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High-level segment on building back better from the coronavirus disease (COVID-19) while advancing the full implementation of the 2030 Agenda for Sustainable Development: high-level policy dialogue, including future trends and scenarios related to the Council theme and the long-term impact of current trends

Long-term future trends and scenarios: impacts on the realization of the Sustainable Development Goals

Report of the Secretary-General

Summary

The present report serves to inform the high-level segment of the Economic and Social Council in July 2022. It complements the report of the Secretary-General on the theme of the 2022 session of the Council (E/2022/57). It is aimed at supporting policymakers in looking beyond today's crises and emergencies and reflecting on scenarios on how the world can reach the Sustainable Development Goals and its climate change objectives. It responds to the General Assembly mandate for the high-level segment of the Council. It builds on the call of the Secretary-General, in his statement presenting Our Common Agenda, that we must make full use of our unprecedented capacity to predict and model the impact of policy decisions over time.

The present report takes stock of recent technological and policy trends and their impacts on the achievement of the Sustainable Development Goals. It concludes that the world's actions in the past year have largely not been in line with the global "best-case scenario" (the low energy demand(LED) better futures scenario) highlighted in previous reports (E/2020/60 and E/2021/61). It also, however, highlights several positive developments that indicate a possible acceleration of the global sustainable energy transition and policy action towards net-zero greenhouse gas emissions, while promoting energy access, as an enabler for all Sustainable Development Goals.

The report further outlines a new possible sustainable development pathway developed by eminent scientists that would enable the realization of the Sustainable Development Goals and global climate aspirations. The sustainable development

pathway would result from policies that build on new insights on synergies and trade-offs among the Goals and pursue decent living standards for all. It would also be made possible through the use of a wide range of new technologies. This includes, in particular, using the significant untapped potential of digital innovations aimed at responding better and more effectively to the needs of consumers and at improving related production and other processes. It offers an inclusive and effective path for the achievement of the 2030 Agenda for Sustainable Development in the context of the decade of action and delivery for sustainable development. It identifies several urgent actions that should be taken today in order to deliver on sustainable development and our climate objectives in the coming years and by 2050.

I. Introduction

1. The present report serves to inform the high-level policy dialogue on future trends and scenarios and the long-term impact of current trends on the realization of the 2030 Agenda for Sustainable Development of the Economic and Social Council,[1] to be held on 18 July. It takes a long-term future perspective towards 2030 and beyond. It thus complements the report of the Secretary-General on the theme of the 2022 session of the Council (E/2022/57), which discusses the most recent efforts to recover and build back better from the coronavirus disease (COVID-19) pandemic and their immediate implications.

2. The 2030 Agenda for Sustainable Development outlines a broad, aspirational vision "for people, planet and prosperity". Its Sustainable Development Goals and targets provide a vision of the world that all countries would like to achieve by 2030[2] and a road map to that end. The 2030 Agenda outlines policy recommendations and actions, including quantitative targets. However, it does not offer precise guidance on how coordinated actions could feasibly unfold over time to reach the Goals. This is what scenarios are designed to explore.

3. Scenarios are critical tools for making sound policy decisions to advance the Sustainable Development Goals. They are consistent and plausible paths describing developments in the future. They coherently bring together scientific and technical knowledge from all relevant disciplines and sources to improve understanding of possible future developments and support decision-making. Policymakers often refer to scenarios as pathways, a term that is used synonymously in the present report. However, scenarios are not predictions. Instead, scenario analysts make assumptions about an inherently uncertain future and ask "if/then" questions. Scenarios focus on identifying solutions that do not breach physical, technical, economic or sociopolitical boundaries but that truly add up and are grounded in the best available science and evidence. The Summit of the Future, to be held in September 2023, will be the opportunity to consider possible pathways to achieve the better world envisioned in the 2030 Agenda and protect the planet.

4. In 2020, the Secretary-General presented the "low energy demand (LED) better futures scenario" as a best-case scenario for the achievement of the Sustainable Development Goals and sustainable development by 2050 (see E/2020/60). In the report, he highlighted what is at stake by contrasting the LED scenario with prominent business-as-usual and worst-case scenarios. It considered the potential long-term consequences of near-term decisions in two areas: responses to COVID-19; and new Internet and artificial intelligence technologies. The report suggested that actions in these two areas might strongly influence our capacity and available options to deal with the other significant sustainability challenges that humankind is facing in the long term.

5. In 2021, the Secretary-General took stock of the extent to which the world's actions in the past year had been in line with the LED better futures scenario and what could be done in the near term for the world to be placed on that desirable pathway (see E/2021/61). This near-term analysis was undertaken in particular in the context of tapping into the potentially large benefits of digital consumer innovations in order

[1] In accordance with General Assembly resolution 72/305, the final day of the high-level segment of the Council, following the ministerial segment of the high-level political forum, will focus on "future trends and scenarios related to the Council theme, the long-term impact of current trends, such as the contribution of new technologies, in the economic, social and environmental areas on the realization of the Sustainable Development Goals, based on the work of the United Nations and other regional and international organizations and bodies as well as other stakeholders. It should aim at enhancing knowledge-sharing and regional and international cooperation".

[2] With selective targets for other years.

to transform end-use efficiencies in transport, buildings, food and energy. The report provided further details on how the LED scenario outperforms many other sustainable development scenarios, both in terms of achieving the entire range of Sustainable Development Goals and in terms of achieving high living standards that provide far more than basic needs for everyone. It again took stock of trends in COVID-19 responses and digitalization and concluded that, despite some positive signs, the world was not on track to achieve its aspirational long-term goals.

6. The present report builds on the reports of the past two years. It takes stock of the extent to which the world's actions in the past year have been in line with the LED scenario or other sustainable development pathways that would enable the achievement of the Sustainable Development Goals and the world's climate aspirations. It provides an outline of a new sustainable development pathway and of how these pathways address Sustainable Development Goal synergies and trade-offs, how they propose to achieve decent living standards for all, and the role of new technologies. It also contains a discussion of the potential impacts of recent technological and policy trends that promise an acceleration of the global sustainable energy transition.

