18th Annual Meeting

STS *forum* 2021

Summary

October 2, 3, 4 and 5, 2021

Kyoto, Japan

Science and Technology in Society *forum*

Summary of STS *forum* 2021

STS *forum* 2021 - 18th Annual Meeting

October 2-5, 2021

Program

(Hours in Japan Standard Time, UTC+9)

Invitation Only

			Kyoto	Delhi	Riyadh	CEST	Greenwich	US East	US West
			UTC+9	UTC+5.5	UTC+3	UTC+2	UTC+1	UTC-4	UTC-7
Tuesday, September 14									
19:30-21:30		Funding Agency Presidents' Meeting							
Thursday, September 30									
20:00-22:00		Young Leaders Program (Group A)							
Friday, October 1									
00:00-2:00		Young Leaders Program (Group B)							
21:00-1:00 (Oct. 2)		Regional Action on Climate Change (RACC13)							
22:30-24:00		Academy of Engineering Presidents' Meeting							
Saturday, October 2									
14:00-16:40		Kyoto Symposium							
19:00-21:00		10th Global Summit of Research Institute Leaders							
20:00-21:30		University Presidents' Meeting							
20:00-21:30		S&T Ministers' Roundtable							
22:00-23:00	[100]	**Opening Session: Science and Technology for the Future of Humankind**	22:00	18:30	16:00	15:00	14:00	9:00	6:00
23:00-24:00	[101]	**Green Recovery for Sustainable Society**	23:00	19:30	17:00	16:00	15:00	10:00	7:00
Sunday, October 3									
13:00-14:00	[200A]	**Breaking Silos in Education -- Lifelong Active Learning in Inclusive Society**	13:00	9:30	7:00	6:00	5:00	0:00	21:00 (Oct. 2)
	[200B]	**Disruptive Technologies for Industries**							
– Intermission –									
21:00-22:00	[201]	**Global Pandemic -- Lessons Learned and Forecast (Preparedness)**	21:00	17:30	15:00	14:00	13:00	8:00	5:00
22:30-23:30	[202]	**Analysis and Synthesis in Science -- Earth and Commons**	22:30	19:00	16:30	15:30	14:30	9:30	6:30
0:00-1:00 (Oct. 4)	[203A]	**Advanced and Precision Medicine and Bioengineering**	0:00 (Oct. 4)	20:30	18:00	17:00	16:00	11:00	8:00
	[203B]	**The Second Quantum Revolution and Society**							
Monday, October 4									
13:00-14:00	[300A]	**Basic Science, Innovation and Policy**	13:00	9:30	7:00	6:00	5:00	0:00	21:00 (Oct. 3)
	[300B]	**AI and Robotics**							
– Intermission –		18:30-20:00 Academy of Science Presidents' Meeting							
21:00-22:00	[301]	**Enhancing Collaboration in Global Health**	21:00	17:30	15:00	14:00	13:00	8:00	5:00
22:30-23:30	[302A]	**Lights and Shadows of Digital Economy**	22:30	19:00	16:30	15:30	14:30	9:30	6:30
	[302B]	**International Collaboration in S&T**							
0:00-1:00 (Oct. 5)	[303A]	**Nurturing S&T Talents in Developing Countries**	0:00 (Oct. 5)	20:30	18:00	17:00	16:00	11:00	8:00
	[303B]	**State of the Arts Energy-Related Technologies**							
Tuesday, October 5									
13:00-14:00	[400]	**Science and Technology to Build a Resilient Society**	13:00	9:30	7:00	6:00	5:00	0:00	21:00 (Oct. 4)
– Intermission –									
21:00-22:00	[401]	**Collaboration among Academia, Industries and Government**	21:00	17:30	15:00	14:00	13:00	8:00	5:00
22:30-23:30	[402]	**Path Toward Net-Zero Emission**	22:30	19:00	16:30	15:30	14:30	9:30	6:30
0:00-1:00 (Oct. 6)	[403]	**Closing (Key Messages from the 18th Annual Meeting)**	0:00 (Oct. 6)	20:30	18:00	17:00	16:00	11:00	8:00

Table of Contents

Program 2

Sessions

Opening Session: Science and Technology for the Future of Humankind 6
Green Recovery for Sustainable Society 13
Breaking Silos in Education -- Lifelong Active Learning in Inclusive Society 20
Disruptive Technologies for Industries 28
Global Pandemic -- Lessons Learned and Forecast (Preparedness) 35
Analysis and Synthesis in Science -- Earth and Commons 44
Advanced and Precision Medicine and Bioengineering 52
The Second Quantum Revolution and Society 60
Basic Science, Innovation and Policy 67
AI and Robotics 75
Enhancing Collaboration in Global Health 82
Lights and Shadows of Digital Economy 90
International Collaboration in S&T 97
Nurturing S&T Talents in Developing Countries 104
State of the Arts Energy-Related Technologies 111
Science and Technology to Build a Resilient Society 119
Collaboration among Academia, Industries and Government 127
Path Toward Net-Zero Emission 135
Closing (Key Messages from the 18th Annual Meeting) 143

STS *forum* 2021 - 18th Annual Meeting: Statement 149
Board Members 154
Council Members 156
Members 161

Sessions

Opening Session:
Science and Technology for the Future of Humankind

[Chair]

Komiyama, Hiroshi, Chairman, Science and Technology in Society *forum* (STS *forum*); Chairman, Mitsubishi Research Institute, Inc., Japan

[Speakers]

Abe, Shinzo, former Prime Minister, Government of Japan; Honorary Chairman, Science and Technology in Society *forum* (STS *forum*), Japan

Anyang Agbor, Sarah Mbi Enow, Commissioner, Human Resources, Science and Technology, African Union Commission (AUC), Ethiopia

Handoko, Laksana Tri, Chairman, National Research and Innovation Agency (BRIN); former Chairman, Indonesian Institute of Sciences (LIPI), Indonesia

Gabriel, Mariya, Commissioner for Innovation, Research, Culture, Education and Youth, European Commission, EU

Tokura, Masakazu, Chairman, KEIDANREN (Japan Business Federation); Chairman of the Board, Sumitomo Chemical Co., Ltd., Japan

McNutt, Marcia, President, National Academy of Sciences, U.S.A.

Remarks

Prof. Hiroshi Komiyama, Chairman, Science and Technology in Society *forum* (STS *forum*); Chairman, Mitsubishi Research Institute, Inc., began by welcoming the participants and expressing his gratitude for their attendance. He also thanked the sponsors, members and supporting organizations for their contribution. Prof. Komiyama then spoke about how advances in science and technology have enhanced living conditions and human longevity. At the same time, humankind is dealing with a wide range of challenges such as climate change, desertification, pollution and disparities in various forms. Human activities have grown exponentially and manmade objects have covered the Earth's surface. Furthermore, 30% of CO_2 in the atmosphere is due to human growth. Humanity now has

Komiyama, Hiroshi

the greatest influence on change on Earth. Humans have the power to determine their future, but will we resolve the social issues we face and rebuild the beautiful natural environment of the Earth or face the decline of humanity?

Abe, Shinzo

There are several reasons for hope. One is solar energy, a powerful and renewable energy source. Second is saturation. Population and manmade objects are reaching a state of saturation, at which point metals and other resources will be in such circulation and re-circulation in society that it will no longer be necessary to dig them up. Third is the vast knowledge that humans have built up. If the right knowledge can be applied in the right way, it can solve most, if not all, of the problems humankind faces. However, knowledge is becoming increasingly abundant and localized, and must be integrated. To that end, STS *forum* has added two new themes this year: analysis and synthesis, and breaking silos. Lastly, Prof. Komiyama outlined his vision of the Platinum Society Network, a sustainable and prosperous world where all can achieve self-fulfillment, and expressed his hope that, if leaders from all walks of life participating in STS *forum* discuss, draw conclusions and take action to transform society, society will move in the right direction.

Mr. Shinzo Abe, former Prime Minister, Government of Japan; Honorary Chairman, STS *forum*, expressed his belief that science and technology are creating greater value now than at any time in the past. Humankind owes so much to scientists and their work, which have enriched human life and offered hope in the face of crises, such as developing the messenger RNA vaccine for COVID-19.

Mr. Abe commended Founding Chairman Koji Omi for recognizing the importance of science and technology when he launched STS *forum* 18 years ago, and praised his vision, action and passion. He also praised the decision to appoint Prof. Komiyama as the new Chairman, under whose leadership STS *forum* will surely continue to grow. Finally, Mr. Abe expressed his hope that the participants would be able to meet in person at next year's meeting, in the autumn beauty of Kyoto.

Dr. Laksana Tri Handoko, Chairman, National Research and Innovation Agency (BRIN); former Chairman, Indonesian Institute of Sciences (LIPI), shared examples of Indonesia's efforts to promote COVID-19-related innovations during the pandemic. BRIN has produced many such innovations, which fall into five categories: protection, screening and diagnostics, treatment, medical devices, and social science / humanities studies of the impact of COVID-19 on people.

Dr. Handoko also offered Indonesia's perspective on promoting international collaboration and innovation. The establishment of BRIN and placement of all governmental research institutions and activities under the management of one agency has improved the research and development ecosystem by increasing the critical mass for human resources, research structure and funding. Indonesia has also launched platforms for international collaboration in areas such as oceanic research and biodiversity. Furthermore, Indonesia has launched programs for promoting researcher mobility, in partnership with local and foreign universities and institutions. In addition, Indonesia holds the G20 Presidency in 2022 and it is organizing a special session on research and innovation and organizing working groups to discuss topics such as research collaboration in various fields. In closing his remarks, Dr. Handoko stressed the important role of researchers and scientists for addressing global challenges such as the COVID-19 pandemic.

Prof. Sarah Anyang Agbor, Commissioner for Education, Science, Technology and Innovation, African Union Commission (AUC), stated that the world in general, and Africa in particular, is facing unprecedented socio-economic challenges, including issues such as malnourishment and education exclusion. Addressing these and other issues, the African Union (AU) formulated a 50-year plan called Africa 2063: The Africa We Want. This vision can only be achieved through the consolidation of science, technology and innovation (STI) strategy of Africa. Under the plan, African countries are to transition into innovation-led, knowledge-based economies with STI deployed across socio-economic development sectors.

Handoko, Laksana Tri

Anyang Agbor, Sarah Mbi Enow

The AU has also adopted the Digital Transformation Strategy for Africa (2020-2030). In addition, it has endorsed an approach based on digital connectivity, online and offline learning, teachers as facilitators and motivators of learning, safety online and in schools, and skills focused learning (DOTSS) for transforming the African educational environment. Another important initiative is the Pan African Virtual and E-University (PAVEU) for accelerating the development of human capital and STI by enhancing digital access to tertiary education. The AU has also been holding an annual education technology exposition for promoting the systemic adoption of education innovation.

Lastly, Prof. Anyang Agbor stressed four points: the need to promote STI collaboration among government, industry and academia and disseminate scientific knowledge; the importance of the mobilization of domestic excellence and financial resources, and collaboration for STI; the need to establish and strengthen legal, regulatory and policy frameworks for STI for sustainability; and the need to integrate formal and informal education.

Tokura, Masakazu

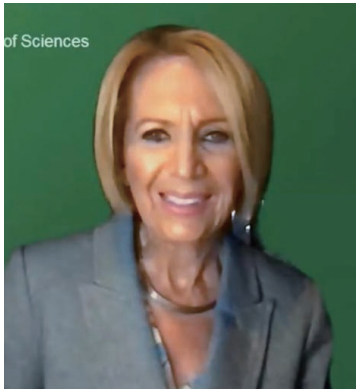

Gabriel, Mariya

Mr. Masakazu Tokura, Chairman, KEIDANREN (Japan Business Federation); Chairman of the Board, Sumitomo Chemical Co., Ltd., stated that KEIDANREN shares the same vision and values as STS *forum*. STS *forum* is an international forum for discussing science and technology for the future of humankind, casting light on positive and negative aspects. KEIDANREN also emphasizes the value of science and technology and is working with the Japanese government to achieve Society 5.0, which is a vision for resolving social challenges and creating social value by leveraging science and technology.

Mr. Tokura then pointed out that COVID-19, climate change and accelerating digitalization have made humanity feel closer to science than ever before. Only with science and technology can humankind overcome these challenges. At the same time, cutting-edge technologies, such as digital and biotechnologies, can pose a threat to humanity. Not only natural scientists but also social scientists and members of the humanities must come together to discuss the future challenges of humankind. STS *forum* brings together such experts, as well as leaders in government and industry, to jointly discuss science and technology and find the way forward for the future of humanity.

Ms. Mariya Gabriel, Commissioner for Innovation, Research, Culture, Education and Youth, European Commission, stated that the pandemic has brought shadows and lights, reminding humankind of the importance of science and technology for its future. Science and technology have offered humanity a way out of the current crisis in the form of COVID-19 vaccines. These vaccines were developed so rapidly due to an unprecedented level of collaboration. The EU is promoting such international collaboration under Europe's Global Approach to Research and Innovation, which is aimed at promoting multilateralism, reciprocity and openness. Such an approach is essential for tackling global challenges

such as the pandemic and climate change. The EU intends to work with others to develop and deploy green, digital and health transitions on a global and unprecedented scale to ensure no one is left behind, while respecting fundamental shared rules and values.



McNutt, Marcia

The EU also believes in strengthening multilateral collaboration and, in the spirit of international openness, has opened up its Horizon Europe program to countries with strong STI profiles and shared values with the EU. The EU's ambitious Horizon Europe program recognizes the importance of research and development for achieving a sustainable and inclusive society. Five new Horizon Europe missions were recently announced, aimed at the major challenges of fighting cancer, climate-change adaptation, oceans restoration, smart cities, and soil pollution.

The EU believes that science and technology is surely the only way forward for a sustainable recovery for all. It also believes that open science and collaboration accelerate scientific discovery. Indeed, this helped to drive the rapid development of vaccines against COVID-19. To that end, the EU is developing the European Open Science Cloud and also the EU COVID-19 Data Platform. Another key element it is promoting is standardization, particularly for new technologies.

Dr. Marcia McNutt, President, National Academy of Sciences, U.S.A., highlighted five major points for promoting science and technology for the future of mankind. She first summarized four key points from the remarks made by the other speakers. The first point is the need to give science a seat at the table. For example, in the United States, the chief scientific advisor position has been elevated to a cabinet position. Second is to break down silos in government. The complex challenges countries face involve interlinked issues that span the jurisdictions of multiple ministries and agencies. Third is the need to harness all talent, otherwise, it will not be possible to overcome the major challenges facing society. Fourth is the need to have open access to science, making science broadly available to governments, businesses and the public.

Dr. McNutt then added a fifth observation of her own: the need to actively counter misinformation. She pointed out that, in the United States, vaccine misinformation and disinformation have resulted in 70 million people refusing the COVID-19 vaccine. Such misinformation and disinformation have become especially rampant in the age of social media. Scientists need to counter the misinformation and disinformation they encounter and governments must put pressure on social media platforms to take down such content. Young people must also be educated to be critical consumers of online information.

Green Recovery for Sustainable Society

[Chair]

McKinnell, Henry A., former Chairman & CEO, Pfizer; former Chairman, Moody's, U.S.A.

[Speakers]

Chu, Steven, Professor of Physics and Molecular & Cellular Physiology, Department of Physics, Stanford University, U.S.A. [Nobel Laureate 1997 (Physics)]

Dunford, Beth, Vice President, AGRICULTURE, HUMAN AND SOCIAL DEVELOPMENT, AFRICAN DEVELOPMENT BANK, Cote d'Ivoire

Koundouri, Phoebe, Professor, Department of International & European Economic Studies, Athens University of Economics and Business (AUEB), Greece; President-elect, European Association of Environmental and Resource Economists, Italy

Ueyama, Takahiro, Executive Member, Council for Science, Technology and Innovation, Cabinet Office (CAO), Japan

Luers, Amy, Global Lead, Sustainability Science, Microsoft, U.S.A.

Hohn, Christopher, Manager, Children's Investment Fund (TCI), U.K.

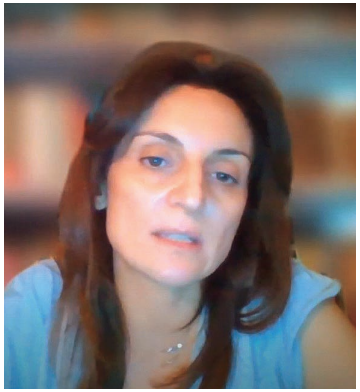
[QA Moderator]

Zehnder, Alexander J.B., President and Founder, Triple Z Ltd., Switzerland; Member, Board of Trustees, Nanyang Technology University, Singapore

Pre-recorded Statements

Dr. Henry A. McKinnell pointed out that in spite of all the good intentions and the objectives that have been set by international bodies to combat climate change, not even the most modest goals are being achieved. Dr. McKinnell wondered what needed to be done to change this situation and encouraged the panelists to discuss possible solutions, such as regulation, voluntary compliance, and a carbon tax, in order to achieve better results for humankind. Finally, he reiterated founding Chairman Koji Omi's belief that the only way to achieve great results in this, or any other science and technology-related challenge, is for government, science, academia, and business to work together.

McKinnell, Henry A.



Koundouri, Phoebe

Luers, Amy

Prof. Phoebe Koundouri believed that the world is facing four simultaneous crises: the COVID-19 crisis, the economic recession, climate change, and biodiversity collapse. The recession derives not only from the pandemic, but also humankind's inability to sustainably manage its environment and ecosystem. Humanity needs to build resilience to regional interactions between climate, biodiversity, and public health. To that end, all relevant stakeholders, including scientists, technology developers, politicians, policymakers, financial institutions, businesses, NGOs, and civil society, must collaborate with each other to develop detailed, holistic, and interdisciplinary pathways towards a sustainable future. It is hoped that upcoming high-level policy fora, such as the UN Food Systems Summit, the UN Biodiversity Conference, and the UN Climate Change Conference (COP26), will facilitate such efforts.

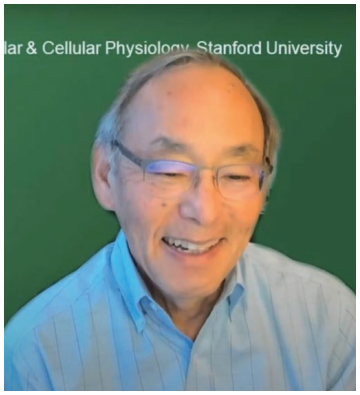
Dr. Amy Luers shared initiatives by Microsoft to accelerate transformations to sustainability. Microsoft has four sustainability commitments for its own operations and those of suppliers and customers. These are to, by 2030, be carbon negative, be water positive, produce zero waste, and protect more land than it uses. Microsoft is guided by five ways to act: reduce impact, remove emissions, invest in innovation, share what it learns, and empower others. Microsoft is aiming to get to 100% renewable energy by 2025, become carbon negative by 2030, and remove all its historical emissions by 2050. Microsoft is empowering its customers and partners with sustainable products and services, and by helping them to build tools to accelerate their own sustainability journeys. Lastly, Microsoft is sharing what it learns through its Global Sustainability Science Program.

Dr. Takahiro Ueyama explained Japan's environmental policy, as described in the country's Sixth Science, Technology and Innovation Basic Plan. The Plan has two future goals: ensuring people's safety and security through sustainability and resilience, and protecting and facilitating the wellbeing and happiness of Japanese nationals and global citizens. Global environmental issues pose grave threats to the resilience of society, and green recovery is therefore one of the most important pillars of the Plan. Japan is enhancing its efforts to address anthropogenic climate change and aiming to achieve a carbon neutral society by 2050. The Japanese government is also implementing a long term national strategy to create a sustainable future society through national investment in science and technology. Japan recognizes the need to redesign its economy and society, and is aiming for three transitions through government-industry-academia collaboration: a decarbonized society, a circular economy, and a decentralized society.

Ueyama, Takahiro

Discussion

Dr. McKinnell called for a greater focus on results and objectives. He pointed out that the current global discussion on climate has featured lots of talk and not much action, as well as lofty goals but not much being accomplished. He then invited the speakers to offer their views and advice on the way forward.

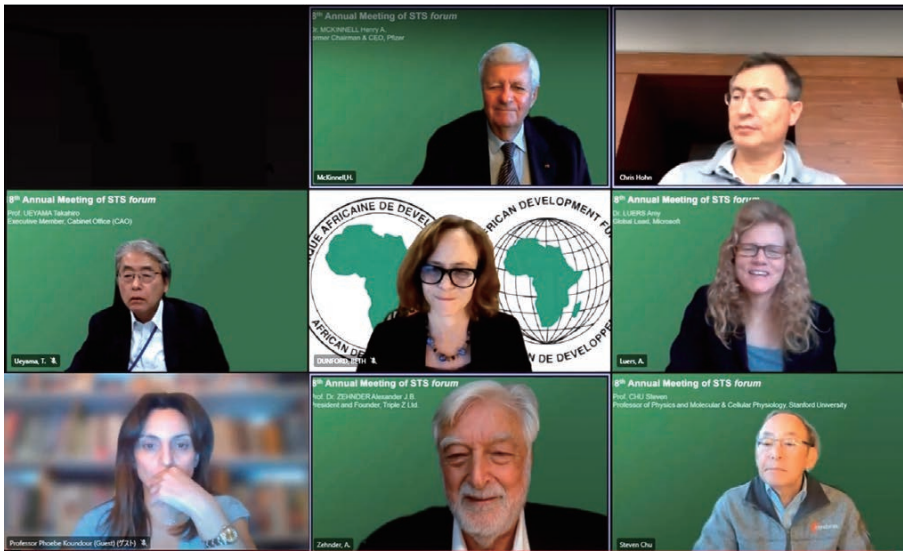


Chu, Steven

Prof. Steven Chu pointed out that humanity is facing a dire situation and that it will take decades to make the necessary changes. Furthermore, the full impact of humans' effect on the atmosphere will not be fully felt for perhaps 50 years. One way forward is for the public to put pressure on their governments. A measure that would help, but has been very difficult to achieve, is raising the gasoline tax. Voters and consumers need to tell politicians that this is not only acceptable but the right thing to do. They also need to convince politicians that dealing with climate change is a point of world stability as the impending crisis will cause human migration at an unprecedented scale. In addition, individuals all need to take personal action and make personal choices that help.

Dunford, Beth

Dr. Beth Dunford pointed out that just 4% of global emissions come from Africa but 60% of the world's top-ten countries at risk of drought are in Africa. In recent years, climate shocks have become more frequent, more unpredictable, and more devastating. The African Development Bank is therefore increasing investment in climate adaptation. An important focus of this is climate-resilient agriculture technologies for Africa, such as heat-tolerant wheat, as well as digital technologies for receiving timely weather and market information. The African Development Bank scales these innovative technologies with programs such as Technologies for African Agricultural Transformation (TAAT). The African Development Bank's programs are producing results. For example, the deployment of drought-resistant maize in response to the 2019 drought in southern Africa helped farmers survive the drought and even increased production.



Nevertheless, there is a need to scale up these efforts further. To that end, the African Development Bank has helped to launch a new financing facility for food and nutrition, which aims to bring climate-smart agro-tech to 40 million farmers and produce enough food to feed another 200 million people. In addition, the majority of Africans do not have access to power and the African Development Bank is working to provide access to energy to Africans and do it in a green way. An important initiative is Desert to Power, a solar initiative centered on the Sahel region that will turn Africa into a solar energy powerhouse.

Prof. Koundouri shared the situation in Europe. Europe and the world have taken too long to deal with sustainability and the climate crisis, only doing so when they started to feel the effects in the form of more extreme climate events. In addition to global efforts, such as the launch of the Sustainable Development Goals (SDGs) and the United Nations Climate Change Conferences, in 2019, the EU launched the European Green Deal.

In 2020, the COVID-19 pandemic began. In planning its response, the EU has taken a medium and long-run perspective, which is essential for achieving environmental, social and economic sustainability. The EU's recovery plan focuses on investing in projects that are green and digital. The EU has also launched an EU climate law, turning the commitment to zero carbon by 2050 into a legal one, as well as the EU Taxonomy for identifying sustainable projects. In addition, it has launched the FIT for 55 package of legislative proposals to revise the European legal framework to enable EU to reduce greenhouse gas levels by 55% compared to 1990. Overall, Europe is trying to introduce correct incentives and pricing of externalities to streamline economy and society towards achieving a reduction in CO_2 emissions. Similar efforts are also being seen elsewhere around the world.

Dr. Ueyama shared his thoughts and experience from formulating Japan's Sixth Science, Technology and Innovation Basic Plan. While the danger of global warming is commonly understood, not enough has been done to mitigate it. Japan recognized the need for bottom-up and shared understanding, and a deepening of bottom-up efforts from the government level to the public level. It also understood the need for a persuasive vision to touch the minds of the public and businesses. The Japanese government has made great efforts to expand its investment in science, technology and innovation, understanding that the benefits are not only for scientists and engineers, but the public. In this regard, Japan has produced breakthrough innovations such as next-generation solar cells and hydrogen energy. Japan also recognizes the role of social scientists in understanding and changing people's mindsets and behaviors, and is taking an all-disciplines-approach to policymaking

Hohn, Christopher

for addressing global challenges such as climate change. In addition, international cooperation is essential to ensure a coordinated and concerted approach.

Dr. Luers stressed three key measures: the need to understand the planetary crisis as an interconnected crisis of climate, water and biodiversity; the need to put a price not only on carbon but also other externalities that fuel said crisis; and the need to strengthen carbon and ecosystem accounting. She believed that these measures would incentivize companies to build solutions that lower companies' footprint and build industries that are nature positive and carbon negative.

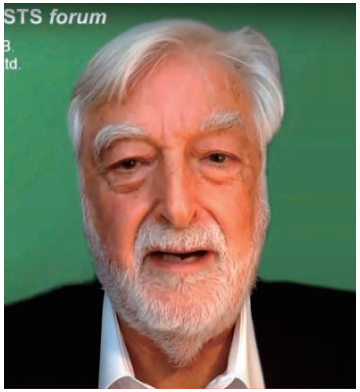
Sir Christopher Hohn believed that humankind will not achieve change by leaving it to the goodwill of people and companies. The private sector needs to be forced to change through aggressive regulation and taxation. Europe has demonstrated that this can work, for example in the electrification of cars. Significant financing is also necessary. Banks need to be forced to adjust credit and capital weightings applied to loans, to make it expensive for high emitters to borrow and inexpensive for low emitters to borrow. This is consistent with the risks that high emitters cause to society and the economy. In addition, new technologies will also be essential. The current amount of funding for these technologies is far too low compared to the level of need. Governments need to invest in these technologies, in partnership with the private sector.

Shareholders must also step up their efforts. Most companies do not have a credible climate action plan and shareholders do little about it. Governments must regulate that businesses must disclose their emissions and a climate action plan. This information should then be used for carbon taxation. Overall, there is a lack of urgency and a level of naivety around the climate crisis.

Dr. McKinnell noted different levels of optimism regarding changing how humans act. He asked how human behavior could indeed be changed.

Prof. Chu believed that the American people could put pressure on politicians to raise the carbon tax and to do so to a meaningful level. This would encourage industry to rethink its practices. Strong and rapid efforts need to be made as soon as possible.

Dr. Luers pointed out the difficulty for corporations to reduce Scope 3 emissions, which are emissions among their value chains and supply chains, as so much is out of the corporation's direct control. She wondered how this could be done more effectively and suggested that carbon accounting would be an important step.



Zehnder, Alexander J.B.

Dr. McKinnell believed that there needed to be appropriate pricing and incentive-setting.

Prof. Alexander J.B. Zehnder noted that agriculture is a major source of greenhouse gas emissions, while pointing out that the majority of farming in Africa is subsistence farming. He asked how it would be possible to encourage such subsistence farmers to move in the right direction.

Dr. Dunford explained that the African Development Bank's focus is on climate adaptation in agriculture, through technologies that have been proven to increase yields. African Development Bank is working with governments to help farmers transition from subsistence to commercial viability and to do so in a green way. At the same time, it will be important to increase technological capacity. To that end, it is necessary to increase science and technology talent in Africa by increasing scholarships, and investing in science and technology education.

Breaking Silos in Education
-- Lifelong Active Learning in Inclusive Society

[Chair]

Chen, Wenchi, Chairman and President, VIA Technologies, Inc., Taiwan

[Speakers]

Frank, Joachim, Professor, Biochemistry and Molecular Biophysics & Biological Sciences, Columbia University, U.S.A. [Nobel Laureate 2017 (Chemistry)]

Sweeney, David, Executive Chair, UKRI/Research England, U.K.

Kikuchi, Yasunori, Associate Professor, Institute for Future Initiatives, The University of Tokyo; Associate Professor, Presidential Endowed Chair for "Platinum Society", The University of Tokyo, Japan

Yonath, Ada E., Director of The Helen and Milton A. Kimmelman Center for Biomolecular Structure and Assembly, and The Martin S. and Helen Kimmel Professor of Structural Biology, Faculty of Chemistry, Weizmann Institute of Science, Israel [Nobel Laureate 2009 (Chemistry)] (Pre-recorded Statement Only)

Hagiuda, Koichi, Minister of Education, Culture, Sports, Science and Technology, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan (Pre-recorded Statement Only)

Yanagi, Takashi, Senior Deputy Minister, Ministry of Education, Culture, Sports, Science and Technology, Japan (Live Session Only)

Sheil, Margaret, Vice-Chancellor and President, Queensland University of Technology (QUT), Australia

Chen, Wenchi

Pre-recorded Statements

Prof. Joachim Frank shared his academic background and journey of lifelong education, first by describing his paths into various subfields of physics research. Beyond science, he expanded his lifelong learning by striving to become fluent in English, his second language. He described the shift away from pre-determined career paths set by one's trade and training in the past decades. Learning has expanded so greatly that learning institutions can no longer keep up, so Prof. Frank emphasized that training in critical, rational thinking will continue to be vital to navigate the sea of information, both true and false. Finally, he posed a question of whether lifelong learning should be structured and institutionalized.

