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

Report of the Secretary General

The present report informs the high-level segment of the Economic and Social Council in July 2023, pursuant to General Assembly resolution 72/305. It complements the reports of the Secretary-General on the theme of the 2023 session of the Council (E/2023/xx) and on "Progress towards the SDGs: Towards a Rescue Plan for People and Planet" (A/78/xx-E/2023/xx). It looks beyond current crises and emergencies to reflect on long-term trends and scenarios towards achieving the SDGs and climate change objectives while leaving no one behind.

Despite some positive developments, business-as-usual means that none of the SDGs would be achieved and that development would be decisively unsustainable by 2050. Recent scientific and technological breakthroughs could become "game-changers", but they would require unprecedented levels of global cooperation and support to make these new possibilities work for everyone. Recent SDG pathways and sustainable development scenarios illustrate what would be needed in terms of globally coordinated policies and high-impact actions.

I. Introduction

1. The present report serves to inform the ECOSOC high-level policy dialogue 2023 on future trends and scenarios and the long-term impact of such trends and new technologies on the realization of the 2030 Agenda.[1] It looks beyond the current crises and emergencies and takes a long-term futures perspective towards 2030 and beyond, all the way to 2050. It thus complements the SG's report E/2023/xx on the ECOSOC theme, which discusses recent efforts to recover from the COVID-19 pandemic, the present crises, and their immediate implications, as well as report A/78/xx-E/2023/xx on "Progress towards the SDGs: Towards a Rescue Plan for People and Planet".

2. The 2030 Agenda for Sustainable Development outlines a broad, aspirational vision "*for people, planet and prosperity*".[2] Its Sustainable Development Goals (SDGs) provide a quantitative and qualitative snapshot of what the world aspires to achieve by 2030.[3] It also outlines policy recommendations and actions, but it does not offer precise guidance on how coordinated actions could feasibly be undertaken over time to reach the SDGs. This is what scenarios are designed to explore.

3. Scenarios are internally consistent and plausible paths describing developments into the future. They coherently bring together scientific and technical knowledge from all relevant disciplines and sources, in order to improve our understanding of possible future developments and support decision-making. Policy makers often refer to scenarios as pathways – a terminology that is used synonymously in this report. However, scenarios are not predictions. Instead, scenario analysts make assumptions about an inherently uncertain future and ask "*if, then…*"-questions. Scenarios focus our thinking on identifying solutions that do not breach physical, technical, economic or socio-political boundaries but that truly add up and reflect the best available science and evidence.

4. As the world gears up for the SDG Summit and the Summit of the Future, insights from sustainable development scenarios are an important means of identifying possible pathways, prioritizing actions and understanding the longer-term implications of policies. They provide us with a best guess of what is possible. It should be noted, however, that they are based on scenario models that are limited in terms of capturing all the complex aspects of systems, especially at local and national levels.

5. Secretary-General's reports in this series (E/2020/60, E/2021/61, and E/2022/58) presented the *"LED better futures scenario*" as a global best-case scenario for the achievement of the SDGs by 2030 and broader sustainable development by 2050. The reports also considered the potential long-term consequences of near-term decisions in our responses to COVID-19 and to AI technologies, as well as the potential of a myriad of digital consumer innovations for transforming end-use efficiencies in transport, buildings, food and energy. Among others, the reports concluded that the world was not on track to achieve its long-term goals and that it had largely not taken actions that would have been in line with the global best-case scenario, despite several positive developments.

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[1] In accordance with General Assembly resolution 72/305, the final day of the high-level segment of the Council 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. Its aim is to enhance knowledge-sharing and regional and international cooperation*".

[2] A/RES/70/1 - Transforming our world: the 2030 Agenda for Sustainable Development

[3] With selective targets for other years

6. This year's report continues building on these earlier reports. It takes stock of long-term trends across all SDG areas, describes the scenario of a business-as-usual future (Section II), discusses the potential of rapidly emerging technologies as "game changers" to accelerate sustainability (Section III), reports on the latest findings and policy implications of futures and sustainable development scenarios for the SDGs and beyond (Section IV), and concludes with a brief summary of the way forward (Section V).

II. Long-term trends and the scenario of a business-as-usual future

7. The SDG progress report 2023 provides a comprehensive picture of recent progress towards the SDGs since 2015 and provides an extensive list of policy recommendations. This section looks at longer-term historical trends and what they might entail for 2030 and even 2050, if the world continues along the current path without a significant course correction through globally coordinated action from governments, businesses, and individuals alike. The business-as-usual (BAU) future reported in this section is primarily based on the "middle of the road" SSP2-NDC scenario of IPCC where trends broadly follow their historical patterns and assume implementation of the Nationally Determined Contributions (NDCs) under the Paris Agreement. It is important to note that trends are closely interconnected, and hence, the business-as-usual SSP2 scenario differs in important ways from simple extrapolations of individual trends.

8. Science and technology have driven human development in the last half century which has been termed the "great acceleration". In relative terms, many improvements have occurred including reductions in the shares of global population suffering from poverty and lacking access to electricity, as well as increased access to clean cooking fuel, drinking water, education, and health. In absolute terms, science and technology has helped lifting billions from poverty and provided a better life, even as billions have been left behind.

9. In overall terms, the world has made important progress in most of the SDG areas over the past three decades, but progress has largely been too slow compared to the SDG aspirations and for achieving sustainable development. In fact, if current trends continue, the resulting business-as-usual future will be starkly unsustainable in most SDG dimensions. Table 1 provides a selective overview of historical trends, the current situation, and a business-as-usual future until 2050. Key elements for the 17 SDG areas are described below.