II. What it may take to achieve the Sustainable Development Goals: the low energy demand better futures scenario and alternative sustainable development pathways

7. Since the United Nations Conference on Sustainable Development (Rio+20 Conference) in 2012, many scenario modelers have developed global sustainable development scenarios. Since 2015, they have also developed more specific Sustainable Development Goal scenarios emphasizing economic, technological or political approaches. However, in the past eight years, unabated global increases in the use of energy, materials and land, together with their associated environmental, social and health consequences, have required analysts to make increasingly ambitious assumptions to arrive at scenarios in which the Sustainable Development Goals could be achieved in the remaining years leading up to 2030.

8. For example, to limit global warming to the 1.5 degrees Celsius goal, in 2019 the United Nations Environment Programme (UNEP) estimated that greenhouse gas emissions would need to be reduced by 7.6 per cent per year until 2030, compared to a reduction of only 3.3 per cent per year, had decisive action already been taken 10 years prior.[3] For comparison purposes, global carbon dioxide (CO_2) emissions declined by 6.4 per cent in 2020 owing to the COVID-19 crisis.[4] Successive reductions of this magnitude would be required, every year, for the entire decade. Instead, energy-related CO_2 emissions increased by 6 per cent, or 2 billion tons, in 2021, the largest absolute annual increase ever, primarily owing to increased use of coal. With every passing year, the attainment of internationally agreed climate goals through emissions reductions alone has become more challenging. Attaining those goals is critical for realizing all the Sustainable Development Goals and for the future of humanity.

9. To achieve the required ambitious goals, many scenario analysts have long stressed the determining role of technological fixes, such as bioenergy with carbon capture and storage, to produce negative emissions at a large scale, especially 30 years from now. While mostly theoretical until a few years ago, many demonstration projects on such technologies have now appeared. However, many issues related to the deployment of these technologies at scale remain to be resolved, such as the

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[3] United Nations Environment Programme (UNEP), *Emissions Gap Report 2019* (Nairobi, 2019).

[4] Jeff Toleffson, "COVID curbed carbon emissions in 2020 – but not by much", *Nature*, vol. 589, No. 7842 (January 2021).

logistics of safely storing billions of tons of CO_2 every year and the potential impacts on ocean and terrestrial ecosystems.

A. The new approach advocated by the Secretary-General in 2021: the low energy demand better futures scenario to achieve the Sustainable Development Goals and decent living standards for all

10. Against this backdrop, in 2018, several eminent scenario analysts and scientists took a different approach and designed an aspirational pathway inspired by the latest technological developments, behavioural change and high impact business innovations. The scenario is aimed at achieving the Sustainable Development Goals while making exceptional progress on sustainable consumption and production (Goal 12) through rapid transitions to lower energy demand and very high-efficiency end-use technology and practices in energy, water, land and materials usage.

11. This low energy demand (LED) scenario[5] would enable the achievement of the Sustainable Development Goals and the 1.5 degree climate target without relying on negative emissions technologies. As a result, hundreds of millions of hectares of cropland could be spared. The scenario was featured in the report of the Intergovernmental Panel on Climate Change entitled "Global warming of 1.5°C" and is one of two scenarios highlighted in the contribution of Working Group III to the sixth assessment report of the Panel, published in April 2022.[6]

12. Based on the original energy scenario, consistent, detailed scenario implementations were developed for land use and food (the "better futures" scenario),[7] water[8] and other Sustainable Development Goals areas. The result, the combined LED better futures scenario, translates into important benefits for all Goals. Related but somewhat different scenarios have also been developed by the Netherlands Environmental Assessment Agency[9] and the International Energy Agency.[10,11]

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[5] Arnulf Gruebler and others, "A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies", *Nature Energy*, vol. 3, (2018), pp. 517–525.

[6] Valérie Masson-Delmotte and others, eds. *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* (Intergovernmental Panel on Climate Change, 2018).

[7] Food and Land Use Coalition, *Growing Better: Ten Critical Transitions to Transform Food and Land Use* (2019).

[8] Simon Parkinson and others, "Balancing clean water-climate change mitigation trade-offs", IIASA Working Paper, No. WP-18-005. (Laxenburg, Austria, International Institute for Applied Systems Analysis, 2018).

[9] Detlef P. van Vuuren and others, "Integrated scenarios to support analysis of the food–energy–water nexus", *Nature Sustainability*, vol. 2, No. 12 (December 2019), pp. 1132–1141; Detlef P. van Vuuren and others, "Alternative pathways to the 1.5 °C target reduce the need for negative emission technologies", *Nature Climate Change*, vol. 8, No. 5 (May 2018), pp. 391–397; and Detlef P. van Vuuren and others, "Pathways to achieve a set of ambitious global sustainability objectives by 2050: explorations using the IMAGE integrated assessment model", *Technological Forecasting and Social Change*, vol. 98 (2015), pp. 303–323.

[10] International Energy Agency sustainable development scenario, contained in the World Energy Model – scenario analysis of future energy trends (*World Energy Outlook 2019*).

[11] International Institute for Applied Systems Analysis, Low Energy Demand database, available at https://db1.ene.iiasa.ac.at/LEDDB, as related to Gruebler and others, "A low energy demand scenario for meeting the 1.5°C target"; and International Institute for Applied Systems Analysis, Shared Socioeconomic Pathways database, version 2.0, available at https://tntcat.iiasa.ac.at/SspDb, as related to Keywan Riahi and others, "The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: an overview", *Global Environment Change*, vol. 42 (2017), pp. 153–168.

13. The key goal of the LED better futures scenario is to reduce overall global energy, water and land use, despite increasing population and economic activity and rapidly increasing living standards. This is possible owing to the significant untapped potential for increasing end-use efficiencies through a combination of technological, behavioural and business innovations and would entail a transition fuelled by information and communications technology.

14. The scenario describes a world that becomes increasingly interconnected and focused on education, science and technology. It is a world with rapid global diffusion of technology, in which open science is leveraged for sustainable development. Many digital technologies and artificial intelligence applications would be deployed, vastly increasing service efficiencies. In what becomes a high-technology interconnected world, the Sustainable Development Goals are achieved by 2030, and broader sustainability by 2050.

