Background note on science, technology and innovation

for the High-level Political Forum on Sustainable Development 2020

Results of online survey and consultations conducted by the IATT

New York, 24 June 2020

In response to a recent call by the President of ECOSOC for online stakeholder consultations in preparation for the science, technology and innovation (STI) components of the High-level Political Forum on Sustainable development (HLPF), the Interagency Task Team on Science, Technology and Innovation for the SDGs (IATT) under the UN Technology Facilitation Mechanism reached out to all interested STI stakeholders to provide written responses to a series of survey questions on: (1) STI action on COVID-19; (2) STI solutions and good practices for the Sustainable Development Goals (SDGs); and (3) cross-cutting STI issues and "levers" of change.

In her letter the President of ECOSOC invited all interested policy makers, scientists, engineers, innovators, entrepreneurs, and organized science communities, to engage in these online consultations. As of 7 June, a total of 187 written inputs were received, including eleven from Member States, eight from the TFM 10-Member Group, eleven from the IATT (ECLAC, ESCWA, FAO, IAEA, ILO, ITU, OOSA, UNIDO, UN Technology Bank, WIPO, World Bank), and 157 from other TFM stakeholders. In addition, the IATT and 10-Member Group organized and engaged in a number of online consultation meetings and events. All these inputs are summarized in the present Secretariat's background note for the HLPF session on science, technology and innovation. They complement the broader thematic online consultations for the HLPF.

More detailed information is available in extensive Annexes to appear on the TFM website, with updates from selected IATT work streams and other UN system projects, listings of TFM partners' related STI conferences, forums and initiatives, as well as of initiatives and actions at the national and local levels that were collected through the survey.

Contents

A. Science, technology and innovation action on COVID-19

Science, technology and innovation (STI) are at the heart of the responses to the COVID-19 pandemic. This section reports on selected findings from the survey and online consultations in terms of STI solutions for COVID-19 response and recovery (Section A.1), ways and means to strengthening science and technology advisory systems (Section A.2), and international cooperation (Section A.3).

1. STI supporting COVID-19 response and recovery

The COVID-19 crisis is a stark reminder of the wide ranging social and economic costs of a sudden pandemic, plunging the world into a state of 'war against an invisible enemy'. Global cooperation in science, technology and innovation (STI) can however play an invaluable role in bringing the crisis to an early end and in supporting the subsequent recovery.

The pandemic reinforced the need for rigorous and responsible scientific research to inform policy and collective action. Scientific knowledge allows us to understand the fundamental relationships between people and nature, to assess and implement solutions to today's complex challenges, and to identify new and emerging threats and opportunities. It is essential to counter the spread of misinformation that undermines our ability to act decisively and in solidarity. Thus, science needs to be advanced as a global public good. Science needs to be effectively used in decision-making. Scientific capacities need further development in all parts of the world. Open science policies and practices are important, and international, inter-disciplinary scientific collaboration need to be strengthened.

COVID-19 response

The COVID-19 pandemic we are facing all around the world has taught us more about the scientific, research and innovation systems than any other event so far. It has reached every corner of the world and has shown how exposed and vulnerable humanity is and how as well. The science and research systems are robust but agile. There are individuals, teams and institutions, excelling in their efforts to provide us with suitable cures and vaccines. There is increased open access to published scientific articles that enables researchers all around the world to scan through the millions of achievements of the human mind, in support of the response to COVID-19. This is science and research, and it is giving its best to find the light at the end of the tunnel, using AI and massive cloud storage available for data processing. However, there is another side of the coin. There are challenges that may have remained hidden even before COVID-19 and have become even more salient now: poverty, hunger, schooling, inequalities, access to water, and public health. To raise the importance of such essential matters, communication about the problems is of utmost importance.

From a technology perspective, the development of vaccines, treatments and testing equipment are top priorities to overcome the COVID-19 crisis. To this end, as declared in the G20 Leaders' Statement issued in March 2020[1], G20 leaders committed themselves to increasing research and development funding, leveraging digital technologies, and strengthening scientific international cooperation. They also emphasized the need for better coordination with the private sector towards rapid application of new technologies.

Mobilizing existing knowledge and technologies is essential for overcoming the crisis. Large-scale research and development of new vaccines, drugs, and treatments are underway around the world. WHO and Member States take coordinated action based on science and evidence, focused on tackling the spread of COVID-19 and mitigating both its impacts in support of the poorest and most vulnerable, ultimately reducing the risk of future waves of infection. They support vaccine development and delivery through international cooperation and public private partnerships. Many UN entities are supporting these efforts in their areas of expertise.

[1] https://g20.org/en/media/Documents/G20_Extraordinary%20G20%20Leaders'%20Summit_Statement_EN%20(3).pdf

In response to a recent UN call for technology solutions on COVID-19 and its immediate impacts organized by DESA and IATT partners, more than 180 technology solutions were received and accepted for being featured on the 2030 Connect Online Technology Sharing Platform. They are proven, affordable and scalable technology solutions that can accelerate progress towards providing basic health functions, especially for vulnerable people. Twelve of the solutions were submitted by UN entities themselves that are active IATT members, which a testament to the considerable expertise and substantive reach of the IATT (see table 1).

Table 1. UN system COVID-19 technology solutions submitted in response to the IATT call

COVID-19 technology solutions	UN entity/IATT member
Field Office Brazil - medical grade refrigerator equipment	UNIDO
ICGEBResPage (International Centre for Genetic Engineering and Biotechnology) – open access COVID-19 resource platform)	ICGEB
System Dynamics Modelling for vulnerable populations at risk from COVID-19	UNEP
Diagnostic detection on COVID-19 by RRT-PCR protocol and preliminary evaluation (RT-PCR test kit)	IAEA
Space technologies and geospatial data in responding to the COVID-19, e.g. Coronavirus COVID-19 Global Cases Dashboard	UNOOSA
Telemedicine PPPs to reach all, including the most vulnerable	ILO
Enhanced use of geospatial technologies for improved facilities for hand washing	FAO/UNHabitat/UNEP/ WHO/GGIM
iSDG Model	UNEP
ASYCUDA	UNCTAD
Food Project	FAO
Humanitarian Access Project	WFP
Grain ATM	WFP

Source: submitted in response to the IATT call

A wide range of technology solutions were submitted in the following areas: epidemic prediction models, protective equipment, COVID-19 diagnostic technologies, disease analysis and drug design technology, public consultation and governance support technology, medical equipment, and other technologies.

The UN call for COVID-19 technology solutions is a good example of the decentralized, working level modus operandi of the IATT in which 43 UN entities are now active. The call was separately disseminated by IATT members among their constituencies and stakeholder communities and then the results again used in their own meetings and events. For example, UNCTAD disseminated the call and provided the results on CSTD Website.

The UN Technology Bank launched the Tech Access Partnership to supports developing countries to scale-up local production of critical health technologies needed to combat COVID-19. Most importantly, WHO launched the COVID-19 Tools (ACT) Accelerator – a global initiative to speed the development, production and equitable access to new COVID-19 tests, treatments and vaccines.

In addition, various IATT members are users of advanced technologies in their response actions to COVID-19. For example, ESCWA works with UNHCR and the Data Pop Alliance to harness big data for estimating the impacts of COVID-19 public response policies in Lebanon and Jordan.

Furthermore, TFM partners have set-up online portals with tech solutions. For example, WFEO has set an online portal on the engineers' response to the Covid-19 crisis, including a Knowledge Hub about the engineering solutions developed to face the challenge of quickly adapting industrial production lines, whilst retooling operations to support the medical response. International cooperation between scientific and technological bodies and the wide sharing of knowledge and innovative practices is especially important in the context of global pandemic.

Various UN entities such as UNOSSC's South-South Galaxy Platform and others posted demands and opportunities encouraging joint projects between experts from different parts of the world. All these technology solutions are expected to ultimately become available through the TFM online platform as a one-stop-shop – not replacing but supporting partners' work and extending its reach.

The UN events and communication platforms are of the utmost importance. There is always a possibility to strengthen even more international cooperation around science and research. But the main challenge is to enhance international cooperation in terms of technology solutions that are widely accessible. In the context of a global pandemic the matter acquires added urgency and different aspects may need to be re-visited and models re-thought. How can one maintain the incentives for R&D such as through patents and licensing, and the imperatives of rapid and broad access to technology? What demonstrated examples or political initiatives are there to enable access to the underprivileged? In what way could technologies be made accessible for evaluation to the local problems of the developing countries? After having tested and prototyped a technique in a solution for a local issue, how can this be disseminated more broadly across the world to those in similar circumstances? Could the experiences of this period have broader consequences across the SDGs?

COVID-19 recovery

Globally, there has been a shock to supply because many employees and workers cannot generate goods and services. Even when people have enough money, as in countries with strong social protection systems, they cannot revive the economy in the absence of production. In many places, the situation also gets exacerbated through lost incomes, and reduced physical access to goods and services, adding up also to reduced demand. The sudden contraction in tax revenue can make it harder for governments to support workers and companies.

Since most developing countries depend on external revenues which are the most affected by the pandemic, the net effect on public revenues can be catastrophic. This is amplified by the growing macroeconomic uncertainty and the abrupt contraction of investment and the resulting private spending, added to forced payments abroad (e.g. debt service), to falling export revenues (e.g. oil), speculation, capital flight, pressure against exchange rates and danger of moratorium, suspension of payments, credit default. In this scenario, traditional or orthodox measures are insufficient and other measures such as moratoriums on debt servicing or recycling capital (e.g. acquiring bonds from countries with extreme economic difficulties) may be needed.

Therefore, in most countries it is necessary to find a balance between containing the peaks of the pandemic ("flattening the curve") and maintaining economic activity so as not to cause a socioeconomic catastrophe in the vulnerable population. The COVID-19 pandemic has more serious impact to vulnerable people, such as the elderly, the infirm, and those in countries with poor quality health care services. In some cases, there has been stigma against patients, medical staffs, and essential workers. Now is the time to put the principles of the SDGs into practice with no one left behind. It is important for the world to show solidarity in recovering the enormous social and economic losses and transform our society into something better – a 'new normal' with values such as culture, history, trust, sympathy, compassion and coexistence with nature. The STI for SDGs from now should be an accelerator of such transformation.

There won't be a decisive exit from the present crisis until a vaccine is developed, produced and disseminated worldwide. Meanwhile, measures have been taken to protect and take care of the population (medical and protective equipment, ventilators, healthy distancing and hygienic practices). Nonetheless, there can be no normality until there is a viable exit strategy to the confinement, which is causing economic hardship to the majority of people and businesses. This strategy will depend on massive tests, or combination of tests (e.g., with Test Trace Isolate Apps). Mathematical statistical models need to be used and good practices around the world need to be shared. This requires training and guidelines that can translate into public policy and the adoption of new and innovative technologies.

Economic recovery measures will mainly be attained through strong multilateral achievements, because most countries will be looking for financing at the same time. For this reason, organizations such as the IMF, the World Bank, or new funds, like the UN Fund proposed by Norway must be involved in solutions. We must reconsider that the interconnectivity of the world could generate virtuous cycles of cooperation (and avoid conflict). In any event, many countries are integrated into global production chains that are "too big to fail", and that it is fundamental to avoid the tragedy of the commons and guarantee the common good. This requires preventing the deepening of the crisis, particularly by overcoming future bottlenecks, like lacking infrastructure and means to produce and disseminate future therapies and viable vaccines.

Multilateral and multi-stakeholder initiatives will be important for creating the capacity to develop, manufacture, distribute, and regulate future vaccines equitably and globally.[2] The Coalition for Epidemic Preparedness Innovations (CEPI) complements the work of WHO. Its membership includes governments, international organizations, foundations and the private sector. It develops a broad and articulated perspective on global progress in vaccine development. Multilateral and multi-stakeholder spaces are central to discuss and coordinate the steps to be followed. Both the mass production and the global distribution of vaccines will require international cooperation and coordination of actions and contributions never seen before. This is an example for future initiatives. Governments and stakeholders such as the Bill & Melinda Gates Foundation and have also joined hands to co-fund development of treatments through the Wellcome Therapeutics Accelerator, as well as diagnostic tests through the Foundation for Innovative New Diagnostics (FIND), a global non-profit organization driving innovation in the development and delivery of diagnostics to combat major diseases affecting the world's poorest populations.

2. STI advisory systems

What can be learnt from the COVID-19 responses at national and global levels for improving science and technology advisory systems, in order to be better prepared for future pandemics and sustainability crises? How can science-policy advisory capacities be improved and how public trust in science be strengthened?

The United Nations Department for Economic and Social Affairs (DESA), in cooperation with IATT partners and the 10-Member Group under the auspices of the UN Technology Facilitation Mechanism organized the *UN expert conversation on lessons-learnt from the COVID-19 pandemic for better cooperation on science and technology advice* on 20 May 2020. The expert conversation was attended by 33 experts, including 6 current and former members of the TFM 10-Member Group of high-level representatives, 14 eminent external experts active in the TFM, and 13 expert staff and officials from the UN system that are actively involved in work addressing the science-policy-society interface. The participants included experts, senior officials, academia and representatives of organized science communities and the UN system.

STI advisory system lessons learnt from the COVID-19 responses

Even countries at the scientific and technological frontier with seemingly robust scientific advisory systems have struggled in their current COVID-19 responses, as measured against objective criteria. The mechanics of science-advisory, including institutional architecture issues and capacity building, remains important and a number of key ingredients have long been suggested (see box 1).