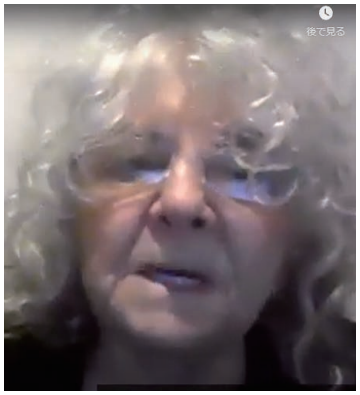
Frank, Joachim

Sweeney, David

Dr. David Sweeney acknowledged the obsolescence of unilaterally teaching the past accumulation of humankind's knowledge. Instead, education should aim to solve societal challenges while fostering human resources. Dr. Sweeney introduced three areas to guide the discussion. The first is the way that lifelong learning has been deployed in medical education. Recent methods including inquiry-based and case-based teaching have introduced a novel contrast to traditional problem-based learning, giving more responsibility and empowerment to students in their own educational journey. The second area is the issue of inclusivity. It is important to consider how to make active learning accessible to all people, not just those who are privileged or particularly self-driven. The third area is how researchers can engage more in the education process and support active learning. Greater cooperation between researchers and educators can be expected to bring benefit to both parties.

Dr. Yasunori Kikuchi introduced his research on co-learning for regional transformation. Regional transformation with science and technology requires three aspects: theory, data, and narrative. The nexus of these three aspects leads to a practical implementation of science and technology, as verified by the case study of Tanegashima, a remote island in Japan that is facing many serious social problems. Scientifically informed planning was crucial to envision a new energy system in Tanegashima, but such planning extends into other topics within regional transformation. There was a so-called "valley of death" between the social issues faced on the island and the resources and success models from outside the region. This gap could be filled through co-learning, which forged connections between outside universities and groups on Tanegashima. Engaging multiple stakeholders will

Kikuchi, Yasunori



Yonath, Ada E

continue to be important for implementing science- and technology-based regional solutions.

Prof. Ada E. Yonath shared her journey of curiosity and passion for science. After taking on much responsibility as a child, she realized the importance of knowledge and informal education. As a doctoral student, Prof. Yonath pioneered the use of computers in chemistry research, but that did not satisfy her desire to originate thought about established progress. As a young researcher, she became fascinated by genetic translation to proteins. Understanding this process required determining the structure of the ribosome, setting her on a two-decade-long quest for knowledge in the face of challenges, disbelief, and even ridicule from the international scientific community. Her breakthrough findings helped scientists understand how pathogens develop resistance, and thus play a crucial role in the creation of antibiotics. Now, next-generation, eco-friendly antibiotics are being designed.

Mr. Koichi Hagiuda remarked on the importance of education and science, technology, and innovation (STI) in responding to the rapid changes in modern society and realizing our self-potential. Climate change and the COVID-19 pandemic have shown that global challenges are growing ever more complex. Towards resolving these issues, people must take initiative to use new technologies, and the role of education and STI is becoming increasingly important. MEXT has been promoting online and digital technology, as well as inquiry-based learning and proactive learning towards creating a sustainable society. The whole of society must actively cultivate an environment and culture where students can deal with rapid changes, and where everyone can continue to learn. MEXT supports STI measures from a backcasting approach to resolve various issues, for example through research and development in various fields to maximize positive economic and social impacts such as achieving zero-carbon and digital societies. Mr. Hagiuda stressed the importance for each member of society to recognize global issues as their own through education, and seek to create a better and sustainable society.

Hagiuda, Koichi

Prof. Margaret Sheil explained the priorities of Queensland University of Technology, focusing particularly on aspiration and inclusion. In Australia, some measures towards more inclusive and diverse student populations have been taken in the past, but they are not enough. While online learning has helped provide opportunities to postgraduate level students in remote areas, there are still many barriers faced by students of low socio-economic status and those from non-English speaking backgrounds. Also, as highlighted by the pandemic, undergraduates particularly value on-campus learning and support. The global skill shortages may also be a strong driver for education going forward, so access to programs and education for mature learners is also becoming increasingly important.

Sheil, Margaret

Discussion

Mr. Wenchi Chen opened the session by acknowledging the challenges raised by the COVID-19 pandemic when it comes to education. He pointed out that accessibility of education and creation of educational contents are vital to prepare for upcoming challenges and inspire generations of active lifelong learners. Mr. Chen suggested that technologies such as artificial intelligence and virtual reality must be used as new tools in the future of education. He then invited the speakers to share their ideas on the topic.

Prof. Frank reiterated his experience of lifelong learning, starting from his childhood experiments, up to a Nobel Prize nearly 70 years later. He pointed to his path from physics to chemistry to biology as an example of active learning. However, cutting-edge science and what is taught in textbooks are facing a widening discrepancy. Prof. Frank believed that the goal of institutionalized education should be radically different. The classroom should be

used to show examples of human trials and triumphs, and methodologies should be taught, not accumulations of knowledge.

Western education has traditionally had a strong liberal arts base. However, early tracking resulting from industry pressure has put this at risk, at a time when a broad humanistic base is important for students to understand their shared fate on an endangered planet. New technologies have potential to aid in education, but likewise have their own inherent risks.

Prof. Frank commented on his shift from German to English writing, which was an opportunity for reinvention and active learning. He brought up the contrast between the creative freedom offered through fiction-writing and the tight system of rules within science. This interplay has helped him find a balance between his passions and maintain motivation.

Dr. Sweeney spoke about how technology is transforming the way we learn, yet pedagogy has not kept up. Therefore, research on better learning methods is very important. He acknowledged Prof. Frank's point that we must be wary of new challenges resulting from technology. Dr. Sweeney explained the need to learn from various examples to develop

the best solutions going forward, referencing Dr. Kikuchi's research.

Yanagi, Takashi

The experience of the learners needs to be considered. In the past 18 months, there have been significant shifts in teaching and in learning experience, almost like a massive experiment on a global scale. Young people desire a return to the old style, but the lessons learned from this recent experience must inform educational design going forward and be used to create an ideal blend of online and in-person learning. Finally, Dr. Sweeney reiterated the importance of bringing together research and educational expertise to seek optimal solutions, referencing Prof. Sheil's deep expertise in both research and education.

Dr. Kikuchi explained how his research worked with people in regions of Japan facing severe social issues, and how co-learning could address the gaps between the communities and the resources they needed to solve problems. He envisioned a learning ecosystem, spanning disciplines, generations and institutions, where these collaborations could enrich the knowledge of all participants. The trial in Tanegashima showed that bringing together people in the region to do workshops and seminars can be an effective way to create solutions. Research activities must expand beyond their current limited scope.

Mr. Chen suggested that central governments can play an even bigger role than local governments in solving problems of education.

Mr. Takashi Yanagi talked about how digitalization and carbon neutrality have transformed our lives drastically, along with the COVID-19 pandemic. Inquisitiveness and curiosity are considered important in the Basic Plan for Science, Technology and Innovation formulated in spring 2021. Mr. Yanagi offered two aspects related to enabling the transformation of education methods. The first is realizing personalized and optimized learning processes utilizing ICT. The second is utilization of practical learning to address social challenges. Mr. Yanagi identified three important items regarding optimal learning utilizing ICT: hardware, contents, and the ability to teach students. Mr. Yanagi believed that nurturing those three items will lead to enhanced broad knowledge across disciplines. Given the huge number of

public schools in Japan, working together with localities and industry will be vital to making significant changes to the educational system in Japan and ensuring a bright future.

Prof. Sheil described steps taken by the Australian government in widening the coverage of educational opportunities. Especially beyond the capital cities, there have been many gaps, especially when it comes to Aboriginal and Torres Strait Island peoples. Prof. Sheil pointed out two important challenges. First is encouraging children and parents to want to be educated, especially in aboriginal communities. Second is the wide disparities between schools. Assessment of potential, taking into account the students' backgrounds, and offering support for them to succeed are both vital. Online learning has deepened the divide between the two groups. Availability and technological literacy have contributed to this "digital divide," even in a developed country like Australia.

Prof. Sheil has been working with communities and teachers to create a more inclusive notion of merit for students. The younger the students, the more they want the social dimension of in-person learning, whereas online learning is more popular as a career change tool. However, signals sent by leadership are needed in a strategy to reimagine education. A multi-pronged approach including educated communities will be key to making progress.

Q&A Session

A set of three questions was raised. First, the panel was asked how one might introduce quantification into the analysis of education. Second, Dr. Kikuchi was asked how the presence of the rocket facility in Tanegashima impacted the relationship between the community and the rest of Japan. Third, Dr. Sweeney was asked how the example of Russia, with its separation of research institutes and universities, should inform our understanding of the relationship between research and teaching.

Dr. Kikuchi explained that the rocket facility is one of many resources on Tanegashima, and also functions as a sightseeing resource. Other resources are needed to enrich social systems there. Education, technology, and system design are all being considered, and there are many lessons to be transferred from the example of Tanegashima as a regional transformation.

Dr. Sweeney touched on recent studies about value added in higher education but acknowledged the incomplete picture of research in quantifying education. He proposed that the economy and society of a country greatly affect how learning translates into economic and

societal growth, so examining individual countries' systems may yield interesting results for economists.

Prof. Sheil added that while research is being conducted on value and costs of higher education, her university makes a point to integrate research and teaching. Researchers are more productive while engaged with teaching, and teaching has benefitted from the expertise of the researchers.

Mr. Yanagi commented that during the remote education expansion, various support was necessary. Since 2020, the Japanese government and MEXT introduced new curricular guidelines and began providing one ICT terminal per person. In addition to the OECD academic achievement survey and Japan's academic achievement survey, MEXT is also conducting a survey on lifestyle. Regarding recurrent education, MEXT is additionally conducting surveys on the needs of industry and the specialized fields of researchers.

A member of the audience asked if the gaps between countries have been widening or narrowing due to COVID-19. Prof. Sheil responded that gaps are likely to widen due to unequal access to technology, at least in the short term.

Dr. Sweeney agreed with Prof. Sheil, putting particular emphasis on the necessity to try to address the inequalities. He pointed out that countries seeing success in closing educational gaps, including Australia, are a resource to learn from.

Mr. Yanagi commented that gaps left unaddressed will only continue to expand. MEXT tries to convert such challenges into an opportunity to develop social infrastructure, helping those without adequate technological environments and supporting teachers' use of ICT materials for education.

Disruptive Technologies for Industries

[Chair]

Johnson, Ray O., Chief Executive Officer, Technology Innovation Institute, U.A.E.; Former Senior Vice President and Chief Technology Officer, Lockheed Martin Corporation, U.S.A.

[Speakers]

Haseltine, William A., Chair and President, ACCESS Health International, U.S.A.

Hauser, Hermann, Co-Founder and Partner, Amadeus Capital Partners, New Zealand

Takahashi, Masayo, President, Vision Care Inc., Japan

[QA Moderator]

Evans, Chad, Executive Vice President & Board Secretary, Council on Competitiveness; Board Treasurer, Global Federation of Competitiveness Councils, U.S.A.

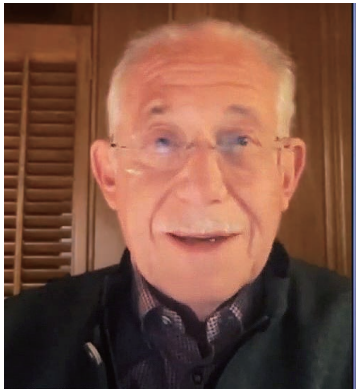
Pre-recorded Statements

Dr. William A. Haseltine first talked about the differences among how countries encourage disruptive technologies, the fundamental structures that encourage disruptive technologies, and the people who are engaged. The U.S. environment is special because it has a deep and long-term investment in higher education. Also, the U.S. has an investment in people. For example, young people and old people have the same advantages. Young people and old people also have opportunities to access finance for their ideas. Having access to capital regardless of previous experience or age makes the U.S. almost unique. He also explained that innovative technologies match the ability of newly created ideas and technologies to fulfill perceived human desire. The U.S. may be the leader of this. Putting all of these aspects together creates a good opportunity for disruptive technologies. One more aspect that Dr. Haseltine highlighted as being important for disruptive technologies was that there are government regulations to protect the investor and consumer protection.

Johnson, Ray O.

Dr. Hermann Hauser presented the four technologies that will change our lives in the next five to 10 years. Number one is quantum computing. Quantum computers allow us an exponential increase in performance not seen

in classical computers, which has important consequences in financial modeling, cyber security, and molecular modeling. Number two is artificial intelligence (AI) and machine learning. A lot of progress in AI comes from big data, which is owned by the big tech companies. Number three is synthetic biology. Gene therapy will change life because we will be able to design lives instead of simply following evolution. However, it needs an appropriate regulatory scheme. Number four is blockchain and smart contracts, which will revolutionize business processes and make the economy more efficient. Central bank digital currencies are an important change that this technology will bring. These four technologies will be breakthroughs and change the way we live.

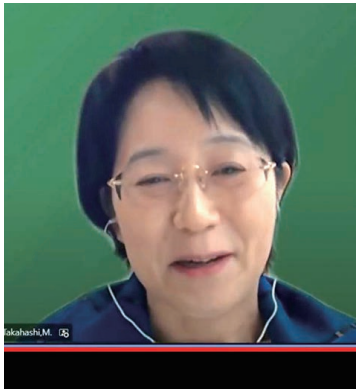


Haseltine, William A.

Hauser, Hermann

Dr. Masayo Takahashi presented on new technologies in medicine. Gene therapy produces many treatments especially for cancers and degenerative diseases. Issues in gene therapy include patent licenses, precision medicine, and public insurance. Regenerative medicine using ES and iPS is promising but with few treatments on the market, and organoid research is a breakthrough. In these areas, there are gaps not only between academia and pharmaceutical companies but also between pharmaceutical companies and clinical treatments, so suitable regulations or rules are needed. AI and machine learning are used in basic research often, but in the medical field, AI software or tools are not commonly used yet. Robotic biology is the evolution of life science research. AI will choose what to research and the experiments will be done by AI robots. These new technologies will change medicine and research in the near future.

Dr. Ray O. Johnson said that the disruptive technologies in question are a vast deployment of sensors, the Internet of Things (IoT), AI, big data, quantum computing, gene editing, nanotechnology, and autonomous systems. Each disruptive technology and those still


Takahashi, Masayo

emerging have numerous applications across industries and sectors. Economic growth, job creation, and enhancement of living standards are going to hinge on the transformation and transition of these emerging, breakthrough technologies in science, technology, and engineering getting into companies for commercialization. How to get companies prepared to adopt these technologies, such as the necessary ecosystems that must be put in place, needs to be considered. As we think about the lights that new and emerging disruptive technologies bring, it is also necessary to think about the shadows and get ahead in terms of biotechnology and autonomous decision-making systems.

Discussion

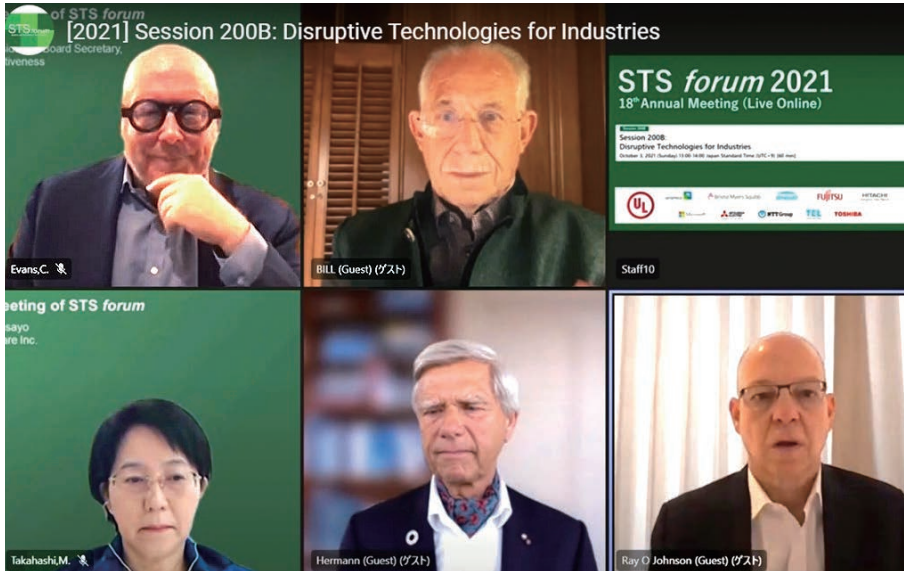
Dr. Haseltine started by talking about biotechnology, which has entered every part of our life from health to food. An important aspect of biotechnology in the future will be bio-manufacturing. He explained that living systems arrange atoms, and build living creatures and ecosystems. Now, through biotechnology, we have the ability to take that power to make materials that are useful for us, which is a fundamental change from what we could do a few years ago. This can lead to a greener technology not reliant upon fossil fuels. Another important aspect of the future of biotechnology is decoding and changing our DNA. We can use technologies to change organisms including humans, which gives rise to ethical issues. When talking about making changes to humans to prevent disease, there is not much resistance to gene therapy. Resistance comes when talking about enhancing human abilities.

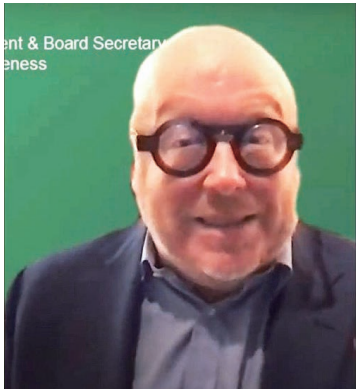
Dr. Hauser explained that there are four technologies that will change our lives in the near future. The first is AI and machine learning. He highlighted a great problem in biology that was coming up with proteins from a sequence of amino acids. It was AI and machine learning which solved this problem. The second is blockchain and smart contracts. The basic mathematics of using ledger technologies have opened the opportunity to rationalize and make business processes more efficient, such as introducing central bank digital currencies which will replace cash in more efficient ways. The third is synthetic biology. Gene sequencing involves the lights in terms of a better understanding of diseases, and also the shadows in terms of enhancing human characteristics. The fourth is quantum computing.

In five to 10 years, we will have computers based on quantum technologies that will be able to perform exponentially better than current computers. Finally, Dr. Hauser touched on technology sovereignty, particularly how these technologies influence the relationship between different countries.

Dr. Johnson added that it is clear that China has disallowed cryptocurrencies which will have implications on the rest of the world as it moves towards adopting cryptocurrencies. The first quantum computing company has entered the U.S. stock exchange as a public company, which is an indication of technological advancements made in that area.

Dr. Takahashi first introduced her background to give insight on her perspective, which is that the patients should be the ones receiving benefits from disruptive medical technologies. Until now, the goal of small molecule medicine is the end product of the company. In regenerative medicine, the end product is not the goal, rather, it should be thought of as a whole therapy. She highlighted that a new regulatory system is needed because there is a gap between patients and companies. If we have brand new technologies in science, we need a new social system and rules. Therefore, she emphasized that if we have brand new technologies, we need innovation and inventions in social science, such as with SDGs. Dr.





Evans, Chad

Takahashi also explained the development of robotic biology in basic research because biology research conducted by humans often ends in failure due to factors such as technique. Finally, she emphasized that the focus should be on the individuals who are benefiting from the disruptive technologies.

Mr. Chad Evans commented on a project to frame a new innovation agenda for the U.S. with a goal to improve the numbers, diversity, and speed of innovation deployment. This project is underway because the distance between the technologies that are emerging and tomorrow's realities is becoming less. He then touched on three trends. One is that powerful technologies are continuing to scale, such as sensorization and IoT. We are also moving faster towards hyperconnectivity, driving datafication. Two is convergence creating a new kind of innovation space for industries and society. Also, they are going to require new models of organization in the innovation process. Three is that new disruptive technologies are on the horizon, such as general AI performing cognitive functions and quantum science.

Dr. Johnson touched on the shadows of ethical, societal, regulatory, and security issues around AI, genomic technologies, and autonomous systems. To manage this, governments will and shall take as much control as they can, as we saw in the handling of COVID-19 around the world. He also highlighted that in the U.S. Congress, there are few members who have served in the military, yet they are making decisions about the military without having that experience. That can also be said for ethical, societal, regulatory, and security issues around disruptive technologies and science. So, it is important to consider the implications of the government's role in this area and continue to influence governments to go in the right direction.

Dr. Hauser commented that the root cause of issues is the fact that the political class is undereducated in STEM subjects. The number of engineers in the Chinese leadership is much more than in Western countries. On a positive note, Dr. Hauser explained that COVID-19 has produced great scientific success because of the speed and technology that the vaccine was created with. This has given science a more positive image in society.

Dr. Haseltine explained that without cooperation and open discussions, we are entering a world that is problematic. A big issue is the rift that has been created between the U.S. and China. Many of the discoveries, companies, and products that the U.S. has created would not have happened without Chinese colleagues. Nationalism and anti-China sentiment have become prevalent to an extent that we do not discuss the remarkable achievements that China has accomplished in controlling COVID-19. He also emphasized that a defining characteristic in how we use technology is about the fabric of society in which those technologies will be applied.

Dr. Takahashi explained that COVID-19 is a tragedy but has changed the world also in a good way. For example, the general population is now interested in sciences and aware of issues in the current medical system as revealed by COVID-19.

Mr. Evans added that there has been a lack of technology diplomacy. In the U.S., there needs to be more action and a renewed commitment to technological and scientific diplomacy trying to build a robust core of leaders who are knowledgeable about the scientific enterprise.

Q&A Session

Dr. Johnson touched on the concept of the "valley of death," which is the gap between academia-based innovation and its commercial application. He then raised two questions to the panelists. One is with the disruptive technologies, considering the valley of death, if we are on the verge of a technology-driven innovation productivity boom, and how long that would take. Two is about how disruptive technologies will change patterns of individual lives.

Dr. Hauser explained that the European Innovation Council has a 10 billion euro effort on making sure disruptive technologies survive the valley of death. Also, this effort is a way of addressing the fact that the U.S. has more venture capital. There is a recognition across the globe that surviving the valley of death is essential, making sure to translate breakthroughs for the benefit of society. Regarding the changes to the patterns of our lives, this can be imagined as positive or negative. For example, from the positive point of view, no one has to work any longer because robots do everything. On the other hand, the world can be like the 1984 Orwellian state.

Dr. Haseltine highlighted that the valley of death requires risk capital. The new nationalism in the U.S. has begun to cut the sources of this capital. For example, one of the great

sources of capital to overcome the valley of death was the Chinese capital willing to take risks that other capital was not. The new mindset that the real value is intellectual effort is dangerous for emerging economies. Instead, the real value is how we use that effort and how society is structured.

Dr. Johnson added that the role of governments in funding high-risk, high-payoff efforts is also in question.

Dr. Takahashi said that mass production may not be needed in the future in medicine. For example, medicine is now sold to the mass market without knowing who benefits from it and who should take it. However, medicine is advancing to precision medicine, which is not created on a mass scale. The goal will no longer be the end product, but it will be the system and the whole situation.

Dr. Johnson echoed that personalized medicine will be transformative, and the application of messenger RNA to other diseases will certainly move forward.

Mr. Evans commented that there has been a massive transformation in how society is organized due to COVID-19. However, he highlighted the negative points of online meeting fatigue, the impact on our productivity, and the need to find a better balance.

Global Pandemic -- Lessons Learned and Forecast (Preparedness)

[Chair]

Haug, Gerald H., President, German National Academy of Sciences Leopoldina, Germany (Pre-recorded Statement Only)

Narmann, Ruth, Deputy Head, Department of International Relations, German National Academy of Sciences Leopoldina, Germany (chaired on behalf of Dr. Haug)

[Speakers]

Leo, Yee Sin, Executive Director, Executive Director's Office, National Centre for Infectious Diseases, Singapore

Dzau, Victor J., President, National Academy of Medicine, U.S.A.

Riza, Hammam, Principal Expert Engineer, Research Organization in Assessment and Application of Technology (OR-PPT), National Research and Innovation Agency (BRIN); former President, Agency for the Assessment and Application of Technology (BPPT), Indonesia

Fauci, Anthony S., Director, National Institute of Allergy and Infectious Diseases (NIAID), U.S.A.

Kurokawa, Kiyoshi, Chairman, Health and Global Policy Institute; Professor Emeritus, National Graduate Institute for Policy Studies (GRIPS), Japan

Skipper, Magdalena, Editor-in-Chief, Nature, U.K.

Pre-recorded Statements

Prof. Dr. Gerald H. Haug introduced the session theme, stating that, despite scientists long warning of a devastating pandemic, many countries were not well prepared for COVID-19.

Haug, Gerald H.

There are lessons to be learned that could prevent similar incidents in the future. Next, he shared the experience of the German National Academy of Sciences Leopoldina. The Academy published nine statements on various aspects of the pandemic, formulated by interdisciplinary working groups spanning the natural sciences, social sciences and the humanities. The Academy's profile was raised by the pandemic and it is generally perceived as an honest broker for scientific knowledge. Nevertheless, maintaining the public's trust in science is a constant endeavor. Raising

Dzau, Victor J.

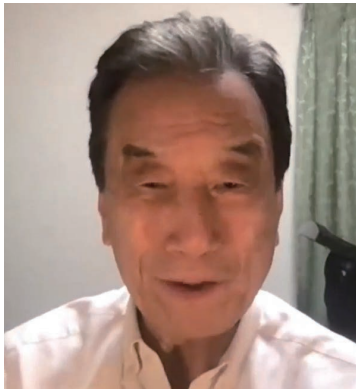
Fauci, Anthony S.

scientific literacy so that the public understands that science is an iterative process is important. Countering misinformation is another crucial factor. Last but not least, it is essential to clearly differentiate between scientific policy advice and actual political decision-making processes.

Dr. Victor J. Dzau believed that COVID-19 revealed the world's collective failure to address pandemic prevention, preparedness and response, including deficient detection systems, lack of global coordination, and initial gaps in the R&D ecosystem. There have, however, been some bright spots, such as the unprecedentedly fast vaccine development. Nevertheless, many challenges remain, such as insufficient financing and supplies, and continued vaccine inequity. Important future directions include accelerating all countermeasures, distributed and equitable manufacturing, multilateralism, financing, responsible leadership, and engaged citizenship. For the scientific community, scaled up surveillance and forecasting, faster and modernized clinical trials, social and communication science to foster trust and combat infodemics, and fast end-to-end research systems will be important. Overall, an all-of-society approach based on science is essential.

Dr. Anthony S. Fauci focused his talk on the development of pandemic countermeasures, an important component of the biomedical research approach to pandemic preparedness. This consists, fundamentally, of diagnostics, vaccines and therapeutics. The National Institutes of Health (NIH) approaches vaccine development through three components: the priority pathogen approach, which assumes the high risk of certain well-recognized pathogens; the platform approach, which concerns the optimization of vaccine platform technologies; and the prototype pathogen approach, which builds on prior experiences with a particular family of virus. As for therapeutics, the NIH is screening for already produced therapeutics, while also establishing an antiviral program for pandemics, including not only COVID-19 but also

other viruses with pandemic potential. This program has two components: the development and reutilization of existing compounds, and the discovery of new molecules.



Kurokawa, Kiyoshi

Dr. Kiyoshi Kurokawa presented data showing how COVID-19 ranked among causes of death in different countries. While COVID-19 ranked high among the causes of death in major developed countries such as the United States, the United Kingdom and France, it was low in Japan. Among developing countries in Asia, it was a major cause of death in Malaysia but not so in Thailand, Vietnam or South Korea. Even among countries on the same peninsula, namely Sweden and Norway, COVID-19 was a major cause of death in the former but not the latter. Dr. Kurokawa called for an investigation of the factors behind the different level of impact of COVID-19 in different countries.

Leo, Yee Sin

Prof. Leo Yee Sin centered her remarks on the biological clinical characteristics of SARS-CoV-2. The virus has high transmissibility and can spread silently and very rapidly. It has immune-invasive properties and is able to even evade the immune system in individuals who have had past infections or vaccinations. The virus has caused a disparity within regions and even within countries. It remains highly unpredictable with rapid evolutions, and the world needs to stay flexible and adaptable. This is no time to be complacent, even though in some regions the situation seems to be under better control. The international community needs to continue to study the virus and its impacts, and must respond with global solidarity.

Dr. Ir. Hammam Riza spoke about Indonesia's efforts to generate many innovative products during the pandemic. He also explained that Indonesia is advancing a plan called "Indonesia 4.0 Toward Smart Society," highlighting two of its strategies: formation of an innovation ecosystem and building national digital infrastructure. Indonesia is promoting

Riza, Hammam

Skipper, Magdalena

digital infrastructures such as artificial intelligence (AI). It has also launched a national AI strategy, setting out priority areas for AI implementation. This strategy is aligned with the Indonesia 2045 Grand Vision, which focuses on research and industrial innovation, AI talent and development, infrastructures and data, and ethics and policy studies. Dr. Ir. Riza then introduced examples of Indonesia's application of AI-related technologies, including COVID-19 detection and disaster warning systems.