15. The scenario outperforms alternative scenarios in terms of progress on achieving the Sustainable Development Goals. It also foresees rapid improvement in living standards in developing countries to a level far beyond the basic services described in the Sustainable Development Goals, or "decent living standards", essentially enabling such countries to catch up with the developed world. At the same time, global energy and resource use would decline. Decent standard of living requirements ensure that people have the means to pursue a decent life and include amenities that ensure good health and quality of life and enable people to engage with society.[12]

16. All of the above is achieved through overall strategies to (a) electrify energy end use worldwide; (b) bring homes, appliances and transport modes to the technological efficiency frontier; (c) support multifunctionality through the convergence of multiple services onto single devices or business models; (d) promote a generational shift from the ownership of material goods to the accessing of services; (e) increase the utilization rates of goods, infrastructure and vehicles (sharing and circular economy); (f) promote user-oriented innovation; (g) ensure decentralization, allowing new roles for end users not just as consumers but also as producers, innovators and traders; and (h) achieve pervasive digitalization and rapid innovation in granular technologies.

17. The LED better futures scenario shows the way towards a highly desirable sustainable future, with multiple benefits and the potential for preventing various global sustainability crises. With so much at stake, current policies and actions must be closely assessed against this pathway. While there are important and promising new technological and policy developments that have the potential to accelerate the world's transition towards such an optimal scenario (see sect. III below), at the global scale the world has not been on track, either in terms of the required end-use transformations or in in terms of behavioural changes.

B. An updated sustainable development pathway consistent with the Sustainable Development Goals

18. While the LED better futures scenario may still be the world's best bet to achieve the Sustainable Development Goals and broader sustainable development in the coming decades, in view of the latest unsustainable trends, alternative sustainable development pathways have been developed and were presented by leading scientists in 2021. They quantify the entire range of the Goals. The resulting findings provide a

[12] Narasimha D. Rao and Jihoon Min, "Decent living standards: material prerequisites for human wellbeing", *Social Indicators Research*, vol. 138, No. 1 (July 2018), pp. 225–244.

pragmatic portfolio of actions to embark on a path towards achieving most of the Goals despite the unsustainable existing infrastructure and recent trends.[13,14]

19. In contrast to the LED scenario, the sustainable development pathway scenario does recognize the recent findings of Working Group III of the Intergovernmental Panel on Climate Change that, to achieve the climate goals, negative emissions technologies will ultimately be needed at a sizable scale. The sustainable development pathway scenario developers explored six broad clusters of interventions in the areas of development: resource efficiency and lifestyle changes; climate mitigation; shifts in consumption patterns (energy and land use); international climate finance; and national poverty alleviation programmes financed from carbon pricing revenues. Key elements of the sustainable development pathway scenario are outlined below.

20. **Planetary integrity**: the sustainable development pathway scenario shows a path towards good progress towards achieving Sustainable Development Goals 13, 14 and 15. Greenhouse gas emissions are reduced to 33 and 10 billion metric tons CO_2 equivalent in 2030 and 2050, respectively. Sizable reductions in agricultural methane and nitrous oxide emissions beyond what is common in other 1.5 degree scenarios in the literature limits the required scale of negative emissions. The overall warming slightly overshoots 1.5 degrees by 2050 and reaches approximately 1.3 degrees by 2100. Importantly, ocean acidification is limited to a level that does not further endanger marine organisms, such as corals, clams, oysters and some plankton. The scenario also shows a path towards decreasing annual human-induced nitrogen fixation to conserve primary forests, halt biodiversity loss and reverse some of that loss, all by 2050.

21. **Provision of material needs and sustainable resources** (Sustainable Development Goals 2, 6, 7 and 12): the sustainable development pathway scenario achieves zero hunger by 2050 and a halving of malnourishment by 2030. Food waste is reduced and agricultural water use is reduced by a quarter by 2050. This reduces the economic pressures that cause higher food prices. Annual per capita energy use for buildings and mobility almost doubles by 2030 and more than triples by 2050.

22. **People** (Sustainable Development Goals 1, 3, 4 and 5): in the sustainable development pathway scenario, extreme poverty could be reduced to 180 million (or about 2 per cent of the population) by 2030, compared to 750 million in 2015, and poverty eradication could be achieved by 2050. It leads to 5 and 25 million fewer life years[15] lost by 2030 and 2050, respectively, but the health impacts of air pollution remain above World Health Organization target levels. In the sustainable development pathway scenario, all young people will have benefited from a school education by 2030.

23. **Prosperity** (Sustainable Development Goals 8, 9, 10 and 11): income grows rapidly in the developing world, converging towards that of the developed world, but regional disparities remain. The within-country relative poverty rate decreases from 19 per cent in 2015 to 15 per cent by 2050. The clean energy share in industry grows slowly to 26 per cent by 2030 and more rapidly to 62 per cent by 2050. Urban air pollution is reduced by 40 per cent by 2050.

24. **Institutions and partnerships** (Sustainable Development Goals 16 and 17): the sustainable development pathway scenario assumes a general increase and convergence in institutional quality across the board. It thus requires making institutions effective, inclusive and accountable, as decided in Sustainable

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[13] Bjoern Soergel and others, “A sustainable development pathway for climate action within the UN 2030 Agenda”, *Nature Climate Change*, vol. 11, No. 8 (August 2021), pp. 656–664.

[14] This work is ongoing in the form of a multi-model scenario projects entitled “Sustainable development pathways achieving human well-being while safeguarding the climate and planet Earth (SHAPE)”, results for which are expected by summer 2022. See https://shape-project.org.

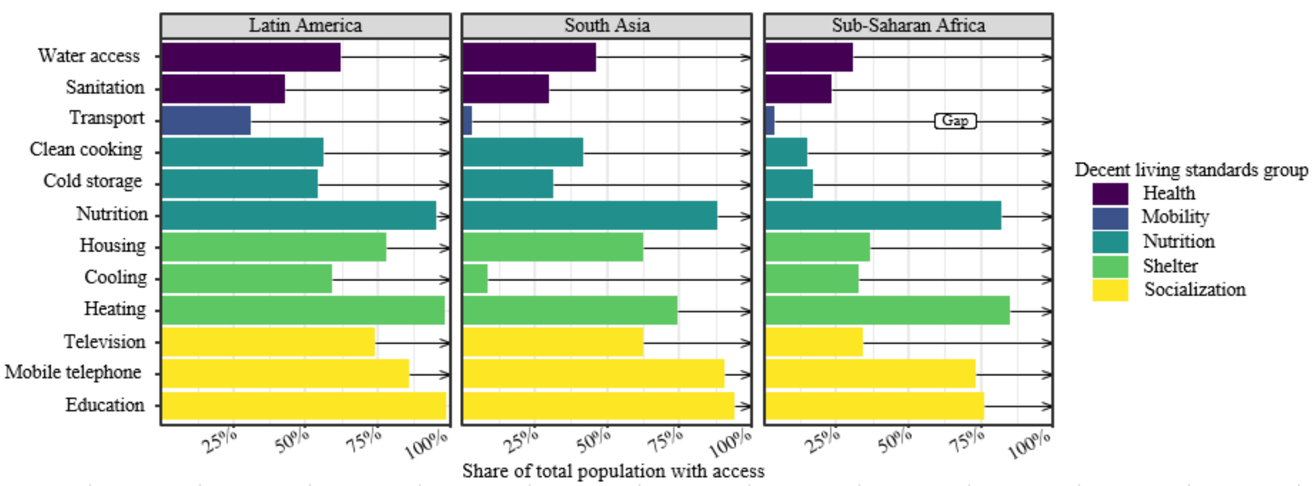
[15] Disability adjusted.