However, several countries had all these institutional ingredients of a good science-advisory interface infrastructure in place yet failed in their COVID-19 responses – in some cases even catastrophically. It has been argued that additional intangibles were responsible for these failures, including aspects of culture, politics, history, ethics, and values. In some cases, outright culture wars and upcoming elections made the situation even more unmanageable against the backdrop of scientific uncertainty.

[2] See, for example, UN GA Resolution 74/274.

Box 1. Ten things that countries can do to improve the "mechanics" of their science advice (Colglazier, 2018)[3]:

1. Appoint a chief science advisor to the head of state and create an advisory committee of non-governmental scientists and technologists to assist the chief science advisor
2. Appoint science advisors for each of the relevant government ministries and connect them in a network with the chief science advisor
3. Create civil service positions for individuals with scientific and technical backgrounds for serving in government ministries
4. Provide fellowships for young and mid-career scientists, engineers, and medical professionals to experience working in government
5. Solicit independent scientific advice on key policy issues — both science for policy and policy for science — from the most respected non-governmental scientific and technical institutions in the country, and have that advice made public
6. Create a unit with scientific and technical professionals to serve the legislature on issues where scientific input is needed
7. Encourage scientific professional societies to present awards for high quality science journalism
8. Encourage universities to create courses on science and technology policy and train students for careers that combine competence in science and technology with knowledge about policy in the public and private sectors
9. Encourage the domestic scientific and technical community to engage and collaborate with the best scientific and technical communities around the world
10. Utilize science and technology as a means of improving relations with other countries and helping to solve regional and global problems.

All these institutional and intangible aspects strongly shape the overall credibility of science-policy advice in each country and at the global level. And this credibility has proven to be the single most important trait for the effectiveness of science and technology advisory systems in the current COVID-19 responses. Lack of national leadership and willingness to collaborate have been other key factors for failure in the case of COVID-19, compared to Ebola and SARS epidemics of the past. The Fukushima reactor accident was highlighted as another example that showed the weaknesses in the science-technology-policy systems.

UN system organizations and NGOs have tried to fill the gap with collecting, sharing and using data and lessons-learnt globally. This has also helped understanding what is going on at the country level. Against this background, the UN should consider creating general principles of science advisory systems. They should be built on whole-of-government and trans-disciplinary approaches. Each country should build its own system, taking into account their cultural and historic specificities. This should also include close coordination of science-advisory mechanisms at the UN, including but not limited to the TFM 10-Member Group of High-level Representatives and the Independent Group of Scientists for the GSDR.

Building public trust is just as important as giving science advice. The names of science advisors and the findings and evidence must be publicly accessible. Scientists and science advisors need to provide advice free of politics. Scientists should not get involved in policy or political decisions. Scientists need to make it clear where there is uncertainty and where value judgements are coming in. Institutions need to listen to the public and the wider society and their concerns. Above all, they need to make sure that society is prepared for the ramifications of governments following their advice.

COVID-19 has also spurred many examples of useful, direct public engagement by scientists. For example, some of their podcasts on COVID-19 have millions of followers and have had strong influence on public trust in science and understanding of scientific findings. For example, in Germany public trust in science has greatly increased during the pandemic, whereas in some other countries it has reduced.

There is also a wider issue of social media and its dynamics leading to "echo chambers" and highly polarized views that are not grounded in scientific facts. In this context, it is also important to find better

[3] https://medium.com/sciencediplomacy/ten-things-countries-can-do-to-improve-their-science-advice-b91da6256ceb

ways to credibly flag fake news and for scientists to be accessible and visible on social media to people when they're looking for scientific facts.

Following this pandemic there should not be a going back to the science-policy ways of the past, but to improved, coordinated and cooperative science-advisory systems.

Improve science-policy advisory capacities

With COVID-19, arguably the biggest "experiment" of science and technology advice is underway. Events continue to unfold, and it is not yet clear what the broader implications will be on the capacities of science-policy advisory systems to deliver in future pandemics and other sustainability crises. With TFM partner's inputs, DESA recently published a policy brief on better cooperation at the science-policy-society interface which contains further answers to these and related questions.[4]

Science advice is needed to guide the economic recovery. Science advice occurs through two major routes: formal processes and informal processes. Both formal and informal advice are critically needed, but informal advice and intangible knowledge for interpreting scientific results are especially important. More informal networks allow sharing practice, not only at the global level but also at the regional level. During this crisis, much of scientific advice was not implemented due to political and economic barriers. COVID-19 crisis is and will amplify the nationalism and isolationism. For reducing the barriers, more case studies, the inclusion of social scientists and connectivity between formal and informal scientific advices should be further considered. In this context, INGSA and ISC are currently working on guidelines.

Transparency is important, especially about the kind of evidence that is presented. While there is a clear need for diverse disciplinary inputs, most often a sufficiently wide range of evidence has often not been available. In particular, it has been hard to assess the epidemic models and the models that estimated socio-economic impacts of various policy measures.

A number of attributes of individuals that serve as science advisors have proven essential, including the ability to earn trust, show humility, an ability to communicate uncertainty issues to the general public, as well as diplomatic skills that go beyond "speaking truth to power." Similarly, ethical issues merit great attention and the conduct of individual scientists is important. In particular, their egos should not become an issue when they are influential. Formal training of scientists to interact with society at large and politicians in particular would be useful. Diplomatic skills are also important and hence capacity-building for science diplomacy is needed.

Diversity in science advice is important and needs to include both natural and social sciences. Risk assessments/management and organizational skills are also important. Expert advice is needed not only at global and national levels, but also at municipal and local government levels. A general lack of scientists in governments and their bureaucracies is a fundamental problem in many countries, including at the local and provincial government levels. It comes as no surprise that countries that have strong medical and public health systems, but where politicians drove the COVID-19 response out of political rather than evidence-based calculations have had troubling COVID-19 records.

Significant investments are needed in resilience and prevention, in order to make the systems "fit for purpose". While purely crisis responses are politically popular, prevention measures are much more valuable, yet politically less popular. More generally, this fact also constrains effective SDG investments.

The COVID-19 response has highlighted the worst in people but has also encouraged collaboration at all levels. Science organizations need to join forces and avoid duplication of efforts. The UN should lead a high order system science policy interface for this crisis, eliminating the gaps among regional, national and international policy groups in respect to local needs and culture, and should encourage scientists to

[4] The COVID-19 pandemic: a wake-up call for better cooperation at the science–policy–society interface, Policy brief no. 62, https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/PB_62.pdf

be involved in local policymaking. Local responses are also the key. There is also the need to change the current policy environment so that scientists don't work under political pressure.

The long-term effects of COVID-19 lockdowns are not yet known. It is also noteworthy that many science-policy systems do not yet have clear and evidence-based exit strategies. More effective and trust-worthy State-institutions are needed, in line with the aspirations of SDG 16. It was noted that some regional bodies, such as the African Union CDC reacted very well to COVID-19. Exit strategies and dealing with long-term effects on society will be important areas for policymaking.

Digital technologies have played an important role in keeping the economies alive and for safely exiting lock-downs. Looking beyond the pandemic, digital and green economies with these new growth sectors could support sustainable economic recoveries. Open platforms, where alternative policies and the evidence they are based on are made available for scientific and public debate, will be more important than ever in the future.

Build public trust in science, including global scientific assessments

Building public trust in science is essential. In this context, transparency is important in terms of making the names of the scientists public who participated in advisory panels and in terms of promoting open scientific data. The ability to communicate uncertainties is critical for maintaining credibility. Communication with societies is equally important as communication with scientists. During the crisis, scientists worked on a new virus but also learned how to work in policymaking and how to react to false information spreading. Social media needs to be used more effectively to promote better understanding of the scientific findings, uncertainties and issues.

In order for science advice to be conveyed effectively in a pandemic scenario, convincing words of scientists based on rich experience and deep thought are important to navigate the interface with political administration. We must ensure that epidemiological data – provided by national and local governments – is easy to access and is interpreted responsibly by a reliable and trustworthy "broker". This in turn will help the general population to better understand the situation and to act in a rational manner.

Scientific organizations need to engage more in cyberspace and actively oppose fake news and made-up facts. For this purpose, authoritative assessments are needed to combat fake news. While it is important for scientific progress in generally that scientists continually and critically question current scientific findings, in public discourse the resulting many voices of science are often sidelined or discredited for political or lobbying purposes. One example is the debate on the effectiveness of wearing different kind of masks. Rapid scientific assessments that include scientists with different views can shine light on these controversies and help the world move forward. Without more effective science-policy architectures that prevent political hijacking, many governments will continue to fail regarding scientists as clear partners.

Public awareness is an important aspect that was found to be lacking during the ongoing crisis. Proper awareness helps to deal with misinformation and fake news issues. Public awareness programs should therefore be initiated on all communication platforms to allow control of ongoing pandemic and other unexpected future health crisis. For example, DFID and Unilever fund a global programme to reach a billion people worldwide raising awareness and changing behavior encouraging everyone to regularly wash their hands with soap.

Scientific assessments are necessary for showing the areas of consensus and the degree of disagreements among scientists, but also for drawing the borders between scientific cooperation and competition. There is a need to identify areas for scientific assessments, such as those identified by the "The World in 2050" (TWI2050) initiative or the related six entry points suggested by the UN Global Sustainable Development Report. In the current crisis, it is especially important to seek synergies between health, technological and economic actions. TWI2050 is one such international effort that examines the role of innovation in

achieving the SDGs in a post-COVID world. The 17 SDGs create enormous complexity for governments. Hence, the GSDR and TWI2050 approaches will be more useful structures for assessments than goal by goal approaches.

Assessments like the IPCC and IPBES constitute successful examples of science-policy interfaces. They determined critical strategies and actions for the public and private sectors. The IPCC model could and should be replicated in other areas.

Governments around the world have pledged trillions of US dollars for recovery from COVID-19 impacts. Science and scientific facts should also play a role in deciding where these investments are made, in order to build resilience for future pandemics and other sustainability crises. For example, climate change aspects should be included in any exit strategy. Exit strategies from the lockdowns will become de-facto "mini roadmaps" and will lock-in investments and technologies for years to come. Hence, the importance for STI roadmaps for the SDGs in a post-COVID world. Such roadmaps could support readiness for future sustainability crises. Among the various actions in this regard, it was proposed to establish a global crisis response budget that would be independent of political ownership.

The complexity of the SDGs typically discourages local governments to develop and implement roadmaps. Yet, local practices are particularly important, as evidenced by local SDGs initiatives that took action over the COVID crisis. These good practices should be collected and reported using a standardized reporting system.

Beyond the scientific assessments, research and technology cooperation that engage many different approaches have been extremely useful. For example, the Coalition for Epidemic Preparedness Innovations (CEPI) not only built an infrastructure for rapid vaccine development that has dramatically shortened the time needed for development, testing and roll-out of COVID-19 vaccines, but it also built credibility with private and public R&D partners for the latter phases of COVID-19 vaccination trials.

The UN should continue discussion on the science-policy interface as a core workstream of the TFM. It should establish a permanent advisory system for the UN Secretary General and relevant UN organizations. To do so, collaboration with OECD, the International Network for Government Science Advice, the Foreign Ministries S&T Advice Network and with the International Science Council is strongly recommended.

3. International cooperation and actions

How can we strengthen international cooperation around science and technology to better deal with challenges such as the COVID-19 pandemic? What can and is being done in this regard?

Multilateralism and science diplomacy

The COVID-19 pandemic has proven the vital role of science, technological-progress and innovation in fighting existential risks and easing the perennial burdens of humanity. It has raised awareness of the role of science diplomacy in fostering innovation, and of the need for global cooperation and coordination directed by a robust and functional multilateralism.

The UN and all stakeholders should help narrow the gap between public awareness of the problems we face, and the innovative technological solutions at hand. The present crisis has proven that combating the pandemic - or any unexpected sustainability crisis - requires an understanding of the problem and an ability to swiftly and effectively react. This depends on global cooperation, coordination, effective toolkits, active measures and dissemination of best practices. Hence, existing international and multilateral organizations that already handle different kinds of crises should be evaluated, adapted, upgraded and empowered. On-going or new taskforces should be asked to review and propose solutions in the light of present weaknesses.

The pandemic has proven the need of free flow of relevant scientific l data and information, and different types of enforceable test, track and trace programmes. There are convincing examples of how good preparation and early action can save thousands of lives and ease the economic burden by making exit strategies more efficient and flexible. They also show the power of technology in bringing together large amounts of information, from genetic to circumstantial, and in mining it effectively.

The pandemic reconfirms the lesson that all countries should have broad and equal access to accurate, useful and timely information provided by the multilateral system, in order to generate knowledge of the problem they face, fight fake news, expose bad practices and confirm reliable information. This includes identifying the origins, characteristics, dimensions, reach and dynamics of the crisis factors, so that interaction models can be generated at the national or multilateral level to evaluate various policy options and make decisions. For example, we should review existing global early warning systems, protocols and the technologies they use to contain and respond to future eventualities in a timely fashion and their interaction with the devastating dynamics that can bring about, or accelerate, global sustainability risks.

The pandemic has confirmed the need for well-organized and effective State intervention, and of the need for a more adaptive governance and regulatory framework, particularly for preventing and responding to future emergency situations, including bioterrorism. In this regard, a serious effort should be made to identify sources of irrational, belligerent, abusive or negligent technological applications, and stop them.