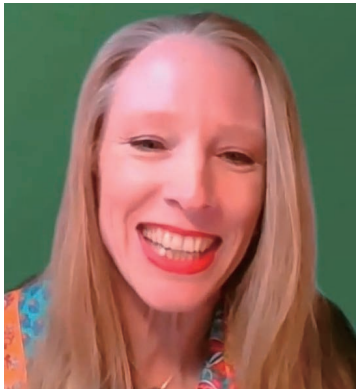
Dr. Magdalena Skipper pointed out that society must not only take stock of the lessons of the pandemic but also resolve to put them into practice. There have been two main science-related lessons. The first is the importance of embracing global collaboration and sharing of data and information. The early sharing of genomic data enabled the swift characterization of the disease agent and, consequently, unprecedentedly quick vaccine development. Furthermore, recent advances in science and medicine required extensive collaborations across borders, disciplines, and sectors. The second is the need to retain science's visibility and importance within policymaking. Time and again, those nations that followed the science fared much better than those that did not. These lessons are applicable not only to the pandemic, but also to other global crises.

Discussion

Dr. Ruth Narmann opened the discussions by asking the speakers to share key lessons in fighting the pandemic.

Prof. Leo cited the need to learn from many outbreaks as they are all different, and to make system-wide investment to prepare for the next one. She also pointed out the need to keep an open mind and maintain flexibility, as the SARS-CoV-2 is a relatively

new pathogen and understanding of it continues to evolve.



Narmann, Ruth

Dr. Dzau stressed the importance of science in all areas, from infection prevention and response, to policymaking. The human dimensions and social contexts are also important, including leadership based on science, social cohesion, and global solidarity.

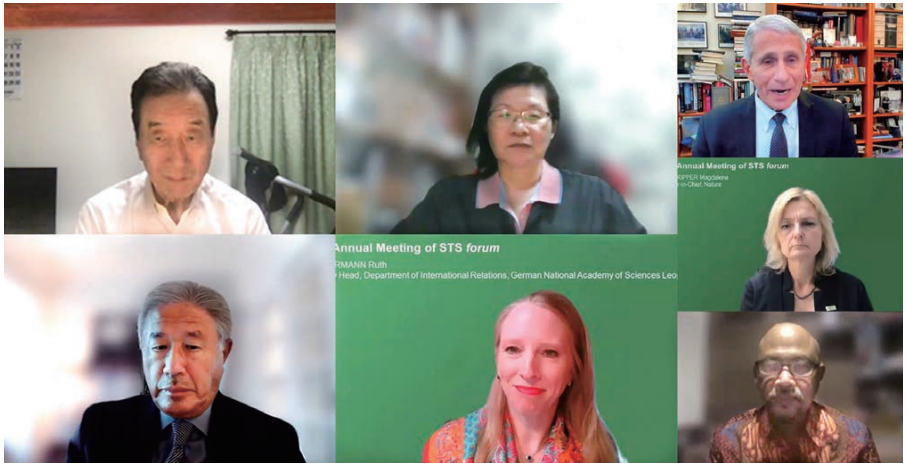
Dr. Ir. Riza believed that Indonesia was able to establish an innovation ecosystem that united the efforts of many different people to tackle COVID-19. Many businesses produced solutions such as mobile bio-labs and rapid diagnostic kits that were rolled out at the local level, including Indonesia's many remote areas.

Dr. Fauci pointed out the extraordinary importance of investment in biomedical research not only in response to a pandemic, but before, during and after. The unprecedented speed with which safe COVID-19 vaccines were developed was a huge success and was possible thanks to investment and scientific work occurring for many years before the pandemic struck.

Another important lesson is the power of social media, both positively and negatively. It can be a vehicle for spreading information rapidly, but also one for misinformation and disinformation. To counter that, the scientific community and governments need to continue to put forth true and correct scientifically-based information.

Dr. Kurokawa believed that the hyper-connected world enables countries to learn from each other's best practices. In addition, policymakers need to focus on the production and equitable distribution of vaccines. Dr. Kurokawa also highlighted the value of basic science and research, which contributed to the development of messenger RNA-derived COVID-19 vaccines.

Dr. Skipper called for scientific collaborations across the globe, rising above any geopolitical issues, as well as across different sectors, spanning academia, government and industry, and across different disciplines, including the social sciences, which are essential for



understanding and influencing social behavior. It is also important to share information freely and rapidly. In addition, societies need to constantly prepare for future challenges and many of the lessons learned from the pandemic can be applied to other crises, such as climate change.

Dr. Narmann then asked Prof. Leo how responding to the SARS-CoV-2 outbreak compared to other outbreaks she has dealt with.

Prof. Leo pointed out that Singapore tried applying the management lessons from the SARS outbreak to the SARS-CoV-2 one but did not enjoy much success because the means of transmission were so different. Fortunately, Singapore was able to sample a clinical cohort to better understand the virus progress, shedding, and so on, and inform policies based on that. This highlights the importance of flexibility and open-mindedness.

She also noted the value of social science aspects. SARS-CoV-2 is a very divisive disease, affecting the elderly and the impoverished more heavily. Governments need to adopt the right communication strategy for different strata of society.

Dr. Fauci believed that the pandemic showed that many countries around the world have allowed the attrition of fundamental public health infrastructure. Continued investment in public infrastructure is essential.

Dr. Fauci also agreed with the importance of open-mindedness and flexibility. Over the course of the pandemic, the knowledge about the virus continued to evolve, and many aspects of it were unprecedented. Societies and policymakers must flexibly adapt their responses alongside the evolving understanding about the virus.

Dr. Dzau called for better planning and coordination, both nationally and globally. He also pointed out the fragmentation between different systems, such as research, detection, and deployment, and the need for an end-to-end ecosystem spanning all of them. Speed is also essential, as is financing. The level of investment around the world is currently far from sufficient. Lastly, better coordinated and more coherent governance is vital as well.

Dr. Ir. Riza said that the world is undergoing digital transformation, and, with COVID-19 affecting all aspects of people's lives, IT will be a core part of the solution as IT systems connect multiple systems. Improved regulation for implementing digital transformations and implementing IT systems is also needed.

Dr. Narmann asked Dr. Skipper about how to balance rapid reporting and quality control, particularly the role of scientific journals.

Dr. Skipper agreed that speed must not come at the expense of quality and pointed out that there are different means of communication at speed. For example, there has been a significant rise in the adoption of preprints during the pandemic. This goes hand in hand with scrutiny by editors, fellow researchers and other experts. There is no substitute for such review, but scientists must also embrace other forms of communication, including social media and multimedia formats such as podcasts. These are essential for reaching the broader public. In addition, multidisciplinary journals help to bring together researchers from different disciplines and foster communication among them and beyond the research community.

Dr. Skipper also echoed the other speakers' call for greater investment at the global level. In addition, she advocated enhanced global governance, such as incorporating scientific advice at the level of the United Nations General Assembly.

Q&A Session

Dr. Narmann introduced a question from the audience, concerning whether Nature would be interested in pioneering the publishing of negative results.

Dr. Skipper agreed with the importance of publishing negative results and pointed out that Nature and its portfolio journals do in fact already do so.

Another question was raised on the future of traditional vaccines in view of the success of the new messenger RNA-based COVID-19 vaccines.

Dr. Fauci clarified that the success of the messenger RNA and vector-based COVID-19 vaccines does not mean traditional, tried-and-true vaccine platforms cannot be effective for future disease outbreaks. He then emphasized the importance of ensuring the equitability of the availability of countermeasures in real-time. There is a need to build capabilities in production and scale them up in countries around the world so they are not dependent on the leftover supply from other countries.

A question was also received on how to build trust and how scientists can effectively communicate with governments.

Dr. Dzau agreed on the importance of social cohesion and trust. Trust means credibility, transparency, consistency, and civic engagement. Scientists and governments cannot foster trust without action and communication. There is also a need to recognize that science and data are evolving and avoid drawing conclusions too early, which later generates mistrust. Risk communication and empowering the community to understand the messages from scientists and governments is essential, as is combatting misinformation and disinformation.

Dr. Skipper stressed the value of honesty, including the mistakes made in the research community. The more transparent the research community is, the more obvious and clear it is to the public that science is evolving. Dr. Skipper also pointed out that there is a huge stigma associated with retracting published papers but that need not be the case as only a small minority are associated with fraud or misconduct. Most retractions are just a reflection that previous conclusions need to be revised in light of new findings.

In relation to engaging the general public, Dr. Skipper highlighted the importance of co-creation and including the public in the process from the beginning. This may not be possible at all stages, but greater co-creation in the development of solutions will make science more trustworthy and transparent. Transparency will also help to combat misinformation.

Dr. Narmann asked the speakers if they had any key takeaways they wished to add.

Prof. Leo pointed out the dangers of overpromising, which can erode trust.

Dr. Ir. Riza called on societies to embrace the technological changes brought about by the pandemic so they can emerge even stronger from it.

Dr. Dzau called for equity, solidarity and multilateralism.

Analysis and Synthesis in Science -- Earth and Commons

[Chair]

Ishii, Naoko, Executive Vice President, Director of Center for Global Commons, Professor of Institute for Future Initiatives, The University of Tokyo, Japan

[Speakers]

Srivastava, Leena, Deputy Director General for Science, International Institute for Applied Systems Analysis, IIASA, Austria

Colombani, Pascal, Honorary Chairman, VALEO SA, France

Nakicenovic, Nebojsa, Deputy Chair of the Group of Chief Scientific Advisors, European Commission, Austria

Holliday, Jr., Charles (Chad) O., former Chairman, Royal Dutch Shell plc; former Chairman of the Board, Bank of America; former Chairman and Chief Executive Officer, DuPont, U.S.A.

Gupta, Joyeeta, Professor, Law and Policy in Water Resources and Environment, University of Amsterdam and IHE Delft Institute for Water Education, Netherlands

[QA Moderator]

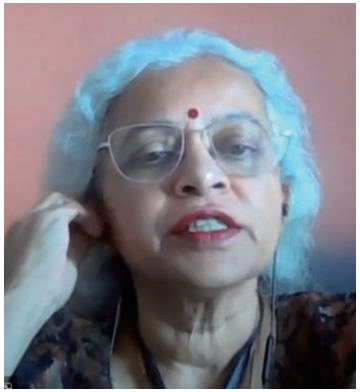
Boright, John P., Executive Director, Office of International Affairs, National Academies of Sciences, U.S.A.

Pre-recorded Statements

Dr. Naoko Ishii pointed out that humanity has forgotten that its economic development has been supported by the global commons of the Earth system. Earth system scientists warn that humankind is approaching or already transgressing several planetary boundaries. Geologists warn that humankind is in the Anthropocene, an era where humans alter functions of the Earth system. For a sustainable, inclusive and resilient future, humanity needs to change its economic system. However, the world has yet to identify an effective mechanism for governing the global commons. The University of Tokyo has recently proposed a framework for governing the global commons. It consists of six indicators for safeguarding the global commons and calls for the transformation of 40 economic systems, ignited by the four action levers of policies, finance, social norms and data.

Ishii, Naoko

Dr. Leena Srivastava talked about the challenges in governing the global commons. There is a fragmented understanding and analysis of, and across, the system components, which poses a major barrier to an early comprehensive response. The difficulty of combining the components into a coherent whole in a timely manner could also translate into gaps between science and policy or action. Furthermore, global commons and their challenges are colliding with and compounding each other. The mal-understood and mal-designed human-developed commons are also a major barrier to corrective action. The world needs to take the following five actions, amongst others: launch unprecedented multistakeholder partnerships; provide unfettered access to data, knowledge and tools; support large scale sustainability entrepreneurship and innovation; establish globally integrated crisis response mechanisms; and make the common man a key stakeholder in the global commons.

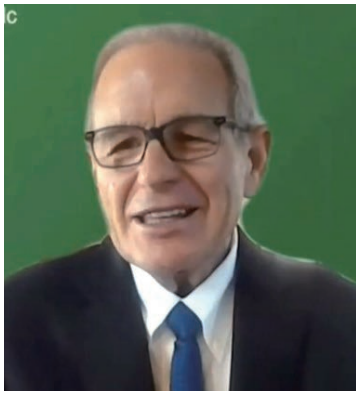


Srivastava, Leena

Colombani, Pascal

Dr. Pascal Colombani expressed doubt that humanity is at a critical juncture, but agreed that it is facing significant challenges, including climate change. He believed that science and technological innovation coupled with appropriate regulation would solve many of these challenges. In fact, the world is already undergoing a revolution that is changing many processes and outlines a path consisting of availability of huge computing power, availability of huge databases coupled with artificial intelligence, availability of artificial intelligence itself, developments with simulation, and rapid prototyping. These components will hopefully transform humankind for the better. There are also risks and, therefore, a need for new regulations and safeguards. However, multistakeholder coalitions will likely bridle, rather than generate, innovative solutions. Instead of a new governing body, a new regulatory body addressing the availability of data, their use, and the channels used to communicate them, is needed.

Nakicenovic, Nebojsa



Holliday, Jr., Charles (Chad) O.

Prof. Nebojsa Nakicenovic pointed out that the scientists have recognized that humanity may be transgressing planetary boundaries and tipping elements of the Earth system. For example, in the case of climate change, the current 1.1 degree Celsius global warming compared to preindustrial levels is already endangering many Earth systems. The way forward will require radical changes and innovations in all human activities. Prof. Nakicenovic and his colleagues have quantified a number of such potential tipping elements and proposed targets for a safe and just future for all. For the climate, an immediate reduction of emissions and achieving net zero by 2040 or 2050 at the latest are required. In addition, biodiversity loss needs to be net zero immediately, with nature positive changes by 2030 and hopefully full recovery of the Earth systems and ecosystems by 2050.

Mr. Charles O. Holliday, Jr. spoke about the need for a transition in the energy system. There have been many transitions in the energy system in the history of the Earth, such as from kerosene lighting to electric lighting. Each time, people made such a change because the new system offered a better combination of value and cost. To make the next transition, it is necessary to provide an energy system that people prefer based on quality, functionality and costs and to highlight the specific aspects of such a new system that the users care about. The Mission Possible Partnership is applying this approach to try to develop new systems for the seven hardest-to-abate sectors, which account for 30% of the overall greenhouse gas emissions.

Discussion

Dr. Ishii invited comments from the speakers on how science and technology can effectively address global-level challenges, including addressing challenges across and within systems, closing the lead time between new knowledge and the actual state of the world, bridging silos and the gap between scientists and decision-makers, igniting technological innovation, and transforming critical systems in a fair and just way.

Dr. Srivastava pointed out the need to recognize that the global commons are very complex systems with multiple users, which makes reaching consensus very difficult. Therefore, by the time humankind recognizes a problem, the problem is already very advanced. Global commons consists of component systems and there is a need to analyze how each contributes to the overall problems. However, such analysis often runs up against vested interests, leading to gaps in understanding. The scientific communities analyzing these different components are also fragmented, preventing formulation of a coherent action plan for policymakers. This is compounded by the fact that the world is running out of time.

Another major issue is the lack of trust in science. To address that, there needs to be unfettered access to knowledge, data and tools. To fill in knowledge gaps, more transdisciplinary and interdisciplinary approaches through unprecedented multi-stakeholder coalitions are necessary. As for innovation, transformative changes need to begin at the grassroots level.

Dr. Colombani believed that the world faces significant challenges that are not limited to climate change. Generally, the world faces the challenge of preserving Earth resources in

the face of a growing human population, and closing the disparities between rich and poor. When basic needs are fulfilled, there is also a need to address the legitimate requests for greater quality of life. The solutions to these challenges lie in innovation, appropriate regulation, and innovative approaches to managing risk. New and innovative approaches are possible thanks to huge amounts of data and computing power, new materials, and the possibilities of bioengineering. These can change the ways things are done and improve the future of humankind. At the same time, regulation is needed to ensure that these innovations contribute to a better quality of life and sustainability. Furthermore, the world needs a regulatory body, not a new governing body, of which there are already many.

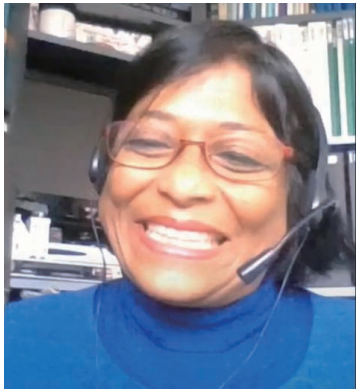
Prof. Nakicenovic listed major challenges facing humanity, including COVID-19, climate change, and a digital future. All of these can only be overcome through transdisciplinary and interdisciplinary approaches. It is necessary to focus on synergies and to avoid tradeoffs and barriers. In that sense, the Sustainable Development Goals (SDGs) are hugely valuable for providing a visionary and aspirational agenda. However, their major shortcoming is their great complexity. The World in 2050 was organized with the aim of synthesizing the SDGs agenda and focusing on the synergies. It advocates six fundamental transformations for realizing a safe, just and resilient future for the people and the planet, including global commons.

Prof. Nakicenovic also pointed out that the world needs science, technology and innovation (STI) roadmaps and action plans to bring the 2030 Agenda to policymaking and immediate action. He also called for an integrated, long-term plan focusing on six priority areas for transformation: digitalization, decarbonization, education, health, circular economy, and sufficient production and consumption.

Mr. Holliday pointed out that there is no limit to what people can accomplish if they do not care who gets the credit. He also shared the work of the Mission Possible Partnership, which aims to transform the seven hardest-to-abate sectors that account for 30% of total greenhouse emissions. In these sectors, early action is needed. Partnership is also key and entire value chains need to work together to find the right short and long-term solutions

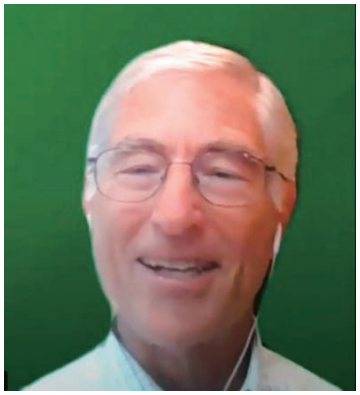
Prof. Joyeeta Gupta raised six points from the work of the Earth Commission. These are that achieving the SDGs will require some degree of redistribution and advances in science and technology; a new indicator of wealth and development to replace GDP is needed; social sciences must play an important role in any transformation; advances in technology and

innovation must not create unemployment, create monopolies, nor use unsustainable amounts of resources; companies' technological research has tended to externalize risks and a precautionary approach is needed; and there is a tendency for existing vested interests to be used to create new vested interests. Summing up these points, Prof. Gupta concluded that innovation must be embedded in a just system.



Gupta, Joyeeta

Dr. Ishii asked for the speakers' views on governance of the global commons. She expressed her belief that there is currently no effective system for governing them and suggested distributed multistakeholder coalitions as a possible new system of governance.



Boright, John P.

Dr. Srivastava believed that such issues go beyond governments. She also commented that to create knowledge-based societies, decision-makers and regulations need to continue to update their knowledge. In addition, Dr. Srivastava called for the creation of a shared vision that every stakeholder must commit to. She also pointed out that the discussion of net-zero emissions does not deal with issues such as cumulative emission and responsibilities, which leads to lack of trust.

Prof. Nakicenovic commented that not only the STI process but also governance is fragmented. He believed that it would be difficult for governance based on voluntary contributions by sovereign states to protect and guarantee essential services of the Earth system. He therefore advocated for more inclusive and multi-stakeholder governance.

Prof. Gupta suggested that the international legal system needs to be rejuvenated to ensure legally binding systems among countries.

Mr. Holliday called for data, information and reporting to be standardized. If not, they are not reliable, and appropriate discussions and action cannot take place based on them. Reporting must be common, accurate, and timely.

Dr. Colombani recommended prioritizing practical measures such as carbon pricing, rather than pursuing grand schemes such as worldwide governance. He suggested that proceeding with practical measures in a step-by-step manner will help to eventually build a broader consensus. The regulation of data and its use, however, needs to occur immediately.

Q&A Session

Dr. John P. Boright moderated the Q&A session. The first question from the audience concerned trust. It suggested that trust not only in science but also in policymakers is needed, and wondered if education in science might be a first step in achieving greater trust.

Dr. Srivastava commented that trust in policymakers and in science come hand in hand and are mutually influential.

Prof. Gupta agreed with the importance of educating the public. She also suggested that states need to reach different parts of the population. They need to fulfil this public communications function themselves or delegate it, say, to universities.

A question was also raised about how to transform the food system.

Dr. Srivastava pointed out that many supply-side recommendations are constrained by the availability of financial and other resources. She suggested starting from the demand side instead and exploring how to influence demand towards a higher level of sustainability and accountability.

Prof. Gupta noted that the food trade is a massive source of emissions and called for more discussion on how to deal with trade, including the possibility of reducing it.

Another question from the audience concerned the importance of population in the discussion of these issues.

Prof. Nakicenovic noted that, today, two billion people are left behind and another two billion may be left behind by 2050 if nothing is done about it.

Prof. Gupta pointed out that in societies that are educated and where there is low infant mortality, people have fewer babies and the population growth rate will eventually decline. Thus, implementing the SDGs, such as those concerning education and gender equality, can help.

Dr. Ishii asked the speakers to share any concluding comments they have.

Dr. Srivastava stressed the need to find more bespoke solutions to empower local communities.

Mr. Holliday noted that talk about ideal solutions could go on forever, and suggested that the world needs to just start taking more action and doing whatever it can.

Prof. Nakicenovic agreed, pointing out that the world is running out of time and that it knows roughly the right direction to move in.

Dr. Colombani stated that it is very difficult to start to build consensus among diverse stakeholders. He advocated beginning with practical steps and emphasized the importance of innovation balanced with regulation and the need to pursue economic benefits for all stakeholders.

Prof. Gupta highlighted the importance of a carbon conscience.

Advanced and Precision Medicine and Bioengineering

[Chair]

Hamaguchi, Michinari, President, Japan Science and Technology Agency (JST), Japan

[Speakers]

Beutler, Bruce, Director, Center for Genetics of Host Defense, University of Texas Southwestern Medical Center at Dallas, U.S.A. [Nobel Laureate 2011 (Physiology or Medicine)]

Ciechanover, Aaron, Professor, Technion Integrated Cancer Center (TICC), Faculty of Medicine, Technion - Israel Institute of Technology; Israel [Nobel Laureate 2004 (Chemistry)]

Gao, George Fu, Director-General, Chinese Center for Disease Control and Prevention, China

Hersey, Sarah, Vice President, Precision Medicine, Bristol Myers Squibb, U.S.A.

Tuan, Rocky S., Vice-Chancellor and President, The Chinese University of Hong Kong (CUHK), Hong Kong

Pre-recorded Statements

Dr. Michinari Hamaguchi spoke about the lights and shadows of advanced and precision medicine and bioengineering technologies, such as clinical trials of regenerative medicine using iPS cells, genome editing technologies, and messenger RNA vaccines, and how to manage them. The complex issues surrounding science and technology require the involvement of diverse stakeholders from each sector of society. For academia, industry and government to better communicate and suppress the risks of science and technology, it is necessary to converge wide-ranging knowledge. Incorporating the perspectives of humanities and social science, such as ethical, legal and social issues, is essential for ensuring the social acceptance of research results. Inclusiveness, science communication and science education are also key. Academia, industry and government must also endeavor to understand the public's attitudes toward controversial scientific topics and tackle their concerns.

Hamaguchi, Michinari

Prof. Bruce Beutler made the case for classical genetic methods as the way forward for precision medicine. Target discovery is everything in precision medicine. For the longest time, target discovery was left entirely to the immune system. With genetic methods, however, researchers can do target discovery themselves. There are instances in which monogenic mutations prevent or mitigate a particular disease, but in humans, it is extremely hard to find such mutations. On the other hand, as shown in Prof Beutler's research, it is possible to identify which mutations may be causing cancer resistance in mice with faithful models of cancers that afflict humans. In some cases, the affected genes have exact counterparts in humans, making it possible to envision therapies based on them. Such research suggests that rare phenotypic exceptions caused by point mutations can provide insight into how to intervene in many different diseases.

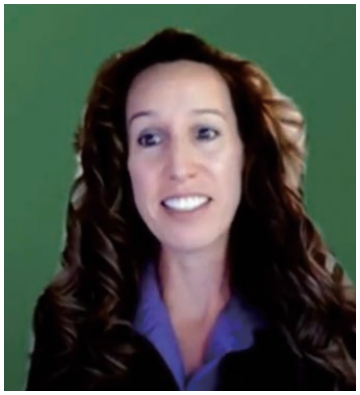
Beutler, Bruce

Ciechanover, Aaron

Prof. Aaron Ciechanover talked about the revolution brought about by personalized medicine. Until now, medical treatment has been focused on the disease, regardless of who the patient is. However, results vary among patients because no two patients are the same. Furthermore, sometimes diseases that are thought to be the same are in fact different. In the future, medicine will be based on people's genetic makeup and will shift from a one-size-fits-all approach to a tailored one. By sequencing patients' DNA, it will become possible to identify the specific mutations driving diseases in particular patients, distinguish between seemingly identical diseases in different patients, and treat each patient accordingly. It may even be possible to detect diseases far before their occurrence and replace damaged DNA using gene-editing technology, but such technology also comes with ethical and privacy concerns that must be considered.

Prof. George Fu Gao first spoke about the potential of personalized and precision medicine, and 21st-century technologies. As an example, he cited personalized messenger RNA technology and expressed his belief that this would open up new ways to tackle rare diseases, tumors and genetic disorders. Prof. Gao also highlighted the importance of social science

Gao, George Fu



Hersey, Sarah

for combatting infodemics around science and technology, and the need for natural scientists, social scientists, and the public to communicate with each other. In addition, he proposed the 4C principles (Cooperation, Competition, Communication and Coordination) for advancing science for the future of humankind. Lastly, Prof. Gao stressed the importance of global solidarity.

Ms. Sarah Hersey outlined the ongoing journey to make precision medicine a reality for all. For decades, a one-size-fits-all approach to drug development was the norm. The shift to precision medicine has the potential to enable patients to receive the right treatment for them personally, which can improve quality of life, shift medicine from reactionary to preventative, and minimize the frequency and severity of adverse drug interactions, among other benefits. Continued progress in scientific understanding and stronger collaboration among health authorities, industry and academia have helped to advance precision medicine. Nevertheless, deeper scientific understanding is still needed. There are also infrastructure limitations that act as barriers to the uptake of precision medicine. Fortunately, new technological advancements spurred by the pandemic have helped to accelerate the world's telemedicine capabilities, alternate collection modalities, digital medicine, and point-of-need testing platforms, which have the potential to reduce the aforementioned barriers.

Prof. Rocky S. Tuan gave a presentation on microJoint, a tissue-chip-based approach to understanding, and developing therapeutic treatment for, degenerative joint diseases, in particular osteoarthritis. Osteoarthritis is characterized by the degeneration of the cartilage in the articular joint and is projected to affect 130 million people worldwide by 2050. Unfortunately, there are currently no disease-modifying osteoarthritis drugs. Tissue engineering and regenerative medicine offer a new approach, combining cells, materials, and physical manipulations to engineer tissue with the biological and physical properties to replace diseased or damaged native tissue. A more recent tissue engineering approach involves the creation of an engineered tissue or microJoint platform that simulates native tissue to enable the understanding of the disease mechanism and to test or screen therapeutic candidates. This new human-on-a-chip approach has surely opened a brand new chapter for the research and development of therapeutics.

Discussion

To open the discussion, Dr. Hamaguchi asked the speakers to elaborate on the key points of their remarks.

Prof. Beutler pointed out that advances in science and technology have made it possible to identify phenotypes in real time, which enables the use of mice models for a better understanding of diseases. This points to a new means of target discovery with genetic validation upfront. More broadly, progress in science and technology have improved quality of life and extended human longevity.

Prof. Ciechanover stated that medicine will move from a focus on the disease to the disease in the context of the patient. This revolution in personalized medicine has enabled precise profiling of patients, understanding of the specific factors underlying various diseases, and

Tuan, Rocky S.

tackling of these specific factors. At the same time, such advances raise many bioethical issues, such as privacy, that society must carefully consider and solve.

Prof. Gao emphasized the importance of precision preventive medicine for preventing and controlling pandemics. He also reiterated his call for the 4C principles in precision preventive medicine. In addition, Prof. Gao believed that messenger RNA COVID-19 vaccines have demonstrated the potential of precision medicine to tackle genetic diseases, rare diseases, and metabolic diseases. Precision medicine will also enable precise definitions of new viruses, as was the case for SARS-CoV-2.

Ms. Hersey stated that personalized medicine has made significant strides that enable better treatment for patients. It has also demonstrated that knowledge and understanding of disease states and preexisting genetic conditions are extremely powerful. Understanding of hereditary risks also enables the shift from reactive to truly preventive medicine. However, advances in personalized and precision medicine also have disadvantages, including widening healthcare disparities. In addition, many precision medicine solutions have so far been derived from a very homogenous patient population with minorities often being underrepresented.