Development Goal 16. International climate financing is increased beyond the current $100 billion target to $350 billion by 2030 and $910 billion by 2050. The sustainable development pathway scenario explores the outcomes of a significant part of these funds being used to finance poverty alleviation rather than being reinvested in new infrastructure and technologies. This means drastically increasing public and private climate resources, which have been insufficient for years.

C. Decent living standards for all

25. The sustainable development pathway scenario shows a pathway towards ensuring decent living standards for all. The concept of decent living standards goes well beyond basic services and the eradication of poverty. It addresses nutrition (food, preparation and conservation), shelter (housing, thermal comfort), health (health care, water and sanitation), socialization (education, communication and information) and mobility (motorized transport). Less than one third of the current global average annual final energy consumption per capita is needed to provide decent living standards. The largest per capita gaps are in sub-Saharan Africa, South Asia and Latin America, but regional differences are sizable (see fig. I below). In sub-Saharan Africa, final energy use would need to grow from 20 gigajoules (GJ) per capita now to 31 GJ to fill the gap. Under the Intergovernmental Panel on Climate Change "middle-of-the-road" scenario, 89 exajoules[16] will be required for new infrastructure for all in sub-Saharan Africa by 2050.

Figure I
Decent living standards provision in 2015



Source: Jarmo S. Kikstra, Setu Pelz and Shonali Pachauri, "Eliminating multidimensional poverty by providing decent living standards for all" (May 2022).[17]

26. The energy gaps that prevent the achievement of decent living standards across regions are most significant in terms of transport, but there are also sizable gaps in the areas of clean cooking, cold storage, sanitation and cooling. The cooling gap is

[16] Jarmo S. Kikstra, Setu Pelz and Shonali Pachauri, "Eliminating multidimensional poverty by providing decent living standards for all", Science-policy brief for the Multistakeholder Forum on Science, Technology and Innovation for the Sustainable Development Goals, held in May 2022, in the Interagency Task Team on Science, Technology and Innovation for the Sustainable Development Goals (IATT) report 2022.

[17] Ibid.

especially significant in South Asia. In many parts of the global South, cooling is among the fastest growing energy use in buildings, yet only rarely the focus of sustainability efforts. Heat stress affects the health and productivity of billions of people. According to the Cooling for All initiative, at least 3.4 billion people face cooling access challenges in 2021, including 1.1 billion rural and urban poor and 2.3 billion lower- to middle-income people.[18]

27. Across the Intergovernmental Panel on Climate Change's shared socioeconomic pathways scenarios, the global population affected by the cooling gap is estimated to include between 2 and 5 billion people by 2050. To close the cooling gap with air conditioning and fans for the global South, the equivalent of approximately 14 per cent of global residential annual electricity use would be needed. Higher efficiency air conditioning systems could reduce these requirements by approximately 16 per cent, and better insulation by another 34 per cent.[19]

28. Passive design strategies for buildings, such as shading, improved natural ventilation and cool roofs, can improve thermal comfort and reduce energy demand. Evaporative cooling can be an effective and less energy-intensive technology compared to air conditioning in dry climates. Above all, promoting access to electricity (Sustainable Development Goal 7) and to affordable, efficient and low-emitting cooling systems is key for closing the cooling gap while reducing the burden on the environment and reaching climate targets (Goal 13).

D. The role of emerging carbon dioxide removal technologies

29. The Working Group III contribution to the sixth assessment report of the Intergovernmental Panel on Climate Change makes it clear that the 1.5 degrees target will no longer be realistically feasible without a range of carbon dioxide removal technologies. In most of these climate stabilization scenarios, carbon dioxide removal technologies not only offset residual emissions but also achieve net negative emissions to return to 1.5 degrees. Technologies such as direct air carbon capture and storage or bioenergy with carbon capture and storage are being demonstrated at a small scale, and various other carbon dioxide removal technologies are emerging from lab studies. Nature-based solutions such as afforestation, whereby new forests are planted across land without trees, and soil enhancement are in synergy with efforts mitigating biodiversity loss. Many carbon dioxide removal technologies are being explored by Member States and are already mentioned in over 100 updated nationally determined contributions.

30. The mix of carbon dioxide removal technologies deployed in the coming years will have important implications for the achievement of Sustainable Development Goal 14 on oceans and Goal 15 on terrestrial ecosystems. For example, the ocean plays a major role in buffering the global climate system by capturing and storing CO_2 away from the atmosphere. It acts globally as a net sink for anthropogenic CO_2 and significantly reduces the rate of global warming. Coastal vegetated ecosystems, such as seagrass meadows, tidal marshes and mangrove forests, accumulate and store large stocks of organic carbon in their sediment, with rates of burial per hectare that are estimated to be an order of magnitude greater than those of terrestrial forests.

[18] Alessio Mastrucci, Bas van Ruijven and Shonali Pachauri "Closing cooling gaps in a warming world" (May 2022).

[19] Ibid.

III. Recent technological and policy trends that promise an acceleration of the global sustainable energy transition towards net-zero greenhouse gas emissions with an impact on all Sustainable Development Goals

31. Without a successful rapid global sustainable energy transition, most of the other Sustainable Development Goal ambitions will also remain out of reach. Clean energy solutions also have the potential to deliver universal energy access in a way that is safe and powers economic development for everyone.[20]

32. Recent technological and political trends hold promise for accelerating the global sustainable energy transition.[21] While the challenges to achieving a sustainable energy transition towards net-zero greenhouse gas emissions remain significant, especially in terms of globally coordinated investments, increasing political will and promising recent technological developments show a way forward. This includes progress in digital consumer technologies that can help to accelerate the energy transition by "doing more with less".