Table 1: Historical trends and business-as-usual future in key SDG areas, 1990- 2050

			Historical trend			Today	Business-as-usual future (continuation of historical trends)			Unit
2030 Agenda areas	SDGs		1990	2000	2012	2022	2030	2040	2050	Year
People	Population	World population (UN medium variant)	5.3	6.1	7.1	7.9	8.5	9.2	9.7	billion people
		Above 65 years of age	0.32	0.42	0.56	0.78	1.01	1.33	1.6	billion people
		Urban residents	2.29	2.87	3.63	4.5	5.17	5.94		billion people
	SDG1	People in absolute poverty	1.95	1.78	1.17	0.69	0.57	0.28	0.19	billion people (latest projection)
							0.44		0.12	billion people (SSP2 scenario)
	SDG3	Under-5 deaths	12.8	9.9	6.7	4.9	3.8	2.6	1.4	million children
		DALYs lost from PM2.5			200	200	214	224	227	million DALY per year
	SDG4	Share of adults without education			15	12	10	8	6	%
	SDG5	Secondary education gender gap		6.8	3.4	2.6	2.4	1.8	1.3	percentage points
Provision of material needs and sustainable resources	SDG2	People underweight		0.75	0.73	0.66	0.61	0.57	0.52	billion people
	SDG6	Agricultural water withdrawal		2.8	3.0	3.2	3.5	3.9	4.4	1000 km3 per year
	SDG7	People without electricity access	2.0	1.6	1.2	0.7	0.7	0.6	0.5	billion people
		Useful energy per capita in buildings and mobility		12	13	15	17	20	23	GJ per capita per year
	SDG12	Food waste		440	580	650	700	740	780	kcal per capita per day
Prosperity	SDG8	Global economy size	35	47	73	104	142	184	230	trillion US$2005 (PPP)
	SDG9	Industry clean energy share		18	19	21	25	31	41	% (final energy)
	SDG10	Relative poverty rate			18.4	19.0	19.1	18.9	18.6	% (w.r.t median income)
		Global income convergence		26	32	37	40	44	47	PPP per capita ratio to OECD (%)
		Global middle-class (US$11 to $110/day (2011PPP))	1.2	1.8	2.5	3.5	4.8	6.0	6.5	billion people
	SDG11	Urban residents	2.29	2.87	3.63	4.5	5.17	5.94		billion people
		Megacity residents (>10 mill.)	0.15	0.23	0.35	0.53	0.73	1.0		billion people
		Slum dwellers	0.67	0.78	0.87	1.01	1.6	2.0		billion people
		Urban PM2.5 concentration			34	31	31.6	30.8	28.7	ug/m3
		Premature deaths from ambient air pollution (PM2.5)	2.9	3.1	3.3	3.3	3.6	3.9	4.2	million people
Planetary integrity	SDG13	GHG emissions	38	41	52	54	54	48	43	GtCO2equiv. per year
		Global mean temperature increase			0.9	1.2	1.4	1.6	1.8	Kelvin
	SDG14	Aragonite saturation state (oceans)			2.94	2.85	2.77	2.71	2.66	-
		Nitrogen fixation			151	190	219	248	268	MtN per year
	SDG15	Biodiversity intactness		0.798	0.794	0.792	0.791	0.789	0.788	-
Institutions and partnerships	SDG16	Rule of law and civil liberties			0.60	0.61	0.64	0.68	0.71	index
		Peace (conflict/battle-related deaths)				0.3	2	8	26	probability of <20,000 fatalities
	SDG17	Internet users	0.003	0.36	2.4	4.9	7.5	8.7	9.5	billion people

Data sources: Soergel et al. (2021)[4], GSDR 2014[5], Van Vuuren et al. (2022)[6], UN statistics database, UN World Population Prospects 2022, World Bank, and estimates by UN Secretariat.

Notes: Business-as-usual future primarily based on IPCC's SSP2-NDC scenario; absolute poverty = below int'l poverty line of less than $2.15 per day in 2017PPP. DALY = disability-adjusted life years.

People (SDGs 1, 3, 4, and 5)

10. The world's population has increased by an average of almost one billion people in each of the last three decades and reached about 8 billion in 2023. It is expected to continue to grow, even though at a lower rate, to 8.5 billion in 2030, and 9.7 billion in 2050.[7] The majority of this growth will be in Africa and South Asia, where fertility rates remain relatively high. Quite a few developing countries in Africa have entered the early phase of a demographic dividend where the working-age population is rapidly rising as a share of the total population.[8] Overall, however, the global population is ageing, with the number of people aged 65 and above expected to double from 0.76 billion in 2022 to 1.6 billion in 2050[9], and those 80+ expected to triple

[4] Soergel, B., et al. (2021). A sustainable development pathway for climate action within the UN 2030 Agenda. Nature Climate Change, Vol.11, Aug. 2021, pp.656-664, and data repository: https://zenodo.org/record/4787613

[5] UN (2014). Global Sustainable Development Report 2014, https://sdgs.un.org/gsdr/gsdr2014

[6] Van Vuuren, D., et al. (2022). Defining a sustainable development target space for 2030 and 2050. One Earth, Volume 5, Issue 2, 18 February 2022, Pages 142-156.

[7] UN medium projection, in: UN (2022). World Population Prospects - 2022 revision, https://population.un.org/wpp/Download/Standard/MostUsed/

[8] World Social Report 2023, UN DESA

[9] https://population.un.org/wpp/Download/Standard/Population/

from 0.16 to 0.46 billion. Most developed and many developing countries will see their populations peak and then shrink after 2040. The world's economic old-age dependency ratio will increase from 20% in 2020 to 27% in 2030.[10]

11. In a business-as-usual future, progress is too slow to achieve the moral imperative of eradicating absolute poverty anytime soon. Despite population growth, the total number of people in absolute poverty[11] decreased by around 600 million in the 2000s and 500 million in the 2010s, but in 2020, it rose for the first time in three decades, by 70 million. It has since continued to decline, reaching about 670 million by the end of 2022. In the long-run, it is expected to drop further - but at a slower rate. Simple projections see it dropping to 575 million by 2030, which means that only one-third of countries would have halved their national poverty rates from 2015 to 2030. Even in a slightly more optimistic BAU scenario, there would still be 440 million people in absolute poverty by 2030 and 120 million in 2050 - absolute poverty would not be eradicated even by mid-century.