Prof. Tuan pointed out a built-in contradiction that has been highlighted by the COVID-19 pandemic: personalized medicine on the one hand, and public health on the other. How can both be realized? Looking at genomics is specific to one person. How can we look at the information for an entire population? One potentially promising approach is to create a large number of "little patients" in the form of tissue chips which are microphysiological systems that reflect the biology of a particular tissue under specific conditions. The tissue chip systems allow high throughput screening and thus simulate "human clinical trials," since human cells are used. In this manner, they can enable understanding of the mechanism of action as well as testing of potential treatments.

Dr. Hamaguchi asked Dr. Tuan what challenges he is facing in his work and how he is tackling them, as well as what kind of collaboration beyond sectors is needed.

Dr. Tuan answered that the field faces challenges among mainly three groups: researchers, private sectors, and the government. The first step is to accrue sufficient scientific evidence to convince researchers that are skeptical of the biological relevance of the technology. In the case of industry, the question is where the tissue chip would fit in the drug development pipeline. Right now, industry is not totally ready to accept the idea of tissue chips replacing animal models. The biggest and most wide-ranging challenges concern government in terms of including tissue chips as a valid platform for regulatory actions.

Dr. Hamaguchi asked how the gap between the haves and have-nots could be bridged.

Ms. Hersey stated that generating innovation and achieving broad-based adoption are difficult. The different rates of adoption around the world can create disparities. Fortunately, the pandemic accelerated the development of some potential solutions, such as telemedicine and other technologies. Overall, all sectors need to be aware of the potential to widen disparity gaps and to think about solutions to support all regions of the world early during their planning phase (e.g. one-size-fits-all precision medicine solutions may not work).

Dr. Hamaguchi asked Prof. Gao for his thoughts on mitigating the effects of infodemics and who should be responsible for dealing with this problem.

Prof. Gao believed that fighting infodemics is everyone's responsibility and scientists have to address and answer the questions raised by the public. Scientists and governments also need to work to popularize science and science education.

Dr. Hamaguchi pointed out that, in the future, it may become possible to treat diseases before they occur or even before the patient's birth, such as through the manipulation of the human genome and embryos. Such approaches will surely raise concerns among the public. How can they be addressed?

Prof. Ciechanover agreed that the revolution of personalized medicine will completely transform the three canonical pillars of medicine: disease, patient and treatment. It will raise not only medical questions but also ethical ones that society must think carefully about it. It can also raise new economic issues, such as those around insurance.

Dr. Hamaguchi asked Prof. Beutler for his thoughts on the potential application of genome editing on humans in the future.

Prof. Beutler pointed out that such technology is very far away, so the question is not such a pressing one. That said, in general, scientists work to determine how things operate and also expose what is possible, but it is society that decides what is acceptable, which is a complex question with many perspectives to consider.

Prof. Tuan stressed the need to be aware that there are very important social determinants of health. Inequity is a major underlying cause of poor health and scientists and educators have a responsibility to educate young people to be socially responsible and to reduce inequity in society.

Prof. Gao commented that a healthy life consists not only of physiological health but also psychological health. This must not be overlooked.

Q&A Session

A member of the audience asked about whether individuals can play a central role in accumulating their health data and being more informed in health decisions, amid the proliferation of data for precision medicine about individual health markers.

Ms. Hersey believed that there is indeed an opportunity for individuals to play a role and have an active voice. The relationship between individuals and physicians should be one of partnership.

Prof. Beutler pointed out that the gene-sequencing information that is currently commercially available to people is very shallow and amounts to misinformation. Most people lack the scientific education to be able to make appropriate judgements based on such information.

Prof. Ciechanover pointed out the value of far-reaching health systems that provide a minimum level of care regardless of income.

The next question from the audience concerned how to reduce waste in the development of medical products.

Dr. Hamaguchi suggested that such waste is almost inevitable and part of the learning process.

Prof. Tuan agreed that there are lots of inherent failures involved in the current drug development process. The tissue chip platform could help to cut costs by reducing animal models and better facilitating or triaging early clinical trials.

Prof. Ciechanover pointed out that the majority of the cost comes from clinical studies, particularly phase three studies, which is also where the majority of drug candidates fail.

Prof. Tuan agreed and suggested that if a drug candidate will ultimately fail, human tissue chips could potentially help them fail sooner in the process, and thus better streamline drug development.

Dr. Hamaguchi concluded that while science and technology are helping us to extend lifespans and quality of life, we must also overcome challenges including widening disparities and acceptance of innovation by society. The science community has responsibility not only for creating cost effective and widely applicable technologies, but also for properly informing leadership as well as wider society about the benefits of these technologies.

The Second Quantum Revolution and Society

[Chair]

Adem, Alejandro, President, Natural Sciences and Engineering Research Council of Canada (NSERC), Canada

[Speakers]

Northup, Tracy, Ingeborg Hochmair Professor of Experimental Physics, University of Innsbruck, Austria

Phillips, William Daniel, Fellow, National Institute of Standards and Technology (NIST), U.S.A. [Nobel Laureate 1997 (Physics)]

Garcia, Jeannette (Jamie), Senior Manager (Quantum Applications, Algorithms, and Theory), IBM Research, U.S.A.

Sata, Yutaka, Corporate Officer; Director, Corporate Research & Development Center, Corporate Research & Development Center, Toshiba Corporation; President, Japan Society of Mechanical Engineers, Japan

Tanzilli, Sébastien, Scientific Deputy Director in charge of Quantum Science and Technologies, Institute of Physics, National Center for Scientific Research (CNRS), France

[QA Moderator]

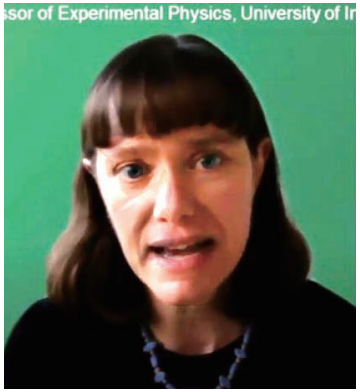
Baron, Shaun, International Policy Advisor, Strategic, Corporate and Public Affairs, Natural Sciences and Engineering Research Council of Canada (NSERC), Canada

Pre-recorded Statements

Adem, Alejandro

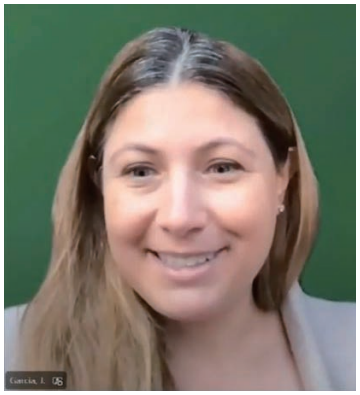
Dr. Tracy Northup enthused at the remarkable developments that are currently being made in the field of quantum physics, building off of knowledge since gained and with the possibility to now leverage knowledge of entanglement and superposition to control the quantum world. Dr. Northup's research group focuses on trapped ions and their viability as an interface between quantum computers but there are various consortia of other academic and industry groups looking to build quantum computers and investigate applications, expanding on fundamental research and opening the possibility of applications that

are beyond the scope of one single team. There are many unanswered questions in the field, such as the best hardware platforms for quantum computing and how to use quantum computing to solve relevant questions. Innovation in the field will require collaboration across a wide range of disciplines and continued long-term fundamental research.



Northup, Tracy

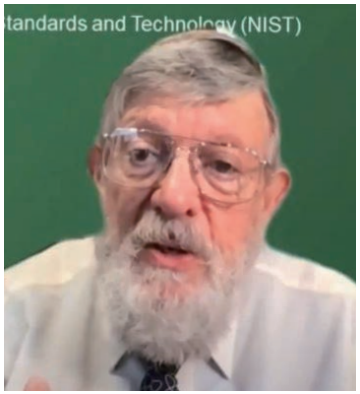
Dr. Jeannette Garcia reminisced on the chance encounter at an IBM research center that revealed to her the connection between chemistry and quantum computing and sparked her desire to work in the field. Her work covers various areas from application to theory and investigates how these systems may outperform classical computers via quantum advantage. IBM's quantum computers are built by collaborative teams working on theory, development in software and programming, and hardware, pushing for higher fidelity and higher qubit counts, to be able to solve questions in industry and fundamental research. Dr. Garcia has seen rapid progression in the field over her career and envisions seeing million-qubit devices in the future.



Garcia, Jeannette (Jamie)

Dr. Yutaka Sata explained Toshiba's beginnings in quantum research and achievements to date, such as the first quantum dot based entangled photon emitter and the fastest quantum key distribution. Quantum key distribution enables theoretically unbreakable communication but faces limitations, such as in the distance of key distribution. Toshiba's advances have been able to overcome some of these challenges and it is engaging in proof of application. In quantum computing, Toshiba has invented the quantum bifurcation machine based on superposition, and the simulated bifurcation machine running on a classical computer and expects to see application in finance, materials, medicine and other areas. There is much promise for quantum technology and its application, and collaboration between providers and users will be critical to success in its development.

Sata, Yutaka



Phillips, William Daniel

Discussion

Dr. Alejandro Adem based the discussion on the second quantum revolution and highlighted the impact and transdisciplinary insights its application could have on global challenges and opportunities. He posited how humanity can use the "light" from the quantum revolution while at the same time, controlling the "shadows" of this technology.

Dr. Northup explained her experimental research group and the possible applicability of trapped ions, a current candidate choice for a quantum computing platform and quantum simulators and how her team explores how to connect these computers over long distances.

Dr. William Daniel Phillips explained the National Institute of Standards and Technology's work in measurement and its joint quantum institute with the University of Maryland which investigates laser cooled trapped neutral atoms for quantum information.

Dr. Sata explained the areas that Toshiba is researching alongside Toshiba's Cambridge Research Laboratory in quantum physics, quantum optics, and quantum key distributions. Toshiba is pursuing application of technology from the second quantum revolution through its quantum key distribution business.

Dr. Sébastien Tanzilli introduced his work in quantum science and technologies in the National Center for Scientific Research, and his work in quantum photonics, quantum cryptography and entangled states at the Institute of Physics, Nice.

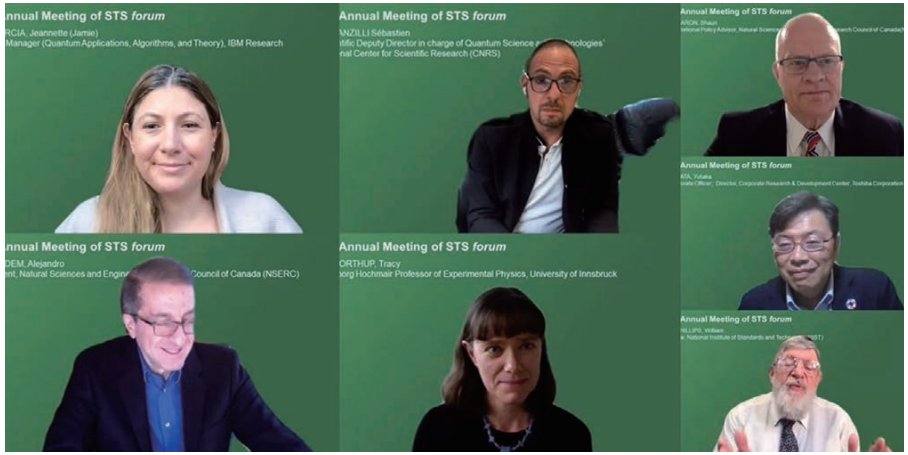
Dr. Garcia explained her background in chemistry and materials and the work at IBM Quantum that her team is doing in applications, algorithms and theory in the development of superconducting qubit devices.

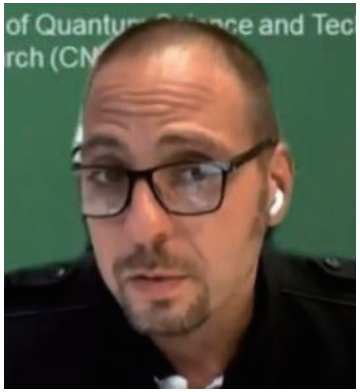
Dr. Adem asked the panel how much progress has been made and what the fundamental challenges are at this stage in the second quantum revolution.

Dr. Northup explained that there has been a vast amount of progress made in the field and elucidated some of the routes to develop quantum technologies into systems that may be able to solve problems that cannot be solved with classical systems. The challenges lie in development and scaling quantum technologies to deal with these relevant problems as contemporary systems are not complex enough and robust enough at this stage.

Dr. Phillips explained the history of the quantum revolution and the ideas and industries based on quantum mechanics that led to discoveries such as semiconductors during the first quantum revolution. The revelation that particles are waves led to such technology, but the second revolution is based around the ideas of quantum entanglement and superposition. Researchers are still identifying the applications of entanglement and superposition, while also addressing other areas in the field such as squeezed states or quantum advantage systems that could help beat fundamental limitations of noise in computing. Indeed, gravitational wave programs have used such advantages in their studies. Nevertheless, we have yet to produce a significant industrial technology from these areas of quantum mechanics.

Dr. Garcia expanded on the technologies of quantum computing that IBM has spearheaded since its first quantum computer. The progress has been rapid and a device with more than





Tanzilli, Sébastien

1000 qubits may soon come to fruition. Coherence times in quantum computing are a challenge and reducing these times through continuous improvements requires improvements in other areas such as materials. Researchers must also identify which problems would benefit from quantum computing, and there may be an advantage in quantum machine learning. But more exploration will be required from those in industry and national laboratories to discover the best avenues for progress in quantum computing.

Dr. Sata explained the progress made by Toshiba in quantum computing and its cloud-based services for materials, pharmaceuticals and finance, but expansion is also needed. Academia in Japan lacks the appropriate resources in manpower. This may pose a challenge as industry seeks quantum-ready talent and there may be an impact further in the future.

Dr. Tanzilli elaborated on the numerous numbers of technologies that already exist and leverage quantum technologies in our daily lives such as lasers and transistors. The technologies being developed currently in the field have made huge leaps in the last 30 years since that point. Dr. Tanzilli's teams are creating a framework of applications for possible use in defense and society at large that demonstrate a quantum advantage. Despite the fact that quantum technologies are being developed by corporations such as IBM and Toshiba, fundamental research will still be vital in discovering new concepts, new material platforms, and facilitating industrial transfer.

Dr. Adem inquired as to how the field might develop given that quantum computing currently has no dominant architecture.

Dr. Northup explained that even to expect a single architecture might be misguided. Quantum communication will likely take place via light, such as in quantum key distribution, whereas superconducting qubits may be promising for quantum computing. Therefore, we may see a landscape of different applications utilizing different platforms, and these will have to be able to interact with one another. The current open playing field of platforms has benefits in that different technologies can be explored on different platforms, as seen recently in the case of harmonic oscillators for encoding information.

Baron, Shaun

Dr. Phillips further added to the discussion on landing on one particular platform highlighting that platforms once considered to not be viable are now well researched such as superconducting qubits. Different quantum elements may have different advantages, such as ions having good coherence times for memory, superconducting qubits for operations and the numerous availability of neutral atoms, and thus a plethora of systems will come to being. The commercial success in the field has been astounding and has led to great reduction in the size of quantum computers. One notable group is the Quantum Economic Development Consortium which is pushing for the commercial development of quantum technology.

Dr. Garcia expressed her agreement that the differing platforms in the field will be beneficial. IBM is working with a large number of organizations which has led to an adaptable system with varied backends that speaks to the richness of innovation that comes from the variety of platforms. Nevertheless, there remain challenges for organizations in acquiring skilled talent. Programming in the field also has room for advancement and could leverage both the quantum and classical components. Scaling the technology in superconducting qubits will also be a critical area of interest because the fundamental technology will not change significantly as the field advances towards a general quantum computer. The variety of platforms is advantageous for the field and will help reveal interesting science.

Dr. Sata agreed with the necessity for quantum research in quantum systems, such as computing and communications, and various types of quantum architectures. Current systems for communications use fiber transmitting single encoded photons but to extend the lens of encoded communications and expand the scope of quantum communications, entanglement in optical fiber will be paramount. The collaboration and communication within the field and without should also be broadened and include those from fields which are candidates for application such as finance, pharmaceuticals and materials. In this regard, the Quantum Strategic Industry Alliance for Revolution was founded to develop

the quantum industry itself. The alliance considers business domains and the hierarchy of systems for future application of quantum systems.

Dr. Tanzilli added to the discussion stating that, in quantum communications, the use of photons to transmit information needs to be interfaced with matter systems. These matter systems can serve as the analogue of repeaters in current communication networks. The adaption of the information from the photons to the matter systems is a remaining challenge. Quantum computers, which garner attention in society compared to communications and measurements, rely on high powered solutions thus should solve problems faster than classical computers will. And there are various other technologies, such as superconductors and carbon nanotubes, etc., which are being developed in synchronicity and bring certain advantages despite still having limitations currently. To gain transfer to industry and societal adoption, a wide variety of these technologies must be developed in unison. This is also true for development in academia and in fundamental research. Nevertheless, the application of quantum technologies has increasingly become a driving force for the field.

Mr. Chris Cramer inquired about the current conceptions of green computing, and any associated challenges in the area, in quantum computing.

Dr. Garcia responded that when viewed in totality including the proposed applications of quantum computing, such as carbon dioxide reduction from advancements made in materials, there may be benefit for industry as a whole. The largest green impact may be in application such as sustainable materials, and subsequently, it may be pertinent to address the energy impact of the devices themselves once the concept has been proven.

Dr. Tanzilli explained that as it is a problem of thermodynamics and, fundamentally, quantum computing should consume less than classical computing equivalents.

Basic Science, Innovation and Policy

[Chair]

Sandvik, Pia, CEO, Research Institutes of Sweden (RISE); Board Chairman, KTH Royal Institute of Technology, Sweden

[Speakers]

Bourguignon, Jean-Pierre, Honorary Professor, Institut des Hautes Études Scientifiques (IHÉS), France; former President, European Research Council, Belgium

Kitson, Anne, SVP, The Lancet and Cell Press, Elsevier Ltd, U.K.

Hunt, Tim, Visiting Researcher, Okinawa Institute of Science and Technology (OIST), Japan; Emeritus Group Leader, The Francis Crick Institute, U.K. [Nobel Laureate 2001 (Physiology or Medicine)]

Südhof, Thomas C., Professor, Stanford University School of Medicine, U.S.A. [Nobel Laureate 2013 (Physiology or Medicine)]

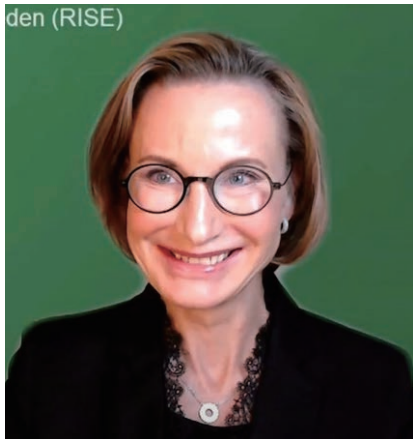
Darzi, Ara, Professor of Surgery, Faculty of Medicine, Imperial College London, U.K.

[QA Moderator]

Yeh, Nai-Chang, Professor, Physics, California Institute of Technology (CALTECH), U.S.A.

Pre-recorded Statements

Dr. Pia Sandvik pointed out that policymakers tend to be short-term focused and event-driven in addressing crises. However, the COVID-19 vaccines would not have been possible without long-term basic research over decades. Scientists are mainly driven by curiosity, innovators focus on implementing research results to develop industry and society, and policymakers manage societal challenges and prioritize the needs of citizens. Dr. Sandvik posed questions about reframing the intersections between science, innovation, and policy to solve societal issues and achieve sustainable development. New avenues of collaboration between the three branches, while safeguarding their merits, should be explored going forward.



Sandvik, Pia

Prof. Jean-Pierre Bourguignon emphasized that research is an ecosystem requiring people

Bourguignon, Jean-Pierre

Kitson, Anne

and institutions. Therefore, political institutions must understand the purpose of research. Basic research enables scientists to put forth their best ideas and visions, so finding the balance between top-down and bottom-up research is critical. The European Research Council (ERC) has been seeing success in supporting such basic research. The COVID-19 pandemic has highlighted the tendency for policymakers to prioritize short-term solutions to problems that require a strong scientific basis and understanding. However, solutions including the vaccine were only made possible because of long-term scientific research. Prof. Bourguignon therefore proposed that a significant portion of politicians must adopt a long-term view of scientific development. Moreover, the scientific community must inform policymakers of the positive impacts on society that can stem from basic research.

Ms. Anne Kitson shared that publishers play an important role in supporting scientific discovery and innovation. Trust in science is needed to enable collaboration and garner support towards scientific endeavors, yet threats to this trust are emerging in digital society. The process of scientific discovery must be further streamlined, such as improving reproducibility, which allows research to build cumulatively and reduce waste. Joint action between educators, funders, and publishers is needed to find diverse and targeted solutions. Ms. Kitson shared how her publishing company is helping to increase data sharing and enhance collaboration. To address the challenges ahead, transnational cooperation, development of new methods and standards, and unlocking novel research will all be crucial. Ms. Kitson closed her remarks by calling for all stakeholders to realize their responsibility to drive progress towards a more equitable world.

Dr. Tim Hunt shared about his basic research into messenger RNA, which was ultimately crucial in the development of COVID-19 vaccines. Thousands of scientists were involved in

the basic research of messenger RNA over decades, and only through their cumulative efforts were the recent breakthroughs in vaccine production made possible. Dr. Hunt pointed out another example of innovations made possible through basic research: the GPS. Theoretical subatomic physics research in the 1940s served as a foundation for developing the GPS many years later. Now, nearly all of us have GPS-connected devices in our pockets. Dr. Hunt acknowledged the need for balance between basic research, and the policymaking and commercial aspects of scientific innovation.

Hunt, Tim

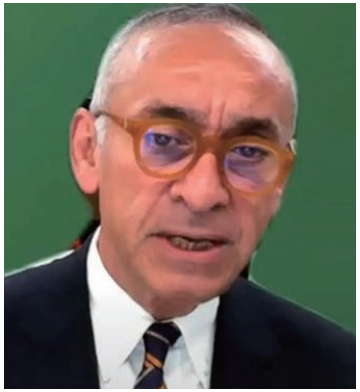
Discussion

Dr. Sandvik opened the session and introduced the panelists. She acknowledged the global focus now on sustainable development, and its impact on basic research, innovation, and policy. Additionally, there are prerequisites, including trust in basic science, needed to achieve solutions to complex scientific challenges. The first questions proposed by Dr. Sandvik were how science, innovation, and policy can collaborate to manage these challenges, and what the role of science and innovation can be.

Südhof, Thomas C.

Prof. Bourguignon addressed the first question by stressing the importance for stakeholders to work together. Science requires patience, but the policymakers with much shorter time horizons also must be involved to make these transformations. Better understanding from all sides, including the general public, is needed to understand how science can productively contribute to solutions.

Dr. Thomas Südhof offered a contrasting viewpoint on the issue. He noted that working on implementing policies or innovative solutions on the ground-level is equally necessary. Achievement at such a level requires people who can make decisions on implementation. Regulations and other details must be taken into consideration, with close integration


Darzi, Ara

between scientists and politicians. It can be difficult for policymakers to see where the problems lie, so scientists can step in to fill that gap.

Prof. Ara Darzi started by comparing the 17 SDGs with the COVID-19 pandemic. The pandemic led to expedited coordination between research, innovation, and various policy areas. This cooperation has led to identifying gaps in science and potential for innovation. Prof. Darzi noted that coordination between different governmental departments may be the most difficult gap to bridge. Two accelerating factors: uncertainty and urgency, when combined with a robust scientific background, led to identifying the need for policy coordination between and among governments. The COVID-19 pandemic highlighted the potential for such coordination, so that needs to continue into addressing sustainability goals.

Ms. Kitson offered a publisher's perspective on learning from the COVID-19 pandemic and mentioned how such a perspective can inform scientific progress and policymaking in the future. She stressed the need to create incentives for citizens to work towards solutions, noting carbon taxes as a policy example.

Dr. Hunt suggested that more politicians having scientific backgrounds would be beneficial, especially regarding understanding of basic research. Developing messenger RNA research to the point of practical use took half a century of intensive basic research. Yet, when breakthroughs such as a vaccine are achieved, it is up to policymakers and others to find the appropriate implementation into society. Knowledge of basic research will allow for informed perspectives.

Dr. Sandvik expanded the conversation by asking about the conflict between policymakers' desire for short-term solutions and the long-term nature of science.

Dr. Südhof commented on the differing time horizons of policy and science. He advocated for greater accountability for politicians, as well as all members of society, to create long-term solutions for society. Scientists and innovators must make efforts to engage with politicians. Short term goals are only worthwhile when they yield long-term benefits. Dr. Südhof added that companies worked on the vaccines because they had an understanding about basic science, not because of guidance from policies. Private enterprise and public science should work to inform policy to address societal problems.

Regarding COVID-19, Ms. Kitson added that vaccination distribution is exposing the risk of widening disparities between the global south and rich countries. Additionally, the pressure to publish early results has led to risks of non-peer-reviewed research findings being misinterpreted by politicians or the general public. In response to Dr. Südhof, Ms. Kitson added that including perspectives and opinion pieces in publication, with science at their core, is very important to inform the policymakers in solving issues.

Dr. Hunt agreed that science journalists serve a crucial role as the interface between scientists and the public. Regarding the differing timelines of policy and science, he brought attention to the cumulative nature of the climate change crisis, and long-term scientific innovations such as lithium ion batteries. Matching the pressure for action in parallel with an appropriate scientific approach is an ongoing challenge.

Prof. Darzi believed that academia should be primarily commissioning research, with steering and support from governments. Blue-sky research must be protected, and private sector funding is crucial to making progress. In the UK, the Advanced Research & Invention Agency (ARIA) was established to allow scientists to explore areas of research without needing to seek government approval. Prof. Darzi named this as a step in the right direction, but more progress needs to be made in balancing science and policy, especially to tackle climate change in coming years.

Prof. Bourguignon expanded the discussion on climate change, noting that sustained effort for many years will be necessary. Energy production and energy mixes is an essential consideration. He noted the example of Germany, which has made massive investments into renewables, yet will see record CO_2 emissions this year. Convincing people that changing their way of life is not only necessary, but effective and the right thing to do, is a massive challenge. A large proportion of the population must agree that a new policy is needed to address the issue, and make sustained efforts over decades.

Dr. Sandvik noted that young people feel the urgency to address climate change, so they will be critical to implementing timely solutions. She then asked the panelists if there is a need for increased international and interdisciplinary collaboration, and how to encourage such collaboration.

Prof. Darzi asserted that international collaboration is undeniably necessary. He mentioned ways in which the UK has been seeking to maintain its status in the international science community following Brexit. Regarding interdisciplinary research, Prof. Darzi noted that cooperation between sciences is the new paradigm, and we saw that in the COVID-19 pandemic. However, he reiterated the unwavering importance of basic research. The pandemic had some effects of bringing scientific communities together, but also exposed policy flaws, especially in data sharing between countries and the distribution of vaccines.

Ms. Kitson added that international communication and research is highly impactful. Looking at academic papers in Japan, the impacts were 2.5 times greater when done in collaboration with other countries. On the importance of interdisciplinary work, Ms. Kitson's company has been creating opportunities for experts to build new connections to tackle global problems. Research is becoming increasingly interdisciplinary, but support and international expansion are needed.

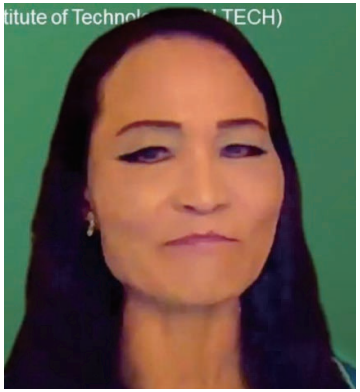
Prof. Bourguignon stressed that those outside of the science world tend to misunderstand competition in science. Scientists welcome competition and understand that it does not hinder collaboration. Policymakers must acknowledge that tackling the issues facing society requires competition and collaboration across the global scientific community.

Dr. Südhof agreed that there has been great international exchange within science, but also acknowledged an opposing shift. China and other countries, including the U.S., are enacting greater restrictions on international collaboration. Some researchers are growing fearful of international contacts. Action must be taken to help policymakers understand that these shifts can be detrimental to scientific progress.

Dr. Hunt agreed that international collaboration is crucial to filling in gaps of specialized knowledge in science. In setting up the Okinawa Institute of Science and Technology, he realized the challenges of working across disciplines, but drawing from historical examples, he stressed the importance of interdisciplinary collaboration to lead to certain scientific breakthroughs.

Q&A Session

Prof. Nai-Chang Yeh commented that collaboration between academia and industry is often most impactful and direct. She shared two related questions from the audience. The first question asked how countries could advance collaborations, and whether inclusive dialogue between developed and developing countries could be beneficial. The second question asked which strategies should be put in place to prioritize more incentives to perform basic research to promote innovation.


Yeh, Nai-Chang

Prof. Bourguignon addressed the question by giving the example of the European Framework Programme. Its goal was to promote innovation in Europe in ways including the creation of the European Innovation Council (EIC). Many initially viewed the EIC as being at odds with the bottom-up-focused ERC. Currently, the ERC and EIC are collaborating, making it easier for scientists to connect with investors. While their mechanisms are different, there should not be a barrier between them.

Prof. Yeh fielded another question on how countries can encourage the inclusion of academia and students in the development phases of innovation.