A. Increasing consensus on the extraordinary challenges and opportunities ahead

33. The global sustainable energy transition is essential for sustainable development progress in all other areas. Since the Brundtland report was published in 1987 (A/42/427), a series of United Nations reports have indicated that the energy transition is one of the most important transitions for achieving sustainable development, as it will be essential for all other sustainability transitions. This includes a comprehensive transformation of the entire energy system, from the extraction of primary energy to end-use and energy services, such as heating, cooling and mobility. A successful transition requires complementary actions beyond the energy sector in transport, housing, industry and agriculture and digitalization.[22] The importance of such a transition is strikingly evident against the backdrop of the climate crisis, the pursuit of the Sustainable Development Goals and the impacts of ongoing conflicts.

34. For several decades, Governments have pursued various policy mixes to build a sustainable energy system to support economic, social and environmental goals, including the Sustainable Development Goals. At the global level, a sustainable energy system should be more integrated, highly efficient, affordable, reliable and cleaner, with rapidly increasing modern renewables capacities and other low-carbon options. While the specific characteristics of such a system at the local or national level depend greatly on local conditions, one common factor is the quest for higher energy densities (energy supplied divided by the land area required for its production, including all relevant infrastructure), especially in places with high population densities.

35. However, the share of fossil fuels in the global energy system has barely changed since 1995, requiring an ever-accelerating global energy transition to achieve climate goals. Despite global agreement on climate goals, in particular Sustainable

[20] Liu Zhenmin, Achim Steiner and Damiola Ogunbiyi, "The energy revolution is here – and here's how to be a part of it", Sustainable Energy for All, 24 June 2021.

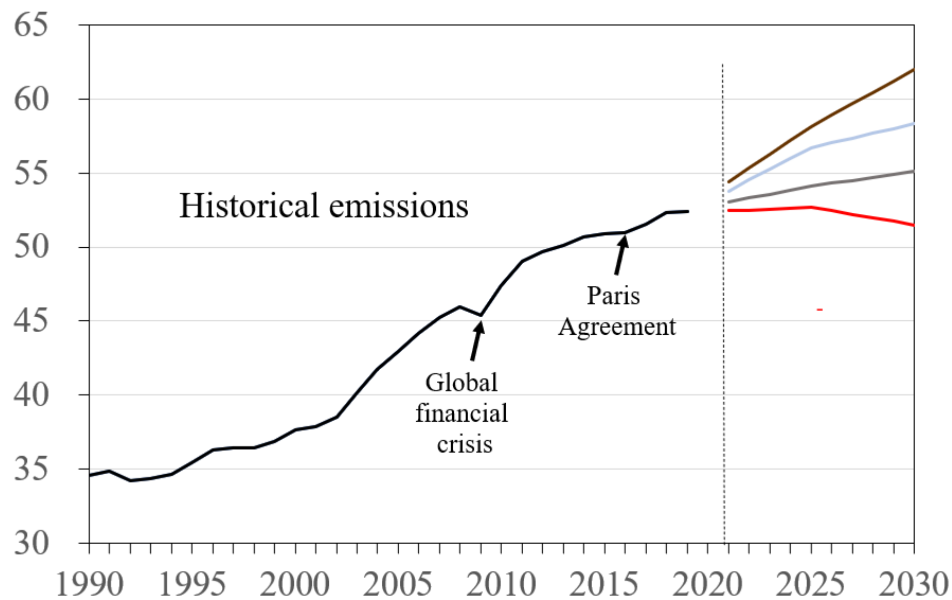
[21] *Financing for Sustainable Development Report 2022* (United Nations publication, 2022).

[22] See, for example, Independent Group of Scientists appointed by the Secretary-General, *Global Sustainable Development Report: The Future is Now – Science for Achieving Sustainable Development* (New York, United Nations, 2019).

Development Goal 13 and the Paris Agreement target of limiting global warming to 1.5 degrees above pre-industrial levels, fossil fuels accounted for just below 85 per cent of global primary energy consumption in 2020, compared to 86 per cent in 1995.[23]

36. Driven by growing global energy demand, greenhouse gas emissions increased rapidly until 2010 and thereafter at slower rates, reaching an all-time high of 52.5 GT carbon dioxide equivalent by 2020 (see fig. II). While the impact of the COVID-19 pandemic reduced CO_2 emissions from fossil fuels by an estimated 5.8 per cent in 2020, emissions are estimated to have reached new record levels by the end of 2021.[24] To achieve temperature goals of either 1.5 or 2 degrees, global greenhouse gas emissions would need to be cut by half by 2030 and reduced to net zero by 2050. To achieve the 1.5 target, greenhouse gas emissions would need to be reduced by 7.6 per cent per year until 2030.[25] The technical feasibility of such a rapid energy transition has been demonstrated in a multitude of studies, but time is running out, and the challenge grows with every year without decisive action.

Figure II
Global greenhouse gas emissions, 1990–2020 and projected until 2030 (in gigatons carbon dioxide equivalent)



Abbreviations: NDC, nationally determined contribution.

Source: Adapted from Synthesis Report by the secretariat on nationally determined contributions under the Paris Agreement (FCCC/PA/CMA/2021/8/Rev.1) (based on 143 nationally determined contributions).

Note: Projections assume full implementation of all the nationally determined contributions to which governments have committed under the Paris Agreement. The top (black) projection line shows the anticipated increase of greenhouse gas emissions based on the commitments as of April 2016. The bottom (red) projection line is based on the commitments as of October 2021, which, if fully implemented, would lead to a peaking of greenhouse gas emissions by 2025, followed by a path of decline. These estimates are subject to significant uncertainty, in terms of timing and absolute levels, and two potential alternative projections are also depicted in the graph, represented by the middle light blue and purple projection lines.

[23] British Petroleum (BP), Energy economics, "Statistical Review of World Energy". Available at www.bp.com (last accessed on 29 January 2022).

[24] UNEP, *Emissions Gap Report 2021: The Heat Is On – A World of Climate Promises Not Yet Delivered* (Nairobi, 2021).

[25] UNEP, *Emissions Gap Report 2019*.