12. The under-5 mortality rate has come down from 93 to 38 deaths per 1,000 live births from 1990 to 2021. However, this also means that during that period about 267 million under-5 deaths occurred. If current trends continue, another 48 million under-5 deaths will occur in the 2020s, most of which due to preventable or treatable causes. Even in 2040 and 2050, millions of children would die every year.

13. In the past decade a roughly constant 200 million (disability adjusted) life years were lost every year, a number that is expected to rise further in the future, and health impacts of air pollution are expected to remain above WHO target levels for almost everyone.

14. The share of adults without an education will continue slowly decreasing from 12% today to 10% in 2030. Similarly, the secondary education gender gap will continue slowly decreasing but would still be around 1% even in 2050.

Provision of material needs and sustainable resources (SDGs 2, 6, 7, and 12)

15. Over the past decades, the number of hungry people and the number of underweight people has slowly decreased despite growing population. However, it still affects more than half a billion people and is expected to remain stubbornly high in a business-as-usual future.

16. Rapid progress has been seen in providing people with electricity access, but progress has significantly slowed. By mid-century, there might still be half a billion people without electricity access, excluding them from all the benefits of an increasingly electrified information society. Useful energy in buildings and mobility rises at accelerated rates to 23 GJ per capita in 2050. As a whole, global energy demand has continued to rise and is projected to further increase by 50% until 2040, driven by population growth, urbanization, and industrialization. Over the same timeframe agricultural water withdrawals will increase by another 22%. Competition for scarce resources, such as water and minerals, will intensify and might lead to increased risks of geopolitical tensions and potential conflicts.

17. Food waste has increased, albeit at slower rates, and might reach as much as 700 kilo-calories per capita per day by 2030 – which is, theoretically, enough to feed an additional three billion people, an unimaginable waste in the face of hunger.

[10] World Social Report 2023, UN DESA

[11] defined as those living on less than US$2.15 per day (in 2017 PPP)

Prosperity (SDGs 8, 9, 10 and 11)

18. The world economy has continued to expand at a long-term average of around 3% per year. Global GDP reached US$104 trillion[12] at the end of 2022, and is expected to continue to expand, increasing by 40% until 2030 alone.

19. The global middle-class[13] has doubled since 2000 to reach 3.5 billion people in 2022, and it is expected to further increase to 4.8 billion people by 2030[14] (mostly due to Asia) and to 6.5 billion by 2050. Yet, economic inequality will persist both within and between countries, potentially leading to higher risks of social unrest, political instability, and reduced economic growth.

20. Within-country relative poverty rate has remained stubbornly high at around 19% and is expected to stay at that level, even though this average masks huge differences between countries, with rapidly increasing relative poverty in some countries. At the global level, income convergence is expected to continue, driven by rapid economic growth in some populous developing countries, but by 2050, average PPP per capita in the OECD region would still be twice that of the rest of the world, and major regional disparities would persist.

21. Today, some 4.5 billion (or 56% of the world's population) lives in cities - 900 million more than just ten years ago.[15] Until 2030, the urban population will increase by another 700 million to reach 5.2 billion. Building the necessary energy, transport, communications, water and sanitation infrastructure, as well intercity infrastructure for an additional 100 million urban residents *per year* will be a major sustainability challenge. Another challenge is the decreasing overall density of urban areas since 1990. If this trend continues, global urban land area will have almost tripled from 2000 to 2030[16], leading to major loss of natural habitats.[17]

22. Cities with more than 1 million residents have grown at twice the rate of the overall population. Half a billion people now live in megacities with more than 10 million inhabitants each, by 2040 it might be around 1 billion, primarily in Asia and Africa. However, most urban growth will occur in medium-sized cities, with 1 to 5 million inhabitants, which are projected to house 1.6 billion people in 660 such cities by 2030. There will also be more and more slum dwellers, as their number is expected to double from 1 to 2 billion between 2022 and 2040.

23. And while the clean energy share in industry is expected to grow at an accelerated rate, doubling from 21% today to 41% in 2050, urban PM2.5 air pollution concentrations would stay stubbornly high and far above WHO standards in most cities and would continue claiming millions of premature deaths every year for decades to come.

Planetary integrity (SDGs 13, 14, and 15)

24. Despite many policy measures taken, in this century, global GHG emissions have continued increasing every year (except in the pandemic year of 2020) and reached 54 GtCO2-equiv. in 2022. Assuming that all NDCs are being implemented, GHG emissions would peak before 2030 and continue staying at very high levels, reaching 43 GtCO2-equiv. even in 2050. As a result, global mean temperatures will continue rising, breaching 1.5°C around 2030 and 2.5°C by 2100. In contrast, staying

[12] In US$2005 PPP terms.
[13] Defined as people with an income per day between US$11 and US$110 (in 2011PPP)
[14] Fengler and Kharas (2021). A long-term view of COVID-19's impact on the rise of the global consumer class, Brookings Institution, May 2021
[15] World Urbanization Prospects 2018, https://population.un.org/wup/Download/
[16] If current trends in population density continue and all areas with high probabilities of urban expansion undergo change,
[17] http://www.pnas.org/cgi/doi/10.1073/pnas.1211658109

within the 1.5°C goal of the Paris Agreement would require global GHG emissions to fall by 43% in 2030 compared to 2019 levels, fall to net-zero by 2050 and then turn net-negative for some years.

25. Large-scale planetary scale changes - on land, in the ocean and in the atmosphere - are already happening. Ocean acidification continues to increase and has reached levels not seen for at least 26,000 years, endangering marine organisms. Melting of glaciers and sea level rise - which reached record levels in 2022 - will continue for thousands of years. Some 3.4 billion people currently live in areas that are highly vulnerable to climate change and this number might rise to 5 billion until 2040, reinforcing the need for climate adaptation.

26. Human-induced nitrogen fixation has become a major concern and is expected to rise further, from 190 MtN today to 270 MtN by 2050. One of the consequences is continued biodiversity degradation.