The pandemic has exposed the dangerous asymmetries between countries and regions in their capacity to monitor and handle the pandemic and its socio-economic impact. This creates an obvious problem because, as has been pointed out repeatedly, if the virus survives anywhere (or the source of any other future crisis), it becomes a potential risk everywhere. So, our immediate concern should be how the world could respond to help reduce these institutional, technological, educational, R&D&I heterogeneities everywhere. This needs to include the great global challenges that humanity faces.

Very dissimilar economies in their institutional strength, their natural and human resources, their capacities for technological adaptation, their innovation ecosystems, demand to get on the 'technological train' without leaving anyone behind. In particular, it is urgent to close the digital divide. A strengthened multilateralism based on the digital revolution, and a new economy founded on impact entrepreneurship, responsive to inclusive and sustainable development, are, today, the necessary responses to the highly disruptive dynamics facing the world - from environmental deterioration to deep inequality. It implies that the business models coincide, both with the interests of investors, and with high levels of positive social and environmental impact, adjusted to risk. Impact entrepreneurs drive innovation, generate quality jobs, revitalize mature industries, and create new markets with products, processes, services, and marketing methods. This is an essential part of the response to ethical capitalism, and to inclusive and sustainable development that induces equal opportunities and securities for all.

Such steps forward towards strengthening international cooperation around science and technology require an integrative foreign policy: agile, multifaceted, versatile, ubiquitous and permanent. With technological acceleration, the new currency and the most important input is knowledge. Multilateralism and diplomatic execution must embrace this new reality. Each country must be helped to identify the spaces in which they add maximum value in economic and commercial promotion, international cooperation, cultural projection, and in political and consular relations between state and non-governmental actors.

Towards a new STI cooperation paradigm

The present global system of international collaboration in science, technology and innovation (STI) is focused on raising the quality of national public research systems, cost sharing through scientific collaboration and international mobility of researchers for mutual benefit. This system has been

successful in advancing knowledge in OECD countries and some emerging economies, but it has been less successful in helping many developing countries mobilize STI for their own development. Instead, many of these countries have had to supplement their domestic resources with official development assistance, multilateral development bank finance, foreign direct investment, and foreign technology imports, in order to make necessary investments in education and science.

A new STI cooperation paradigm is needed to meet global cross-border challenges, such as COVID-19. It needs to promote transformative innovation focused on "global public goods" and specific challenges at hand, rather than just across-the-board science and technology cooperation. Such cooperation would then need a framework for international STI co-operation that goes beyond cost sharing reasons and the expansion of fundamental knowledge through co-operation in basic research or mega-science projects (e.., CERN, ITER, International Space Station). The new paradigm for global STI cooperation requires new governance mechanisms allowing deliberating and designing concrete collaborations that bring together business and private finance actors with multilateral and national development banks. It also requires specific institutional capabilities and new mandates to broker, orchestrate and raise funding for global challenge-driven STI programmes. The new paradigm should also reinforce international collaboration on foresight and anticipatory capabilities in international organizations and governments, in order to mobilize science to strengthen the resilience of public institutions and economic actors.

Elements of the new paradigm are already in place but need to be strengthened. There are already several examples of international collaborations focused on mobilizing STI for the SDGs and other global challenges. They range from mandate-based international organizations such as the CGIAR, the IEA, Mission Innovation and Global AMR R&D Center to partnerships initiated by governments and philanthropies. One characteristic of the new partnerships for international STI co-operation is the involvement of a broader range of stakeholders, including companies and civil society groups, and notably private philanthropies, especially in developing countries. One example is the Coalition for Epidemic Preparedness Innovations (CEPI), a partnership between public, private, philanthropic, and civil organizations to stimulate, finance and co-ordinate vaccine development against epidemic diseases such as COVID-19. Other globally relevant flagship collaborative innovation programmes could also be supported to drive transformative innovation in areas such as specific climate change solutions.

There is much scope for the donor community and STI policy communities to work together to increase investments in STI for SDGs, as their level remains low.[5] It is also important to build a robust and comprehensive international evidence base to better track of investments and the impacts of international collaborations on STI for SDGs, in order to promote policy learning.

The international community needs to encourage a transition from the present competition focused mode of STI to one that is much more collaborative and where shared goals and missions underpin individual and collective STI actions. It also needs to agree on an international system to incentivize and reward businesses and finance to engage and invest in international STI collaboration for the SDGs. It should strengthen international platforms and communities of practice discussing and sharing concrete experiences and good practices of STI policies and innovations relevant for the SDGs, such as the TFM and CSTD. Transformative innovation policy and mission-oriented innovation policies can be used by governments to encourage a more collaborative mode of STI and to help broker international collaborations with a dedicated focus on orchestrating and conducting collective actions to co-develop and deploy innovations at the scale adequate to achieve transformative impact.

[5] Concessional finance to STI is estimated to range from USD 10 billion to over 20 billion per year, representing six to 10% of total concessional finance by DAC members, multilateral organizations and other countries. This may be partly explained by the historical disconnect between policy communities responsible both on the national and international level.

International cooperative actions

Decades-long international cooperation has led to a strongly interconnected world resulting in economic development and greatly reduced poverty levels in most parts of the world. International cooperation on STI has been decisive in this respect. For example, the green revolution has translated international STI cooperation into increased food supply and reduced hunger. It is clear that all efforts need to be made to better understand the great global challenges and risks - new and old – whether COVID-19 or climate change - and address them as shared problems faced by humanity.

The need for international cooperation on science and technology are more important now than ever. Member States, regardless of their socioeconomic status, should collaborate to gather more information on the different threats, challenges, and possible solutions. Direct partnerships between Member States are important as are multilateral initiatives. The multilateral efforts can shape political will, sharing knowledge, technologies and scientific insights, and raise everyone's STI capacity.

The UN, as a global platform, can provide opportunities to nations to communicate and harmonize thoughts and actions and to remove misconceptions among themselves. International cooperative action on COVID-19 is, of course, most evident today in WHO's actions, for example, the "Solidarity" clinical trial for COVID-19 treatments. Also, UNESCO's open science initiative is very relevant and should be adopted at a faster rate.

UN leadership and collaboration of member countries is of critical importance. The UN system and Member States should make efforts to give more political and policy support and resources for STI communities to work together. This can be initiated by organizing the STI community through an international expression of solidarity and a commitment to work together towards solutions to all these challenges beyond political interest and national borders. A clear and strong message from the President of ECOSOC would be important and timely.

COVID-19 has demonstrated that there is a weakness in the existing UN frameworks to deal with major systemic, transferrable, and cascading risks, or in other words, development risks and safety has not been a goal of global priority. This relates especially to the SDGs addressing poverty alleviation, energy, food and water security, infrastructure development, urban development, climate change, and environment. The Sendai Framework for Disaster Risk Reduction and the Paris Agreement address aspects of these issues from their respective angles, but there is a need to explore more in-depth the role of STI for development safety. The STI community should be called upon to suggest solutions in this regard. Closer international collaboration is needed between science and technology researchers.

There are important multi-stakeholder international cooperative actions on COVID-19 and other infectious diseases. The Coalition for Epidemic Preparedness Innovation (CEPI) leads developing vaccines for COVID-19 under international cooperation. GAVI Alliance is another international organization to improve access to new and underused vaccines for children living in the world's poorest countries. Also, research funding agencies for medicine and medical equipment have a global network called Heads of International Research Organizations (HIROs) and facilitate joint funding.

International cooperation among STI communities needs strengthening to build more effective early warning systems that include fast response, effective assessment and monitoring aspects. To this end, STI communities should be supported and encouraged to: (a) improve health surveillance; (b) develop and set new and much stronger protocols and facilities for scientific data sharing and exchange; (c) research and develop standard health variables for early detection of disease; (d) build stronger international programmes to bring together researchers, laboratories, and centers of excellence to accelerate research and applications; and (e) communicate science achievements and technological solutions to the general public, in line with open science and citizen science movements.

The number of COVID-19 infections in developing countries have already surpassed that of the developed countries. What role can the scientific community play in effectively supporting less economically developed countries during and after the crisis? Sharing trustful data and findings openly with developing countries under growing threats is mandatory in a short range.

It is very important to internationally share data between scientists and decision makers, as experienced during the COVID-19 pandemic. STI can help developing cloud-based big data platforms to collect, integrate, and freely share information on the emergence and distribution of pandemic. Analysis of the spread of COVID-19 in different regions of the world, and timely studies on this data can help to discover the scientific response strategies for mitigation and control of the pandemic.

Data and information are critical for decision makers however, they require adequate scientific support to interpret and develop correct strategies. The STI community can help developing data analysis and information products that can facilitate the translation of raw data into decision-making information. At the same time, there is also needed to develop online platforms and channels for efficient dissemination of information and communication of strategy at all levels to ensure effective implementation of relevant policies and actions. In the middle and long term, science communities should pursue new knowledge and enabling technologies as global public goods. Strong UN leadership would be needed for handling intellectual property on new vaccines, therapeutics and testing.

B. STI solutions and good practices for the Sustainable Development Goals (SDGs)

What are the most important ways in which STI can contribute to the achievement of the SDGs? What are the most promising innovations and technology solutions? What are important barriers to the development and deployment of STI for the SDGs? What types of STI policies, partnerships, and actions are needed? This section provides an overview of answers to these questions collected through the online consultations. The Global Sustainable Development Report 2019 highlighted the following entry points with the greatest promise for progress across the entire SDG agenda: improved human well-being, capabilities and resilience; to sustainable and equitable economic and urban systems; to securing global environmental commons; and to ensuring sustainable systems in food and nutrition, accessible energy. The online thematic consultations for these entry points included questions specific to science and technology issues, policies and solutions. They are documented in the respective background notes for these sessions and are thus not repeated here. However, they are complemented with additional STI specific technology solutions, innovations and issues that were collected through the IATT survey and online consultations. The "*Workshop on Science, Technology and Innovation for the SDGs - Meeting of the IATT and 10-Member group under the TFM in preparation of the Multi-Stakeholder Meeting on Science, Technology and Innovation for the SDGs 2020*" was organized by DESA, UNCTAD, UNOSD, OOSA, and UNIDO in Vienna from 3-5 February 2020.[6] It was the starting point for the STI consultations process in 2020.

It is important to note that due to the diversity of the SDGs, there is no single list of the most promising technologies and innovations for the SDGs. Country contexts are different and dynamic. The history of industrial and technological revolutions has taught us, that there is always the next turn, the next challenge, the upcoming change. From steam machine to robotics and AI, we have still not learned that the only suitable technological solution is the one that helps everyone, including the animal world and nature, and in every corner of the world. However, technologies that reach developing countries may accelerate global achievement of the SDGs most. To achieve that, we not only need to find solutions by and through scientific and technological means. We need to find ways to distribute them, to dispatch them, and to put them in wide use.

[6] https://sustainabledevelopment.un.org/?page=view&nr=3268&type=13&menu=1634

1. Technology solutions for resilient homes, infrastructures and cities

Small cities and towns are home to about 34 percent of the global population and, particularly in low-income countries, they are significant contributors to sustainable development, especially due to activities deriving from agriculture and food systems. Job creation and diversification in off-farm activities in those areas are also vital for reducing unforced migration of the growing young population.

From an engineering perspective, the most promising technologies are the ones that enable building and developing resilient communities and infrastructures. This includes ethical and transparent uses of big data and AI technologies, in particular, solutions to improve sanitary and disaster risks management for cities through simulations, alert systems and risk assessment. Those innovations are to be combined with emerging geospatial technologies for smart cities. In order to maximize the benefit of emerging technologies and minimize their potential negative impacts, WFEO has proposed principles for responsible conduct with Big Data and AI innovation and application in engineering.

Modern homes made possible by science and technology and equipped with high-speed digital connectivity have not only offered comfort and safety during the current pandemic, but have also effectively served as schools, doctor's offices, workplaces and gyms. However, these wonders of technology remain out of reach of many who have socio-economically been left behind. Hence, the COVID-19 has highlighted that the SDGs are more critical today than ever.

SDG2 (zero hunger) translates into local food production through available technologies. It is connected to SDG6, (clean water and sanitation). In turn, the achievement of SDG6 will enable people all around the world to produce enough food and avoid being COVID-19-infected, at least to a certain degree. SDG3 is of utmost importance (good health and well-being), as COVID-19 vaccinations - once safe and effective – need to be available to people all around the world. Pre-existing conditions – such as NCDs – jeopardize recovery if infected, and are associated with worse health outcomes. SDG8 (decent work and economic growth) also immensely gains importance in the view of the present COVID-19 pandemic. Many jobs will get lost. Many people will suffer from the change of life as we knew it. Solutions to improve this situation must be sought, to allow for everyone to live a decent and fulfilling life, and scientific results, translated into technologies could be the basis of this cultural change.

Many technologies already exist that can help solve the SDGs including off-grid renewable energy; potable water; off-grid solar-powered irrigation; and off-grid food storage, refrigeration and processing. Sustainable aquaculture for example can contribute to feeding a growing and wealthier global population, effectively triggering progress against eradicating hunger and extreme poverty by 2030 (i.e. SDG 1 and SDG2). New opportunities from marine-based renewable energy may create new jobs and enhance the global energy mix towards a greater share of clean energy, contributing to achieve SDGs 8 and 13. Across all sectors of the economy, digitalization is creating new opportunities for innovation, including in developing countries because digital solutions can reach people regardless of their income group.