37. Governments have significantly increased their ambitions for clean energy transitions since 2016. Under the Paris Agreement, Governments specify planned greenhouse gas mitigation actions, most of which are centred on the energy sector. Figure II above shows the resulting global greenhouse gas emissions under the assumption that all plans and commitments are fully implemented until 2030. The fan lines depict progressively increased ambitions for greenhouse gas reductions. As of April 2016, commitments would have implied continued emissions increases, whereas by October 2021 (around the time of the holding of the twenty-sixth Conference of the Parties to the United Nations Framework Convention on Climate Change), for the first time ever, government plans envisaged a peaking of emissions by 2025. However, much more ambitious action will be needed to meet the 1.5 degree target. The twenty-seventh Conference of the Parties should be a milestone in this regard, while keeping the focus on adaptation.

B. Fiscal support for a "green" recovery from the coronavirus disease pandemic

38. Fiscal stimulus packages related to COVID-19 were more focused on a sustainable recovery in 2021 compared to 2020. Recent data on public spending policies in the world's 50 largest economies shows that, of a total of $18.2 trillion committed to address the COVID-19 crisis by the end of 2021, only $3.1 trillion was directed to longer-term recovery measures. Longer-term measures are essential to strengthen health and social protection systems, build productive capacities, protect the planet and strengthen other dimensions of sustainable development as part of the recovery.

39. Of the $18.2 trillion, 31 per cent ($970 billion) was allocated for "green" or environmentally compatible spending (see table below). On the one hand, this means that only 5 per cent of the total stimulus has been committed for green recovery packages, raising concerns that public investments may lock into a "business-as-usual" pathway. On the other hand, the share of "green" funding in recovery measures greatly increased, from 18 per cent in 2020 to 51 per cent in 2021, as new initiatives with longer lead times were incorporated into public budgets.[26]

Fiscal stimulus packages in response to the coronavirus disease pandemic in 2020 and 2021, worldwide

(Billions of United States dollars)

		Recovery measures		
	Rescue efforts	*Green*	*Not green*	*Total*
2020	11 100	341	1 553	14 594
2021	3 931	629	606	5 166
Both years total	**15 031**	**970**	**2 159**	**18 160**

Source: Global Recovery Observatory.

40. Green recovery spending was concentrated in a few countries, also reflecting the concentration of financial recovery packages, with a focus on sustainable energy. Countries that committed at least 1 per cent of gross domestic product (GDP) and spent at least 30 per cent of recovery funding in an environmentally compatible manner

[26] Oxford University Economic Recovery Project, "Global Recovery Observatory". Available at https://recovery.smithschool.ox.ac.uk/tracking/ (last accessed 30 January 2022).

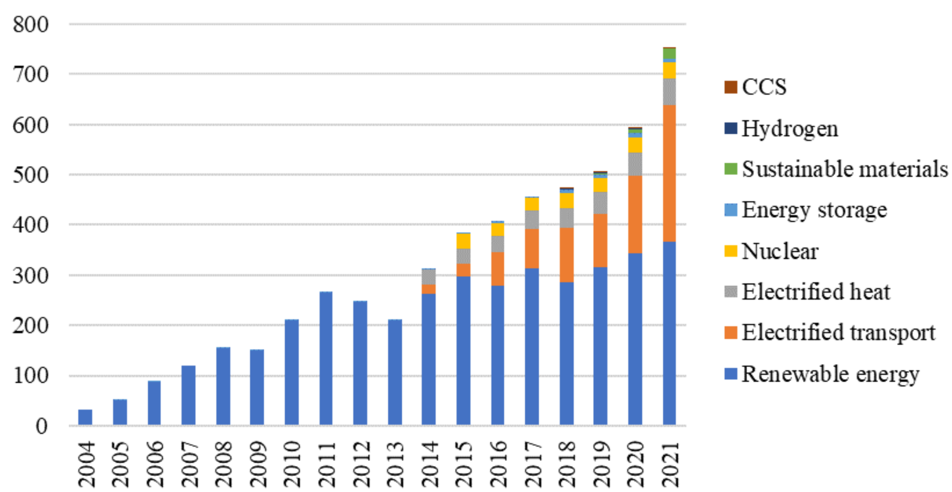
included primarily European countries, as well as Canada and the Dominican Republic.[27] In 2020, most green recovery spending was committed to new electric and hydrogen-fuelled transport and infrastructure, public transport, low-carbon energy supply and infrastructure, energy-efficient building upgrades, and green research and development for decarbonizing aviation, plastics, agriculture and carbon sequestration.

41. The large-scale financial stimulus packages show the feasibility of closing the remaining gap on the unfulfilled promise of $100 billion per year in climate finance for developing countries. The stimulus packages in the sample in 2020 accounted for 23 per cent of GDP in advanced economies and 11 per cent of GDP in emerging market and developing countries. This shows the possibility of raising trillions of dollars on short notice, provided there is political will. The time to muster such political will is now.

C. Total investment in the sustainable energy transition continues to grow

42. In 2021, the public and private sector together invested an estimated $755 billion in the global energy transition. Most of it (approximately $360 billion), was invested in modern renewable energy, a level that has stayed roughly constant since 2015 after rapid increases in the previous 10 years. Falling costs, however, imply continued growth in the annual installed capacities of renewables. More than half of the modern renewable investments were in solar photovoltaic energy. Since 2016, most of the increase has been in electrified transport and electrified heat, with smaller investments in nuclear energy and, most recently, sustainable materials. Much less was invested in energy storage, carbon capture and storage and hydrogen (see fig. III below).[28]

Figure III
Global energy transition investments, 2004–2021
(Billions of United States dollars)



Source: BloombergNEF.
Note: Start years differ by sector, but all sectors are present from 2019 onwards.

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[27] Oxford University Economic Recovery Project, Global Recovery Observatory, "Are we building back better update – COP26: Governments are not reorienting their economies to a green future and vulnerable nations are being left behind" (October 2021).

[28] BloombergNEF, "Energy transition investment hit $500 billion in 2020 – For first time", 19 January 2021.

43. Private sector interest in the sustainable energy transition is also reflected in the market capitalizations of various technology companies. For example, the market capitalization of electric vehicle specialists increased more than fivefold from January 2020 to January 2021, when their value reached that of all traditional automakers combined.

D. New opportunities from recent energy technology and systems innovations

44. A peak in greenhouse gas emissions by mid-decade, as envisioned by political commitments, is technologically feasible. Technological change and innovations have reached critical levels, especially in modern renewables (including solar photovoltaic energy), electric and hydrogen-fuelled transportation and digital consumer innovations.