Institutions and partnerships (SDGs 16 and 17)

27. Despite regional disparities, the global long-term trends towards a better rule of law and civil liberties are expected to continue. Furthermore, for the SSP2-NDC scenario, it was estimated that the probability of the world seeing less than 20,000 conflict/battle-related fatalities per year was estimated to increase from 0.3% in 2022 to 26% in 2050.

28. There are now 4.9 billion Internet users in the world, and by 2030 there may be 7.5 billion users, or almost 90% of the global population. This will facilitate the exchange of information, ideas, and resources, driving further innovation and economic growth.

29. The growth of global trade is expected to continue, driven by the expansion of the digital economy, the proliferation of global value chains, and the increasing integration of developing economies into the world market.

30. The world's scientific and technological knowledge base and overall data volumes will continue greatly expanding. The annual number of peer-reviewed articles in science and engineering published per year has grown from 1.5 million in 2015 to 2.1 million in 2022 and is expected to double to 3 million in 2030. As many scientific and technological papers will be added in the next 7 years until 2030 as in the entire human history until now. Disciplines have further specialized and narrowed. AI is increasingly needed for obtaining a comprehensive picture of scientific knowledge across disciplines to inform policy and actions.

31. The amount of data created and shared almost instantly across the globe has increased even faster. By 2022, the world had accumulated an estimated 100 zettabytes of data, which was ten times the amount of 10 zettabytes in 2015. In 2022 alone, we added 15 zettabytes of new data, which was about as much as we accumulated throughout human history until 2017. Deep learning and big data business strategies mean that this growth will likely continue if not accelerate further. By 2030, data volumes may be 400 or more zettabytes, with at least 40 zettabytes of data being added per year.

III. Rapidly emerging technology - a "game changer"?

32. Section II painted a business-as-usual future that is highly unsustainable, resulting from a continuation of long-term historical trends. However, we live in times of rapidly emerging new technologies with important implications for sustainable development. This section briefly discusses selected science and technology trends

and whether they could become "game changers" for sustainability. [18] This provides important background for understanding technological change as a major ingredient of the sustainable development pathways described in section IV.

Scientific and technological advances – a means to accelerate SDG progress but also an enormous challenge

33. Rapidly emerging scientific breakthroughs and technologies are upending old development models and offering new opportunities, but they also present enormous challenges to institutions in all countries, especially in many developing countries. Rapid changes can be seen in technology development, demonstration and diffusion, with increasingly significant impacts on countries at all levels of development. Almost all countries that are not at the technology frontier with respect to these new technology clusters face increasing disadvantages, as the export-oriented development model based on technological upgrading that has been extremely successful in recent decades is becoming increasingly difficult to follow. One related phenomenon is "premature de-industrialization" in developing countries.

34. A growing disparity in STI capabilities between countries and within societies could lead to rapid increase in socioeconomic disparities and significantly reduce equal opportunities for all. At the same time, STI communities are undergoing major institutional and organizational changes, as their societal and economic roles are shifting. Just one example is the emergence of sustainability science as a fully integrated, practical kind of science that links with many different disciplines across natural and social sciences.

35. The level and distribution of current R&D expenditures can provide a glimpse of future capabilities. Global R&D spending continued to increase and reached US$2.5 trillion from all sources in 2022. However, investments remain highly concentrated in a few developed countries and China, with limited resources going to the Global South (low-income countries account for only 0.3%). Both public and private sectors play a vital role for R&D. Current governmental R&D funding amounts to about US$200 to 300 billion per year. Private R&D funding remains crucial for translating research findings into marketable products and services.

36. In other words, unless developing countries and disadvantaged communities are fully integrated into the new R&D driven world economy, modern STI will fall far short of making a positive difference for the SDGs and widen the gaps further.

Environmentally compatible technologies and the emerging "green economy"

37. The green economy has emerged very rapidly since 2018, driven by a technology revolution in advanced digital production technologies, green and low-carbon technologies, electric vehicles, solar-photovoltaics, hydrogen, smart grids, and digital consumer technologies. Globally, the green economy has become the fifth largest industrial sector by market value at US$7.2 trillion, larger than retail, financial services, or oil & gas.[19]

38. Global investments into the energy transition alone rose to a new record of US$1.1 trillion in 2022, especially due to electric transport and solar-photovoltaics. In fact, for the first time ever, energy transition investments surpassed fossil fuel investments in 2022. China alone accounted for 49% of this total and for 91% of

[18] See also the draft report of the Secretary-General's 10-Member-Group of High-level Representatives on "Science-Technology, and Innovation for the SDGs – Progress, Future Vision, and Recommendations", 1 May 2023. https://sdgs.un.org/sites/default/files/2023-05/10MG%20report%202023%20-draft%202023-05-01%20posted.pdf

[19] UN (2023). Chapter III.G in: Financing for Sustainable Development Report, Inter-agency Task Force on Financing for Development, March 2023

global investments into clean energy manufacturing. Many other developing countries, however, face serious challenges in raising the necessary resources for sustainable energy investments.

39. Targeted policy strategies drive this technology adoption. For example, zero-emissions vehicle targets now already cover 40% of the global automobiles market. These technologies will increase productivity, energy efficiency and provide solutions to major sustainability challenges. With right policy choices, they could also lead to more jobs and development. But they can also increase the risk of widening income gaps between and within countries.

40. The UN Technology and Innovation Report 2023[20] suggests that these trends offer "green windows of opportunity" for developing countries, based on an empirical analysis of trade data and identification of potential future technology trajectories. To which extent developing countries will be able to reap the benefits will also depend on the degree of openness of our trade and STI systems in the coming years. Advances might also 'raise the bar' for firms in developing countries and foreclose traditional development pathways. Without major capacity building efforts, green windows of opportunity might remain a "mirage" for many developing countries.