These technological solutions should (in principle) make it even more affordable and feasible to achieve many SDG targets – especially in the least-developed countries. However, in almost all cases, the binding constraint is not a lack of scientific expertise, technological know-how or proven, cost-effective solutions. Instead, it has to do with the general problems of social, economic and political development. It also has to do with the silo mind-set in government ministries and the "not invented here" phenomenon. To foster innovation across the SDGs, there is a need to focus on system innovation and transition of socio-technical systems key for wellbeing and healthy ecosystems, such as mobility, food, energy, rather than focus mostly on specific technologies. There is also a need to ensure that innovation and technology pathways are adapted to local contexts and consider the role of social innovation and business models mobilizing new collaborations between businesses, social actors and communities. Social innovations combined with technical innovation such as digital technologies are important because social innovation can engage participation by civil society and digital technologies can enable inclusive innovation that cuts

across income groups ; together they can empower communities to speed up solutions to developmental problems (poverty reduction, education, agriculture, food, and water systems).

The TFM's online platform - which is in its prototype version active – aims to operate as a gateway for information on existing science and technology solutions, initiatives, mechanisms and programs. It is to provide insight into the technological advancements of humanity to all, not just to the selected few. Within the Enterprise Europe Network, supported by the European Commission, some improved interoperability of the internal market and the flow of innovation has already been achieved, and similar benefits could be achieved globally with the TFM.

2. Digital ICTs, space technology and big Earth data solutions

Digital ICTs

COVID-19 is the first pandemic in human history where information and communication technologies (ICTs) and social media are being used on a massive scale, driving the global collective response to the disease and digital transformation across the world. COVID-19 has highlighted the fundamental importance of ICTs to economies and societies everywhere. From teleworking and e-commerce to telemedicine and remote learning, digital technologies are supporting continued access to education, healthcare, essential goods and services and family and friends. COVID-19 has shown that nobody is safe until we are all safe. At a time when just over half of the world is using the Internet, we will not be able to use the full potential of ICTs until we are all connected.

Telecommunications/ICT are a key enabler to achieve the Sustainable Development Goals (SDGs) and to build a world where social, economic, environmental, and technological development is sustainable and available for everyone, everywhere. Technologies such as mobile communications, the Internet of Things, connected cars and cities, the fourth industrial revolution and artificial intelligence, all depend on telecommunication networks, services and applications, and increasingly rely on radiocommunications to provide the basis for ubiquitous connectivity.

ICTs plays a catalytic role in helping the world achieve all the 17 SDGs owing to its cross-sectoral application. Efficient and affordable ICT infrastructure and services allow countries to participate in the digital economy and to increase their overall economic well-being and competitiveness. ICTs can achieve results at a scale, speed, quality, accuracy and cost not imaginable just a decade ago. They are means to deliver quality goods and services in the areas of health care, education, finance, commerce, governance and agriculture, among others. Emerging technologies such as Artificial Intelligence, robotics, and Internet of Things can help to reduce poverty and hunger, boost health, create new jobs, mitigate climate change, improve energy efficiency and make cities and communities sustainable.

Smart energy grids are supporting more efficient energy distribution and consumption. Connected vehicles and automated driving hold great promise to improve road safety and reduce congestion and emissions. e-Health services are bringing more people within reach of advanced medical care. Digital financial services show great potential to extend the reach of the financial system. ICTs are supporting more efficient agriculture and traceability in food supply chains. Data-driven Smart Sustainable Cities and Communities will be cleaner, safer and more responsive to citizens' needs.

As of end of 2019, an estimated 4.1 billion people were using the Internet, reflecting a 5.3 per cent increase compared with 2018. The global penetration rate increased from nearly 17 per cent in 2005 to over 53 per cent in 2019. In developed countries, most people are online, with close to 87 per cent of individuals using the Internet. In the least developed countries, on the other hand, only 19 per cent of individuals are online in 2019. About half the world's people do not use the Internet. Disenfranchised populations need to be included in a digital society to meet all 17 SDGs.

Despite the existing digital divide, most least developed countries are recording impressive progress towards SDG 9, with significant impact in the areas of financial inclusion, poverty reduction and improved health. However, more needs to be done in line with SDG Target 9.c on universal and affordable access to the Internet. The international community (governments, private sector, research institutions, development partners) should double their efforts by investing more in ICT infrastructure investment, creation of an enabling environment (pro-ICT policies, legal and regulatory frameworks) capacity building, and institutional strengthening. Governments are encouraged to take deliberate policy measures to bridge the connectivity gap, the affordability gap and the socio-economic gaps if the SDGs are to be achieved on time. Also, as digitization is increasingly and fundamentally changing societies and economies and disrupting many sectors, there is a continuing need for trusted, secure and reliable ICT infrastructure.

Space technologies

In the six decades of the space era, satellites have transformed the society as we know it in virtually every sector. Around 40 percent of the SDG targets are benefiting greatly from geolocation and Earth observation. Monitoring more than half of the essential climate variables is dependent on space infrastructure.

Tele-epidemiology, telemedicine and space spinoffs; increased food production through precision farming; waste reduction; reduced use of harmful substances and reduced emissions; greater efficiency in transport, agriculture and supply chains; many global climate mitigation, resilience and adaptation efforts; and disaster risk management – all depend on satellite services. Space assets are essential for understanding sustainable development and filling data gaps in the monitoring of SDGs. Satellite data services are contributing to the verification of treaties and agreements, helping us tackle human and wildlife trafficking, poaching, illegal fishing, smuggling, illegal waste dumps and alike.

Space technologies also offer a source of inspiration for technology innovation which occasionally finds its way to commercial gadgets and tools. Hundreds of technologies developed from the space programme are now widely used in other sectors around the world. Satellites are great tools to improve efficiencies in a wide range of sectors, which often leads to improvements on the output spectrum while reducing the requirements on the inputs spectrum.

One such example is agriculture. Without improvements in efficiencies, more agricultural output would require more land and more resources, including pesticides, fuel, water or fertilizers. Through geolocation and remote sensing services and applications, farmers can plant seeds more accurately, monitor levels of humidity and evapotranspiration, reduce time needed for ploughing, or assess land productivity among other benefits. Through enhanced efficiency, farmers can increase their crop yield while reducing costs and impact on the environment by saving fuel, using less pesticides and herbicides, and in some cases reducing land use.

Satellite communications can distribute large amounts of data over a wide geographical area, bridging the distance between learners and instructors/teachers only using low cost equipment at the reception sites. Similar approaches can be used when seeking medical help in remote locations or with conditions that prevent patients from travelling. Distance health services can protect both the patient and the doctor from infections while at the same time allow for a more rapid diagnostics and treatment. Both tele-health and tele-education are critical in times of emergencies and greatly help in remote locations with limited access to schools, training centers and hospitals. With almost 260 million children and youth out of schools and at least half the world's population lacking access to essential health services, utilizing SatCom techniques makes a real difference.

Satellites are also critical for planning and developing especially climate related projects which can address a range of Sustainable Development Goals as the richness of data gathered from space allows project managers to understand the current conditions and estimate the potential impact of their projects based on the historical data in the initial phase. Subsequently, satellites can help monitor the progress and support final

evaluation after project delivery. Such evidence-based approaches allow for the best possible use of scarce resources.

Big Earth Data

Digital technology and big data are powerful tools for the SDGs. One example is the use of smartphones in contact-tracing in the era of COVID-19. Smart agriculture, smart city and smart manufacturing are other examples. Big Earth Data can help both international communities and the nations to detect, measure, analyze and understand the important changes in at least 6 SDGs (food, water, cities, climate, ocean and seas and biodiversity) and more than 30 SDG targets and their respective indicators around the world. And doing it in much better, much more timely and precise manner. In fact, any innovation and technology solutions, such as big data that enhance mobility, connectivity, and efficiency can accelerate progress towards the SDGs. Green energy can increase economic efficiency and mitigate climate change and major environmental problems. High speed transportation, such as high-speed railways can bring the world closer and narrow the gap between north and south, and between urban and rural areas. Mobile telecommunications and e-commerce can help collect and deliver information around the globe to support decisions and policy making. And least developed countries and the rural poor get access to valuable information.

Big Data, including Big Earth Data, which can reveal tends in an efficient way and helps to understand the gaps between reality and potential in a comprehensive way. Smart agriculture which is based on big data and Internet of things could precisely control the whole process from crop growth, food storage, food processing, food transportation, trade and retail. It offers hourly, daily detection of crop growth and deviation of crops from the ideal state, helping to increase food production while decreasing environmental impacts. It also tracks food transportation, minimizing food waste that accounts for one third of global food production, and connects food production with food retailing.

At present, the implementation of SDGs faces serious data gaps. Globally, methods and data are only available for 45% of the 230+ SDGs indicators. For 39% there are methods but no data. One reason for the lack of SDG data is the capacity gap between countries and regions in obtaining and applying ICT for statistical systems. Many developing countries fail to effectively collect and analyze high-quality data. Big Earth Data analysis technology is a core support technology for SDG management.

3. Smart agriculture and sustainable agro-food technologies

The ways we eat, live and work are defined to various extent by science, technology and innovation, and achieving sustainability in all these areas will require STI-based solutions. Here we look at ways to create and scale up STI solutions to make food production more effective and sustainable and promote improved nutrition. The food production system will need to undergo a transformation if the world is to feed the 8.5 billion people who will inhabit it in 2030 without precipitating an environmental collapse.

Smart and science-based agriculture and food systems

Smart agriculture improves livelihoods and increases crop production, but saves time, fuel and harmful substances. STI is key in shaping the types of agricultural, marine, forest, and livestock patterns of production and consumption that will be adopted in the coming years. They will be fundamental in protecting and preserving natural resources, as well as in designing systems that protect instead of degrade these resources. STI can help to advance the way crops are produced, in the way inputs are accessed and developed, and the way technology is shared will be key in both meeting the demand for food, protecting the environment, and eliminating poverty.

Enabled, well-functioning and demand-driven agricultural research systems and extension and advisory services are needed to achieve food production systems that reduce food loss and waste and produce more food, of greater nutritional value, and with less environmental damage. In this context, equitable access and the sharing of appropriate technologies is important. It will be critical to understand the linkages

between rural and urban areas, as 70% of people are expected to be living in urban areas by 2050. The design of sustainable, green cities will be key, particularly in how it fosters relations and opportunities with rural areas. In terms of urban food systems, STI can support in-depth spatial analyses, enabling effective land use for each phase of the local food system while protecting biodiversity hotspots and rural-urban synergies. In support of such a transformation, STI can determine optimal interventions; develop integrated approaches; create user friendly tools for evidence-based decision; create systems for improved food labelling and recycling; link producer and consumer more closely; and provide policy guidance and assess production and value chains.

STI can address the myriad challenges food systems face, including the exclusion of vulnerable groups, environmental degradation, food safety, transboundary diseases, urbanization, food loss and waste, and disruptions in supply chains resulting from COVID-19 and other crises. To take the example of food loss and waste, STI can identify synergies between reducing food loss and waste on the one hand and reducing GHG emissions on the other; be used in the form of block chain, Internet of Things, big data, and AI technologies for optimizing operations in the food supply chain, monitoring food product conditions, quality and safety, and facilitating improved logistical management and marketing/distribution practices that lead to reduced food loss and waste; and improve the functionality of packaging to prevent or reduce food loss and waste and develop cost-effective, environment-friendly and user-friendly packaging options.

STI is critical for reducing costs and improving profitability and competitiveness; for promoting inclusiveness through improving access and ensuring participation in markets by vulnerable populations (e.g. development of labour-saving technologies can help disabled and the elderly), small-scale actors and even small/disadvantaged countries; and for solutions that facilitate adaptation to and mitigation of climate change and variability, reducing degradation of terrestrial and aquatic ecosystems and biodiversity, and reducing environmental pollution and natural resource depletion. In developing countries, STI can support a better understanding of consumer patterns and promote behavioural change towards sustainable consumption and production patterns. STI can help in designing sustainable and circular bioeconomy strategies that integrate waste streams of the food industry. This also implies targeting the valorization of food manufacturing byproducts and providing support to enhance the sustainable management of food packaging. STI will be crucial in deciding what investments to make, how to coordinate the investments and ensure they follow responsible principles (CFS-RAI).

STI tools for measuring sustainability can identify areas where there are complementarities or trade-offs, informing governments, investors and civil society. STI can support changes in technology, infrastructure, product design, new business and market models and consumer behaviours in the transition to a more circular bio-economy model. The 2021 Food Systems Summit to be convened by the UNSG in 2021 will highlight such solutions and catalyze actions around them based on sound scientific knowledge and technical expertise.

Clean energy and efficiency in the agro-food sector

In the agro-food sector, the key is improving access to efficient and clean energy services and investments in R&D on clean, affordable and climate friendly options. Limited access to energy is one of the challenges that must be overcome especially for SMEs involved in post-harvest handling and agro-processing in rural areas. STI is crucial in identifying efficient options in crop drying, evaporative cooling, refrigerated storage and cold chains, milk cooling centres, fish smoking ovens. Innovations to reduce energy use, increase energy efficiency and integrate renewable energies can go a long way to improve the inclusiveness, sustainability and economic competitiveness of the food processing industries. A key area for STI is in the using by-products, residues and wastes from SMEs to provide energy in an environmentally sound way.

Nuclear techniques against malnutrition

The world is facing a double burden of malnutrition: undernutrition and obesity coexist, both contributing to the development of non-communicable diseases. Nuclear science, technologies and innovation can

offer solutions a number of solutions. Stable isotope techniques can be used so that nutrition and health professionals can develop and evaluate actions to combat all forms of malnutrition, both in developing and developed countries alike. Nuclear applications can be used to help improve the specificity, sensitivity and accuracy of nutritional evaluations, for instance by assessing body composition and physical activity, bone mineral density, total daily energy expenditure, intake of human milk in breastfed infants, vitamin A status, and bioavailability of micronutrients and proteins from foods. They are also used to assess the health effects of environmental factors, such as environmental enteric dysfunction, and the influence of changes in dietary and physical activity patterns on the risk of overweight and obesity.

The Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture advances and supports the safe and appropriate use of nuclear and related technologies in food and agriculture. It supports global food security and sustainable agricultural development worldwide through adaptive research and development IAEA's laboratories and through coordinated research projects, capacity-building and technology transfer through technical cooperation projects across the globe.

4. Sustainable energy technology solutions for the global commons

Access to sustainable energy is an important factor towards sustainable economies. The ways we generate power, live and work are defined to various extents by science, technology and innovation, and achieving sustainability in all these areas will require STI-based solutions.

Scaling-up sustainable energy technology solutions

STI solutions need to be created and scaled-up to expand access to renewable energy and foster sustainable urban development. In some respects, the technologies for an energy transition already exist (e.g. large-scale renewable energy), but the adoption of these technologies is unacceptably slow. In other respects, new or improved technologies may be needed—including off-grid solutions to reach communities and individuals currently without access to safe and modern energy.

Optimal sustainable energy solutions depend on the local and regional context, economic densities, resource availabilities, renewable energy potentials and other factors. For example, the adoption of renewable energy in Latin America and the Caribbean has been slow, because the electricity sector does not have enough flexibility to absorb large volumes of variable renewable energy. Also, the transport sector in the region is 99% dependent on fossil fuels. Therefore, a transformation to an electric transport sector implies a major structural change. The most urgent need for Latin America and the Caribbean is a reliable and sustainable storage system. STI should focus its efforts in the region on developing monitoring technology for electricity consumption in homes and industries, in order to implement more effective energy efficiency measures. Along with the above, research efforts should focus on developing electricity storage systems that are more energy dense, have a longer operating life, and are made from minerals that are abundant and not rare metals, which are expensive and poorly recoverable though recycling. Having a renewable electric matrix is a must for Latin America and the Caribbean. A full renewable electricity matrix will facilitate the transition to a full electric city, therefore, a sustainable electric transportation system and heating/cooling systems. However, the poor flexibility of the electric grids in the region, the lack of regional electric market and the current economic crisis is impacting the energy transition in the region. Also, significant progress with regards to storage technology for electricity is needed to have fully sustainable and less polluted cities.

Interventions to establish and maintain a robust system of institutional, regulatory, legal, industrial and other infrastructure (including human capital) are critical for the adoption and dissemination of existing technologies and for R&D on new technologies. Comprehensive milestones approaches can be used to assist countries in their consideration of various energy technology options. STI interventions can address the challenge of investing in and developing new technologies through policy making and partnerships. Cross-sectoral policies at the national and sub-national levels should incentivize R&D and support the creation of innovation ecosystems. Strategic partnerships between the public and private sectors, civil

society and marginalized communities, as well as financial and workforce development incentives can support the development of clean innovative technologies.

Nuclear power, a low-carbon technology, is also going through an accelerated innovation phase with the design of small and modular reactors that can be integrated in a decentralized grid alongside renewables energies. STI provides important tools to assess the life cycle of energy technologies, and the planning from the onset of waste management and decommissioning. STI can therefore support circular energy production, with the reuse of valuable material and the recycling of used fuel.

STI as a toolbox for protecting the global environmental commons

STI can provide a toolbox of solutions for protecting the global commons, including key constituents such as the climate, biodiversity, and the ocean. New and holistic ways are needed to deploy STI solutions for the global commons.

Often local data and mobilizing local action are key to address global issues. However, the actions need to be context specific. STI can allow individuals to see what action they can take to contribute to global objectives and allow stakeholders to oversee the policy impacts. Although there remain STI knowledge gaps especially at the local level, these can be overcome. One of the major issues is the fact that for many stakeholders, such as farmers, CCM is not a priority, for others they may have reservations on providing data on environmental impacts of their interventions. Systems therefore need to realize environmental co-benefits while meeting core productivity and income needs.

STI solutions include markers that allow for improved traceability of products from sustainable production. They can also be used to develop, for example, drought-resistant crops for increased resilience and/or productivity. Large scale satellite monitoring and modelling allow for tracking of environmental damage or restoration as well as for the identification of hotspots, and modelling of the effect of climate change on ecosystems and biodiversity.

Genomic technologies allow for the identification of biological mechanisms across species that can be used for health, food and agriculture. Lab grown foods may reduce the environmental impact of food production as well as food safety. Digitalization and automation allow for more efficient input use and weed/pest control. Other promising STI solutions include satellite monitoring and modelling, integrated pest management, lab grown food/cellular agriculture and other biotechnology, early warning systems and natural capital accounting for impact assessment and decision-making.

Further afield – governance of STI solutions for the global commons

Effective and agile governance structures for promising STI solutions are needed at various levels. Citizen science and public participation can play an increasing role in biodiversity monitoring and to public awareness to ensure sustainable choices. Improved and strengthened governance systems are needed for monitoring and evaluating the status of biodiversity; for environmental risk and impact assessments; FPIC; for the application of the precautionary principle; for the fair and equitable sharing of benefits derived from the utilization of genetic resources; for accountability in political and financial commitments; for capacity building to implement multilateral environmental agreements, as well as for national plans of action on biodiversity, agroecology, and biodiversity-friendly and climate-smart agricultural practices. Global agreement may be explored on the legal status of digital sequence information, as well as on the conservation of and access to biological diversity in areas beyond jurisdiction.

Science diplomacy and cooperation enables nations to share the best ideas to solve common and pressing problems with cutting-edge and efficient responses. The wide range of topics and dialogue tools that can be offered, allow stakeholders find solutions, mitigate risks, include a growing diversity of actors involved in global governance processes and translate STI information into public policies. This could lead to the creation of new spaces for the exchange of knowledge and the sharing of ideas, which is key in a collaborative society that seeks to improve its quality of life and achieve necessary changes in the world

that lead to the SDGs. Multilateral innovation symposiums are proactive platforms where the main agents of change from different disciplines and sectors

Various national good practices exist in terms of STI governance. Some countries have long-term science and technology visions and scenarios, including towards an integration of cyberspace and physical space[7]. Smart and efficient e-government systems are key in such transitions, as are coordinating mechanisms or task forces on STI for the SDGs. Most important are STI for SDGs roadmaps and plans at the local level.[8] In practice, each country or local community would need to choose prioritized themes at intersections of development, SDG and STI plans, taking a cyclic approach as detailed in the IATT's recent "Guidebook on STI for SDGs roadmaps". Public-private partnerships can be useful approaches in this regard (see Annex for examples).

5. STI solutions for improved human well-being and leaving no-one behind

STI has the potential to enhance well-being by improving access to education, healthcare and other services, to build resilience and to strengthen individuals' capabilities to contribute to sustainable development. STI can also help to mitigate trade-offs between economic activities, environmental degradation and social outcomes. But holistic assessments of STI are needed to further these goals, and STI must be pursued and applied in combination with cohesive actions by governments, civil society and the private sector. This is the only way to ensure that STI is aligned with furthering human well-being, reducing inequalities and promoting sustainable economies. The ultimate success of achieving the 2030 Agenda will require well-planned engagement with science, technology and innovation, as advances in this area can both have a strong positive effect, providing solutions for the attainment of certain SDGs, while uneven application of STI may exacerbate inequalities.

Some of the issues and STI solutions

The level of investments made to advance technologies and innovation through R&D is linked to economic performance, and investments have been growing in the previous years (after the 2008 financial crisis and prior to the COVID-19 crisis). While fundamental basic research is mainly driven by higher education and the scientific community, the private sector is a major source of funding. It is also the main driver to take developments forward, to implement major technological developments and innovations, making them accessible to the broader public.

The benefits of advanced technologies and innovations are undoubtedly wide and can address climate change, environmental degradation and related social challenges. The application of new technologies and innovative processes and systems in productive processes enhances resource efficiency, increasing economic and tangible outputs while decreasing the use of energy, water and other resources, thus decreasing CO_2 and other GHG emissions. From the experience of implementing inclusive and sustainable industrial development, it has been found in practice that the holistic and targeted application of innovative policies and technologies can result in synergies for positive economic outcomes, environmental protection and reduced inequalities, rather than trade-offs among these dimensions. The integrated application of STI policies helps decoupling economic growth from environmental degradation, while economic activities create jobs and incomes, promote life-long learning and skills application. People are empowered to play an active role in this transformation, while also benefiting of its advantages.

Social and solidarity economies and cooperatives have demonstrated the role of digital platforms in improving market access and reinforcing their ability to function viably against larger, industrialized firms. STI can contribute mainly in the form of information provision as well as services, reducing time needs, increasing the quality of the provision of services and broadening services.

[7] For example, Japan's Society 5.0

[8] For example, in Japan 60 local cities and prefectures became designated 'SDGs Future Cities'

SDG interlinkages are highly complex and context specific, such complexity can make it difficult for actors to easily determine which are the optimal interventions that could be made, especially taking into consideration future scenarios. STI is essential to determine the solutions to the various challenges, determine optimal pathways and create IT systems, including artificial intelligence and self-learning systems that can support and speed up decision-making. Such systems can provide a two-way flow of information/data to help gather and understand local and national trends and as well as allow for monitoring, including SDG target achievement.

The peaceful use of nuclear technology and related techniques contributes to improving health. Nuclear techniques play a decisive role from prevention to diagnosis and treatment of many health issues, in particular non-communicable diseases such as cancer, cardiovascular diseases, dementia, as well as in complementing non-nuclear techniques, for instance in the area of nutrition. Quality assurance for the safe and accurate use of radiation in medicine is an essential condition, and the IAEA conducts capacity building to adapt to evolving technologies and safety needs. This is part of an overall effort to improve access to quality radiotherapy worldwide, including providing help for applying radiation safety standards.

Going forward

The advancement of human well-being and the sustainable development agenda more broadly requires collaboration and close dialogue between various partners, such as governments, academic institutions and the private sector. The solutions are multidimensional and most often require multilateral cooperation to succeed. The current COVID-19 crisis and the climate crisis both show that international solidarity and multilateral solutions that involve different stakeholders are crucial for success.

The role of governments is to lay the institutional foundation, to involve different stakeholders in the uptake of STI, to promote shared ownership, and to include segments of society that are often neglected, in particular women and youth. The role of the private sector is to drive innovation and to implement new innovations and technologies in an inclusive and sustainable manner. While the government may lay the foundations with public spending on research and education, the private sector shares the responsibility of investing in research and development, in building suitable skills and capabilities and in opening new opportunities.

Access to STI is not equal and automatic; the use of STIs may be limited due to other barriers. Partnerships must thus be developed to ensure inclusive access and use of STI, particularly for rural or isolated communities through strategic investment and policies, in order to increase impact of STI.

There is rich experience in the transfer of affordable, feasible and applicable technologies from industrialized countries to developing countries. The UNIDO Investment and Technology Promotion Offices are a case in point. At the same time, newly developed technologies should lead to transformative change commensurate with the SDGs. Hence, new technologies must be community- and data-driven, needs-based, developed and designed collaboratively with their users, designed with opportunities for scaling, reuse and improvements, ultimately leading to long-term impact.

For STI, “leaving no-one behind” means not only that adequate technical and financial resources are available, but that the resulting prosperity is shared fairly and equally and that deep-rooted inequalities are addressed. STI are often criticized for working in a bubble or to meet the needs of a selected stakeholder group, SDGs complexity and the need to leave no one behind requires that all needs and stakeholder groups are consulted to create guidance and systems for all. An important step for policymakers must be to ensure that everyone is able to contribute shaping the direction of technological innovation.[9] The inclusion of marginalized groups in productive and income-generating processes can increase the skills and capacities while also providing employment opportunities.[10] Often the ones that are being left behind are poorly

[9] UNIDO (2019), *Inclusive and Sustainable Industrial Development: The Gender Dimension*, Vienna

[10] UNIDO (2020), *How industrial development matters to the well-being of the population*, Vienna [provides empirical evidence].

understood and interventions do not target their needs, they also do not have access to services, the Internet, and smart phones, making some ICT systems unsuitable. A recent FAO study demonstrated that climate-smart practices, despite their benefits, were not adopted due to higher up-front costs and risk-aversion by small farmers. By complementing STI with social protection measures, for example, or other pro-poor policies, they are more likely to be adopted and adapted to specific contexts. STIs also have an important role in providing a platform for participatory processes that may otherwise have left behind populations. Finding innovative ways to monitor and incorporate local concerns into planning could lead to more sustainable improvements.

Big differences in STI capacities between countries need also be taken into account. Industrialized economies are characterized by higher productivity, embracing new technologies, intelligent production processes and reducing the effects of industrial production on the environment and climate. Developing economies on the other hand are in the process of structural transformation from traditional sectors to modern industries fueled by innovation and technology, with the corresponding expansion of the manufacturing sector creating jobs, raising incomes and reducing poverty.

Partnerships and synergies with international organisations, the private sector, governmental bodies, academia, civil society, can further contribute and better secure strengthened human well-being and capabilities worldwide, while reducing inequalities.