1. Solar photovoltaic cells

45. A third generation of solar photovoltaic cells is emerging that can overcome the current efficiency limits of conventional solar cells (see E/CN.16/2018/2). Current solar photovoltaic cells are already the only currently available renewable option that could in principle fully support a modern, highly energy-intensive civilization. While their power densities would still be 10 to 100 times less than fossil fuels, they represent a feasible option at the global scale, with multiple environmental advantages beyond limiting greenhouse gas emissions. Greater efforts in research and development and knowledge exchange could facilitate a larger-scale deployment of higher-efficiency solar photovoltaic technology in developing countries as a fundamental ingredient of a menu of energy sources for a stable and reliable electricity supply contributing towards ensuring energy access.

46. The production costs of conventional solar photovoltaics have fallen rapidly, making them increasingly cost-competitive, especially when combined with the emerging managed-charging systems for electric vehicles. The reduction in the cost of solar photovoltaics has been much faster than for any other modern renewable.

2. Electrified transport

47. While a sizeable share of rail transport has benefited from electrification for many decades, recent technological progress has enabled an increasing electrification of passenger road vehicles. The state-of-the-art batteries used in fully battery-powered passenger vehicles have[29] become a viable option for a wide range of applications. Meanwhile, the cost of lithium ion batteries has considerably decreased.[30] However, while today's leading lithium ion batteries have much higher power densities than just a few years ago, they remain rather heavy and bulky (easily increasing the weight of a car by half), which continues to limit the environmental benefits of electric vehicles.

48. Digital technologies are key to building smart-charging infrastructure. Without making full use of such digital opportunities, the introduction of fully electric vehicle fleets would require a significant expansion of electricity generation capacities.

3. Hydrogen

49. Hydrogen produced from low-carbon and renewable sources has become an energy storage option that could replace fossil fuels in most areas. Several countries have launched programmes to investigate how to harness hydrogen production from

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[29] Car and Driver, "Best new EVs and hybrids of 2021", 18 February 2021.

[30] Marian Willuhn, "Battery costs have fallen 97% since 1991, claim MIT researchers", *PV Magazine*, 29 March 2021.

renewable sources for storing the energy captured from intermittent new renewable sources such as wind power and solar photovoltaics.

50. Hydrogen has power densities that are six times higher than those of even the best lithium ion batteries, which makes it a better option for long-range transport and heavier vehicles such as trucks, ships and airplanes.[31] This makes hydrogen fuel cells the only viable option for achieving very aggressive emissions reduction targets in transport without fundamental changes in behaviour. However, there remain challenges regarding the handling, storage and safety of hydrogen, leading many governments to support infrastructure for both electric vehicles and hydrogen fuel cell vehicles. The European Green Deal is a case in point.

51. The industrial sector is among the most difficult to decarbonize, but hydrogen fuel offers a path forward. Spurred by new technologies, renewable hydrogen production is rapidly expanding in terms of refining and steel, ammonia and chemicals production, mostly combined with onsite electrolyzers that create hydrogen gas to avoid the issues of hydrogen storage and transport. Following the adoption of the European Green Deal targets, many European countries are pursuing more rapid technological development and deployment of hydrogen technologies.[32]

52. At present, however, most hydrogen production is carbon-intensive: 80 per cent of global hydrogen production is from natural gas, 15 per cent from coal and less than 5 per cent is produced from renewable and low-carbon energy sources. Further scientific and technological progress must be made to overcome this challenge and expand the use of hydrogen in both developed and developing countries.

4. Digital consumer technologies

53. Digital consumer technologies could greatly reduce primary energy demand, making the global sustainable energy transition easier to achieve. A range of digital consumer-facing innovations in buildings, mobility, food, and energy distribution and use are readily available for local adaptation and deployment across the world. Some of them appeal to low-end and price-sensitive users, whereas others appeal to high-end market and technophile users.

54. Estimates of potential energy and greenhouse gas savings vary, pointing to the importance of context, local adaptation and user behaviour; in some cases, energy demand may increase. For example, digitally enabled home energy systems have led in some cases to energy savings of 91 per cent, while in some outlier cases they increased energy use by 9 per cent (see E/2021/61).

55. Consumer innovations that change how energy is supplied to, generated by or managed by households can also help to reduce greenhouse gas emissions. For instance, fully autonomous vehicles, electric vehicles and e-bikes could lead to large reductions in greenhouse gas emissions, but they could also increase energy use owing to changed behaviours.

E. Global cooperation and investment needs for the energy transition

56. To make use of these opportunities, the energy transition and the promotion of access to sustainable energy must be a global effort. Greatly enhanced levels of international cooperation in technology, finance, knowledge-sharing and concerted

[31] United States Department of Energy, Office of Technology Transitions, *Spotlight: Solving Challenges in Energy Storage* (Washington, D.C., 2019), updated July 2019.

[32] Fuel Cells and Hydrogen 2 Joint Undertaking, *Hydrogen Roadmap Europe: A Sustainable Pathway for the European Energy Transition* (Luxembourg, Publications Office of the Union, 2019).

joint action are needed to achieve a global energy transition at the scale required to meet the 1.5 degree target while securing energy access. Cooperation also makes economic sense, as mitigation costs in developing countries tend to be much lower than in developed countries. However, because of a myriad of other factors, incentives must also be geared towards reducing emissions and providing affordable, reliable and clean energy services everywhere.

57. Some developed countries have achieved reductions in emissions by shifting energy-intensive manufacturing and production to emerging economies. This underscores the importance of global solutions. The global manufacturing share of developed countries fell from over 80 per cent in 1995 to approximately 50 per cent in 2019, and the vast majority of the world's ammonia, steel, cement and plastics production is now taking place in emerging and developing economies.[33] This has intensified discussions about CO_2 border tax adjustments, which would align incentives towards emissions reduction but could potentially constrain the flow of technologies, skills and knowledge that are so essential for making global progress.

58. Developing economies[34] have seen reductions in energy investments by 20 per cent since 2016 and a reduction in clean technology transfer.[35] While much of this is related to reduced spending on oil and gas supply, this trend also reflects challenges these countries face in mobilizing finance for capital-intensive, lower-carbon energy projects, which have been worsened by the COVID-19 crisis. Without strengthened global cooperation and financial instruments, the world will not benefit from the much lower greenhouse gas mitigation costs in these countries.