Dr. Südhof responded with his observation that there is a big difference in the amount of money being channeled towards innovation in places like the San Francisco Bay area and Europe. American innovation funds accept that most startups will fail but know that the small number of successes will contribute to an overall positive trajectory. Dr. Südhof proposed that a shift towards this mindset in Europe could provide a tremendous boost to innovation in the private sector.

Dr. Sandvik closed the session by reiterating the need for interdisciplinary collaboration, which presents many challenges. She also touched on the factors brought up by speakers, including the negative trends of some countries towards protectionism, the need for cross-collaboration between basic science, innovation, and policy, and the importance of creating incentives, especially in addressing climate change.

AI and Robotics

[Chair]

Nemer, Mona, Chief Science Advisor, Government of Canada; former Vice-President of Research and former Director of the Molecular Genetics and Cardiac Regeneration Laboratory, University of Ottawa, Canada

[Speakers]

Myhrvold, Nathan, Founder and Chief Executive Officer, Intellectual Ventures, U.S.A.

Ishiguro, Hiroshi, Professor, Systems Innovation, Osaka University, Japan

Kuai, Charles, Corporate Senior Vice President & GM Mobility Solutions, Mobility Solutions & IoT Technologies Division, Cerence Inc., U.S.A.

Hasegawa, Mariko, President, The Graduate University for Advanced Studies (SOKENDAI), Japan

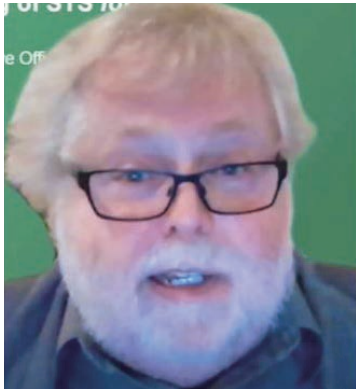
O'Sullivan, Barry, Director, Insight Centre for Data Analytics, School of Computer Science & IT, University College Cork, Ireland

Pre-recorded Statements

Dr. Mona Nemer explained that the robotics industry has come a long way, but its impacts on society have been less dramatic than originally predicted. With the emergence of artificial intelligence (AI) and massive amounts of data, things are transforming rapidly across all industries. AI and robotics have the potential to affect many sectors of our economy and our societies in expected and unexpected ways. We need to consider how this combination will impact our lives in the long run, and how to ensure that benefits are maximized for everyone.

Nemer, Mona

The effect of AI and robotics on society, the lessons learned from past disruptive technologies, ambitious areas where AI and robotics have the potential to improve society, the most pressing challenges, anticipating and mitigating unanticipated consequences, replacing humans with new technologies, the design of AI algorithms and robots, avoiding built-in biases, ensuring that these technological tools promote an equitable and inclusive society, and the role of governments, industry, academia, and citizens in this endeavor will be addressed in this session.



Myhrvold, Nathan

Ishiguro, Hiroshi

Dr. Nathan Myhrvold explained that throughout history, people have worried that new technology was going to replace them in the workplace or make them obsolete. Yet each time, innovations actually added to the overall number and quality of jobs. He highlighted that technology almost always leverages and extends the reach of humans. For example, cervical cancer is widespread with a high mortality rate worldwide, yet is highly treatable when found early. In the many parts of the world that lack medical workers trained to perform accurate screening, AI can be used with appropriate technologies to catch cervical cancer and other diseases before they become lethal. We should be excited about the future of AI and robotics and all the ways they can improve our lives.

Dr. Hiroshi Ishiguro talked about why humanoid robots are necessary. He explained that the ideal interface for humans is another human, so information media devices should be humanlike. In intelligent systems, the challenge is to identify how memory, computation, inference, and learning can be put together to realize human intelligence. Dr. Ishiguro's goal is to understand meta-level cognitive functions by using robots. Also by using robots, Dr. Ishiguro wants to realize a human-robot symbiotic society in the future, which is important because it will allow us to think about humans more.

Dr. Charles Kuai said that, due to COVID-19, instantly, companies and governments had to bridge the technical divide to survive. For example, the call center of his company adopted virtual assistants to reduce the number of people in the call centers and enhance social distancing. This trend will continue post-COVID-19. Machines will become more intelligent, blurring the line between what is human and what is machine, bringing new norms. In the future, we will welcome a world augmented by machine intelligence, which will scale knowledge, efficiently help us take actions, ensure quality is consistent in the way we discover, and consume goods and services. However, the benefits of advancements of AI and robotics must be balanced in ethics, privacy, and equality.

Kuai, Charles

Hasegawa, Mariko

Dr. Mariko Hasegawa explained that, today, AI and robotics assist many aspects of human activities. However, she expressed concern about efforts to invent advanced general AI. Many kinds of machines are extensions of human physical abilities. However, recent various information technologies are not only an extension of human physical abilities but also an extension of human brain activities. The classic information technology issues, the symbol grounding problem and frame problem, are not yet solved. Scientists may be able to solve these problems, but this does not mean that scientists have invented a machine that thinks exactly like humans because machines are not biological. If a computer makes a conclusion as a result of its computing, the process of its thinking is different than that of human thinking.

Discussion

Dr. Nemer asked Dr. Myhrvold if the technological advancement of AI and robotics is different from others in history, and what has been learned from the past that can help us embrace the changes. Dr. Myhrvold answered that every technological revolution has similarities, but people focus on the differences and overlook the similarities. Every time technology progresses, it scares the public. However, technology has never been the cause of the negative societal impacts that the public fears.

Dr. Nemer then asked about the most exciting development from AI and robotics. Dr. Myhrvold explained that people want technological innovation. He expressed optimism about AI and robotics, even in medicine, and observed that innovations in these fields often go hand in hand.

Dr. Nemer raised a question to Dr. Ishiguro about his view of the most ambitious and exciting examples of AI and robotics improving our lives. Dr. Ishiguro answered that he is working on realizing an avatar society. By using avatars, everyone, including the handicapped and elderly, will be able to move and communicate freely. As humans, we have two ways of evolving, and utilizing avatars is one way of enhancing our lives.

Dr. Nemer then asked what Dr. Ishiguro thinks the future will look like in 20 or 30 years. Dr. Ishiguro explained that the population in Japan is decreasing, so there will be a greater need for robots to maintain the quality of life. He hopes to see more robots, mixed with avatars and humans, helping us with our daily lives.

Dr. Nemer said that some systems can become so sophisticated that they can replace humans, and asked Dr. Kuai about his view of the potential in this area. Dr. Kuai explained that the AI and robotics situation replacing creativity is not new. We have seen this situation evolve and occur in society, such as with the invention of vehicles replacing walking or riding horses.

O'Sullivan, Barry

Dr. Nemer added that there are some repetitions and patterns in pathology or radiography which AI could handle. However, she asked about who would be responsible for the creative side, such as diagnosis. Dr. Kuai answered that new diseases will be formed, and other elements of the human dataset will be collected to create diagnostics.

Dr. Nemer addressed Dr. Hasegawa. She asked about the pressing challenges that society must address in this rapidly evolving context. Dr. Hasegawa said that people do not often consider unintended effects when technology is developed. Gradually, people learn the unintended effects of this technology as the technology spreads. AI is an important technology, and there are many positive applications. However, she expressed concern about the effects of human-like AI.

Dr. Nemer then asked Dr. Hasegawa how more agility can be utilized in addressing unintended consequences and preventing them. Dr. Hasegawa explained that we have to consider how advanced AI will be applied. For example, in biology, there is an international committee to discuss ethical issues, such as genetic engineering and the use of stem cells. Dr. Hasegawa added that the most urgent issue is the sustainability of civilization. AI and robots should be useful in reducing the energy that is consumed.

Following this, Dr. Nemer posed a question to Dr. O'Sullivan about how to best harness the benefits of AI and robotics to be more inclusive, and to avoid worsening inequities. Dr. O'Sullivan talked about principles being upheld to ensure safety, accountability, and ethicality. There is convergence as to what is acceptable in terms of AI, and it is important to engage in discussions on this issue. Dr. O'Sullivan added that we have to admit when AI is not functioning well. For example, during COVID-19, AI was not particularly useful. When we use AI, we need to ensure that it will add value.

Dr. Nemer then asked all panelists about the role of different sectors, governments, industries, researchers in academia, and citizens in this context. Dr. Myhrvold first answered that most of the applications of technology are embraced by people, and people are willing to adapt. In technology like radiology or diagnostics, the issue is making it accessible to

billions who do not have access to it. Governments have the responsibility to work with the private sector to make technology available and reliable.

Dr. Kuai explained that it is important to put things into context in terms of time, and what will happen in our lifetimes. Governments, civil society, industry, and researchers will reach equilibrium to solve big issues with big returns on investment and the biggest societal impact.

Dr. Hasegawa explained that we cannot stop developing and deploying advanced AI and robots in society. Therefore, we have to define the issues and overcome negative impacts. She explained that children will grow up differently, leading to different types of human beings, depending on the type of social environment that the children grow up in.

Dr. O'Sullivan explained that AI is not as sophisticated as the media portrays. It is important to consider how society benefits as a whole from AI and no one is left behind. Benefits should be shared equally, which will require governments to work together.

Then, Dr. Nemer asked Dr. Ishiguro if there is something specific to AI and robotics that governments, society, or industry need to pay attention to.

Dr. Ishiguro said that, for example, GAFA (Google, Amazon, Facebook, and Apple) in the U.S. is always taking the initiative. However, in Japan, companies are not as powerful. Accordingly, in Japan, the government needs to be involved. He emphasized the importance of the private sector, which is a strong driving force for developing new technologies. For Japan to enhance development, it needs to be more like the U.S. in terms of the strength of companies.

Q&A Session

Dr. Hasegawa asked about the prospective energy reduction.

Dr. Myhrvold explained that our large-scale energy systems have evolved over a long period and need to be rethought. For example, the electrical grid took electricity from a central station to the consumer. Now, consumers have solar panels and are sending electricity in the other direction, which required an updated electrical grid. The only way out of the current set of dilemmas is to come up with new technologies, which could include AI.

Dr. O'Sullivan added that some AI systems consume significant amounts of energy. Also, care needs to be taken about what is considered human intelligence. For example, an AI system that consumes a great deal of energy and has lifetimes of data is not comparable to the human brain. In addition, powering AI and dealing with energy needs to be carefully considered.

Dr. Ishiguro added that a possible solution could be quantum computing.

Dr. Myhrvold commented that our thinking about AI needs to evolve, and how that can be done needs to be considered.

Dr. Nemer put forward a question from the audience stating that the previous revolutions have not created a just world, and asked if the new revolution will.

Dr. Myhrvold explained that technology did not make the world unjust. The great thing about information technologies is that they have given the average person great access to information. Expecting our technology to end injustice is not practical. It is rather the humans who can end injustice.

Dr. O'Sullivan commented that the purpose of technology is to remove frictions. The risk of removing some friction is that, sometimes, we need friction. AI could result in greater inequalities and greater societal impacts. We do need to spend time to make sure that the governments are society-conscious.

Dr. Nemer concluded that this session has provided insight into the societal impact of AI and robotics, and explained that it is clear that engaging in dialogue with governments and society is necessary to understand where these technologies can help make society more equitable. Trust and a continued dialogue are going to be essential going forward.

Enhancing Collaboration in Global Health

[Chair]

VijayRaghavan, K., Principal Scientific Adviser to the Government of India, Government of India, India

[Speakers]

Abdool Karim, Quarraisha, Associate Scientific Director, Centre for the AIDS Programme of Research in South Africa (CAPRISA); Pro Vice Chancellor, African Health, University of KwaZulu-Natal, South Africa

Berkley, Seth Franklin, Chief Executive Officer, Gavi, the Vaccine Alliance, Switzerland

Gilbert, Sarah, Saïd Professorship of Vaccinology, Jenner Institute, Nuffield Department of Medicine, University of Oxford, U.K.

Schekman, Randy W., Professor, Molecular and Cell Biology, University of California, Berkeley; Principal Investigator, Howard Hughes Medical Institute, U.S.A. [Nobel Laureate 2013 (Physiology or Medicine)]

Semenza, Gregg L., C. Michael Armstrong Professor of Genetic Medicine, Institute for Cell Engineering, Johns Hopkins University School of Medicine, U.S.A. [Nobel Laureate 2019 (Physiology or Medicine)]

Yamanaka, Shinya, Director and Professor, Center for iPS Cell Research and Application (CiRA) Kyoto University, Japan [Nobel Laureate 2012 (Physiology or Medicine)]

[QA Moderator]

Collins, Mary, Provost, Okinawa Institute of Science and Technology Graduate University (OIST), Japan

VijayRaghavan, K.

Pre-recorded Statements and Remarks

Prof. K. VijayRaghavan noted that collaborations in global health have been transformative in ensuring successes in science and technology, and in worldwide public health, with the smallpox vaccine and polio vaccine as major examples. However, the COVID-19 pandemic has highlighted the need for speed in such collaborations, and lessons to be learned, including the need to strengthen the global network of collaborations, to provide support for industry to help mitigate risks, and to look at what changes need to be brought

about to tackle global issues of participation, equity and access. Recent approaches in biology, such as messenger RNA vaccines and the use of CRISPR technologies in testing, have had a major direct impact on handling the pandemic, including understanding the evolution of the virus. However, even the strongest healthcare systems have been stretched by surges in demand. Prof. VijayRaghavan asked the panelists to consider the lessons learned in terms of collaborations that work in a crisis in the areas of science, discovery, and application to society, and in equity and access.

Abdool Karim, Quarraisha

Prof. Quarraisha Abdool Karim pointed out that the COVID-19 pandemic has reminded us of our mutual interdependence and our shared vulnerability amid the devastating loss of lives and livelihoods, and recalled the tremendous hope as effective vaccines were announced within a year, only to encounter issues in equitable vaccine access. All of the leading countries that secured sufficient doses of vaccines either develop vaccines or have bulk manufacturing capacity, reminding us of the importance of long-term investments in science, especially in manufacturing infrastructure, training of experts to develop and manufacture vaccines, public-private partnerships, intellectual property rights waivers for emergencies and disasters, and collaborations across continents. Prof. Abdool Karim highlighted that despite six vaccines being evaluated in vaccine trials in African countries, using clinical infrastructure built in response to the ongoing HIV pandemic, and while there are now enough vaccines for 40% of the world's population, Africa only has enough doses for less than 4% of its population.

Berkley, Seth Franklin

Dr. Seth Franklin Berkley explained that the multilateral COVAX initiative created to provide equitable global access to safe and effective COVID-19 vaccines has delivered 323 million doses to 144 economies, and is aiming to deliver around 1.4 billion doses by the end of the year and more than 4 billion doses into 2022 by ensuring that all necessary

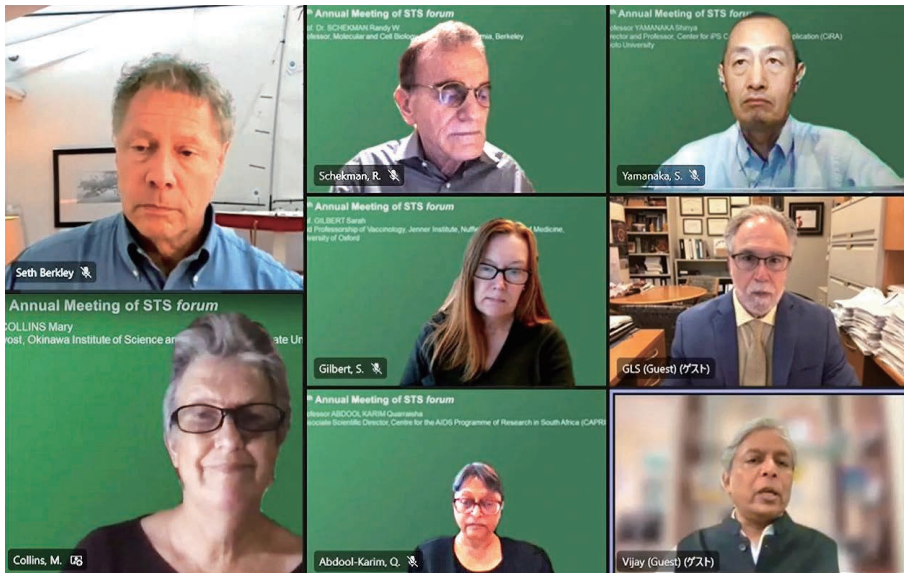
Gilbert, Sarah

Schekman, Randy W.

infrastructure, logistics, personnel, monitoring, and data systems are in place. However, he cautioned that export bans on vaccines and vital components and materials had prevented the free flow of global supplies, and that many wealthy nations with more than enough doses to vaccinate their entire population continue to take orders, creating further delays for billions of people still waiting for their first shot, which increases the risk of new variants emerging, putting everyone at increased risk, including those that are fully vaccinated. He stressed that COVAX remains the world's best hope of ending the acute phase of the pandemic, but only with the support of governments and manufacturers.

Prof. Sarah Gilbert explained that rapid vaccine development was possible due to many existing collaborations in place globally, and also thanks to volunteers coming forward to take part in clinical trials, so that the vaccine could be tested for its safety, its ability to induce immune response, and its ability to protect against virus infection. Prof. Gilbert explained that Oxford licensed its technology to AstraZeneca as they agreed to manufacture at large scale and not for profit during the pandemic and in perpetuity for low income countries. AstraZeneca has 25 different vaccine manufacturing partners around the world that they have supported with extensive technology transfer, as making the IP available alone does not increase supply. Prof. Gilbert noted that the remaining obstacles are the shortage of capacity to manufacture vaccines around the world, particularly in Africa, and the infrastructure to get the vaccines to the vaccine clinics.

Prof. Dr. Randy W. Schekman attributed the inadequate response to the spread of SARS-CoV-2 to a failure of planning and cooperation, particularly in not anticipating the emergence of another deadly coronavirus. Coronaviruses have occupied considerable attention in basic research, and much has been published on the virus life cycle and replication since the days of SARS and MERS. However, these epidemics subsided too quickly to make drug development by the pharmaceutical industry commercially viable. Yet had there been a public-private collaborative effort to continue to focus on drug development, we might have had drugs such as the new Merck inhibitor, that inactivates the enzyme responsible for quality control in replication of the virus, or other drugs targeting features that are likely shared among all coronaviruses. We now have effective vaccines but face new versions of the virus emerging that may eventually evade immune protection. Patients who recovered from the SARS epidemic in 2008 retained immunity for only a season or two, and therefore new vaccines may have to be delivered as regularly as the annual flu shot, and their natural evolution makes it difficult to anticipate a vaccine candidate. In contrast, the core of a virus has less random mutation and the approach used for HIV therapy should therefore guide efforts to master the present and future versions of the coronavirus, sustained with substantial international support for a public-private cooperative effort, even if a successful vaccine for SARS-CoV-2 is developed. Prof. Dr. Schekman also highlighted an international collaborative effort organized to tackle Parkinson's disease, called Aligning Science Across Parkinson's (ASAP). The only way to attack an enormously complex problem is to engage the finest minds in an open collaborative effort, with teams provided with resources and expected to communicate within an online network, sharing new results and



Semenza, Gregg L.

ideas and protocols, and publishing all of their work in gold-standard open access journals.

Prof. Gregg L. Semenza stated that while all participants would agree that public health policy must be guided by science and fact, this is not a universal truth. He noted that autocrats and aspiring autocrats are enemies of science and fact, and seek to maintain or acquire power, not to maintain or improve public health. Many social media are also enemies of science and fact, seeking proliferation of message, regardless of content or consequences. The existential health policy and national security issues facing all countries are the same: effective management and prevention of pandemic disease, and the rapid elimination of fossil fuels as an energy source. Neither of these will occur unless all countries act together to establish common goals and share response strategies that are based on science and fact. Biomedical research provides a model for effective international collaboration based on science and fact. Finally, he noted that because the obstacles to resolving these issues are political, not technical, a much greater effort must be made by medical and scientific societies to engage and educate the public.

Prof. Shinya Yamanaka highlighted the fact that while reported numbers of COVID-19 cases per million people suggest that African countries have been less affected than the UK and USA, the reality found by looking at seropositivity in blood donor samples shows that more than 40% of Kenyan people had been already infected as of February 2021, a number which would be even higher at present, while vaccination coverage is only 4% in Kenya compared to 60% or 70% in many developed countries. One thing learned during the pandemic is that translation of basic science to public health depends heavily on collaboration between academia and industry. The research underlying the messenger RNA vaccines was initially used to establish iPS cells ten years ago. Industry found a way to translate this into a tangible medical product. Collaborations among biotech companies and pharma companies were also critical for delivering the vaccines, and regulatory bodies also played a crucial role, and volunteers for clinical trials are also important collaborators. However, he cautioned that there remains a great imbalance in distribution, and that if the vaccination rate in any area is low, we risk more deadly variants. Vaccination across the globe is the only way to prevent this from happening. For this goal, now is the time for developed countries to

consider not only their own vaccine supply, but also the allocation to developing countries.

Yamanaka, Shinya

Q&A Session

A member of the audience asked about whether there is work underway to increase the shelf life or increase the storage temperature of vaccines to get around some of the delivery problems that we are now seeing.

Prof. Gilbert explained that prior to the pandemic, work was done on thermostability of the adenoviral vectored vaccine such that it requires only refrigeration rather than freezing, using a sugar-glass thermal stabilization technique, successfully making it stable at up to 45 degrees for up to six months, which would cope with any high temperatures anywhere in the world. This is not yet suitable for large scale production, but it demonstrates that the goal is achievable. Further work to make it a practical reality will continue, but there are good grounds to believe that we can improve the thermal stability.

Dr. Berkley noted that for one of the messenger RNA vaccines that is currently stored at minus 80 degrees, there is hope for a new formulation next year that will allow more stability. Longer term, the goal is to create new technologies for delivery using patch technologies, or oral or nasal delivery, that would be transformational in allowing quicker and easier delivery. He commented that it is remarkable how fast the current vaccines were developed, but that it is now time to improve upon the formulations.

A question was received from a participant from the Philippines concerning what the basic steps should be for a country to set up vaccine production.

Dr. Berkley described how the regulatory work on production of a vaccine needs to be able to show that the product will be the same as that which passed the clinical trials, and therefore the first area of focus is on enhancing the regulatory system, building assay capabilities, scientific capabilities, and human capabilities. The next step is to look at fill and finishing, which is the end stage process of the product, and which requires using this regulatory system. Then once this goes well, they can move into making drug substance. It is a stepwise process that takes a long time and a very substantial investment, so any

Collins, Mary

country can do it if they are willing to invest in all of the scientific capability, regulatory capability, and industrial capability.

A question was also received on whether vaccines and therapeutics can be complemented with a robust global viral surveillance and diagnostic capability.

Dr. Berkley pointed out that in general there has been underinvestment in surveillance and diagnostics, leading to great disparities in the use of diagnostics. This is important worldwide to be able to look for variants and new diseases, leading to resilient health systems. He noted that the Ebola outbreak that occurred in West Africa was not diagnosed as Ebola for three months, which led to it spreading around the world during that time.

Prof. Abdool Karim added that investments in HIV, for example in PCR diagnostic platforms, had enabled many countries to pivot fairly rapidly to set up their diagnosis for COVID-19, but pointed out that there are a lot of modern genomic and digital tools that are not being sufficiently utilized for monitoring, and she stressed that long-term political commitment at the national level is required to ensure investment to strengthen health systems.

Another question concerned whether treatment of viruses with drugs would create some immunity or resistance to the virus, or whether eliminating the virus with drugs would be less effective than a vaccination.

Prof. Dr. Schekman stated that while obviously a vaccine is the most powerful worldwide approach of enduring value, when a virus spreads so rapidly it is not possible to have a vaccine available at the outset, and in some cases it is not commercially viable to create a vaccine, as vaccines developed for one virus will likely have limited value against future viruses. With HIV, it has not been possible to make a vaccine because the virus mutates too quickly. We should therefore not forget this lesson and should continue to do drug development even after the current pandemic subsides, because this will happen again in the future.

Prof. Gilbert agreed that prevention is always going to be better than cure, but noted that some people, such as those with compromised immune systems, will not make a good response to a vaccine, so there must be alternatives for them. Part of that is reducing the spread of the virus in the community, and prophylactic use of long acting monoclonal antibodies, or prophylactic use of drugs may be a strategy. Prof. Gilbert pointed out that the immune response following treatment with drugs after infection would also depend on the immune system of the person concerned.

Dr. Berkley stressed that since there are major concerns about antimicrobial resistance, we need to make sure that in addition to vaccines we are developing a large portfolio of products to be able to deal with the ever-changing nature of microbes.

Prof. Abdool Karim stated that treatment and prevention are not mutually exclusive, and in the case of COVID-19 where the majority of those who get infected are asymptomatic or mildly symptomatic, the vaccines help to prevent severe disease as well as the spread of the virus. She reiterated that when dealing with a pandemic, we need to look at solving the issue of intellectual property rights, so that we can think and act as one world, one planet, and bring the best of what we each have to find solutions for all of us, not for one of us.

Lights and Shadows of Digital Economy

[Chair]

Kaili, Eva, Chair, Science and Technology Options Assessment (STOA), European Parliament, Belgium

[Speakers]

Isaksson, Darja, Director General, VINNOVA (Sweden's Innovation Agency), Sweden

Kanda, Masato, Vice Minister of Finance for International Affairs, Ministry of Finance, Japan, Japan; Chair, Corporate Governance Committee, Organisation for Economic Cooperation and Development (OECD), France

Gonokami, Makoto, Professor, Physics, School of Science, The University of Tokyo; former President, The University of Tokyo, Japan

Thompson, Herbert Hugh, Managing Partner, Crosspoint Capital Partners, U.S.A.

Sulaiman, Mohd Yusoff, President & Chief Executive Officer, Malaysian Industry-Government Group for High Technology (MIGHT); President, Malaysia Rail Industry Corporation (MARIC), Malaysia

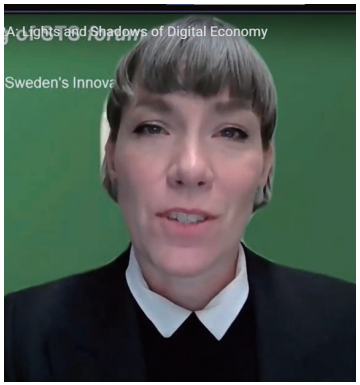
Screven, Edward, Chief Corporate Architect, Oracle Corporation, U.S.A.

Thorp, Holden, Editor-in-Chief, Science Family of Journals, Science / American Association for the Advancement of Science (AAAS); Rita Levi-Montalcini Distinguished University Professor, Washington University in St. Louis, U.S.A.

Pre-recorded Statements

Kaili, Eva

Dr. Eva Kaili explored how the rapid spread of digital economies is creating opportunities and challenges for our societies and politics. Emerging digital technologies such as the internet of things, AI, blockchain, and big data generate opportunity for business and individuals but also generate concerns of privacy, cyber security and ethics. In addition, the benefits that such technologies bring could be unequally distributed exacerbating inequalities. The European Union has drafted legislation to address some of these issues and protect the rights of citizens online. Taking such a position, it hopes to ignite change in other states more broadly, protecting digital space and seeks regulatory alignment with other partners.



Isaksson, Darja

Kanda, Masato

Dr. Darja Isaksson shared the view that digitalization has changed our society at a fundamental level. These tools not only inform our behavior but also how we organize business, education and healthcare. The research and policy response to COVID-19 is one example of these new capabilities. However, digital access is exacerbating inequalities. Furthermore, the challenges of digitalization and cyber security are affecting consumption of social media and integrity of democracies. Digitalization has also, so far, increased its energy consumption. However, humanity needs digitalization and its benefits to improve energy consumption, resilience to challenges and integrity of institutions. Advancements in connectivity and automation are key in transforming energy systems and ecosystems, leading the path to circular and sustainable industry and a society that exists within planetary boundaries. The path forward should be one where citizens are cocreators in a future where digital and green are aligned.

Dr. Masato Kanda spoke on the trend of digitalization and digital currencies and how society can harness the positive effects while addressing the risks. Digitalization is a driver of economic growth that exacerbates disparities. It allowed business to trade online during the pandemic. One drawback is it increases inequality across age cohorts as shown in OECD statistics. Thus, policy support is necessary to enhance inclusiveness. Japan offers digital literacy services to elderly and disabled people to help reduce disparity. On digital currencies, the government of Japan has led the discussions on global stablecoins since its G20 presidency in 2018. Such technology can broaden access to financial services, whilst it requires us to be cautious of multinationals' controlling interest. Central Bank Digital Currencies (CBDCs) may be one solution but it still can carry the risks of privacy, money laundering and instability of the international monetary system. The public

Gonokami, Makoto

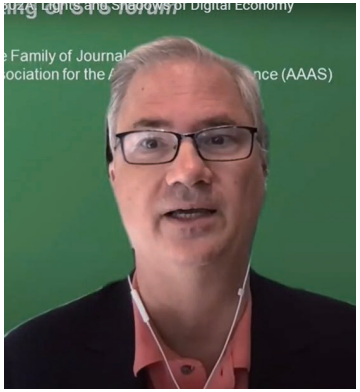
Sulaiman, Mohd Yusoff

sector needs to strike the balance between reaping the benefits and managing the risks in this field.