C. Cross-cutting STI issues and "levers" of change

The online consultations resulted in lots of inputs (hundreds of pages) on the various "levers of change": international cooperation on the means of implementation, STI roadmaps and capacity building, emerging technologies, gender and inclusiveness, open knowledge systems, selected examples of which are summarized in this section. Dedicated work streams exist within the IATT which address these areas, and further information on their activities and those of TFM partners are provided in the Annexes to this background note. This section builds also on the "*Workshop on Science, Technology and Innovation for the SDGs - Meeting of the IATT and 10-Member group under the TFM in preparation of the Multi-Stakeholder Meeting on Science, Technology and Innovation for the SDGs 2020*" organized by DESA, UNCTAD, UNOSD, OOSA, and UNIDO in Vienna from 3 to 5 February 2020.[11]

1. International cooperation on knowledge, capacity and finance

What kind of international cooperation on knowledge, capacity building and finance is needed to understand and effectively leverage interlinkages across the SDGs, ensure that no one is left behind and direct emerging technologies towards positive impacts on sustainable development?

Many different inputs were received from stakeholders and some points of view put forward included the need to re-think globalization, Including the current system of value chains and low inventories driven by business efficiency considerations, changes in how markets work, an attrition of some kinds of businesses, and the emergence and strengthening of others particularly digital ones and leaders in frontier technologies.

The pandemic has exposed dangerous asymmetries between countries and regions in their capacity to monitor and handle the pandemic and its socio-economic impact. This creates an obvious problem because, as has been pointed out repeatedly, if the virus survives anywhere, it becomes a potential risk everywhere. A key issue is how the world should respond to help reduce these institutional, technological, educational, R&D&I heterogeneities.

The pandemic has led many to argue that a "new normal" will emerge at the global and national levels. The digital revolution is likely to accelerate, and many forms of permanent social distancing-systems may

[11] https://sustainabledevelopment.un.org/?page=view&nr=3268&type=13&menu=1634

prevail, although gregarious working conditions are difficult to substitute, as isolation seems to have a negative impact on productivity, mental health, abuse, gender discrimination and domestic violence.

The benefits of these trends toward more intense digitalization of our lives seem to favor large corporations and the most technologically advanced countries. The digital divide that already threatens the most vulnerable may get worse in this new normal, such as turning many into so-called 'digital slaves', exacerbating extreme inequalities and leaving many countries and groups of people that are not technologically competitive in a state of disadvantage or worse: irrelevance.

Similarly, since the onset of the pandemic, AI-based technologies have been employed to mitigate the spread of the virus. Companies that survive the crisis may choose to further automate their activities, bringing robots, chatbots, robotic telepresence-platforms and other AI systems into play, thus intensifying certain types of jobs displacement.

A more robust multilateral system could spread the digitization of economic activities, leaving no one behind. This involves accelerating smart, universal and affordable digital interconnectivity for permanent remote office work and meetings, for purchase-sale and digital logistics systems, for news generation, financial activities, virtual tourism, medical diagnoses and many more. This requires a more robust and responsive governance everywhere; boosting infrastructure-capacity-building for the common global-good; putting greater emphasis on R&D and innovation capabilities; expanding business intelligence and supporting innovative, impact entrepreneurship.

It is important to identify the existing financing and investment gaps in STI for the SDGs, including in specific scientific disciplines. The global institutional framework must be strengthened. The UN should take steps to ensure that the evidence-based inputs from the Multi-stakeholder Forum on Science, Technology and Innovation for the SDGs ("STI Forum") better feed into the HLPF and high-level decision-making processes. The UN Technology Facilitation Mechanism should become a vehicle to assess whether the current stock of technology and knowledge is sufficient for achieving the SDGs and suitable for transfer across the globe. More generally, international cooperation depends on improving funding systems for STI, including increase ODA for STI and public-private joint funding schemes.

STI centres for research, training and data sharing are needed in developing countries, to facilitate international cooperation on data, capacity building, infrastructure development, and technology transfer. Timely and effective communications between scientists and different kinds of stakeholders, including governments, enterprises, and individuals are needed.

For one thing, deep engagements with developing countries and the least developed countries should be promoted. International cooperation is needed on human capacity building which is a good investment for the future. For example, capacity to develop and use technology systems for assessing the impacts of climate change on food production and for monitoring meteorological disaster need to be built. In view of the quite large yield gap in some developing countries, knowledge and technology is needed to recognize yield potentials and constraints on yield improvements.

A number of impactful STI capacity building and financing programmes exist in the UN system, which could be replicated in other areas where there are still gaps. For example, the Global Cleantech Innovation Programme, hosted by UNIDO and financed by the Global Environment Facility, promotes technology innovation to address global environmental concerns and supports entrepreneurs in growing their SMEs and start-ups into viable, investment-ready businesses. The programme creates links entrepreneurs with investors, business and commercial partners, leading to commercialization of new products and services. The expansion of the programme to more developing countries would help close some of the gaps on financing innovations for the SDGs.

Scientists and media should cooperate for broadcasting research findings and creating public awareness, in view of media's significant impact public opinion and actions of governments, enterprises and

stakeholders. Media can also leverage interlinkages across the SDGs by developing harmony among social, economic, and environmental types of stakeholders.

The collection, analysis and dissemination of knowledge regarding frontier technologies and innovation systems, as an input to and main result of diplomatic efforts and multilateral cooperation seems indispensable for achieving the SDGs. There are no feasible and effective pathways towards the SDGs that can ignore this increasingly important factor. Access to that knowledge would strengthen the capacity of all countries to identify new solutions, approaches, and ways of interacting, forging alliances and promoting impact entrepreneurship. It would allow them to absorb technologies, identify best practices and adapt their institutional, legal and technological capacities. This is why the TFM online platform and associated supporting TFM actions are vitally important for policy-making and diplomacy to span different agendas and achieve productive interactions at a national and global levels.

2. STI roadmaps and capacity building

What are the most pressing STI capacity building needs of countries for the SDGs? What institutional mechanisms are needed for a forward-looking perspective? What is the role of STI roadmaps for the SDGs? What kind of financial instruments are needed? What are the main obstacles to scaling-up?

The pilot progamme on STI for SDGs roadmaps commenced last year in five countries. As the work advances, the lessons learned will help inform the scaling up of this effort. Please refer to the IATT progress report in the Annex for further details.

The COVID-19 will not disappear. We should be better prepared with technological solutions to live with COVID-19 in the medium and long-term. The WHO proposal on "A Coordinated Global Research Roadmap: 2019 Novel Coronavirus" of March 2020 is noteworthy in this regard. It is well in line with the UN Guidebook for the preparation of STI for SDGs roadmaps that has recently been completed by the IATT.

STI for SDGs roadmaps are necessary not only for COVID-19 but for climate change, food, water and other SDGs. Today, the IATT supports five pilot countries for STI for SDGs roadmaps, supported by the EU-JRC and Japan as key partners. The pilot programme started in June 2019 and will run until 2021. Global scientific and donor communities are encouraged to engage with the pilot programme.

Many other countries and organizations are also interested in implementation of STI for SDGs roadmaps. It is important to share knowledge and experiences among them and strengthen global partnership. To do so, the United Nations could start a global consortium for extending collaborative work for STI for SDGs roadmaps with wide participation of developing and developed countries, local governments, industry, academia and global organizations.

STI for SDGs Roadmaps are also useful tools for strengthening international cooperation on global challenges. They are a new tool that the UN system and the IATT partners have been promoting to align national STI policy agendas with the SDGs and to develop instruments and partnerships for international STI co-operations that are aligned with domestic policy agendas. The Roadmap process aims to:

- *Build-up national STI capabilities to address the SDGs:* focus on strengthening national STI capabilities, mostly of developing countries, to address challenges underpinning the SDGs; any well-functioning national innovation system needs to be connected internationally.
- *Boost international knowledge and technology flows for the SDGs:* focus on international flows of knowledge and technology across borders and on cross-country STI collaborations for the SDGs.
- *Broker international STI collaborations for the SDGs:* focus on brokering international collective STI actions with an ambition to tackle global public goods and challenges.

The IATT work on roadmaps in pilot countries has illustrated the benefits of "policy roadmapping". Donor countries can improve policy coherence by streamlining challenge-oriented STI policies with ODA. Developing countries can co-ordinate and synergize STI-related efforts among ministries, international partners and key stakeholders. Governments, international organizations, and partners can work

together through cooperative sharing of knowledge and good practices, as well as on new or improved mechanisms. Scientists around the globe should be mobilized to work together to co-develop and deploy innovations at a scale commensurate with the SDGs ambitions, similar to the IPCC efforts on climate change.

Another work stream of IATT dedicated to capacity building has pooled expert skills throughout the UN system to design and deliver a new training programme on STI for the SDGs for government officials that brings together the best of the individual UN entities' capacity building efforts. The group developed three-day and five-day course options that are easily adaptable to the local context and that are structured along three core elements: (a) conceptual framework; (b) design and implementation of STI policies; and (c) monitoring and evaluation of STI policies. The conceptual framework module highlights the role of STI for development and how to leverage STI solutions for the SDGs. The innovation policies module addresses both STI policy content and process in an SDG context. The monitoring and evaluation module discusses methodologies and standards for STI indicators, R&D and innovation surveys, as well as monitoring and evaluation of policy implementation with focus on STI policy instruments, legal frameworks and contextual factors. The training modules are delivered by expert staff that are members of the Interagency Task Team on STI for the SDGs. To-date, two sub-regional training workshops have been delivered, with a first workshop in Jordan in April 2018 held with Jordan's Higher Council for Scientific Research (HCST) and ESCWA[12], and a second workshop in Panama in May 2019[13], organized with Panama's Secretaría Nacional de Ciencia, Tecnología e Innovación (SENACYT) and ECLAC. For 2020, there was demand for 6 to 7 subregional trainings to deliver during 2020. In view of the pandemic the IATT group also works on an online version of the course.

3. New and emerging technologies

What are the most disruptive technologies that could offer new pathways towards the SDGs? What are the socio-economic and environmental impacts of artificial intelligence, biotechnology, and nanotechnology? What are the most important social and ethical dimensions and how should they be addressed?

Convergence in science and rapid technology change

A better understanding based on hard evidence is needed of emerging technologies and their impacts on the 2030 Agenda and the SDGs. The setting provided by the TFM is important for contributing to better understand global challenges related to exponential technological progress and how to address them through cooperative actions at multilateral levels. It has to be complemented with efforts by country groups (e.g., G20, AU and EU) and regional communities.

Since 2016, through the IATT work on new and emerging technologies, hundreds of scientists and engineers have debated and contributed to the TFM their ideas and specific policy suggestions on frontier technologies and their sustainable development impacts. Pursuant to the relevant GA resolutions, a wide range of "*TFM findings on the impact of rapid technological change on the achievement of the SDGs*" [14] were presented in the annual Multi-stakeholder Forum on Science, Technology and Innovation for the SDGs. They highlighted the importance of various clusters of emerging technologies around AI, robotics, biotechnology, nanotechnology, and green technologies, many of which are enabled by various digital technologies. Given that nanotechnology, biotechnology and ICTs are fundamental technologies for SDGs, digital convergence is creating a new horizon for STI activities as a whole. Examples include data-driven decision-making, IoBMT for precision medicine, advanced ITS and human/robot co-existence, material/resource circular system, smart manufacturing and smart agriculture.

[12] https://www.unescwa.org/events/workshop-innovation-policies-sdgs-arab-region
[13] http://www.unesco.org/new/es/natural-sciences/about-us/single-view/news/training_on_technology_facilitation_brings_together_official/
[14] e.g., in the STI Forum 2018: https://sustainabledevelopment.un.org/content/documents/28145AT_IATT_presentation_14_May_2019.pdf

Most recently, digital technologies have been powerful tools in response to the current pandemic. Contact tracing is just one such example among many. In some parts of the world, they have led to a new normal in society, including working from home, distance learning and distance medicine, with consideration on privacy and security. E-government has been a driving engine to digitalize the society. Artificial intelligence (AI) with its key features of autonomy and adaptivity provides immense opportunities. AI enables machines to process and perceive information, reason, plan and learn. This ability is highly dependent on large amounts of data becoming available. AI improves systems by optimizing processes and reducing uncertainties, which is extremely useful for preventative measures and risk reduction. Against this background, it is essential to minimize digital divides through public investment and global collaboration on infrastructures and capacity building.

Convergence in sciences is merging scientific disciplines and technologies, creating biosimilar materials and devices and - in the long run - enabling harmony between the techno- and biospheres. Nature-like and convergent technologies are being used to create new values by designing new materials, products and processes and to pursue circular economy, thus enabling sustainable consumption and production patterns. The new materials created have great potential for realizing energy efficiency and renewable energy, both in conversion and storage. The convergent technologies address human beings' needs. The new materials and systems are used for housing, transport, medicine, production of goods, communication and environmental protection. The convergent technologies also increase people's physical and mental abilities significantly. Convergent technologies will provide break-throughs and solutions for sustainable development. Convergent technology and capacity assessments will be needed. UNIDO has produced report on the conference addressing this.

Capacity building support on new and emerging technologies is essential to harness the benefits, while mitigating the downside risks. Which technology and capacity assessments are needed depends on the readiness of a country for deploying and absorbing the benefits of new technologies, which in turn depends on the quality of available data and countries' development stage. A toolkit to assess these factors should be developed by the IATT and fine-tuned according to countries' needs.

The confluence of geospatial and engineering tools helps to gather and integrate data from various sources and offers cutting-edge, actionable analysis, including through better visualization. Moreover, 3D maps and data modelling systems help discerning adaptive patterns planning resilient and sustainable cities. With geospatial technologies, city planners can leverage nature-based solutions reducing pollution and adapting to climate change. Integrated geospatial and BIM technologies have a critical role, as highlighted in a publication of case studies by the World Federation of Engineering Organizations. The latter also presents a road map for geospatial technology implementation (jointly with the World Geospatial Industry Council and the UN Committee of Experts of Global Geospatial Information Management.