59. Sustainable energy investments must quadruple in developing countries, including through increases in private financing. The International Energy Agency estimates that annual investments of $600 billion would be needed in developing countries by 2030 to limit the rise in global temperatures to 1.65 degrees, and over $1 trillion to achieve net-zero greenhouse gas emissions by 2050 and limit the global temperature rise to 1.5. This must be accompanied by other investments to allow ensuring access to sustainable energy in developing countries, such as in related sustainable infrastructure.

60. While public sources of finance are dominant in today's energy investments in these countries, the International Energy Agency estimates that more than 70 per cent of new, sustainable energy investments, primarily renewables and efficiency, would need to be privately financed by the second half of the current decade. This appears to be feasible, given the high average private returns on such investments. State-owned enterprises and development finance institutions can continue to play a role, especially in terms of reaching remote and underserved communities. With renewables, the capital structure of investments is also expected to move towards more debt, with important implications for capacity-building and skills requirements.[36]

"Doing more with less": digital consumer innovations for energy efficiency gains

61. Digital consumer innovations provide a ready option to "do more with less" by increasing energy efficiency, which would reduce overall investment requirements. A large-scale deployment of technological and behavioural action in areas with untapped potential (such as digital consumer innovations in mobility, food, buildings and energy services) could help to reduce global energy and resource needs despite

[33] In particular, as China became the "workshop of the world", its per capita CO_2 emissions are now higher than those of most European countries.

[34] The figures related to developing countries in these paragraphs do not include China.

[35] International Energy Agency, *Financing Clean Energy Transitions in Emerging and Developing Economies* (Paris, 2021).

[36] Ibid.

rapid increases in living standards. This would make it possible to achieve the 1.5 degree climate target through the deployment of renewable energy without relying on negative emission technologies (see E/2021/61).

62. Such a shift could reduce overall investment requirements for the sustainable energy transition but increase investments in energy end use. This would require the rapid electrification of energy end use, pervasive digitalization and innovation in granular technologies, together with a shift from the ownership of material goods to accessing services, and would need to be supported by strengthened global cooperation on science, technology and innovation.

63. As a result, investment requirements for fuel systems, power plants and networks would need to increase only slightly by 2030. Investments in energy end use and services and related business opportunities would need to initially quadruple, from $0.4 trillion to $1.6 trillion, but much of it would benefit consumers through lower costs for electricity and fuel.

64. This pathway would also have important co-benefits in the food and land use system. Compared with current trends, it could double the growth of rural incomes and create an additional 120 million decent jobs. Agricultural productivity could be increased by more than 1 per cent per year and food loss and waste reduced by a quarter (ibid.). This would also provide additional benefits to developing countries while working towards securing energy access.

IV. Issues for consideration

65. The sustainable development pathways show that the Sustainable Development Goals and the world's climate targets are still within reach. Despite the COVID-19 crisis, decent living standards for all, including in developing countries, can still be ensure, malnourishment can be halved by 2030, zero hunger achieved by 2050, extreme poverty reduced to 180 million people by 2050 and rapid income growth in developing countries ensured. For this to happen, the world must adopt the right policies and step up investments, research and the sharing of technology, with sustainable development as the ultimate objective. Effective governance and institutions are critical, as is peace. International cooperation and solidarity is the sine qua non condition for realizing the sustainable development pathways. The present report shows that supporting the energy transition is a powerful enabler for realizing all these advances and the Sustainable Development Goals. Considerable advances are being made in this regard. However, in all areas, there is a need for political will, focus, continuing research and development, and international cooperation and solidarity. There is no time to lose.

66. The following issues may be considered by Member States and other stakeholders in order to support policymaking for a successful decade of action and complement the policy issues for consideration proposed in the report of the Secretary-General on the theme of the 2022 session of the Economic and Social Council (E/2022/57):

(a) Action inspired by sustainable development pathways:

(i) Use the Summit of the Future, to be held in September 2023, to explore scenarios, such as the sustainable development pathways, that can help guide efforts, policies, financial resources and science and technology towards achieving the Sustainable Development Goals;

(ii) Dedicate a greater share of the resources from COVID-19 recovery packages to long-term objectives and to actions to protect people and the planet;

(iii) Build capacities in scenario analysis and science and technology futures at the national level and support peer learning on tools, insights and institutional arrangements;

(iv) Design plans and share technology to achieve decent living standards for all as a matter of priority;

(b) Accelerate the energy transition and progress towards energy access:

(i) Accelerate actions to implement Sustainable Development Goal 7 on affordable, sustainable and reliable energy for all (implementing the road map and delivering on the energy compacts launched at the General Assembly high-level dialogue on energy, held in September 2021, will go a long way towards this end);

(ii) Consider the long-term sustainable development implications of science and technology policy, plans and programmes in the energy sector, including their linkages to other sectors, in particular plans and programmes related to digitalization;

(iii) Build and further support recent breakthrough developments supporting the energy transition as an enabler for realizing all Sustainable Development Goals (this includes advances in electrified transport, hydrogen in industry and transport, new generation solar photovoltaics, and carbon dioxide removal technologies) and unlock the large untapped potential of digital consumer innovations in mobility, food, buildings and energy services;

(c) Countries and stakeholder cooperation:

(i) Strengthen international cooperation on scenario analysis and science and technology solutions for the Sustainable Development Goals, including energy transition and access (the proposals in Our Common Agenda, such as the Futures Lab and the Scientific Advisory Board, will contribute to such efforts);

(ii) Promote actor coalitions with urban citizens and farmers and consider systemic incentives, in particular with respect to land use, transport and infrastructure;

(iii) Encourage business to explore new opportunities with service-oriented business models, building efficiency, granular end-use and technology innovation;

(d) United Nations system:

(i) Encourage the United Nations system to provide coordinated capacity-building support to the development of national sustainable development scenarios and to engage scientists and technologists;

(ii) Convene scenario analysts, scientists and frontier technology experts under the Technology Facilitation Mechanism to share experiences and technology foresight and synthesize the latest knowledge on the impacts of new technologies on sustainable development and the achievement of the Sustainable Development Goals (this will support informed and innovative debates and outcomes at the high-level political forum on sustainable development);

(iii) Institute a regular exchange between scenario analysts, governments, science advisors and decision makers on high-impact actions for sustainable development;

(iv) Use the high-level segment of the Economic and Social Council in 2022 and 2023 to examine long-term trends and scenarios, as mandated, and pave the way for the Summit of the Future.