Digitalisation

41. Digitalisation has become a pervasive force across all sectors and countries, promising new opportunities for leapfrogging. For example, financial technology has the potential to greatly increase financial inclusion, including in underdeveloped parts of the world. Yet, 3 billion people remain excluded from these benefits due to lack of basic Internet connectivity, technology skills and access. While great progress has been made in closing digital gaps in terms of simple Internet and Web access in many parts of the world, new digital gaps have continuously opened up as new technology infrastructures are being built on top of basic connectivity infrastructure. In particular, the usefulness of AI tech applications for the SDGs is very much constrained by infrastructure and skill gaps.

42. Digitalization is also reshaping production processes. By 2021, there were 3.5 million industrial robots installed world-wide, and installations have surged at rates of over 30% per year. While the current boom in industrial robots remains highly concentrated in a few countries and in the electronics and vehicles sectors, the projected cost advantages will greatly challenge the labour cost advantage of developing countries in one sector after another over this decade. Service robots with increasingly powerful AI capabilities are being deployed and have the potential to transform health care, transportation and ultimately all sectors. These are unprecedented challenges to developing countries which will be left even further behind by these trends, unless global responses address their needs.

Biotech, synthetic biology, and health technology

43. Recent developments in biotechnology and synthetic biology have dramatically reduced the cost of DNA sequencing and also of DNA synthesis, ultimately allowing the "programming" of new organism. As a result of ever cheaper high-tech equipment, "do-it-yourself" biology labs, biohacker spaces, makerspaces and "fablabs" can now be found in a majority of countries in the world. However, levels of equipment, expertise, and biosafety regulations vary greatly. These "citizen scientist" movements can be a promising accelerator towards the SDGs, as much of their work is practical and aimed at solving everyday problems. However, this also poses risks if left unregulated. There is a need to develop regulatory framework that

[20] https://unctad.org/tir2023

nurtures such innovations but at the same put all the necessary guardrails against abusive uses of such technologies.

44. In early 2023, the WHO's global health foresight function identified the following top-five most promising innovations for global health by 2030:[21] genomics for early diagnosis and pre-diagnosis of diseases, improved vaccine production and global distribution, low-cost viral diagnostics, broad-spectrum antimicrobial drugs, and rapid remote diagnostics. To make use of these innovations, technological advancements, skilled health professionals and technicians, leadership and good governance, and a supportive regulatory and policy framework are needed. There are also inherent risks. Innovations may accentuate health inequity, have issues with reliability and accuracy, face challenges with access and affordability, or pose threats to data privacy. There may be difficulties in understanding and interpreting results, maintaining manufacturing standards, managing potential toxicity and safety concerns, and preventing misuse of technology. Again, these innovations show great potential for improving the health of billions of people, but they also require major international cooperation and support.

IV. Sustainable Development Pathways

45. Ever since the Rio+20 Conference in 2012, many scenario modelers have developed global sustainable development scenarios and since 2015 also more specifically SDG scenarios. They emphasize economic, technological, or political approaches. However, in the past eight years, unabated global increases in energy, materials and land use, together with their associated environmental, social and health consequences, have required analysts to make ever more ambitious scenario assumptions to achieve the SDGs in the remaining few years.

46. To achieve the required ambition, many scenario analysts have long assumed 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 have now appeared in this regard. Yet, many issues related to deployment of these technologies at scale remain to be resolved, such as the logistics of safely storing billions of tonnes of CO_2 every year and the potential impacts on ocean and terrestrial ecosystems.

A new approach: the LED better futures scenario to achieve the SDGs and decent living standards for all

47. Against this background, 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 aims to make exceptional progress on sustainable consumption and production (SDG12) through rapid transitions to lower energy demand and very high efficiency end-use technology and practices in energy, water, land and materials. This low energy demand (LED) scenario[22] meets the SDGs and the 1.5°C 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 IPCC's "*Global Warming of 1.5°C*" report and is also one of two scenarios highlighted in the WGIII contribution to the 6th Assessment Report of IPCC published in April 2022.[23] Based on the original energy scenario, consistent, detailed

[21] 2023 emerging technologies and scientific innovations: a global public health perspective — preview of horizon scan results, 26 April 2023, Technical document, World Health Organization.

[22] Gruebler A, Wilson C, Bento N, Boza-Kiss B, Krey V, McCollum D, Rao N, Riahi K, et al. (2018). A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies. Nature Energy 3 (6): 517-525.

[23] IPCC, 2018: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming

scenario implementations were developed for land use and food ("better futures" scenario)[24], water[25] and other SDG sectors. The resulting, combined "*LED better futures scenario"* translates into important benefits for all SDGs. [26] Scenario variants, using different combinations of design elements of the LED scenario have been developed by the Netherlands Environmental Assessment Agency (PBL)[27] , the International Energy Agency (IEA)[28], and most recently the SDP scenarios of the SHAPE project, among others.

48. The key goal of the LED better futures scenario is to reduce overall global energy, water and land use, despite increasing population, economic activity and rapidly rising living standards. This is possible due to the large untapped potential for increasing end use efficiencies through a combination of technological, behavioural and business innovations – a transition fuelled by ICTs.

49. 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 where open science is leveraged for sustainable development. Many digital technologies and AI applications are deployed. They vastly increase service efficiencies. In what becomes a high-tech interconnected world, the SDGs are achieved by 2030 and broader sustainability by 2050. In fact, the scenario outperforms alternative scenarios in terms of SDG progress. It also foresees rapid improvement in living standards in developing countries to a level far beyond basic services described in the SDGs or "decent living standards", essentially catching up with the developed world. Yet, 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, quality of life, and those that enable people to engage with society. [29]

50. All this is achieved through overall strategies to electrify energy end-use worldwide; to bring homes, appliances and transport modes to the technological efficiency frontier; to support multi-functionality through convergence of multiple services onto single devices or business models; to promote a generational shift from ownership of material goods to accessing services; to increase utilisation rates of goods, infrastructure, and vehicles (sharing and circular economy); to promote user-oriented innovation; to ensure decentralization allowing new roles for end-users not just as consumers but also as producers, innovators and traders; and to achieve ubiquitous digitalization and rapid innovation in granular technologies, such as solar-photovoltaics and heat-pumps.