Benefits and challenges of frontier technologies driving the 4th industrial revolution

Frontier technologies, such as digital technologies and their convergence with other scientific disciplines and technologies, are developing exponentially and driving what has been termed the "fourth industrial revolution" (4IR). They are creating opportunities to realize economic, social and environmental gains and to achieve the SDGs. The economic benefits of the adoption of frontier technologies and business models result from an increase in revenues owing to higher productivity, product quality, improved manufacturing process control and customer involvement in the production process, and more resilient reliable and responsive manufacturing, capable to reconfigure itself fast to changing external conditions.

The environmental benefits of frontier technologies include greater resource efficiency and effectiveness, wider access to electricity and water, and reduced emissions of greenhouse gases and other pollutants. They have the potential to contribute to environmental efficiency and effectiveness through circular economy business models that consume renewable material resources and recycle materials.

The social benefits of frontier technologies include improvements in human cognition, health and physical capabilities; better food security and safety; better healthcare; enhancements in creativity and innovation; better access to food, sustainable energy; creation of a knowledge society; and better opportunities for disadvantaged and vulnerable population groups, as well as small and medium-sized enterprises (SMEs), to participate in the real economy.

Alongside the benefits of the frontier technologies, there are multiple challenges and risks. These include threats of a growing demand for energy and certain precious materials; a widening of the technology gap between countries; job losses and rising unemployment for some workers; slow institutional changes (in norms, standards, regulations); cybersecurity threats to industrial security; ethical issues; and threats to global peace and security arising from the military uses of new technologies.

Growing demand for energy and precious materials

The potential of frontier technologies needs to be assessed from the perspective of material and energy efficiency and effectiveness, and circular economy (CE) approaches that apply regenerative and resource-maximization principles. Society must ensure that CE approaches are followed in the ecosystem of frontier technologies by monitoring the energy and material-resource intensity of these technologies and business models as well as the carbon dioxide emissions and toxicity of materials used. The sustainability implications need to be researched properly by multi-disciplinary and multi-stakeholder partnerships.

Digital divide and data divide

The digital divide has many facets. There are gaps in coverage, speed and affordability, gaps between developing and developed nations, between cities and villages, between the young and the older, and between men and women online. The lack of adequate infrastructure and access to ICTs, as well as the lack of digital accessibility and knowledge of digital skills limits opportunities to access inclusive education and labour markets of those left unconnected. Although mobile cellular networks now cover most of the planet, with 97% of the global population within reach of a mobile signal, and at least 93% of the global population able to access 3G or higher mobile broadband services, only 4.1 billion people – or just over 53% of the global population – are actually online. A staggering 3.6 billion remain totally unconnected from the transformational power of the Internet. Most alarmingly, in the world's 47 Least Developed Countries (LDCs), where online services and applications could potentially have the greatest impact in accelerating development and improving people's lives, more than 80% of the population is still offline. And even that dismaying figure often hides a much wider gap at the national level; ITU data show that in the most extreme case, a mere 2% of the population is using the Internet.

Frontier technologies are dependent on data, and in data-driven systems and economies, data become capital in the production and delivery of many products and services. Firms can capture huge economic returns from collecting, compiling and analyzing data without the consent of those who produce the data and without rewarding them, thus creating an asymmetric relationship and distorting the market. Correcting this market failure requires new laws and regulations that recognize data as an asset from which rent can be captured and that establish the legal basis for data ownership. The use of data for public purposes and in algorithms for AI also raises ethical and legal issues related to data ownership, privacy and transparency and requires an institutional framework of accountability, which is still lacking.

Widening technology gap

Despite the rising affordability of frontier technologies, they do not diffuse evenly across countries because of low absorptive capacities in developing countries and especially in LDCs. Countries with high levels of STI capabilities and effective institutions will be the first to reap the benefits of technology breakthroughs. Many developing countries also lack access to traditional and modern infrastructures and basic utilities, such as electricity, water, sanitation, the Internet and related services. Institutions are weak, creating a low-trust environment. Systemic opportunities for interactive learning are largely absent. There is still a lack of industry–academia collaborations; business environments are not conducive to

technological learning, innovation and inclusiveness towards disadvantaged and vulnerable population groups and SMEs; and an embedded approach to industrial governance is weak or absent. These conditions put many developing countries far behind developed ones in innovation systems. Strong R&D capacities and capabilities together with science and technology infrastructures are needed to operate on the technology frontier. Hence, acquiring and mastering technology developed elsewhere will continue to play an important role for many developing countries.

Slow institutional adaptation to frontier technologies: norms, standards, and regulations

Frontier technologies are developing exponentially but relevant institutions are lagging behind, including in terms of norms, standards, regulations, protocols and governance mechanisms of enforcement. Rapidly emerging innovative solutions often cross the boundaries of regulatory frameworks built for traditional domains, raising questions of which regulatory framework applies to them and which regulatory body covers which domain. This regulatory ambiguity can impede the diffusion of new technologies and their ability to serve the needs of all of society. The wide use of frontier technologies requires the intelligent integration of systems across all domains and hierarchies that can be achieved only if technologies, interfaces and formats have been clearly and reliably laid down in standards. As data accumulate and are shared and used as an asset, issues of data security, privacy and ownership need to be addressed as a matter of urgency, through laws and regulations that establish a legal basis for data ownership, recognize data as an economic asset and protect privacy.

Industrial safety and security

Industrial activities are a source of potential harm for humans and environmental well-being, yet at the same time, manufacturing itis key for ensuring economic activity and stimulating job growth. Ensuring industrial safety and security is an important but often overlooked aspect for the SDGs.

Yet, securing industrial safety and security is becoming increasingly challenging. Collaborative robot safety is one such challenge; the occupational risk of additive manufacturing is another. Nanotechnologies, new professions arising from industrial changes and potential psychological risks need to be researched from the perspective of occupational health and safety. Smart manufacturing systems are more vulnerable to cyber threats and attacks as well as to armed drones or unmanned aerial vehicles with sophisticated intelligence guiding them. Drones can strike precise industrial targets with limited side effects and can be used for unequal fights between technologically advanced and far less advanced players. Security threats to data, intellectual property risks from cyber-espionage and cyber-terrorism between state and non-state actors are real and present. Security layers and secure computer coding systems are needed to reduce the system vulnerabilities. Smart factories call for intelligent security responses and the leveraging of new technologies, such as blockchain, in order to improve computer security and manage technology risks.

The development and rapid adoption of modern ICT systems presents an opportunity to increase the quality of monitoring and to improve data collection and benchmarking tools. These new innovations could lead to higher levels of industrial safety and security at hazardous production sites, industrial facilities, industrial parks, and special economic zones. They could allow monitoring the status of industrial assets to better predict and analyze the consequences of accidents.

Partnerships and recommended actions

Strengthening strategic partnerships with governments, international financial institutions, the business sector, UN entities, academia and civil society is crucial for leveraging financial and technical resources for a better understanding of the positive and negative externalities arising from the exponential growth of frontier technologies and of the issues of standards for interoperability. For example, partnerships can promote a better public understanding of 5G technologies and their impacts through comprehensive assessments that include testing technologies in developing countries, that deal with cost-effective

infrastructure and operational complexity stemming from the intersection between 2G/3G/4G and 5G technologies, and that address standards and regulatory issues for 5G deployment[15].

Cooperative actions are vital for addressing the future of work and ensuring that frontier technologies lead to prosperity for all people and all nations, leaving no one behind. Thematic areas for intervention at the multilateral level could include the following:

- Addressing political economy aspects of the 4IR and STI, such as income redistribution and the linkages between labour and capital, taxation and universal basic income.
- Developing metrics to monitor progress in the uptake of frontier technologies at various levels.
- Addressing frontier technology standards and operating systems for interoperability.
- Crafting an intellectual property rights regime that balances incentives for innovation with the greater need for technology diffusion in the 4IR era.
- Safeguarding data ownership and security as increasing amounts of data are created, by reinforcing cyber-security and regulations on data management.
- Ensuring the reliability and stability of cyber-physical systems and data management.
- Strengthening innovation systems at all levels for successful frontier technological learning, innovation and development while addressing the technology gaps.
- Investing in capacity building to increase the absorptive capacity of developing countries for frontier technologies.
- Ensuring that advances in frontier technologies meet universal ethical and moral standards and that competition in the technology sector is fair.
- Bringing frontier technologies to those who lack the means to access them by ensuring greater international cooperation on the generation, diffusion and adoption of frontier technologies.[16]

AI and the future of work

Frontier technologies allow companies to generate more capital by using far fewer human resources due to a substitution of labour-intensive tasks by machine activity. Rising unemployment may become a heavy burden in the medium- to long-run. An estimated 75 million to 375 million workers, i.e., 3 to 14 percent of the global workforce, will have to change occupational categories by 2030. To meet that need, new jobs and job categories that do not exist today must be created and workers must be retrained. Skills that are hard to automate in current circumstances, such as social and emotional skills, will be of great demand in the coming years, along with technical knowledge to handle the machines. Governments, universities, research centres, international organizations, business firms and associations should consider the need to build diverse skill sets in future workers. In addition to increased demand for science, technology, engineering, arts and math qualifications, the 4IR requires digital literacy, continuous technological learning and on-the-job training. Close cooperation with technology-intensive enterprises is becoming crucial to adapting technical and vocational education to the 4IR.

There are significant opportunities to harness frontier technologies for SDG 8. This includes opportunities for the creation of new jobs and SMEs. Technologies can also improve the monitoring of compliance with health and safety standards, wage and hours of work and fundamental workers' rights. They offer new ways of delivering social protection (e.g., through cash transfers) to vulnerable workers and of expanding credit to micro and small enterprises. This could facilitate the formalization of informal enterprises, with clear gains for productivity. The ILO is currently piloting applications of these technologies in an innovation facility on transformative technologies for decent work.

[15] United Nations Industrial Development Organization, 2019. *Bracing for the New Industrial Revolution: Elements of a Strategic Response.* Vienna.

[16] United Nations Industrial Development Organization, 2019. *Bracing for the New Industrial Revolution: Elements of a Strategic Response*. Vienna.

At the same time, there are growing concerns that rapid technological innovations may deepen global inequalities and exacerbate polarization in the labour markets, which could undermine achievements already made. ILO research findings on the impact of AI on employment suggest that it will lead to both the destruction and the creation of jobs, transforming tasks and accelerating job transitions. This will be accompanied by skills mismatches in labour markets, requiring policy makers to upgrade education systems and vocational training systems accordingly. [17] Concerns about the impact on global inequalities have become even more acute as countries deal with the social and economic consequences of the COVID19 pandemic. Instability in trade and global supply chains could accelerate automation and the reshoring of production on which many enterprises and workers in developing countries had sofar relied on for their income.

Even before the current COVID19 crisis, there was evidence that these technologies were impacting on the quality of work. ILO research findings on the conditions of work for those working on micro-task platforms, training AI systems, for example by tagging photographs, show that they typically received hourly earnings below the prevailing minimum wages in their jurisdictions. They did not enjoy paid leave, did not pay social security contributions and had no mechanism for dispute resolution or redress, beyond the private arbitration of the platform. [18] Despite the income-earning opportunities that technological innovations have presented to app-based drivers and delivery workers, the COVID19 pandemic has highlighted the vulnerability of workers in the so-called "gig economy".

While concerns over workers' data privacy has been growing over the last two decades, the increasing reliance of AI to manage work processes has reinforced these concerns. AI systems and the tracking of workers' data is being increasingly integrated into workplaces as tools for recruitment, monitoring, evaluation and task optimization. This has already led to concerns over how these technologies perpetuate bias (e.g. algorithmic bias in recruitment) and the protection of workers' data privacy. This is likely to become amplified in light of the innovations that COVID19-related contact training enables and with the rollout of 5G networks that make it easier to follow the digital traces of physical actions. These practices have important implications for job quality and data protection that deserve further research and analysis, as well as the possible guidelines or certifications from regulators.

The Global Commission for the Future of Work[19] highlighted the potential of artificial intelligence and other technologies to increase productivity and well-being but recommends a "human-in-command" approach to artificial intelligence that ensures that the final decisions affecting work are taken by human beings, not algorithms. The exercise of algorithmic management, surveillance and control, through sensors, wearables and other forms of monitoring, needs to be regulated to protect the dignity of workers and adequate working conditions. Related to the question of AI, the report called for the establishment of "an international governance system for digital labour platforms". The ILO's Centenary Declaration for the Future of Work of 2019 provided a human-centred approach to the future of work which requires the ethical deployment of frontier technologies. ILO's normative framework consisting of a set of international conventions and recommendations provide established ethical principles, norms and standards against which the social and labour impacts of new emerging technologies can be assessed. Fundamental principles and rights at work should shape the development of new technologies. This includes respect for civil liberties such as freedom of association and non-discrimination. For example, as the use of AI has the potential to replicate bias or discriminate against some workers or categories thereof,

[17] See for instance Ernst, Merola and Samaan (2019): Economics of Artificial Intelligence: Implications for the Future of Work.
[18] Berg et al. (2018). Digital labour platforms and the future of work: Towards decent work in the online world.
[19] ILO 2019. Work for a brighter future.

instruments[20] provide a model and criteria to be applied in national laws and regulations. Similarly, international labour standards refer to the impact of technologies on occupational safety and health[21,22]

As new and innovative technologies continue to reshape work and working arrangements, laws and regulations will need to be adapted to ensure decent digital work. This includes clarification and adaption of the scope of relevant laws and regulations, in order to guarantee effective protection for workers who perform work in the context of an employment relationship so that their fundamental rights are respected and they can access social security including health care.[23] Discussion of these legal and regulatory reforms should involve representatives of employers' and workers' organizations. Data protection and privacy is a precondition for trust in the deployment of technology in the workplace. New institutions and regulations will need to be developed to govern data use and algorithmic accountability in the world of work. This will include frameworks for enterprise policies on transparency and data protection, so that workers know what is being tracked.[24]

Further ethical dimensions

Beyond the work environment, frontier technologies also raise important equity, ethical and moral issues, as well as legal issues related to data ownership, which can undermine trust, cohesion, tolerance, peace and stability. The trade-offs between the benefits and the risks of frontier technologies become particularly important in the context of the 2030 Agenda which aims to leave no one behind. This requires a much better understanding of the potential benefits and risks stemming from exponential technological progress—and the associated positive and negative externalities (public goods and public bads)—and of ways to address them through modern cooperative action and social innovation.