Dr. Makoto Gonokami explained how humanity faces major global challenges such as global warming, environmental destruction, and COVID-19 whilst simultaneously must create a sustainable future where individual's free will is valued. Digital tools can reduce disparity, connect remote locations, and foster a diverse society. This harmonious and inclusive society based on science, technology and innovation, economic mechanisms and social systems is called Society 5.0, and shares many values with the Sustainable Development Goals. However, the path to Society 5.0 is fraught with risks of a surveillance society and data monopolies. Nevertheless, data can help greatly to face the challenges such as climate change and COVID-19, and transform behavior leading to new growth opportunities.

Dr. Mohd Yusoff Sulaiman shared the Malaysian experience in developing its digital economy. Digitalization has exacerbated divides between citizens in rural and urban locations and in digital-based learning. Moreover, digitalization and the COVID-19 pandemic have revealed that supply chain disruption can affect the entire economic ecosystem. The government of Malaysia has created a blue paper on the digital economy to help it respond to these divides, create more high-paid jobs and connections to virtual learning content, and improve the financial sector and efficiencies in the economy. Malaysia saw misinformation on vaccines spread during the pandemic and fears other unintended consequences of the pandemic, such as cyber security risks.

Dr. Holden Thorp spoke on the wide-reaching effects of the digital economy on research and how it is conducted and all aspects of society. The family of Science journals is seeing profound impacts from the digital economy on scientific communication and notes current failures. The scientific community has worked excellently on describing COVID-19 but done a poor job on educating the public on the vaccines and COVID-19 control measures. Moreover, the scientific community has similarly poorly communicated to people about structural racism and sexism. Anti-scientific forces are more effective at spreading misinformation via social media, which in turn stands to gain, and the scientific community must address this if it is to solve other global challenges.



Thorp, Holden

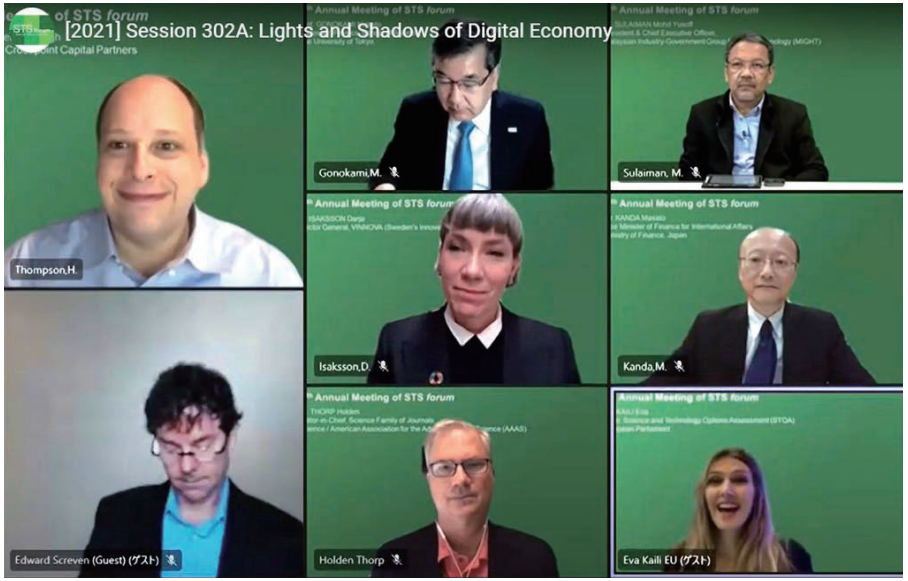
Discussion

Dr. Kaili began the session by highlighting the opportunities and challenges posed by the digital economy and emerging technologies. She noted the particular importance that the European Union places on AI as a disruptive technology with wide reaching impact as it seeks to align with other regulatory bodies on its development and use. Dr. Kaili asked the panel about how to ensure that digitalization can be inclusive of all while being cautious of overregulation.

Dr. Isaksson remarked that the issues of the digital economy are more critical than ever, as the pandemic has brought digital skills and benefits to some and remained unequal for others. The need for upskilling and reskilling extends beyond digital skills and transformation of the education system as a whole is needed to tackle these disparities. Cross-border data flows are held in different regard in different states and regulatory environments and collaboration is critical here to solve for the societal issues downstream.

Dr. Kaili asked a further question on what decentralized models of AI could look like.

Dr. Isaksson explained the vast impact of digitalization and AI have in fact increased consumption of resources and increased inequality and not led us closer to our goals. Therefore, the direction of applied research and innovation must be addressed and must align and not conflict with planetary goals. Addressing ethics in AI can only be achieved by having different disciplines working together and addressing issues from a societal standpoint.



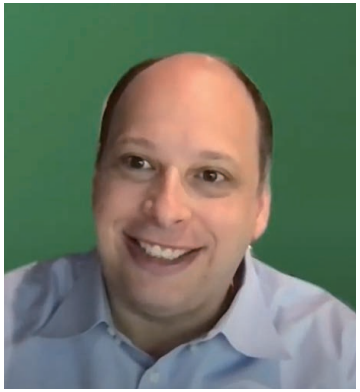
Dr. Kanda explained that digitalization has benefits in efficiency, hygiene and giving better access to services but it can lead to a digital divide, social fragmentation and inequality which needs to be assessed through education, as such disparity can also bring about populism. The convenience, speed and anonymity resulting from digitalization may be harnessed illegally such as cyberattacks and money laundering, therefore safeguards must be created. Moreover, the digital economy has been shown to expand beyond borders. Japan seeks to rapidly advance to meet new challenges in this area and support advanced technologies such as 5G.

Dr. Kaili asked more about regulation of stablecoins and decentralization in the digital economy.

Dr. Kanda explained the intensive discussions on the matter which address privacy and the stability of the financial system. Guidance is being given by international fora including G7/20 on digital money which are deemed to be lacking in transparency and rule of law, as well as a creditable issuing institution. Economies with more thorough regulation and that show patterns of stability may be among the early adopters of CBDCs, although some of them may attempt to assert influence over certain regions through geopolitical pressure. The

impact would have an unprecedented risk without proper oversight.

Dr. Gonokami gave a view on the importance of AI and high quality data, but also expressed his concerns on black box AI technologies. Japan has fallen behind Europe, Canada, China and the United States in AI technology. For AI research, a good set of formatted data and the sharing of data is critical. But based on his experience in the field of lasers, it is often difficult for researchers in Japan to gather data because such data tends to be confidential for companies. What is important is to know the extent to which data can be shared. The University of Tokyo created a consortium to generate and accumulate high-quality learning data for AI at the University and use it at manufacturing sites, aiming to deepen the understanding and accelerate the use of AI technologies in Japan.



Thompson, Herbert Hugh

Screven, Edward

Dr. Hubert Hugh Thompson added his agreement to the panelist's comments. Machine learning at scale has drawn dark "shadows" though also been a "light" in productivity. It is easy for humans to understand the increase in utility that machine learning brings, but humans are not used to identifying risk from emerging technologies. The advertising model in particular shows the ethical and security risks where advertising algorithms may not have humans' best interests at heart. An example is a person who is depressed might receive advertisements for alcohol or extravagant vacations but these algorithms may not be suggesting to the person what is in their best health interests. Machine learning can also be used in an adversarial way through a generative adversarial network to defraud companies via deep fakes. The risk is inherently that human intuition is not adept at addressing such fakery.

Dr. Mohd Yusoff Sulaiman laid out the government of Malaysia's long-term plan for the digital economy and cyber security. In the approach to these issues, funding is a vital part.

Funding traditional sectors to equip them with AI and big data tools is challenging. It is not only startups that need AI funding. The traditional sectors also need to remain competitive. In Malaysia in particular, the pandemic has increased disparity and such technologies could further expand the disparity and the digital divide. Infrastructure, both soft and hard, is necessary and must be ensured by national central governments in the form of laboratories and testing facilities. Regulation is also another critical aspect as it will allow startups and other enterprises to function. Skills and talent are essential for these emerging sectors which do not benefit from existing talent pathways for traditional sectors. Moreover, discussion is needed to find common benefit for all of society.

Mr. Edward Screven expanded on the core essence of AI that it is a set of mathematical tools, computational resources and data. In Oracle's assessment of ethical AI, it considers that people need to be aware of the ethical considerations of using AI and its biases. Oracle ensures when in communication with its clients that they understand that these systems can be biased. If the data for AI comes from human sources which are biased, that data will bring the bias into the AI's output. Moreover, another aspect that must be considered is the explainability of the output. It is also difficult to develop ethical and reliable AI without secure data. Therefore, a positive AI that represents the "light" for humanity has very close ties to security. Adversarial agents have access to the tools, the compute, and the data necessary to use AI in their attacks, but we have the means to protect ourselves from such agents. The positive aspects of AI could be found in providing security to enterprises and protecting against ransomware.

Dr. Thorp explained how AI has been undermining the credentials of scientific truth in response to the pandemic, political tumult, and climate change. Misinformation is spread by news on social media that is either wrong or inaccurate, and it is also spread by anecdotes which are shared on social media which has further reaching effects. Facebook in particular are set to profit from this spread of misinformation and have yet to be held to account. The scientific community remains lax on the issues under the false premise that the truth will out simply because it undergoes scientific rigor. The misinformation was being spread broadly in the pandemic by malicious forces, too, and the scientific community needs to be savvier with how information is consumed these days to combat this. Government control of social media companies seems unlikely at this point and action is needed before humanity faces another pandemic.

International Collaboration in S&T

[Chair]

Dvorkovich, Arkady, Chairman, Skolkovo Foundation; former Deputy Prime Minister, Russian Federation, Russia

[Speakers]

Fire, Andrew Zachary, Professor, Departments of Pathology and Genetics, Stanford University School of Medicine, U.S.A. [Nobel Laureate 2006 (Physiology or Medicine)]

Becker, Katja, President, German Research Foundation (DFG), Germany

Shepherd, John, Emeritus Professor of Earth System Science, Ocean & Earth Science, University of Southampton, U.K.

Leinen, Margaret, Vice Chancellor for Marine Sciences and Director of Scripps Institution of Oceanography, University of California, San Diego (UCSD), U.S.A.

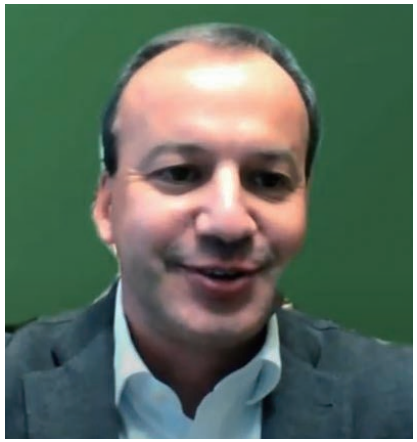
Felippo, Eduardo, President, National Council of Science and Technology (CONACYT); General Secretary, National Council of Science and Technology (CONACYT), Paraguay

Motles, Jennifer, Chief Sustainability Officer, Finance, PMI; Chief Sustainability Officer, Switzerland

Kudelski, André, President, Innosuisse - Swiss Innovation Agency; Chairman of the Board and Chief Executive Officer, Kudelski Group, Switzerland

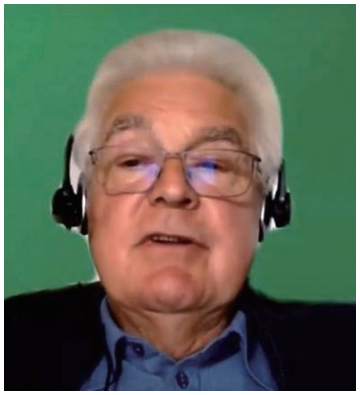
Pre-recorded Statements

Prof. Arkady Dvorkovich began the session by introducing the panelists. In his opening remarks, he stated that it is time to discuss science and technology in the context of what can be done together, which directions should be followed and what instruments should be used. While some countries already believe that global collaboration is the best tool to tackle global issues, others believe that a solo approach is a more productive method during times of uncertainties. It is necessary to find ways to improve the attitude towards joint research and innovation activities, and establish contacts and identify what are the best tools of collaboration as well as incentives. He also stated the belief that in the short run, a number of joint standards in some areas, such as AI, should be set forward without being too restrictive.



Dvorkovich, Arkady

Becker, Katja



Shepherd, John

Prof. Katja Becker stated there is a critical demand for research and knowledge. The pandemic has demonstrated that research can provide crucial solutions to pressing problems in a short time. In order to respond to global pandemics quickly, sufficient resources for funding, a huge knowledge repository established over many decades of basic research within each respective field of science and the humanities, academic freedom to select and carry out research, and international cooperation are all necessary. Complex challenges cannot be met by one team of researchers alone. The best in a given field have to cooperate, and it is rare that those best contributors are located in a single country. Therefore the emergence of new and secure knowledge must be supported by guaranteeing that researchers all over the world can share their data and findings, and can cooperate as freely and constructively as possible. Prof. Becker also stated that the call for cross border collaboration has never been higher. No matter how international modern research might be or become, it remains imbedded in national patterns. As a science organization, the focus must be on the framework conditions for free and border crossing research.

Dr. John Shepherd presented on international collaboration in the ocean and earth sciences. There is already a great deal of collaboration here, and Dr. Shepherd supported this with several examples. Most of the collaboration that is going on is currently bottom up by researchers and managed by institutions. The funding mostly comes from governments, and the programs are largely coordinated by international organizations and agencies, many of which are UN bodies. When it comes to developing policies and laws to protect the environment, these are largely implemented and enforced by international organizations and their commissions. While there are UN treaties on the climate and the UN Law of the Sea, there is nothing covering the atmosphere, for which a new treaty is really needed, possibly under a new framework to act as an umbrella for all the other Rio environmental treaties.

Dr. Margaret Leinen explained the UN Decade of Ocean Science for Sustainable Development, an international S&T collaboration that represents a 10 year period of intensive, large scale and international oceanographic inquiry that would focus on questions of sustainability, and which focuses international resources and efforts on the ocean. An important aspect of the Decade is the acknowledgment that the current leadership of senior scientists must actively plan for the next generation to take over leadership for the next 10 years.

Leinen, Margaret

Mr. Eduardo Felippo introduced the vision of Paraguay regarding the development of science and technology innovation and its importance to Paraguay as a young population, and that Paraguay founded the National Council of Science and Technology (CONACYT) with this in mind. It is managed by a council in which the private and public sectors participate equally, and it has been strongly backed over the last 11 years.

Felippo, Eduardo

Ms. Jennifer Motles explained Philip Morris International (PMI)'s goal of creating a smoke-free future, with cigarettes being replaced by science-based smoke free products as soon as possible. These goals must be achieved sustainably, and sustainability is an opportunity for innovation, growth and long-term value creation, and a means to minimize the negative externalities while maximizing operational efficiency and resource allocation. Stakeholder engagement and collaboration are a crucial part of innovation, as they help inform product development. Ms. Motles stated that PMI will continue to leverage its life sciences capabilities with the goal of having a net positive impact on the world.

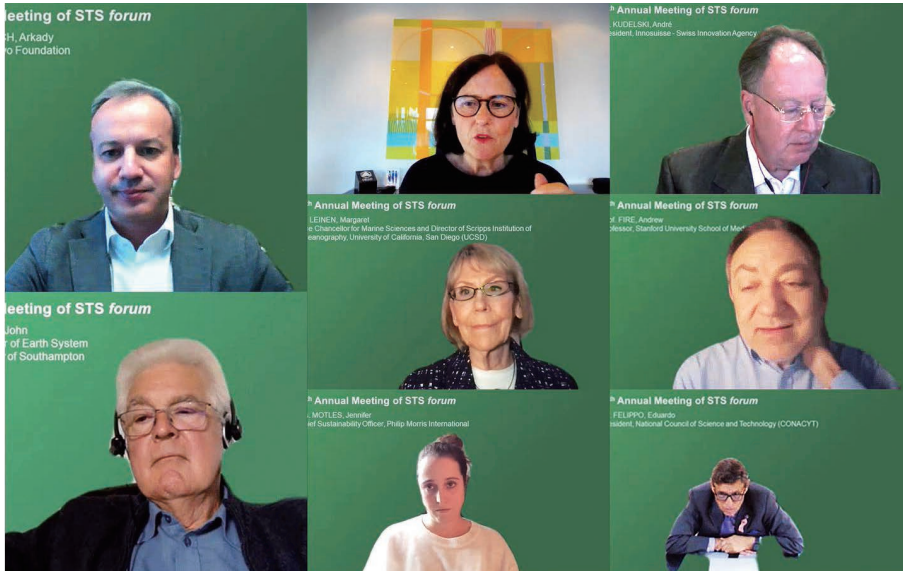
Mr. André Kudelski began by introducing examples of where collaboration has had a major impact and success, and how Innosuisse, the Swiss Innovation Agency, is proposing solutions where collaboration between companies and academic research centers can get

funding for international projects. International collaboration can be extended, but organizations and people need to know each other, which creates an opportunity for STS to serve as an attractive independent exchange platform.

Discussion

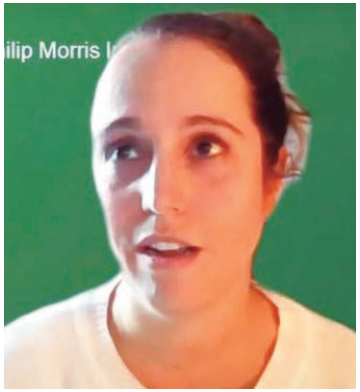
Prof. Dvorkovich pointed out two main subjects that can be drawn from the presentations; everyone is in favor of deeper collaboration, especially focusing on the areas where it is possible to expand the limits beyond national borders, and all the members understand that global challenges require international efforts. He then asked Prof. Fire to share his thoughts on the concept of introducing a culture to society on understanding global goals, and what are the main things that should be done to achieve those goals.

Prof. Andrew Zachary Fire reiterated the importance of collaboration, and that the impetus for it comes from three sources: from non-government organizations, and the freedom they provide to operate; from governments, which are a key part of making science work in the world and that also have to give scientists the opportunities to cooperate across boundaries; and most of all from science and technology institutions where innovation takes place. Institutions need to promote freedom in research, so keeping the outlook for institutions



broad is important. Finally, Prof. Fire emphasized that inspiration is the key, as it can drive research by encouraging governments and organizations to act.
Prof. Dvorkovich then opened the discussion by asking Prof. Becker on how to reconcile the value of academic freedom, especially with the priorities that governments set and fund as a result of political interests in the long and short terms.

Prof. Becker answered that freedom of academic research in the broader sense is a core value of the world. There is a critical demand for research and knowledge that needs to be communicated to all peoples of every country. That knowledge depends on the overall quality of basic research, and the degree of political freedom and independence of research. To create an environment for the advancement of knowledge, freedom of critical thinking is essential. Prof. Becker emphasized that such freedom, i.e. scientific freedom, should be regarded as a basic human right as in the German constitution, and academic freedom is not negotiable since it is a foundation of a knowledge based society. Of course, science must also adhere to the principle of ethics and integrity. The concept of science diplomacy can be of great value in order to spread the principles of academic freedom.

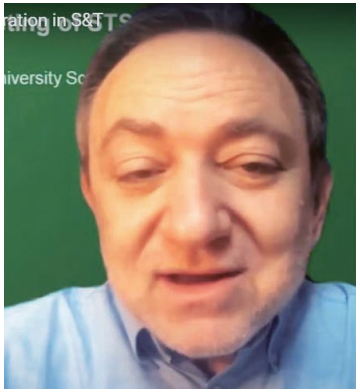


Motles, Jennifer

Kudelski, André

Prof. Dvorkovich then asked Dr. Shepherd to give more details regarding his statement on the need for another international convention that would also cover the atmosphere to improve the framework regarding research of our planet and oceans.

Dr. Shepherd agreed with previous speakers, but from an oceanic field, said that there are a large range of international programs that require international support, and require international treaties that enable countries to prevent dangerous activities. There is a framework on climate change, but the whole situation is very fractured. Some countries are considering


Fire, Andrew Zachary

modifying the climate, and no one knows if that will work or if it is a good idea. The fact is that at present there is no international law preventing it. Some countries are in favor of pushing this idea forward, and others are in favor of slow progress. Dr. Shepherd emphasized that this is a problem that may become urgent in the future, and the rate of progress must be increased.

Prof. Dvorkovich agreed on the need to be more active in informing governments on the need to cover this gap. He then asked Dr. Leinen to name the priorities that should be funded from international sources and co-funded from countries.

Dr. Leinen stated that the geographic scale and magnitude of the challenge of addressing many of the problems in the ocean makes international collaboration essential. The UN Decade of Ocean Science for Sustainable Development has really allowed the world to come together to discuss and decide on some priorities. Two major topics being resonated include the connection between ocean and climate, and food. There is an essential need to understand how things are changing and how they will continue to change with climate change. Climate hazards are also a recent issue in the UN, affecting not only coastal communities but inland communities.

Prof. Dvorkovich asked Mr. Felippo to explain the experiences and the tools used to develop the research community in Paraguay, and to describe broader research priorities.

Mr. Felippo explained that the only issue for Paraguay is economic development. To develop the economy happily, the government in recent years considered it important to develop sciences, and so the government made available funding to develop technology in general. However, there are only 1000 people fully dedicated to the sciences, and they are not connected to universities. They are autonomous, and Paraguay has to be careful that this autonomy is not led towards only economic success. However, Mr. Felippo emphasized that the reality in Paraguay is different, but international collaboration is paramount and they always seek to work closely with other countries. First Paraguay has to teach the people the importance of developing sciences and technology, and the only way to gain public support is by giving people results.

Prof. Dvorkovich next asked Ms. Motles what are the right steps and the right incentives to complement science with politics.

Ms. Motles explained that the private sector is where there are systemic issues that are complex to resolve, and different parts of society need to work together to respond to them. Some issues are so profound that they cannot be addressed by a single part of society alone. She explained her belief that bringing together different parts of society fosters changes and impacts the status quo. There is also a need for openness. Different parts of society come from different places, but great minds coming together will be able to drive change. For change to happen, everyone needs to come together and think of ways to collaborate and combine the best solutions each sector has.

Prof. Dvorkovich then asked Mr. Kudelski what he believes are the other possible tools besides funding from research support agencies that can foster collaboration in science and technology.

Mr. Kudelski focused on two key elements: academic freedom and the possibility to collaborate on important issues that no country can sufficiently address alone. It is the key to provide an ecosystem that can foster stimulating new innovation, as there may be initiatives that can bring important value for society and not only economic value. International collaboration is important, but one issue is that global crises are not planned or expected; often, they come as a surprise. To find a solution without knowing in advance who to connect with, it is extremely important to find ways to quickly identify the institutions and people who can supply new ideas. Mr. Kudelski emphasized the need for opportunities for new sciences to be developed.

Prof. Dvorkovich mentioned that his foundation is an open system for international collaboration and invited new efforts for new projects.

Prof. Fire was asked for a final statement, and spoke of his dream that there will be a young generation of scientists that will share the opportunities in the world and the responsibility of changing the world.

Nurturing S&T Talents in Developing Countries

[Chair]

Roberts, Richard J., Chief Scientific Officer, Department of Genome Biology, New England Biolabs, U.S.A. [Nobel Laureate 1993 (Physiology or Medicine)]

[Speakers]

Inglesi-Lotz, Roula, Co-Chair, Global Young Academy (GYA); Professor, Department of Economics, University of Pretoria, South Africa [Young Leader 2021]

Kirloskar, Vikram S., Vice Chairman, Toyota Kirloskar Motor Private Limited (TKM); Immediate Past President, Confederation of Indian Industry (CII), India

Gross, David J., Chancellor's Chair Professor of Theoretical Physics, Kavli Institute for Theoretical Physics (KITP), University of California, Santa Barbara, U.S.A. [Nobel Laureate 2004 (Physics)]

Vilela, Evaldo Ferreira, President, National Council for Scientific and Technological Development (CNPq), Brazil

Pre-recorded Statements

Dr. Richard J. Roberts spoke on improving STEM education and forging talent in developing countries like Africa. Brain drain in the continent has disastrous consequences for the region's development overall. New England Biolabs created an initiative to aim to develop an institution in the developing world, emulating its own beginnings of selling enzymes to academia. The company was built from a small base and it distributes profits to the employees. Its initiative is based on the assumption that the same business model could work in Africa. Previous attempts to train and fund startups failed, so New England Biolabs now plans to completely fund and create a company in a developing country, with the aim of transferring its controlling shares once the company is successful. New England Biolabs is searching for a leader and the appropriate environment in which to start this company.

Roberts, Richard J.

Mr. Vikram S. Kirloskar explored the utility of science and technology for India and the possibility of developing science and technology that reduces social and economic inequities. Science and technology should

be developed in a holistic manner and to truly solve for inequity in education. Developing nations suffer from poor infrastructure and low-quality teaching that neglects the teaching of the scientific method itself. Thus, teacher training should also be reformed to accommodate this end result. This is especially important for the developing world, where a scientifically literate populace would allow it to solve local problems with local solutions. One initiative, Caring With Colour, seeks to support such experimental approaches to teaching and learning in India.

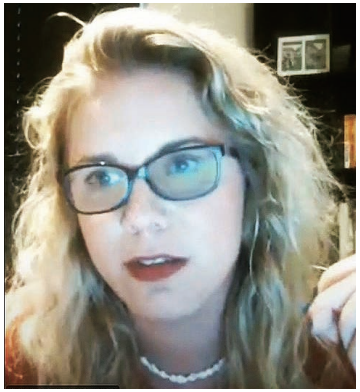
Kirloskar, Vikram S.

Prof. Evaldo Ferreira Vilela expressed his support for engagement in science and technology all over the world. The Brazilian National Council for Scientific and Technological Development has a tradition for supporting young talent in science and technology and to engage in scientific activities. It provides a vast amount of scholarships to the end of promoting scientific research, supporting the development of skills, and to give students the encouragement to enter research careers. It also promotes collaboration between students and world class research groups for interdisciplinary collaboration and extends support beyond doctorate levels.

Vilela, Evaldo Ferreira

Discussion

Prof. Roula Inglesi-Lotz explained the Global Young Academy and its initiatives in attracting talent to STEM. The pandemic has revealed existing issues in the education system. Young learners from developing countries do not have the resources to begin studies and bring with them their own concerns for current and future financial security, considering the high unemployment rates of these regions. Our youngest generation of students holds transparency and has social impact in high regard, which are values that STEM can offer them in their careers. Unfortunately, discussions in policy, social media and academic environments portray an image of STEM in which scientists are in conflict with policy makers, that the field is a challenging one with a lack of diversity and where scientists experience mental health



Inglesi-Lotz, Roula

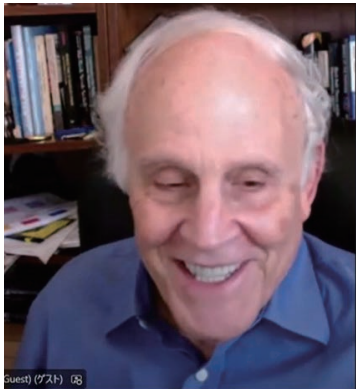
issues. Prof. Inglesi-Lotz asked if it was possible for the current generation of scientists to change the system from the inside.

Mr. Kirloskar explained his background in industry in India and stated that one major issue facing the workforce is the education and skilling of human resources. Changes in education are needed to give advantage to the disadvantaged and to develop scientific minds. This situation requires a complete behavioral change to realize long-term results.

Prof. David J. Gross remarked that he is always impressed with the young people of the developing world who are interested in advanced science. Excellent minds who could have careers in science are spread around the world but the poverty in these states and lack of opportunity pose significant challenges. Many who do study science in a developed nation like the United States do not return to their countries to do research. This brain drain has disadvantages, in that the talent who are developed may not return and prepare the foundations for others, and advantages, in that it establishes intellectual ties between the countries. Unfortunately, it is a fact that this brain drain will not stop as individuals will always seek opportunity. Centers of excellence may help keep talent in the country, and certain countries like Brazil and India may even aim to become international centers of science themselves.
Prof. Vilela explained his background in agrarian science and its application in food production in Brazil and the work of the Brazilian National Council for Scientific and Technological Development. The council provides more than 30,000 scholarships for young undergraduates. The council has concerns on how to keep young talent in the country and employ them in Brazilian laboratories.

Dr. Roberts asked the panel if there is a way to stop brain drain.

Prof. Vilela remarked that the brain drain is of serious concern because it lessens the quantity of scientists in the workforce. Some of the scholarships from the Brazilian National Council for Scientific and Technological Development help give direction to young scientists on their career paths. Economic growth is a major challenge in Brazil which compounds the issue and leads to a lack of opportunity for young people.



Gross, David J.

Prof. Gross explained that there is no way to stop the brain drain, but there may be lessons to be learnt from some successes and failures. In fundamental science, talent rarely returns to a developing country not because of economic reasons but due to lack of opportunity to do fundamental science. Thus, it is important to also provide native opportunities for talent so that trained scientists have a reason to return.

Prof. Inglesi-Lotz stated that her own experience is an unusual one as a Greek national who works in science in South Africa, and that her department (Department of Economics, University of Pretoria) is also very international. The movement of talent internationally should not be seen as a negative but must occur in both directions: brain drain to brain exchange. The issue should be addressed from the point of view of education. There is the assumption that education is better in the global north and this should be rectified so that the young talent can see the value in staying in the education system in the global south or returning.

Dr. Roberts added that the opportunities for fundamental science are few in the global south but there may be opportunities from the technological side.