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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

[24] FOLU (2019). Growing Better: Ten Critical Transitions to Transform Food and Land Use. The Global Consultation Report of the Food and Land Use Coalition, September 2019.

[25] Parkinson S, et al. (2018). Balancing clean water-climate change mitigation trade-offs. IIASA Working Paper. IIASA, Laxenburg, Austria: WP-18-005

[26] LED database, https://db1.ene.iiasa.ac.at/LEDDB related to Gruebler et al. (2018); SSP database, https://tntcat.iiasa.ac.at/SspDb related to Riahi et al. (2017).

[27] PBL's Nexus, 1.5°C and roads from Rio scenarios: Van Vuuren, D.P., et al. (2019). Integrated scenarios to support analysis of the food–energy–water Nexus. Nature Sustainability, Vol.2, Dec. 2019, p. 1132–-1141. Van Vuuren, D.P., et al. (2018). Alternative pathways to the 1.5°C target reduce the need for negative emission technologies. Nature Climate Change, Vol. 8, May 2018, p. 391–397. van Vuuren, D.P., et al. (2015). Pathways to achieve a set of ambitious global sustainability objectives by 2050: Explorations using the IMAGE integrated assessment model. TFSC 98 (2015) 303–323.

[28] IEA's sustainable development scenario in the World Energy Outlook: IEA (2019). World Energy Model - scenario analysis of future energy trends. World Energy Outlook, Nov. 2019.

[29] Rao, N., Min. J. (2018). Decent Living Standards: Material Prerequisites for Human Wellbeing, Soc Indic Res (2018) 138:225–244.

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

Comprehensive Sustainable Development Pathways consistent with the SDGs

52. Alternative variants of sustainable development pathways (SDP) have been developed by leading scientists in the context of the SHAPE project, with results presented in early 2023.[30] The resulting findings provide a pragmatic portfolio of actions that can get us onto a path towards achieving most of the SDGs despite recent unsustainable trends.[31] The SDP scenario developers explored six broad clusters of interventions in the areas of development; resource efficiency and life-style changes; climate mitigation; shift in consumption patterns (energy and land use); international climate finance; and national poverty alleviation programmes financed from carbon pricing revenues. They highlight the benefits of synergies between climate change and sustainable development objectives, especially in the long-term beyond 2030.

53. The SDP scenarios go further than earlier work and quantify the entire range of the SDGs, including many social and institutional aspects. This is important and should be useful for translating the scenario findings into specific polices and actions.

54. Key elements of the SDP scenario are outlined next.

55. *Planetary integrity.* The SDP scenario shows a path towards SDGs 13, 14 and 15. GHG emissions are reduced to 33 and 10 GtCO2-equiv. in 2030 and 2050, respectively. Sizable reductions in agricultural CH_4 and N_2O emissions beyond what is common in other 1.5°C scenarios in the literature allows a 100Gt higher CO_2 budget which limits the scale of negative emissions that would be needed. The overall warming slightly overshoots 1.5°C by 2050 and reaches about 1.3°C by 2100. Importantly, ocean acidification is limited at a level that do not further endanger marine organisms such as corals, clams, oysters, and some plankton that use carbonate ions to create their shells and skeletons. The scenario also shows a path towards decreasing human-induced nitrogen fixation to 120 MtN per year, to conserve primary forests, halt biodiversity loss and reverse some of that loss, all by 2050.

56. *Provision of material needs and sustainable resources* (SDGs 2, 6, 7, and 12). The SDP scenario achieves zero-hunger by 2050 and a halving of malnourishment by 2030. Food waste and agricultural water use are reduced by a quarter by 2050, which reduces pressure for higher food prices. Per capita energy use for buildings and mobility in low-income countries almost doubles to 6.4 GJ per capita per year in 2030 and more than triples to 15 GJ in 2050 (compared to the world average of 22 GJ).

57. *People (SDGs 1, 3, 4, and 5)*. In the SDP scenario, extreme poverty could be reduced to 180 million (or about 2%) in 2030, compared to 750 million in 2015, and poverty eradication could be achieved by 2050. It leads to 5 and 25 million fewer (disability adjusted) life years lost by 2030 and 2050, respectively, but health impacts of air pollution remain above WHO target levels. 11 million under-5 deaths would be

[30] Multi-model scenario project entitled SHAPE: Sustainable development pathways achieving human well-being while safeguarding the climate and planet earth, see https://shape-project.org.

[31] Soergel, B., et al. (2021). A sustainable development pathway for climate action within the UN 2030 Agenda. Nature Climate Change, Vol.11, Aug. 2021, pp.656-664.

averted in the 2020s alone. In the scenario all of the younger generation will have benefitted from a school education by 2030.

58. *Prosperity (SDGs 8, 9, 10 and 11)*. Income grows rapidly in the developing world converging towards those in the developed world, but regional disparities remain. The within-country relative poverty rate decreases from 19% in 2015 to 15% in 2050. The clean energy share in industry grows slowly to 26% in 2030 and more rapidly to 62% by 2050. Urban air pollution (PM2.5) is reduced by 40% by 2050.

59. *Institutions and partnerships (SDGs 16 and 17)*. The SDP scenario assumes a general increase and convergence in institutional quality across the board. International climate finance is increased beyond the current US$100 billion target to US$350 billion by 2030 and US$910 billion by 2050. It explores the outcomes of large part of these funds being used to finance poverty alleviation rather merely reinvested in new infrastructure and technologies.