Data generation, availability in sufficient quantity and quality and their accessibility in line with ethical principles represent a challenge, especially for developing countries. Since AI is strongly data-driven, AI research and deployment are mostly possible where there is data. Hence, it is important to ensure sufficient data that addresses privacy concerns, especially in developing countries. Against this background, the multilateral system needs to act cooperatively to create global standards for data privacy and ownership rights.

Digitization of health systems makes them vulnerable to digital attacks. Security must have first priority when designing digitized systems. Stand-alone solutions are potentially more secure than cloud-based systems. Regulation of the Artificial Intelligence sector is needed, but there needs to be a balance between security and privacy issues and the freedom that is vitally important for innovation.

Ethical issues arise also with advances in genetic modifications that can affect human health and safety and can even have consequences for transforming the human species. Global ethical standards, reflecting fundamental human values adopted and enforced globally, will be instrumental in guiding further advances in these technologies. Ethical standards related to health and genetic technologies need to address the possibility for off-target effects of genetic modifications that can affect long-term human health and safety. These standards need to reflect fundamental human values and to guide further advances in convergent technologies. The European model is a step in this direction. In May 2018, the European Union adopted the General Data Protection Regulation, which brings under the scope of the protections of this law all data of EU residents that are collected and processed. The law specifies the rights of individuals and the obligations of those who use the data.

[20] e.g., ILO's Discrimination (Employment and Occupation) Convention, 1958 (No. 111)
[21] E.g., ILO's Occupational Safety and Health Recommendation, 1981 (No. 164)
[22] Paragraph 4 of the Occupational Safety and Health Recommendation, 1981 (No. 164)
[23] See the Employment Relationship Recommendation, 2006 (No. 198)
[24] The ILO's 1997 Code of Practice on Workers' Data Privacy provides guidance on the protection of workers' personal data at the workplace. It is currently being updated to reflect recent technological developments.

The variety of neural networks used in deep learning (a sub-field of AI) is widely used to predict and classify hundreds of patterns. This has resulted in increased productivity and efficiency in many fields. However, their characteristics make it impossible to trace with certainty how exactly they achieve their output. Machine-learning algorithms, just as any technology, are not exempt from errors and can be deceived, intentionally or unintentionally. Artificial Intelligence is not the only means to an end: while its promises are real, the hype around deep learning carries the risk of overstating successes and understating failures. The pressure on researchers to present successes is high, resulting in inevitable failures being underreported. Explainable AI (or XAI) is rapidly becoming a research field of its own attempting to address such risks.

4. Gender, youth, and inclusiveness

Which policies and strategies at the regional, national and institutional levels can help encourage the participation of girls and women, youth and other underrepresented groups in STI for the SDGs? What is the best way forward to engage broader participation and support?

STI solutions need to incorporate a wide range of diverse perspectives, including from groups that have traditionally been prevented or discouraged from participating in science and technology. This section looks at strategies and approaches for increasing and deepening the participation of women, young people and other underrepresented groups in STI, both to enrich and enhance STI for the SDGS in general and also to help ensure that STI for the SDGs includes solutions that promote equity and inclusiveness and address the needs of all that are at risk of being left behind.

Emerging technologies and inclusion

Enhancing economic and social inclusion is vital to ensuring that disadvantaged and/or vulnerable population groups, such as women, youth, people with disabilities, and ethnic minorities, do not suffer inequalities in the workforce or as consumers and recipients of public and private products and services.

Gender stereotypes continue to negatively affect men and women's private and family lives as well as their education and career aspirations and working lives. Many labour markets remain highly segregated by gender, with men concentrated in technology and engineering occupations and women in health and social care, education, fashion, food retail and labour-intensive tasks. Frontier technologies could exacerbate this imbalance in the medium term because of the shortage of women in science, technology, engineering and math professions. While non-standard types of employment (gig economy, platform economy, e-commerce) that allow for more flexible working hours are proliferating, they also raise issues about formality/informality and about social protection and contributions to the government budget. Many education systems are not equipped to teach women the skills that would enable them to participate equally in the economy driven by advanced digital technologies. Women account for only 20 percent of engineering graduates, and fewer still are employed in the real economy, reflecting problems in education systems and the enduring influence of societal stereotype.

Improving employment outcomes for youth requires that business, government and other key players cooperate to align education initiatives, workforce-development programmes and public policy. Enhancing the capabilities of the global youth will enable young people to participate in the design and implementation of frontier technologies.

New and emerging technologies and business models not only create opportunities for small and medium-size enterprises as adopters of new technologies, but also as inventors and suppliers of new technological solutions and business models. However, much of the potential for creating jobs and generating livelihood opportunities remains unrealized and SMEs require support for the transition to the 4th industrial revolution.

Precautions could also be taken to ensure that AI does not amplify gender inequality. Some risks of unintentional bias stem from the fact that most algorithms used to train machines are created by men.

Whether unconscious or deliberate, such biases seep into Artificial Intelligence artefacts and need to be addressed through systematic interventions. For instance, certain Artificial Intelligence products available on the market or displayed in films portray women in roles subservient to those issuing commands. Further research and advocacy for gender equality throughout the entire cycle of designing, testing and deploying Artificial Intelligence applications is needed to ensure that the use of Artificial Intelligence remains inclusive and both genders can equally benefit from it.

Policies and strategies

To harness STI to development more effectively, it is crucial to improve digital literacy and ICT knowledge among larger strata of women and youth populations. Stimulating creativity at a young stage is important, in order to foster a generation of individuals prone to venture into new STI domains and technological entrepreneurship. Regional agendas and many projects have been facilitated by Regional Commissions and by a dedicated IATT work stream (see Annex). For example, the Montevideo Strategy for Implementation of the Regional Gender Agenda includes a specific implementation pillar dedicated to technology.

There is a need to revolutionize processes with digitalization and youth talent. There is a generational obstacle facing effective digitization and smart solutions for solving chronic challenges of SDGs using frontier technologies. Young talents need to lead and older generations (older than 40 years in general) are typically not “digital natives” and can only guide and support, as they often do not have the skills to imagine and implement the adequate and possible solutions.

Building women’s capacity, especially leadership skills, is crucial to build women’s self-confidence in making use of STI for the SDGs. Capacity development enables women to access information about existing producer organizations and relevant technologies and also to become members, and to participate more actively in producer organizations activities as well as decision making processes.

Gender sensitive producer organizations are needed in which the rules, structures, technologies and practices ensure that women and men can equally participate in and benefit from the organizations’ services, networks and activities. Engage with rural women and their organizations in the design and implementation of policies, programmes and strategies to ensure that their needs are considered. Raise awareness and strengthen the capacity of institutions on the relevance of gender equality in policies and programs to ensure that STI benefits underrepresented groups. Specific measures can be taken to create more gender equitable organizational governance structures which help to create the necessary critical mass of women as members and leaders to bring about change in policy and institutional culture of a producer organization benefitting from STI solutions.

It is important to create an enabling policy environment to encourage participation of women and youth in STI for the SDGs. Governments play an important role in creating the enabling environment so that effective, inclusive and gender equitable producer organizations can flourish and act as important contributors to poverty reduction and the achievement of food security by making use of appropriate STI solutions.

The introduction of STI solutions to youth in the agricultural sectors is increasingly demanded, and global challenges, including climate change, environmental degradation and changing diet patterns, call for knowledge intensive agriculture. Yet it should bear in mind that millions of smallholders and family farmers, including rural youth could be left behind and not participate in the expected STI growth because of the lack of skills development and equal access to STI. The disparity between rural and urban youth could be further enlarged from a long-term perspective. Thus, it is important to ensure the inclusiveness is one of the key factors to promote sustainable development of STI to the whole society. While introducing cutting-edge high-technology and innovation to the agricultural sectors, which would most probably benefit the large commercials farms and its relevant value chains, it is necessary to develop and

adopt sustainable and suitable STI solutions that can be adapted to local, rural conditions and could easily to be taken on by young farmers.

Among underrepresented groups in STI for the SDGs, adequate support should be provided to rural youth, including smaller scale or SME type of young "agropreneurs"; young farmers who already participated in the agri-food value chains but are typically less educated and poor; and the poorest rural young people who are not part of the agri-food value chain but are fundamental for local markets in small villages. It is fundamental to provide tailored STI skills training and education, as well as appropriate extension services to them. In some cases, the skills training and education can be provided together with technical and vocational education and training extension, other agricultural sector training approaches and systems, and in combination of the entrepreneurship skills development support. Key will be ensuring policy that allows access to services, land, credit and decision-making powers.

UN entities raise awareness and provide capacity building. They can develop tools and methods for supporting governments to engage with rural women and their organizations in the design and implementation of policies, programmes and strategies to ensure that their needs are considered. They can support governments developing gender-sensitive policies and legislation that take into account differentiated roles and priorities of men and women. They can also support governments to develop STI strategies and roadmaps that promote multi-sectoral perspectives and inclusiveness of all underrepresented populations and institutions.

5. Open knowledge systems

How can open science and open knowledge systems support the achievement of the SDGs? What are the barriers, risks and opportunities? Which innovative models hold the greatest promise?

Open access to research and knowledge is a critical factor for strengthening the use of evidence in policy making and ensuring that the wealth of existing knowledge can be used by decision-makers. As we enter the decade of action to achieve the 2030 Agenda, open access to science that can be applied to achieve the SDGs is of particular importance. Barriers to and opportunities for generating greater access to scientific knowledge for the SDGs should be considered, along with any potential risks.

Open knowledge systems are important for stimulating research and innovation in low- and middle-income countries, and to develop evidence-based policies to tackle development challenges. Researchers in developing countries should be able to access cutting-edge research findings and debate from around the world.

SDGs are highly complex and context specific. Open access and citizen science can greatly support in dealing with this complexity and creating the knowledge for decision making and transitions. It is worthwhile exploring the universal values and principles of "open science", ensuring unrestricted and affordable access to knowledge and knowledge generation. The international community may want to support free, open and open entry the research processes, in any of its stages and contents, and to its use, modification and effective dissemination by all means. It could advocate overcoming certain barriers to sharing products, resources, methods or tools, at various stages of the scientific, technological and innovation research process. It upholds the precept of making the process of generating scientific knowledge more transparent, participatory and collaborative among academic, private and government actors.

Any open science regulatory framework should ensure the integrity of information and equity in the distribution of knowledge in favor of the well-being of society and sustainable development, using best practices, both nationally, and from countries and organizations. international.

Trustworthy data flow and open science are features of science which can bring together diverse researchers across national and institutional boundaries. Trustworthy data flows can also encourage

citizen science. The Wellcome Trust and other organizations have called upon researchers, journals and funders to share their research data and findings rapidly and openly.

In order to accumulate knowledge and data as a global public good, research and development that cannot be achieved through market principles alone, such as that on infectious diseases, could be supported by long-term public-private partnerships. When it comes to inclusive delivery of STI achievements, balance of profitability of enterprises, national security and human welfare are always a matter of discussion. Solidarity with multilateralism is a basic principle incorporated in the 2030 Agenda.

Among many others, an important factor of pursuing a successful initiative of open science is education, especially STEM education. The World Federation of Engineering Organizations is working closely together with the International Engineering Education Alliance to review the current Graduate Attributes and Professional Competences, and to promote a global benchmark standard of engineering education in higher learning institutes to strengthen the scientific foundation, sustainable development knowledge and skills, ICT capability and ethical principles.

The General Assembly resolutions that established and launched the TFM also mandated the STI Forum to provide a venue for the establishment of stakeholder networks and partnerships, "in order to help facilitate development, transfer and dissemination of relevant technologies for the sustainable development goals"[25]. Technology transfer in its various dimensions has a long history in the UN and international affairs. IPR issues have been a major are of contention and from a number of perspectives some key issues remain unresolved. At the same time, there are many promising new initiatives, models and arrangements throughout the UN system and beyond that do facilitate access to technology across stakeholders and international borders.

Experiences show that top down technology transfer approach has benefited high potential areas during green revolution times but costs significant environmental damage and has even proven ineffective and insufficient in some situations. Promotion of participatory approaches, co-creation and co-innovation processes based on demand with stakeholder involved is important to ensure ownership and greater uptake of technologies. The participatory approaches are promoted to ensure ownership and sustainability.

[25] see para 70 of the 2030 Agenda