Mr. Kirloskar agreed with the comments from Prof. Gross stating that the brain drain cannot be stopped. Nevertheless, a lack of opportunity does not equal a lack of capability. Mr. Kirloskar stated that in this regard, his companies spend a lot of money on training. Also, Caring With Colour seeks to educate the most disadvantaged in the method of science with everyday items and is training teachers to teach the skill of science rather than the facts of science. One major challenge in India is the high dropout rate in primary education. In Mr. Kirloskar's companies, its technicians are highly trained and the companies collaborate with small regional colleges to develop talent.

In response, Dr. Roberts asked the panel if teaching scientists business management might also be valuable to enable a better transfer of skills from developed countries to developing countries via business expansion.

Prof. Inglesi-Lotz commented that innovation comes from collaboration of industry, academia and policy making. Therefore, some level of business training for scientists would enable them to contribute to debates and understand a wider perspective to eventually lead to positive change in developing countries.

Dr. Roberts explained that there are more avenues for business creation in the developed world than in the developing world. Perhaps, schemes that help entrepreneurs start small businesses could help cover this gap.

Prof. Vilela stated that in Brazil cooperation with companies is crucial. The Brazilian National Council for Scientific and Technological Development has fellowship programs for entrepreneurs and gives graduate students the opportunity to communicate with companies. Importantly, this gives the students a chance to understand the challenges the companies are facing.

Dr. Roberts inquired if Prof. Gross had any examples of students who went on to success in technology.

Prof. Gross explained that that type of transfer was commonplace when theoretical physicists went to work in finance as quantitative analysts. A training in science is good preparation for many walks of life but opportunities are still lacking. Nevertheless, basically speaking, theoretical science requires only an internet connection and a good network of colleagues and can be done from anywhere in the world. But building these networks needs to be done at the grass roots level. One notable example of such a creation is the African Institute for Mathematical Sciences in South Africa.

Dr. Roberts commented that experienced scientists are often very receptive to giving help and advice and those science students from developing countries should freely solicit them.

A participant asked the panel if the best skill set for the future is traditional science and technological knowledge or soft skills such as teamworking and thinking out of the box.

Prof. Vilela commented that soft skills will be increasingly important, and dialogue between science and society will help people understand the skills needed.

Mr. Kirloskar added that it is important for workers to have a basic science skill, whilst it is also important to learn the soft skills and those of business management later in one's career.

Prof. Inglesi-Lotz expressed her agreement and stated that rapid changes in the workplace will take place due to the fourth industrial revolution. Therefore, the skill of adaptability and the skill of leadership will be vital. The Global Young Academy runs a science leadership program which helps young scientists learn leadership skills and other soft skills such as team working.

A participant stated that scientists in the developing world benefit greatly if there is a network that they can be part of, so that after a scientist has gone abroad for training there is something they can return to. And, Dr. Roberts expressed his agreement to this.

Dr. Roberts asked the panel if they could share what their perception is of science outreach to educate parents about science in the developing world.
Prof. Vilela stated that the education of parents in science in Brazil is only at a basic level and the number of people that understand science and technology must be increased.

Dr. Roberts asked about the acceptance of women in science in the developing world.

Prof. Inglesi-Lotz commented that there is a large difference for women in science in the developing world compared to the developed world. The fundamental differences are perspectives, culture and role models. It is important for young learners to have a relatable role model in science.

Dr. Roberts added that he has heard good stories coming from African women in agriculture in that regard.

Prof. Inglesi-Lotz explained that the younger generation seems to have a strong connection to the Earth, in terms of helping the planet but also in experience of working the land, and that these stories should be shared.

Prof. Vilela commented that in Brazil the stories of women in agriculture come more from the experience of working the land rather than the study of agriculture. But this is improving and female students can apply for scheduling for childcare in the curriculum.

A participant asked the panel if teaching students to learn how to code should be done at an earlier age.

Prof. Gross stated that young people should definitely learn how to code but the challenge at the primary level is that the teachers do not know how to program.

Mr. Kirloskar explained that the advent of information technology in India has had a massive impact, with its biometric identity cards allowing for government funding to directly reach its end person and students will have to learn and adapt at this fast rate of change. But Mr. Kirloskar stated that science is also important.

Prof. Inglesi-Lotz remarked that the collaboration in science and the multidisciplinary methods of answering questions are also skills that need to be taught at an early stage.

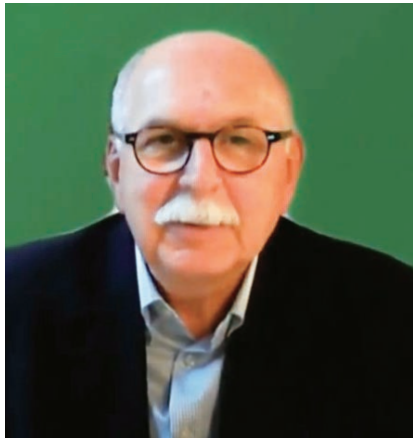
State of the Arts Energy-Related Technologies

[Chair]
Kleiner, Matthias, President, Leibniz Association, Germany

[Speakers]
Günter, Sibylle, Scientific Director, Max Planck Institute for Plasma Physics, Germany
Misewich, Jim, Associate Laboratory Director, Energy and Photon Sciences Directorate, Brookhaven National Laboratory, U.S.A.
Piketty, Laurence, Deputy Chairman, The French Alternative Energies and Atomic Energy Commission (CEA), France
Quirion, Rémi, Chief Scientist of Quebec, Office of the Chief Scientist of Quebec, Canada
Racicot-Daignault, Simon, CEO, Innovation Division, Hydro Québec - InnovHQ, Canada
Terazawa, Tatsuya, Chairman and CEO, The Institute of Energy Economics, Japan

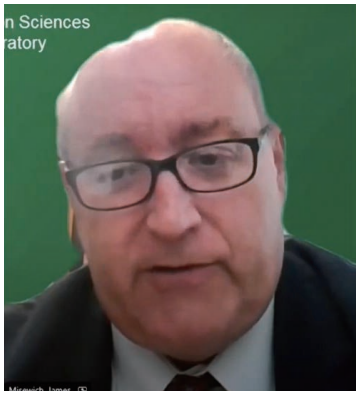
Pre-recorded Statements

Prof. Matthias Kleiner began the session by welcoming and introducing the panelists, then began his presentation by stating that, as humanity is aware of global warming, there is increasing pressure to reduce carbon dioxide emissions as quickly as possible. The energy sector thus has a crucial role to play. In the future, economies must succeed in using new technologies to ensure that industrial production is carbon neutral through electrical or hydrogen based processes. Prof. Kleiner explained that the International Energy Agency published Net Zero by 2050 as a roadmap for the global energy sector, which outlines a possible path to meeting the world's energy needs by 2050 in a carbon neutral way. Lastly, Prof. Kleiner cited that research and innovation must succeed in using new technologies to further reduce carbon dioxide emissions beyond existing technologies.


Kleiner, Matthias

Prof. Sibylle Günter presented how fusion energy could provide a CO_2 neutral baseload of electricity within a renewable energy landscape. She explained that fusion on earth requires extremely high temperatures, and the two ways to create said heat are laser fusion and magnetic confinement fusion. She

Günter, Sibylle



Misewich, Jim

summarized that as a nearly unlimited, world-widely available fuel, with favorable safety properties compared to fission, fusion is a very attractive alternative, but unfortunately fusion will not be available very soon because it still needs a lot of research and big investments.

Dr. Jim Misewich stated that climate change requires significant changes in energy strategy, as science and technology are crucial elements for meeting national and international clean energy goals. To achieve these goals, many issues must be addressed, including energy storage, but the large scale deployment of said technology must also be environmentally friendly.

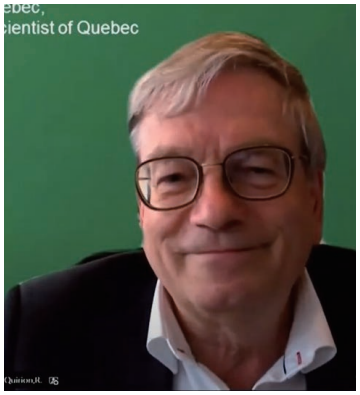
Dr. Laurence Piketty explained that the commitments to fight against climate change require a drastic reduction of the use of fossil fuels and the development of sustainable processes for energy production, management and use. At the same time, the geo-political context reinforces the need for resilient processes to preserve energy security. The development and improvement of new cost effective technologies and solutions will be critical for providing viable options for decarbonization. Electrical generation from renewable and nuclear sources, combined with the deployment of energy storage and conversion systems and management of energy grids, can contribute to the development of decarbonized electricity mixes.

Prof. Rémi Quirion explained that Canada has a major challenge in different parts of the country. In western Canada, the economy of provinces is based on the extraction of fossil fuels, while eastern Canada is focused on green energy. There are more new sciences and technology developments in the field of energy, but sometimes it is not easy to implement them in society. Prof. Quirion explained the hope that by combining the forces of science and technology, and collaborating with the rest of the world, it will be possible to produce greener technology, and that decisions based on science, technology and data will sustain and achieve the targets of the SDGs.

Piketty, Laurence

Mr. Simon Racicot-Daignault talked about the global challenge of energy transition from a local perspective in Quebec. Looking at the overall energy mix, most of the energy is still coming from oil and gas, so there is a need to focus on these areas, such as electrifying transportation, developing green hydrogen and other carbon neutral fuels, and electronic technologies.

Prof. Tatsuya Terazawa shared five promising technologies that are expected to help on the path to carbon neutrality, in relation to sectors of modern society where carbon emissions are high, such as technology to partially apply hydrogen and reducing coke and coal use in the steel sector, and two potential technologies for the cement and concrete sector; CO_2 absorption through concrete curing, and carbon-recycled concrete.



Quirion, Rémi

Discussion

Prof. Kleiner opened the discussion by first asking Prof. Günter to explain how advanced fusion technology is and if it will play a role in achieving the zero emission goals by 2050 or what resource will achieve the goals if not fusion.

Prof. Günter explained that there is still a lot of work to be done for fusion so it will not help the goals by 2050, but there are other technologies that can help, and in the long term, fusion will hopefully replace nuclear fission.

Prof. Kleiner then asked Dr. Misewich about his opinion on how a major aspect of electricity consumption is from transport and conversion to other carrying methods.

Racicot-Daignault, Simon

Terazawa, Tatsuya

Dr. Misewich answered that transportation is rapidly progressing, but the challenges are on the grid, particularly fast charging capabilities, and the acceptance for electric transportation is rapid charging. One sector that is particularly challenging is heavy vehicle electrification.

Prof. Kleiner then asked Dr. Piketty which technologies are available now and which should be improved in order to reach zero emission goals.

Dr. Piketty explained CEA's four main pillars of research, one of which is developing decarbonized energy production solutions, and the other three are technology development to make sense from economical, industrial and societal perspectives. She emphasized the CEA view that innovation is the cornerstone to achieving climate objectives.

Prof. Kleiner asked Prof. Quirion what energy sources will be used to ensure transport in Canada in 2050?

Prof. Quirion stated that electric cars are one solution, as are buses and hydroelectric trucks, but also green hydrogen for trucks. There is a lot of research now in eastern Canada on the production of green hydrogen, with the eventual goal of having green hydrogen planes flying over Canada.

Prof. Kleiner then asked Mr. Racicot-Daignault what are the limits of hydro power production, as hydro power is the most stable energy development but is also linked with climate change.

Mr. Racicot-Daignault stated that as there are a lot of water resources in Canada, it is very stable, and can rapidly replace fossil fuel power, and explained the future need to establish the optimal mix between wind, solar and hydro, taking into account the acceptability, based on the source. Mr. Racicot-Daignault also explained the status of hydro power storage in

Canada is very good now as reservoirs have been adding and storing energy. Reservoirs are not subject to seasonal variability, which will be a big plus to cope with climate change.

Prof. Kleiner asked Prof. Terazawa if the expansion of solar is an opportunity for new collaboration, as solar energy cannot be used in all places of the world.

Prof. Terazawa said there is great potential for solar power in desert areas, but for most of Asia, this option is not possible as there are no transmission lines connecting to those areas. One possibility is to generate power from solar and use it to produce hydrogen, then export it to Japan and Asia, but cooling the hydrogen for shipment is very expensive. Prof. Terazawa explained that the pragmatic step is to convert hydrogen to blue ammonia directly from natural gas and transport that. Ammonia can be co-fired with coal to reduce CO_2 emissions, and the CO_2 emitted in the process can be sequestered through CCS. This can be a step towards the future use of green ammonia and green hydrogen.
Prof. Quirion asked about the difference between blue and green ammonia.

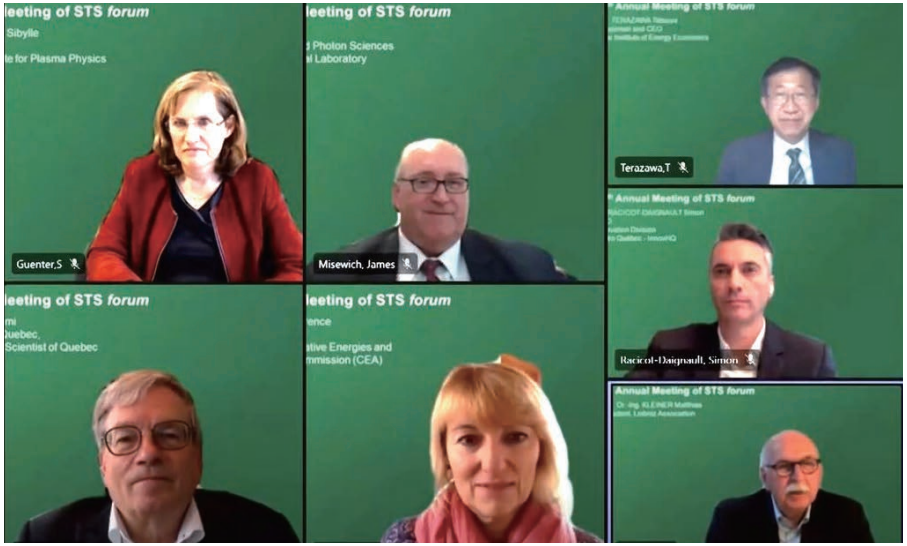
Prof. Terazawa responded that green ammonia is 30% more expensive, because there are extra steps in production involved. In terms of CO_2 footprint, green is better, but because it is costly, blue ammonia and reducing CO_2 emission by co-firing is more practical.

Dr. Piketty added that in France, hydrogen produced using electrolysis, known as pink hydrogen, produces the same level of energy as wind production, so the material production will lead to a reduction of greenhouse gas emissions in industry and transport.

Prof. Terazawa emphasized that the choice of energy depends on the specific situations in each country, such as the difference between Japan and France. Then comes the issue of transporting hydrogen. For Asia, ammonia is the more pragmatic approach, and due to the cost calculation, blue ammonia is cheaper than green ammonia.

Dr. Misewich highlighted that this topic underscores that energy storage is critical and represents a major scientific challenge. He emphasized that the choice of storage depends on the application, and matching it best to the economic policy of that application will vary in different locations.

Mr. Racicot-Daignault agreed with this, and looking at the way the grid will evolve in the future, it is the same situation for hydro power.



Prof. Kleiner asked Prof. Günter about the role that fusion can play in the short and long term.

Prof. Günter said that between 2050 and 2100 the global electricity demand will increase by another factor of three, so fusion will still be needed. She explained that the heat in fusion power plants is planned to not only be used to generate electricity, but also for use of catalysis for solar fuels, but there is no plan for a direct conversion to electricity.

Prof. Kleiner noted that some members mentioned grids as one essential element in the new energy system, and asked Dr. Piketty on the direction of grid development and if there is a need to radically rethink grids.

Dr. Piketty explained that ensuring the integration of more renewable energies in grids calls for an adaptation of grid management for both transport and distribution. Management improvements already enabled some countries in Europe to have up to 50% of renewable electricity in the grid without radical change. Going further will require additional adaptations such as implementing additional storage capacity and improving frequency stabilization capabilities.

Prof. Quirion emphasized the need to involve the public because there will be social impacts. Co-construction of big projects requires society's input or society will fight back against it.

Prof. Kleiner followed by asking if the uncertainty around climate change is measurable and is it affecting peoples mental health and resilience.

Prof. Quirion answered by emphasizing the need to work with younger generations to come up with better solutions, and the need for experts in social sciences to better include society and humanities.

Prof. Kleiner asked Prof. Terazawa if the global carbon price could also have a market regulating affect, and how high will the prices have to be, including their negative impacts.

Prof. Terazawa explained that there will not be a single common price, the price will reflect the unique circumstances of each region or market, and that the carbon pricing system should be designed to induce innovation, and availability of alternative technologies is necessary to make the price mechanism work effectively. He explained Japan's discussion of setting a timeframe to introduce carbon pricing, and within that timeframe, incentivize companies to develop technologies.

Prof. Günter raised a concern that if prices are different in different regions, why would those regions with low prices make changes.

Prof. Terazawa explained the importance for countries to match the pricing by reflecting the circumstances of each region rather than introducing a single price.

On future catalysis, Prof. Kleiner asked Dr. Misewich what developments are pending in the short term.

Dr. Misewich answered that a lot of current catalysts use very expensive metals and there have been a lot of attempts to minimize the amount needed. The other major innovation is the discovery of mixed catalysts, which resulted in dramatic increases in efficiency in catalysts.

Prof. Kleiner posed a final question to all the panelists on what subject they would recommend their children to study in order to support society, as the current generation is

delegating the problems to the next generation, which must be supported and empowered through an excellent education. Each of the panelists gave different answers.

Dr. Misewich highlighted how boundaries between disciplines are being reduced to some extent.

Prof. Terazawa emphasized the need to understand that the vast majority of the CO_2 in the next decades will be from developing countries, and so developed countries have to understand their problems and work with them.

Prof. Kleiner ended the discussion by stating the need for everyone to work together to face the big problems including the problem of climate change.

Science and Technology to Build a Resilient Society

[Chair]

Falk, Jim, Professorial Fellow, Melbourne Sustainable Society Institute, University of Melbourne; Emeritus Professor, The University of Wollongong, Australia

[Speakers]

Clark, Helen, The 37th Prime Minister of New Zealand, Helen Clark Foundation, New Zealand; former Administrator, United Nations Development Programme (UNDP), U.S.A.

Beugin, Dale, Vice President of Research and Analysis, Canadian Institute for Climate Choices, Canada

Isaacs, Eric D., President, Carnegie Institution for Science, U.S.A.

Kajikawa, Yuya, Professor, School of Environment and Society, Tokyo Institute of Technology; Professor, Institute for Future Initiatives, The University of Tokyo, Japan

Keller, Martin, Director, National Renewable Energy Laboratory, U.S.A.

Lim, Chuan Poh, Chairman of the Board, Singapore Food Agency (SFA), Singapore

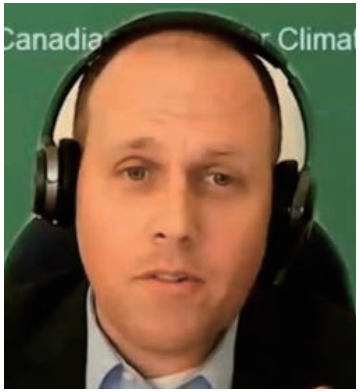
Springman, Sarah M., Rector, ETH Zurich, Switzerland

Pre-recorded Statements

Prof. Jim Falk described the importance of building resilience while mitigating risks. Effective response is not just about which actions are taken but also timeliness. The most recent Intergovernmental Panel on Climate Change (IPCC) report has shown that humans have unequivocally been warming the planet. A massive shift is needed to take humanity off a disastrous trajectory. Building resilient solutions requires that science and technology be ready for rapid deployment, be usable and enabled in diverse settings, and be affordable. Communities from the local to global scale must support situational awareness, seek to lower risk holistically, and allow for regulated deployment of solutions. More global attention is needed to move quickly to build mechanisms and address the converging risks.

Falk, Jim

Mr. Dale Beugin began by defining resilience as being prepared for unexpected shocks. For climate change, there are three important



Beugin, Dale

Kajikawa, Yuya

shocks: climate shocks which cause physical risks to society, market shocks which result from climate shocks, and climate policy shocks. These shocks highlight how society has been failing to manage the risks of climate change. Mr. Beugin then proposed three ways to build resilience. The first is through foresight, thinking about multiple possible futures when planning, both privately and within the government. The second is through market signals, driving capital investment towards more resilient outcomes and choices. The third is by focusing on social resilience, addressing the root causes of vulnerabilities in specific communities and regions. These will all be vital to create an equitable and resilient society.

Dr. Yuya Kajikawa defined resilience as the capability of making a systematic recovery and adaptation from a disturbance. He shared a framework of four components including system behaviors, influencing factors, interventions, and system capabilities. However, he acknowledged that turning a theoretical framework into practice is necessary. Decision makers need to be informed by scientists who are held to standards of credibility, saliency, and legitimacy. Interventions must consider different influencing factors including social norms and narratives which can affect outcomes. Lessons from disasters like the 2011 Great East Japan earthquake and tsunami must inform approaches towards resiliency. Finally, Dr. Kajikawa emphasized that a transdisciplinary approach including the arts and humanities is also needed.

Dr. Martin Keller shared information about the transformation of the electric power system, which will be decarbonized, digitized, distributed, and interdependent in the future. The coming power grid will be overlaid with telecommunications and interconnections. This will be enabled by smart devices spanning across power generation, power distribution, and power users. New autonomous energy systems are needed to run the future grid. Simultaneously,

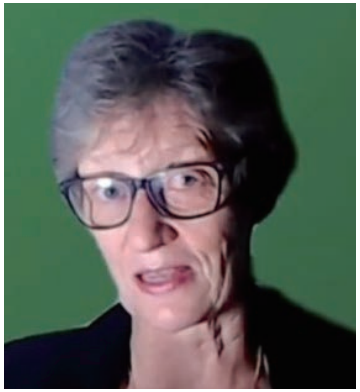
there is a need to address increasing climate disasters, as well as human threats including cyberattacks which will pose an ever-greater threat with an increasingly digitalized grid. Dr. Keller listed several key points spanning technology, forecasting, power system design, and power system operation that must be addressed by research in order to develop new energy systems for the future.

Keller, Martin

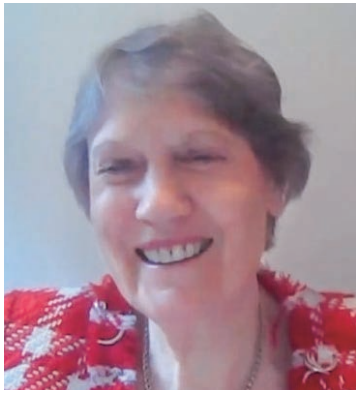
Mr. Lim Chuan Poh outlined how Singapore is seeking to increase the resilience of its food security strategy. Climate change poses grave threats to the global food supply and food safety. Global demand for food is on the rise, and meeting the demand through current methods will only put greater strain on the climate. Singapore primarily sources food through imports but is seeking to raise its local food production proportion to 30% of its nutritional needs by 2030, while only utilizing about 1% of its land area in the process. The Singapore Food Agency is working to push innovative farming projects on land and sea. Science and innovation are critical enablers for society and economy, so Singapore is investing heavily in research and innovation across both the public and private sector, as well as creating meaningful public-private partnerships.

Lim, Chuan Poh

Prof. Dr. Sarah M. Springman gave insight on climate resilience using the example of Switzerland with its many natural disaster threats, as well as from the perspective of a civil engineer. Research-based examination of natural threats including landslides can create more informed policy and resilient measures. Considering education, teaching students about SDGs is also core, alongside critical and entrepreneurial thinking. At ETH Zurich, there are programs that actively promote critical thinking among students and encourage them to understand the importance of resilience. Finally, Prof. Dr. Springman offered an engineer's perspective by emphasizing the need to move from brittle, inflexible systems, to more ductile, resilient systems which inform our decisions throughout the process. Coming



Springman, Sarah M.



Clark, Helen

together and asking for help from the world community is needed to make resilience a reality.

Discussion

Prof. Falk opened the session by noting that climate change is a problem that is now inextricably linked with others, including the decline of biodiversity. The challenges over this century will require work from interdisciplinary fields on local and global scales. Prof. Falk drew attention to a statement that elaborated considerably on this point. He noted the Statement had been produced from the Regional Action on Climate Change (RACC) Symposium held in conjunction with the STS *forum*, the previous Friday. He also noted that the Statement and accompanying video presentation had been placed on the STS *forum* website.

Prof. Falk asked Rt. Hon Dr. Helen Clark what change is needed to build resilience, and how that change might be achieved.

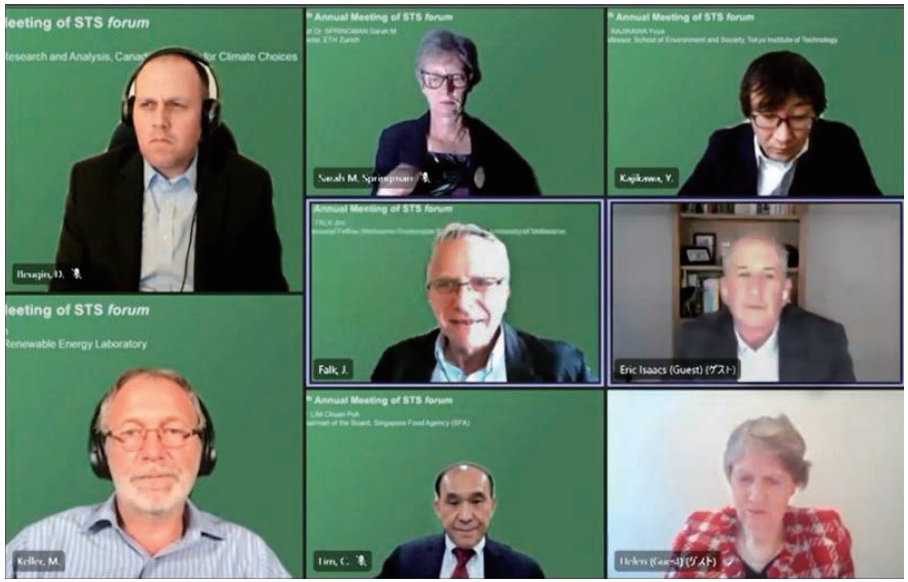
Rt. Hon Dr. Clark pointed out that in times when society is facing a multiplicity of crises, strong leadership is necessary. Strong goals have been established, including SDGs, but the next key step is for leaders, governments, and communities to create win-win solutions that are positive for the climate, biodiversity, and health. Crossing ideological rifts between countries needs to happen to rally to solutions, and wise leaders will play a key role in this.

Mr. Beugin stated that a key to implementing resilience is managing uncertainty of the future. Supporting incremental progress is needed, but "placing bets" on innovation is also important to shift policy and mobilize the private capital market towards resilient investments. Mr. Beugin noted that implementation must run through environmental agencies, but also across entire governments, from local to national levels. Embedding resilient policy measures will bring us long-term, stable investments and create broad solutions.

Dr. Eric D. Isaacs emphasized that there needs to be international efforts, from the basic science level, to business investment in solutions. For research, he advocated a holistic approach where basic science, social science, and the humanities must all receive support in order to understand problems, solve them, implement them in society, and communicate with the general public. Investment in the applied sciences is also needed for scalability going forward.

Prof. Falk commented that scientific communities can tend to be insular while reiterating the need for interdisciplinary collaboration mentioned by Dr. Isaacs. He then asked Dr. Keller about affordability of energy transitions in the developing world.

Dr. Keller agreed with the other panelists, framing how their points also apply to energy transformation. He pointed out that societies around the globe are working on different time scales and rates of development. Individual regions must be examined to find specific solutions in energy and technological innovation. Global research collaboration is critical, as is energy justice. It is critical to not allow transitions to leave people behind, as that would inevitably lead to failure on a global scale. The problem of energy justice is everywhere.



Isaacs, Eric D.

On the topic of transdisciplinary cooperation, Dr. Kajikawa pointed out that it is important for leaders to have supporting staff who can bridge the gap between academia and politics and identify credible, salient, and legitimate solutions. There must be different levels of action and different levels of leaders. A network of networks and global coalition towards solving problems are needed to empower those different levels and build a comprehensive view.

In response to a question on balancing self-reliance and global cooperation, Mr. Lim emphasized that both are needed to address Singapore's food sourcing problem. Source diversification will remain as Singapore's main way to ensure food security, and local production efforts are meant to complement to add robustness to the food security strategy. Mr. Lim pointed out that Singapore takes a very international approach towards research and innovation, and Singapore itself can serve as a testbed for startups and new solutions.

Prof. Falk added that agriculture is particularly significant when it comes to facing climate change, and that Mr. Lim's points are indicative of a necessary future for agriculture. In response, Mr. Lim commented that there is immense potential for innovation, including carbon negative indoor farming, and such solutions must be scaled to become affordable.

Prof. Dr. Springman explained that changes being made in education are very positive, noting students at ETH Zurich as an example. Math, science, and methodological teaching are necessary to build an educational foundation, but students must develop critical thinking to work together across disciplines to create solutions. Ethics is now a key part of students' education at ETH Zurich, and this trend is growing throughout Switzerland. More conversations are happening to rethink education and empower students to lead to a future that is more resilient. Prof. Dr. Springman also brought up the mental health crisis, which highlighted another need for resilience within individuals. Schools and governments must work in conjunction to address individual resilience.