International burden sharing and expanding fiscal space

60. A globally just transition that leaves no one behind needs to recognize various factors including capacity constraints and differences in capabilities across countries and within countries. The SDP scenario goes a long way in this regard. For example, it foresees all countries successively adopting a carbon price that is determined by income levels. Low-income countries would initially have very low carbon prices compared to high-income countries, but a globally uniform carbon price would be achieved by 2050. A fraction of the revenues from carbon pricing in high-income countries would be earmarked for international climate and development finance, including for direct cash transfers to poor households, contributing to the reduction of extreme poverty. At a national level, removal of fossil fuel subsidies and carbon prices consistent with the 1.5°C target could create fiscal space of about 20% of the public financing needs for the SDGs (in the median across countries), but with large differences between countries (from close to 0% to 90%). This share would be large in countries with already high-infrastructure stocks and relatively low in LDCs, highlighting the importance of international burden sharing.[32]

Decent living standards for all

61. The SDP scenario shows a pathway towards ensuring decent living standards for all. The concept of decent living standards goes well beyond basic services and eradication of poverty, but 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). The largest per capita gaps are in Sub-Saharan Africa, South Asia and Latin America, but regional differences are sizable. [33] Decent living gaps are biggest in terms of transport across regions, but there are also sizable gaps in clean cooking cold storage, sanitation and cooling. The cooling gap is especially large in South Asia. In fact, in many parts of the Global South, cooling is among the fastest growing energy use in buildings, yet only rarely the focus of sustainability. Heat stress affects 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 lower to middle income people.[34]

[32] Soergel et al. (2022), Joint implementation of the SDGs, climate change mitigation and biosphere protection: Policy options for tackling multiple crises simultaneously, Policy paper by the Potsdam Institute for Climate Impact Research, https://doi.org/10.48485/pik.2022.003

[33] Jarmo S. Kikstra, Setu Pelz, and Shonali Pachauri (2022). Eliminating multidimensional poverty by providing decent living standards for all. Science-policy brief, in: IATT report 2022.

[34] Alessio Mastrucci, Bas van Ruijven, Shonali Pachauri (2022). Closing cooling gaps in a warming world. In: IATT report 2022.

62. The SDP scenario shows that only about 17 GJ of energy per capita per year is needed to provide decent living standards, which is no more than one third of the current global average final energy consumption per capita. In Sub-Saharan Africa, final energy use would need to grow from 20 GJ per capita now to 31 GJ to fill the gap. To close cooling gaps with AC and fans in the Global South would require about 786 TWh per year which could be reduced by half with higher-efficiency systems and better insulation. Passive design strategies for buildings, such as shading, improved natural ventilation, and cool roofs can improve thermal comfort and reduce the energy demand. Evaporative cooling can be an effective and less energy-intensive technology compared to AC in dry climates.

Innovations in scenario analysis: political institutions[35]

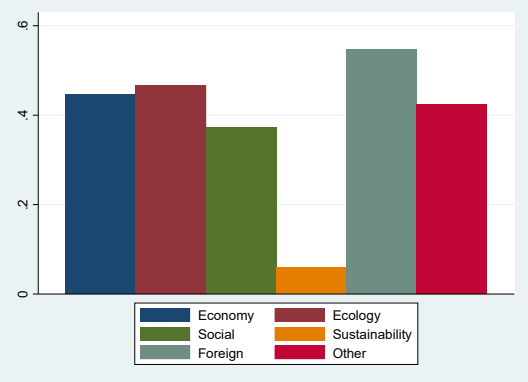
63. The SDP scenario process also shows major innovation in terms of modelling the effectiveness of political institutions and thus capturing the implementation dimension. In particular, it includes rule of law projections for 2015-2050 for the SDP scenarios and a comparison with IPCC scenarios.

64. Strong and effective political institutions are essential for SDG implementation. They formulate sustainability policies and ensure implementation of policy goals. While the fundamental importance of governance is enshrined in SDG16, until recently institutional governance issues have rarely featured explicitly in SDG scenario analyses. Yet effective institutions and political futures are essential ingredients for the actual feasibility of scenarios, something also highlighted by the IPCC.[36] In fact, assumptions on political institutional futures made in IPCC scenarios were far more positive than might be expected from extrapolations of empirical historical trajectories – for rule of law, inclusive institutions, and violent conflict.[37]

65. This work has important implications for making institutions fit for SDG implementation. It analysed institutions responsible for SDG implementation, as described in the VNRs, and highlighted the importance of effective accountability and governance mechanisms.[38] To create synergies between SDGs and minimize trade-offs, political institutions need to integrate different sectors instead of working in silos.[39] Hence, the participation from line ministries will need to be widened and deepened in SDG planning and implementation, beyond environment and foreign ministries (figure 1).

[35] Leininger, J., Wingens, C., Breuer, A. (2023). Political futures – not as rosy as SDG implementation would require. IDOS, German Institute of Development and Sustainability.
[36] IPCC AR6 WGIII Chapter 3, pp. 379-382
[37] Soergel et al., 2021
[38] Breuer, A., & Leininger, J. (2021). Horizontal Accountability for SDG Implementation: A comparative cross-national analysis of emerging national accountability regimes. Sustainability, 13(13), 7002.
[39] Breuer, A., Leininger, J., Malerba, D. (2022). Governance mechanisms for coherent and effective implementation of the 2030 Agenda - A Cross-national Comparison of Government SDG Bodies.

Figure 1: Percentage share of national SDG-implementation bodies, including each line ministry 2016-2021.



Source: Breuer, Leininger and Malerba (2022).[39]

Policies and actions in the Sustainable Development Pathway

66. Scenario modellers that developed the SDP and LED scenarios modelled a package of policies and high-impact actions which would need to be pursued in a globally coordinated way, in order to achieve sustainable development and the SDGs. This includes, among others, the following policy package and complements additional near-term actions recommended in the earlier reports in this series.

Technology and resource efficiency

67. The scenario shows what is possible with an unprecedented global effort to ensure the necessary capacity, financing and access to technology for all to make sure that no one is left behind - neither countries nor communities.

68. Long-term national plans are adopted and implemented to dynamically ratchet up product efficiency and increase energy efficiency in buildings, transportation and consumer goods at a level that adds up globally to two- to four-fold increases in overall eco-efficiencies by 2050. In particular, the scenario explores the rapid development and deployment of break-through innovations – at scale - in electrified transport, hydrogen industry and transport, and new generation solar-photovoltaics, and unlock the potential of digital consumer innovations in mobility, food, buildings, and energy services.

