expected to undertake activities on an ongoing basis. An initial project may be an appropriate starting point for developing capabilities and experimenting with procedures. Some activities may be carried out with management from a key government ministry, yet it is not enough to delegate responsibility to any available staff member without ensuring the requisite expertise and authority. It is critical for a senior figure to be a champion of technology assessment and technology foresight, namely, someone who can defend the activity, mobilize engagement from members of the ministry and other parts of the Government and ensure that results are adequately disseminated and acted upon. In addition, the project scope should clarify the sorts of processes and outputs needed in order to attain policy impacts and which stakeholders will be engaged. The product champion needs to be someone who is respected, or can build respect, among a range of stakeholder communities, including academia, civil society and industry.

43. With regard to securing policy impacts, the science, technology and innovation agenda may be reaching a critical point, with the need for policies to address particular technology choices or to set the course for the application of science, technology and innovation towards sustainable development. Technology assessment and technology foresight work can feed into the development of such policies, but needs to be timely and well-evidenced. Timeliness may be particularly problematic, since decision makers may require results in short time frames and this urgency can create strain, particularly among academic researchers who typically conduct studies over extended periods. In such cases, challenges are faced not only in maintaining motivation but also in achieving the necessary

depth and quality in urgent reports, to meet the high standards aimed at in technology assessment and technology foresight exercises. Researchers may need to shift from presenting comprehensive scientific findings to offering expert opinions based on less complete information. However, the focus should remain on ensuring quality, avoiding superficiality and maintaining thoroughness, even when time is limited.

44. Evaluation of the success of technology assessment and technology foresight exercises appears relatively underdeveloped and undertaking independent evaluations could offer significant lessons for practitioners. The technical quality of work can be assessed by expert peers, which may require contacting global technology assessment or technology foresight communities. However, a more thorough documentation of policy outcomes of such exercises, as well as instances in which outcomes are limited or absent in certain policy domains and communities, may be informative. Actual policy formulation and implementation may diverge significantly from the original technology assessment and technology foresight recommendations upon which they were based.

V. Conclusion and recommendations

45. It is evident that neither technology assessment nor technology foresight are easy or inexpensive processes. Their use may provide immediate benefits, such as helping to make technology choices or shaping national science, technology and innovation programmes, yet their developmental impact may not become apparent for some time. However, the world faces grand challenges and is undergoing a complex, long-term transition. Addressing complex, long-term issues requires robust strategic planning that, in turn, requires an assessment of alternative futures and an appraisal of the role that science, technology and innovation can play in shaping desirable development paths. Technology assessment and technology foresight are increasingly vital tools in building local capacity for anticipatory technology governance worldwide. However, achieving this objective presents significant challenges. National efforts alone are insufficient, particularly in developing countries, making international collaboration essential in overcoming barriers and fostering effective implementation.

46. The question to be considered is how to best organize technology assessment and technology foresight exercises. There is no one-size-fits all answer and some experimentation may be required in areas where local experience in these practices remains limited. For example, in some countries, exercises are authorized by the legislative branch and, in others, by the executive branch. This institutional difference means that technology assessment and technology foresight are archived and managed in separate organizational structures, potentially making integration challenging.

47. The scope of work in this context can be envisioned in several ways, depending on particular needs and objectives. One approach is for the work to be a one-time activity. For example, if a prompt policy response to rapid technological developments is required or if policymakers need timely guidance on whether such developments warrant policy action, then technology assessment and technology foresight exercises can serve as key reference points. An alternative approach involves establishing or maintaining a permanent unit within the Government or an external centre of excellence that goes beyond merely responding to government requests and has a proactive role in setting the agenda for its work. This is likely to involve a combination of ongoing assessments of the technology landscape, together with deep dives into particular technological challenges and problem areas in which science, technology and innovation are liable to play a significant role in addressing the issues. Some areas may require ongoing activity, particularly the more immediate and recurrent challenges associated with health-related technology assessments and the types of impact assessments required by ministries of the environment and similar bodies. Organizations responsible for such tasks should possess capacity to conduct or commission the necessary assessments and implement appropriate measures based on findings.

48. Another consideration is whether technology assessment and technology foresight exercises should be conducted internally or outsourced. If the Government has little experience of such work, it may make sense to employ external expertise, which might

involve resources from other countries. If external contractors are engaged to lead particular projects, at minimum, internal capabilities are still required, to manage work and relations with policymaking. If activities are carried out internally, the team responsible should receive training or have experience in applying related methodologies. In addition, they should have access to appropriate facilities to independently conduct exercises and develop a work programme, if the activities prove beneficial to policymaking. In a well-resourced setting, it may be appropriate to combine both approaches. Consultant groups may prepare methodological guides and senior academics or industry figures may lead projects examining particular topics. The expertise or reputation of the project leader in such cases can help with the recruitment of participants and the achievement of results. Regardless of the type of team responsible for executing the project or programme of work, the Government should ensure it has sufficient absorption capacity for technology assessment and technology foresight expertise, which is critical in integrating results into policy formulation effectively, ensuring that insights are both relevant and adequately considered. In addition, the Government needs to be capable of asking the right questions to guide assessments. If technology assessment is primarily conducted as a service for parliaments and committees, these bodies require a designated liaison unit responsible for coordinating such activities. In contrast, technology foresight activities may necessitate the establishment of an office under a particular ministry, while maintaining links with others, or direct reporting lines to the head of State, the highest-level decision-making authority or, where applicable, the most senior science, technology and innovation official.

49. Determining whether activities will involve a more technology assessment-oriented focus on short-term issues and responses or a more technology foresight-oriented focus on long-term challenges and opportunities is another key consideration. Ideally, both should be undertaken, but circumstances, and particularly crises, affect the urgency with which each is set in motion. Given the recurrent need of policymakers to have rapid advice on emerging technology-related issues, ready recourse to an institution and/or network that can provide adequate evidence is almost always important. Another way to frame this question is to consider the extent to which there should be a division of labour between groups focused on shorter-term and those focused on longer-term issues.

50. Technology assessment and technology foresight functions are often undertaken jointly. In some developed countries, separate institutions handle these functions, with technology assessment bodies providing immediate advice to parliamentarians on shorter-term issues and technology foresight bodies informing strategic policymaking. Global platforms that could work to raise the standard of technology assessment and technology foresight in general could be established and could support countries embarking on related activities for the first time or from a fairly limited base.

51. In this regard, developing countries may wish to consider the following suggestions:

(a) Initiate or strengthen dedicated institutions for technology assessment and technology foresight, to scope projects that inform science, technology and innovation-related policy decisions, since proper scoping is critical in ensuring that projects are aligned with national and regional priorities;

(b) Identify champions to advocate for technology assessment and technology foresight exercises, ensuring cross-government collaboration and the effective implementation of recommendations from both practices;

(c) Maintain independence, to prevent bias in assessments, ensuring that the use of technology assessment and technology foresight does not simply reinforce existing policies but provides objective insights;

(d) Embed considerations of social justice and environmental sustainability and actively involve women, marginalized communities and diverse stakeholders, to ensure inclusive policy outcomes from technology assessment and technology foresight;

(e) Adapt technology assessment and technology foresight to national and subnational contexts, to ensure relevance and effectiveness in addressing local challenges;

(f) Break down silos between ministries by promoting cross-sectoral technology assessment and technology foresight activities, to address complex, overlapping issues in science and technology;

(g) Explore collaborations across national and regional borders, to pool resources and address shared challenges effectively;

(h) Explore the potential of artificial intelligence and other digital technologies to enhance technology assessment and technology foresight exercises;

(i) Build capacity to undertake technology assessment and technology foresight at the national and, where appropriate, regional levels.

52. The international community may wish to consider the following suggestions:

(a) Focus on identifying and mobilizing resources for technology assessment and technology foresight exercises through appropriate sources and help countries leverage successful technology assessment and technology foresight models;

(b) Develop methodological standards for technology assessment and technology foresight at the international level, to promote mutual understanding and learning of both practices across national and regional contexts, to enable consistent comparisons across countries and to promote the use of shared tools, to address global technological challenges;

(c) Build national capabilities to conduct technology assessment and technology foresight projects independently, reducing reliance on external expertise in order to ensure sustainable and long-term capacity for innovation and policy formulation;

(d) Create a global framework to provide technical assistance, funding and knowledge-sharing for countries developing technology assessment and technology foresight capabilities;

(e) Formulate guidance for United Nations Member States on technology assessment and technology foresight in the context of developing policies for rapid technological change, with focus areas related to artificial intelligence, robotics, biotechnology and the energy transition;

(f) Harness the Commission on Science and Technology for Development as a forum for strategic planning and sharing lessons learned and best practices in technology assessment and technology foresight exercises.

53. The Commission on Science and Technology for Development is invited to consider taking the following steps:

(a) Facilitate resource mobilization for developing countries and promote best practices in technology assessment and technology foresight implementation using successful models;

(b) Align methodological standards for technology assessment and technology foresight, to enable consistent global assessments and facilitate comparisons of national results;

(c) Encourage regional collaboration through joint studies, workshops and reports on technology assessment and technology foresight, to address global challenges and advance on achieving the Sustainable Development Goals.