69. It assumes a much higher level of global cooperation, to make effective use of the world's R&D capacities and share lessons from demonstration projects in energy, food, climate, biodiversity, health, water and sanitation. One option could be the creation of a global institution, another option to create a network of strengthened national and regional institutions on sustainability science and technology.[40] In the scenario, global governmental research funders significantly increase R&D spending across the board from fundamental to applied research, which would also include a significant boost to R&D spending for the SDGs (on the order of at least 20% over the next five years).

Climate change and a just transition

70. In the scenario, the world immediately ceases to start building any new coal-fired electricity generation capacities, and quickly phases-out of fossil fuel subsidies in all countries. Without these actions and a broad global understanding on minimum

[40] One option in this regard would be the recent proposal of the 10-Member-Group of High-level Representatives for a global sustainability science and technology centre.

direct or indirect CO_2 price, the 1.5°C goal of the Paris agreement is not attainable under reasonable assumption. In the SDP scenario, CO_2 prices are adopted in all countries that are differentiated according to average incomes and which would ultimately converge to a globally uniform price by 2050. In this scenario, a rather moderate CO_2 price proves to be a sufficient price signal for a 1.5°C future – by 2030 it would reach about US$150 per ton CO_2 in high-income countries and US$25 in low-income countries[41] which is much lower than projections of other leading climate scenarios.

71. At the global level, the policy costs to t developing countries are compensated through a complementary "climate and development" scheme, financed from a fraction of global carbon pricing revenues. In the SDP scenario, this leads to US$350 billion climate finance by 2030. For Sub-Saharan Africa alone, it could mean a US$120 billion per year inflow, boosting GDP by almost 4% and lifting 55 million people from absolute poverty by 2030, while providing an important long-term price signal to move away from fossil fuels.

72. At national levels, the scenario requires compensating the transition cost for low-income individuals through direct cash transfers financed from CO_2 pricing revenues. In fact, the SDP scenarios show superior sustainable development outcomes of such schemes compared to any other options.[42]

Sustainable energy systems

73. New business models and systemic efforts are undertaken especially on granular end-use technologies, improved efficiencies, and renewable energy technology deployment. This necessitates the adoption of long-term strategies to 2050 and investment-ready national plans to 2030 for much improved efficiencies in end-use and upstream sectors in all countries. In the scenario this includes the adoption of ambitious long-term goals to reduce energy intensities: by 75% to 86% for thermal comfort through new building standards in developing countries through doubling the retrofit rate in developed countries; by 70% for mobility, and big reductions in lighting and consumer appliances; by 76 to 90% in terms of energy use per square metre of commercial and public buildings; by 20% for global industrial energy intensity; and by 10 to 50% in freight transport.

74. No new coal power capacity is being built and by 2030, 90% of coal power capacities are prematurely retired in countries with GDP per capita above US$3,000 and 50% in lower income countries. By 2040, traditional biomass for cooking/heating in low-income regions might be almost completely phased out. And global goals of electric vehicle market penetration of at least 25% in 2030 and 40% in 2050 are achieved.

75. Importantly, the employment and social impacts of the energy transition are addressed through just energy transition partnerships, international investment support and regional industrial policies.

Sustainable land and food systems

76. Public sector consumption is leveraged to encourage the acceleration of trends towards healthier and more sustainable and more plant-based nutrition and diets. The remaining forests and carbon-rich ecosystems, such as peatlands, are protected and afforestation considered, in line with local needs and food security. The conversion of remaining intact ecosystems is limited and 20% of working lands conserved as

[41] For comparison, Sweden's carbon price increased from about EUR25 in 1991 to EUR122 in 2023.

[42] This statement is based on academic, peer-reviewed publications and the implied SDG progress projections have not been verified by the UN.

natural or semi-natural habitats to maintain their ecological function. Importantly, the global bioenergy potential is restricted to 100 EJ per year in the long-term.

Global development, equity and cooperation

77. The SDP scenario is only feasible with strengthened global cooperation and major international technological and financial support. It assumes international finance on climate alone on the order of US$160 billion by 2025, US$350 by 2030, US$480 by 2040 and US$910 by 2050. This is in line with and underlines the feasibility of the Secretary-General's broader SDG stimulus plan to the tune of US$500 billion per year. In the longer-term, this implies boosting broader global public investment in SDGs and suitable options for a fair burden sharing and fiscal space. To strengthen systematic, focused international cooperation, sustainable development strategies, roadmaps, or plans for STI are needed at global, regional and national levels that truly integrate priorities across sectors and achieve "decent living"-standards for all, far beyond basic needs, and that build multi-stakeholder partnerships to support implementation.

V. Conclusion

78. This report provides options for responding to the Secretary-General's call "Towards a Rescue Plan for People and the Planet.". In a business-as-usual future not only none of the SDGs would be achieved, but – despite all the achievements and positive developments in some areas – on the whole it paints a worrisome picture of unsustainable development towards mid-century. This report also highlights that recent scientific and technological breakthroughs could make a decisive positive difference for sustainable development but would require an unprecedented level of global cooperation and efforts to make these new possibilities work for everyone. Most importantly, this report highlights recent sustainable development scenarios that achieve the SDGs by 2030 and broader sustainable development by 2050. Member States, the UN system, decision-makers and other stakeholders are encouraged to consider the globally coordinated policies and high-impact actions that have been explored by the scenario and that will be needed for a sustainable future that leaves no one behind.

79. Finally, the UN system should be encouraged to work together in a one-UN model to: (a) support a better understanding, in real-time, of overall sustainable development progress and of the latest technology "accelerators" and "green windows of opportunity" for achieving the 2030 Agenda; (b) support peer-learning and provide technical support and capacity building to governments on scenarios, tech futures, roadmaps, and tools in support of making the SDP scenario a reality; and (c) convene scenario analysts, government advisors, scientists, and frontier technology experts under the UN Technology Facilitation Mechanism to share experiences and synthesize the latest knowledge on the wider impacts of emerging technologies and sustainable development model of the 2030 Agenda.