Rt. Hon Dr. Clark pointed out that reaching sustainability goals is geophysically and economically feasible, but it requires political leadership to become a reality. Populism denies and

obstructs progress in this regard. Rt. Hon Dr. Clark reiterated Dr. Keller's point that energy justice is imperative. Decisions which impact regions must account for those impacts and offer just alternatives to those in the region. Especially with developing countries, it is necessary to provide funding aid to make just energy transitions. Finally, Rt. Hon Dr. Clark added that young people are eager to break out of their silos, be educated on social issues, and find ways to help.

Prof. Falk posed a question on whether resilience on a global scale requires a redistribution of financial resources. In response, Rt. Hon Dr. Clark noted the importance of solidarity funding. Developing countries do need financial support, and the costs are not prohibitive in global terms. Equitable funding must be examined and developed to build resilience in developing countries.

Mr. Beugin added that building trusting, stable cooperation across borders is another necessary aspect. That would also lead to stability across the globe, adding to resilient solutions. Prof. Falk mentioned the need to build the necessary international institutions to update price signals to reflect the unpriced values of natural services. If price signals remain wrong, industries will pursue destructive behavior in pursuit of profit.

Dr. Keller noted that research was traditionally designed to benefit a country. However, the problems faced now are global. Thus, developing countries need to work together with emerging countries to help the global community, and politicians need to acknowledge the need to aid in energy transitions.

Dr. Isaacs emphasized that leaders alone cannot make this transition. Ground-up efforts must be implemented, and the challenge is having science leaders, engineers, and business leaders come together to make a feasible start towards resiliency.

On the topic of leadership, Mr. Lim added that a key is creating effective global governance, which does not yet exist. On the other hand, he observed that there are signs that beyond the public sector, businesses are increasingly seeing sustainability as good business, and this can be a significant positive change.

Dr. Kajikawa pointed out that specific countries must pay the costs when it comes to global issues like protecting biodiversity. Equity and governance of a resilient global value chain are vital considerations, and implementing solutions becomes a political challenge.

Prof. Dr. Springman added that the role of educational institutions can be powerful in bringing together parties, providing funding, and providing intellectual capital towards addressing problems. That is not enough on its own, but a joint effort, globally and across institutions, is needed.

Q&A Session

A question from the audience asked how to address large CO_2 emissions from countries, including China as the largest emitter, as CO_2 is a gas without borders.

Rt. Hon Dr. Clark mentioned that international climate change talks in the late 1990s specified the need for rich countries to take decisive action addressing climate change. Only later did it become apparent that a concerted effort beyond just rich countries would be necessary. Therefore, countries like China must make huge transitions, but commitment from all major countries is needed.

Prof. Falk closed the session by recapping the importance of learning to cooperate and harnessing science to triumph in the face of adversity.

Collaboration among Academia, Industries and Government

[Chair]

Wallberg, Harriet, Professor and former President, Karolinska Institutet, Sweden

[Speakers]

McDonald, Arthur B., Professor (Emeritus), Department of Physics, Engineering Physics and Astronomy, Queen's University, Canada [Nobel Laureate 2015 (Physics)]

Nakanishi, Tomoko M.,President, Hoshi University; Emeritus Professor & Project Professor, University of Tokyo, Japan

Collins, Francis S., Director, U.S. Department of Health & Human Services, National Institutes of Health (NIH), U.S.A.

Mitchell, Dervilla, Deputy Chair, Arup, U.K.

Stoffels, Paul, Executive Vice President and Chief Scientific Officer, Johnson & Johnson, U.S.A.

Pre-recorded Statements

Prof. Harriet Wallberg introduced the panelists, and then began her presentation by saying that COVID-19 has impacted almost all countries and people in the world, but at the same time, we have witnessed an unprecedented effort to rapidly produce effective vaccines against COVID-19, which would not have been possible without collaboration between scientists and industry. In addition, to make the vaccines accessible, governments have had to come together to solve the challenge of distribution. However, we are facing a huge inequality in terms of distribution of vaccines to all countries, which has yet to be solved. The world is also seeing other devastating challenges, such as climate change and inequalities. The UN SDGs are a call for action by all countries in a global partnership. Now these challenges cannot be solved by any single government or institution, thus the 2030 agenda cannot be achieved without coordinated, strong collaboration between academia, industries, and government.

Wallberg, Harriet

Dr. Arthur B. McDonald gave an example of cooperation between academia, industries,

McDonald, Arthur B.

Nakanishi, Tomoko M.

and government to address urgent needs during the pandemic, which demonstrated the depth of capability that there is to respond to an international need. He focused on the impact of COVID-19 in Milan in March 2020, which stimulated an international group of basic scientists from 10 countries including Italy, Canada and the U.S. to develop a new design of ventilator for COVID-19, under contract to the Canadian government. 7300 have been supplied to the Canadian stockpile and donations to countries in need are now being negotiated.

Prof. Tomoko M. Nakanishi explained about the status of collaboration in Japan, and how it is steadily increasing, reaching levels similar to most of the other countries around the world. The government's policy is that this collaboration should increase three times by 2025. This would bring economical merits as well as human resources and management. Industries are also increasing their collaboration with universities, with the belief that promoting basic science is a key factor to be prepared for future pandemics.

Dr. Dervilla Mitchell said that there are many challenges affecting our planet and humankind that are too complex and too big to be solved by a single organization. Local, national and global collaboration will be required. With academia, industries, and government working together, we can move forward at a greater pace, bringing research and innovation to these problems. To be successful, we need to bring together the right partners with the right knowledge and expertise, and enable their collaboration using the best tools and technology to understand the issues and develop long-term sustainable solutions. Collaboration is easy to say but less easy to carry out successfully. There are two key barriers to success; different mandates or motivations of the organizations involved, and a lack of resources including expertise and funding. The keys to success are common ambition, trusted relationships and joint networking. But none of these keys can happen without frequent and open communication,

and the very best can be achieved if we put human needs at the center of our actions. Collaboration can indeed work, and we should find ways to encourage this approach more frequently at all stages of the project lifecycle.

Mitchell, Dervilla

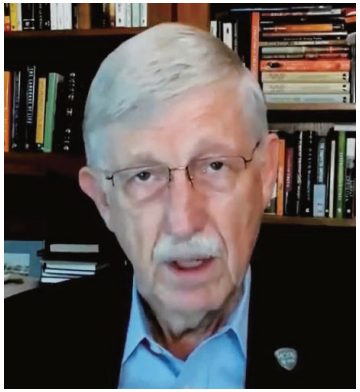
Dr. Paul Stoffels stated that the importance of collaboration in advancing human health has never been more obvious as the world battles COVID-19. The impact of the pandemic has changed the way we live and interact, and has drastically reshaped how we approach health care and innovation, how we invest in pandemic preparedness, and global health infrastructure, and how we view the role of science in society. COVID-19 has emphasized the need for stronger and broader collaboration to tackle global challenges. It has demonstrated that diseases do not recognize national borders, and that global transparency amongst stakeholders is key to stopping public health threats. The global health community has come together in remarkable ways to rapidly advance solutions to diagnose, prevent and treat COVID-19. Looking ahead, we know that novel pathogens will continue to emerge, and existing conditions urgently require new and better solutions. We must apply the learnings from COVID-19 and work in new and collaborative ways to make progress in all of these areas.

Stoffels, Paul

Discussion

Prof. Wallberg began the discussion by asking the participants to give one good example of where academia, industries, and government have worked together to solve one of the world's challenges of today.

Dr. McDonald began by reiterating the ventilator project from Milan, which brought together many international members, and developed a new product that has been supplied to the Canadian government and will be donated to multiple countries in need.



Collins, Francis S.

Prof. Nakanishi highlighted the collaboration carried out in Japan to respond to the Fukushima disaster, based on a huge amount of funding. She emphasized that everyone has to make decisions based on science and facts to make policies in the projects and it is important to inform and educate the public.

Dr. Francis Collins raised the example of what happened early on with therapeutics for COVID-19. Colleagues in academia, industries, and government came together to form the Accelerating COVID-19 Therapeutic Interventions and Vaccines (ACTIV) group, which worked without being concerned about credit to put together a plan to test therapeutics and master protocols to be sure testing gave confident results.

Dr. Mitchell reiterated her experience of creating a master plan for addressing the rapid urbanization of Shanghai City and its water problems, which is a common problem to many countries and the lessons learned can be reapplied to many places.

Dr. Stoffels highlighted that before collaboration on COVID-19 came collaborations on HIV and Ebola, and that this collaboration can be applied to other existing issues outside of pandemics.
Prof. Wallberg raised the question of how much help has there been from previous collaborations such as those brought up by Dr. Stoffels.

Dr. Collins emphasized that previous collaborations did help as they brought scientific talent of all sectors to the same table to make progress on new treatment. He emphasized these efforts created relationships among members, so when the pandemic hit the members knew who to contact and could begin work quickly.

Prof. Wallberg asked Dr. Stoffels to explain the industry view of collaboration and how it worked with government and academia to produce vaccines at an unprecedented pace.

Dr. Stoffels stated that collaboration was absolutely necessary, and highlighted the role of regulatory agencies to accelerate decision making and clinical trials. Lots of data was generated and the regulators needed to review that data and advise rapidly.

Prof. Wallberg asked Dr. McDonald to elaborate on how the collaboration on ventilators worked and whether there were any problems.

Dr. McDonald explained that all the members worked together and respected their expertise in order to meet a major challenge. He emphasized that the basic science that had been done before made it possible to work quickly, especially in the case of vaccines.

Prof. Wallberg asked Prof. Nakanishi to elaborate on her views regarding basic science, including on funding.

Prof. Nakanishi stated the difference in the character of basic science in universities and in companies, brought by the presence of students. The education process by faculty members, through the discussion or unexpected results brought by the students, brings

about new features of basic science. But the problem is many students prioritize careers and not going into research fields when huge funding is proposed.

Prof. Wallberg asked the panelists to comment on how to resolve this issue by promoting collaboration between industry and academia and making it part of careers.

Dr. Stoffels pointed out that facilitating the use of science has been successful in many places, and the outcome should focus not on who invented what, but on what differences were made for society.

Dr. Mitchell added that COVID-19 helped people to focus because there was a crisis, but collaboration when there is not a crisis is also needed. Focusing on the outcomes allows people to think about how they are doing good for mankind and for the planet, and this will enable members to come together more readily around a common objective.

Dr. McDonald stated that education is a very important part of this. Academia has a responsibility to teach the basics of a given discipline, and it is very important to have people look at the latest topic in order to understand what they have to do for the benefit of mankind. The development of that educational transfer will be very important going forward.

Dr. Collins mentioned the issue in the way scientists are educated. Having scientists exposed to different career paths is useful as those with experience have a better sense of what the rest of the world can offer, and better relationships get built.

Prof. Wallberg asked Dr. Mitchell to elaborate on examples where collaboration has made improvements on climate change.

Dr. Mitchell explained that while there have been multiple collaborations, the members do not always have the opportunity to know their partners beforehand, so they have to find ways to rapidly connect and build trusting relationships, including building an environment where one can bring together the context of the challenge together with the diversity of expertise to solve problems.

Dr. Stoffels emphasized the critical importance of networks, as they allow for fast work, as seen during the pandemic.

Prof. Nakanishi emphasized the importance of education, giving an example of a school in Fukushima that promoted preparedness against disasters in curriculum being taught, which saved most of the lives at the school during the disaster.

Q&A Session

First a comment from a guest was raised, that the best way for industry to make big money is to solve unsolved problems and/or to meet unmet needs. Doing so requires research, science, innovation and invention and natural incentives for industry and academia to collaborate.

Dr. Collins agreed but added that mechanisms to promote that effort are also important. It is not enough to have the idea; a framework to base the platform on is also needed.

Dr. Mitchell also added that money must not always be a key driver. Purpose, opportunities, and the ultimate outcome should be prioritized over commercial. A balanced outcome should be sought.

The next question asked about how fake news affects collaboration between academia, industries, and government.

Dr. McDonald pointed out the obvious value that has been shown in national and international cooperation on the pandemic, and the hope it will lead to greater trust in scientists, and in the longer term, to people appreciating the value of science in exposing and addressing climate change. Even if naysayers confront the science, action must be based on scientific advice, and the improved confidence in scientists will influence the population.

Dr. Stoffels added that fake news costs society a lot of money and causes new threats. If fake news is not brought under control quickly, it becomes a hindrance to progress.

The next question asked how young scientists can find themselves amid collaboration, and what opportunities do academia, industries, and government provide for them.

Dr. Collins stated that young scientists who want to take part need only step forward, as there is a great need for them. The pandemic saw a lot of young scientists deciding to work on the virus and they have been well served by taking part.

Dr. Mitchell added that curiosity to go beyond disciplines will bring young scientists to a more collaborative environment.

Prof. Nakanishi stated her belief that young people should pursue basic science. They must not just seek money from collaboration, they should learn and gain something before going into the market.

Dr. Stoffels agreed that basic science is important, but collaborative science can also be a great way to get results.

The next question asked Dr. Stoffels on how his company allocates money between basic science and product development.

Dr. Stoffels answered that 75% is spent on product development and 25% is spent on basic science. But there are also significant collaborative efforts on accessing new science and the role of translating basic science into products for society.

The final question was asked to the panelists on the potential contribution of social sciences and the humanities in collaboration.

Dr. Mitchell answered that social sciences and humanities are essential in delivering required behavioral changes in society.

Dr. Collins agreed and pointed out that, as can be seen from COVID-19, human behavior has huge consequences.

Path Toward Net-Zero Emission

[Chair]

Fujii, Teruo, President, The University of Tokyo, Japan

[Speakers]

Minami, Ryo, Deputy Commissioner for International Policy on Carbon Neutrality, Director-General for Evidence-based Policymaking, Ministry of Economy, Trade and Industry (METI), Japan

Al-Khowaiter, Ahmad O., Chief Technology Officer, Management, Saudi Arabian Oil Company, Saudi Arabia

Bilbao y Leon, Sama, Director General, World Nuclear Association, U.K.

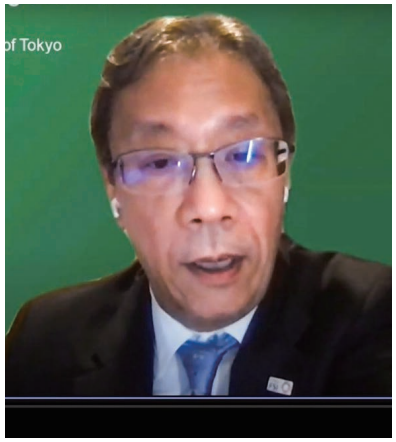
Morita, Ayumu, General Manager, Center for Technology Innovation (CTI), Hitachi, Ltd., Japan

Holleaux, Didier, Executive Vice President, ENGIE, France

Turner, Adair, Chairman, Energy Transitions Commission; former Chairman, Financial Services Authority (FSA), U.K.

Pre-recorded Statements

Dr. Teruo Fujii spoke on the international efforts to achieve the Paris Agreement and explained that as global warming is progressing, even if all pledged countries achieve their targets, global emission will still not have been reduced enough by 2050. In order to take on the challenge of the energy transition, each country must design its own approach towards carbon zero. Nevertheless, there needs to be a shared global strategy for a globally effective approach. Japan has declared its 2050 goal of carbon neutrality and has drafted a green growth strategy. But challenges remain, and industry, academia and society will need to undergo massive transformation to realize a sustainable society.



Fujii, Teruo

Mr. Ryo Minami shared the experiences of Japan on implementing science and technology in policy. Japan has declared its 2050 goal of carbon neutrality and will reduce emissions by 46% by fiscal 2030. In order to steadily implement concrete measures towards its goal, the Japanese Government formulated the Green

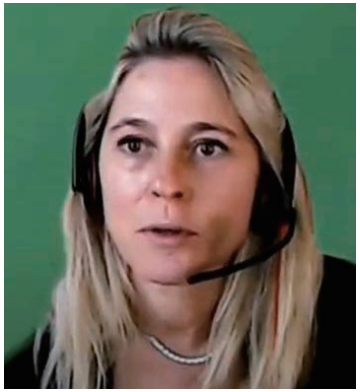
Minami, Ryo

Al-Khowaiter, Ahmad O.

Growth Strategy, to leverage all the available policies to support the efforts of companies. Under the newly launched Green Innovation Fund, the R&D projects in the hydrogen sector have already been started. Climate change is a global challenge which requires the efforts of the entire world. In this respect, each country will need to forge its own pathway to carbon neutrality. Innovation is the key to make all types of technologies available to realize the energy transition. Furthermore, it is critical to engage emerging countries by supporting their introduction of innovative technologies. The Ministry of Economy, Trade and Industry hosts "Tokyo Beyond Zero Week 2021" to facilitate global discussions.

Mr. Ahmad O. Al-Khowaiter noted that there would not be one energy transition but multiple pathways to net zero. One path focused only on massive reductions of hydrocarbon use would entail significant costs in hard to decarbonize sectors, whereas a path that also involves removal, such as carbon capture, utilization and storage, would significantly lower those costs. Better still, a circular carbon economy would utilize reduction in carbon, and also reuse, recycle and permanently remove carbon. Furthermore, in the modern oil and gas industry, there is massive potential to reduce greenhouse gas emissions from industrial processes and Saudi Arabia is a leader in this regard. Even hard to decarbonize sectors are able to reuse carbon dioxide, and carbon dioxide can be recycled in the chemical and materials industries. Carbon dioxide can also be removed and stored in aquifers and depleted oil and gas fields, and used in the production of hydrogen.

Dr. Sama Bilbao y Leon explained that urgent progress needs to be made on the goals to limit global warming to 1.5 degrees. Despite many efforts to increase clean generation, the percentage of low carbon electricity generation has remained unchanged since the beginning of the 21st century. This challenge is compounded because low and middle income countries want to achieve decarbonization while prioritizing sustainable development to improve quality of life for all their citizens, which will result in an increase in energy demand. From that perspective, the benefits of nuclear energy are clear because it is a clean energy source that can contribute to all 17 SDGs and can help decarbonize not only electricity generation but other hard to abate sectors of the economy. Global nuclear generation continues to grow with large and small reactors being developed. Nevertheless, government support that generates confidence is critical to ensure low-cost finance, streamlined regulatory environments and a level playing field in policies and markets with other low carbon technologies.



Bilbao y Leon, Sama

Morita, Ayumu

Dr. Ayumu Morita presented Hitachi's vision for net-zero emissions. The road to carbon neutrality is different for each country and has dependencies in territorial area and energy self-sufficiency. Hitachi deems that energy saving by digital transformation, mass installation of renewables, electrification and hydrogen and new fuels will be the pillars of decarbonization. Hitachi is actively researching the constraints of new energy systems, behavioral changes needed in users, and the technologies to facilitate the transition to renewable energy and electrification. It is collaborating with the University of Tokyo in research and Toyota and JR East in fuel cell vehicles, and developing highly efficient hydrogen co-firing power generation and blue hydrogen production systems.

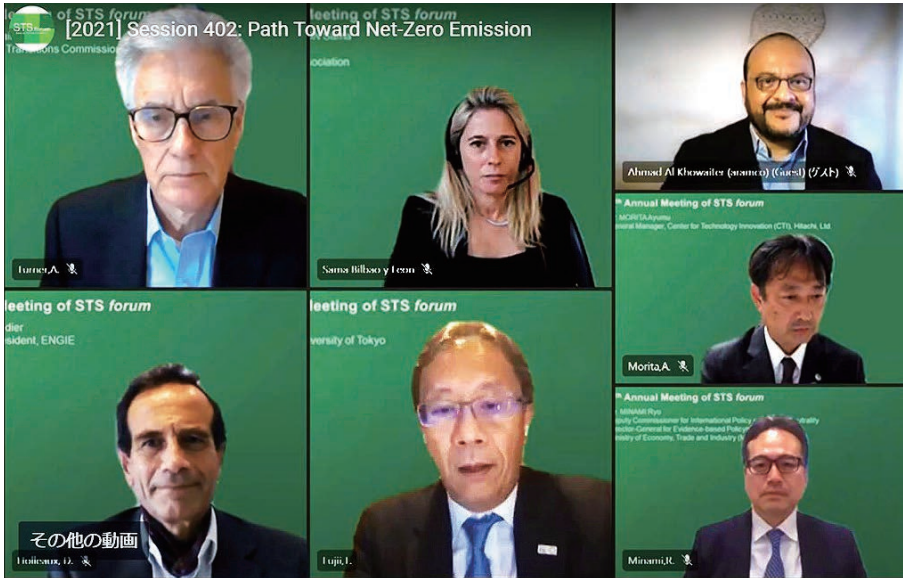
Mr. Didier Holleaux explained Engie's vision for decarbonization. The energy industry should move towards an integrated development for energy projects that involves local communities. Raw materials management will be essential going forward, such as in the hydrogen economy, which currently relies on rare metals for production, and efforts should be made to research production methods that involve more commonly available metals. The world is currently on track to miss the Intergovernmental Panel on Climate Change's

target. This necessitates work on carbon capture technologies, including Direct Air Capture (DAC). Moreover, the storing of data without a use case should also be weighed against its environmental impact.

Lord Adair Turner shared the Energy Transitions Commission's view on decarbonization and the need to realize the Paris Agreement. To this end, developed countries need to reach net zero carbon by 2050 and developing countries by 2060. The commission is confident that these goals can be achieved through a number of technologies. Solar and wind energy have drastically reduced in cost. Batteries and hydrogen via electrolysis of water have also significantly improved, filling the void of the reliability of renewables. Therefore, the economy, and especially road transport, should be electrified. Carbon capture, utilization and storage will be utilized for cement production and hydrogen could be used as a production agent in the steel industry. In addition, heavy transport such as shipping will see the use of ammonia or methanol.

Discussion

Dr. Fujii asked the panel how the international community should change its behavior to achieve net zero.



Mr. Minami stated that achieving net zero requires enormous efforts to meet the challenge and companies will need to change their business models and strategies. The role of government is to provide full support to private companies for their forward-looking efforts. Japan is showing leadership to bring together the wisdom of the world, for example through the "Tokyo Beyond Zero Week". Countries should follow various pathways according to their situation. Creating innovation through R&D, and spreading the innovation to emerging countries is also critical.

Holleaux, Didier

Mr. Al-Khowaiter explained that the international community needs standards for new energy products via emission standards. This certainty (and level playing field) will allow researchers and industrialists to develop carbon neutral technologies and industries. Governments should take a policy-holistic, technology-agnostic approach and align incentives that need to be met, and then companies and researchers will be able to find the most effective solutions that truly deliver fair and orderly energy transitions.

Turner, Adair

Dr. Bilbao y Leon commented that the pledges and commitments on net-zero speak to the importance of the challenge, but concrete actions are going to be critical and so far little progress has been made. The international community is facing the need to decarbonize, but at the same time we need to guarantee a quality of living for all people. These two global goals are somewhat conflicted as economic development requires energy. Thus, the international community should set goals for decarbonization but not mandate the technology to be used to do so.

Dr. Morita explained that zero emission and carbon neutrality is a big challenge. Each country and region needs a specific plan forward. Japan lacks land and will only reach 30% renewables natively by 2050. Because of this, the country looks to imports, nuclear, and

innovation to reach its goals. Japan will lean heavily on its cooperation with other countries to reach zero carbon.

Mr. Holleaux stated that Engie is an energy company which acts with a purpose and is actively engaged in energy transition. The correct solution for accelerating the transition now is not necessarily the same solution that will be used in 2050. The international community will need all energy vectors (electricity, gas (including biogas and hydrogen), heating and cooling networks) in the mix and a sophisticated energy strategy will be required to ensure a resilient system. Humanity must act now to simultaneously reduce carbon emissions today and prepare the solutions for 2050. Countries and companies should adapt their assets for climate change. Furthermore, as the planet will likely overspend its carbon budget by 2050, humanity will need appropriate tools to recapture carbon (like DAC).

Lord Turner stated that the international community needs to combine long-term targets with earlier targets and clear pathways. Commitments to explore pathways will show a clear route forward. As an example, the UK analyzed the situation in reverse to set a final date for the sale of internal combustion engine vehicles from its 2050 net zero goal. Lord Turner agreed that the international community does not need to mandate technologies but stated that electrification must be rapidly and widely achieved. India is an example case for meeting growing electricity demand while ensuring that that growth is carbon neutral. It is predicted that the UK will have a zero-carbon electricity system by 2035 and developed countries should be working on a similar scale. Moreover, negotiation is needed with China for it to self-identify as developed.

Dr. Fujii questioned the panel on the individual actions each organization would take.

Mr. Minami explained that the Ministry of Economy, Trade and Industry of Japan was considering various measures but that innovation would be critical to realize carbon neutrality. The Green Innovation Fund is to help ambitious projects from R&D, demonstration to social implementation in promising fields such as hydrogen, ammonia and carbon capture, utilization and storage funding and development. He stated that the next ten years would be an important period of innovation.

Mr. Holleaux expressed his agreement that electrification will be massively important but not exclusive. He was reluctant to focus too much on innovation as most of the technologies which may have a significant impact before 2050 are already available. Engie is increasing its target for renewables and is working with customers, helping organizations such as municipalities and the mining industry to decarbonize. It is also actively implementing technologies such as biogas and geothermal, and even considering sky cooling technologies.

Mr. Al-Khowaiter added that there are already existing technologies that can move the world along the path to net zero, thanks to the short time and investment needed to scale up. However, the technology barriers to electrification are significant, with 82% of energy consumption currently beyond electrification. This area requires a lot of development. Cement, for instance, produces carbon from its chemical reaction alone. Therefore, decarbonization means a true total transition of the global economy, adjusted to every country's individual needs. Put another way, the world needs technologies that can cover this gap outside of electrification at pace, which is precisely Aramco's focus.

Dr. Bilbao y Leon commented that the World Nuclear Association is working to ensure that current nuclear reactors can be operated as long as feasible. It is also supporting the global nuclear industry towards accelerating the deployment of new nuclear technologies. Large reactors are already operational in more than 30 countries in the world, including the US, Europe, China and Japan to facilitate decarbonization. But more importantly, nuclear is the only low carbon energy source that can produce heat and thus it could be a game changer to decarbonize other sectors, for example fresh water production, industrial heat, district heating and even shipping and air transport, by producing hydrogen, ammonia and other synthetic fuels.

Lord Turner stated that if the target of electrification was clearly identified, it would reveal the size of the task ahead. Beyond electrification, green hydrogen produced via electrolysis will be a critical technology for hydrogen for the shipping and steel industries. Lord Turner expressed his agreement with Mr. Holleaux that the energy technology is already available for the transition. Electrification of road vehicles will most likely be realized, while hydrogen will likely be needed for heavy duty vehicles. Furthermore, there are even lessons to be learnt in energy efficiency from centuries-old architecture, and room for improvement in agriculture.

Dr. Morita commented that the pathway to carbon neutrality is different from country to country so various scenarios should be considered. The circular economy, such as reuse and recycling, will also be critical alongside renewable energy and other measures for carbon neutrality.

Dr. Fujii closed the session stating that though all the speakers have different backgrounds, they could come to at least share a coherent direction to carbon neutrality that involves a variety of alternative and existing technologies.

Closing (Key Messages from the 18th Annual Meeting)

[Chair]

Serageldin, Ismail, Founding Director Emeritus, The Library of Alexandria, Egypt

[Speakers]

Ebrard Casaubon, Marcelo Luis, Minister of Foreign Affairs, Government of Mexico, Mexico

Brady, Terry, President and CEO, Underwriters Laboratories Inc., U.S.A.

Murray, Cherry A., Deputy Director for Research, Biosphere2 and Professor of Physics, University of Arizona; Benjamin Peirce Professor of Technology and Public Policy and Professor of Physicss, Emerita, Harvard University, U.S.A.

Kumar, Ashwani, Senior Advocate Supreme Court of India; former Union Minister of Law & Justice; former Member of Parliament (Rajya Sabha), India

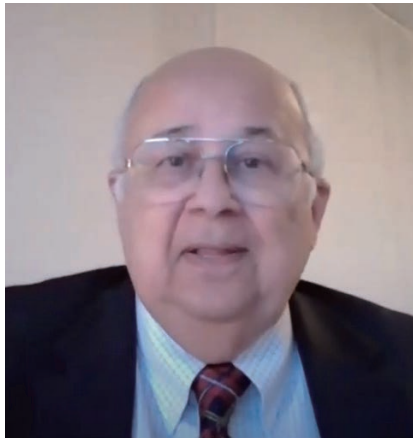
Uchiyamada, Takeshi, Chairman of the Board, Toyota Motor Corporation, Japan

Papadopoulou, Maria, Policy Officer, Directorate-General for Research and Innovation, Euratom Research, European Commission, EU [Young Leader 2021]

Brancalion, Pedro Henrique, Professor, Forest Sciences, University of São Paulo, Brazil [Young Leader 2021]

Remarks

Prof. Ismail Serageldin expressed his appreciation for the honor of chairing the closing session of the 18th STS *forum*. This is the time when members come together to seek the wisdom of some of the distinguished guests, with a view to pull together the threads of all the discussions that have been had on the various topics.



Serageldin, Ismail

His Excellency Mr. Marcelo Luis Ebrard Casaubon introduced the STS Latin and Caribbean Forum that will be held in December, where there will be dialogues and participants will share knowledge not only on the pandemic but on elements that will become the basis for the future of the region and other parts of the world, such as space, mathematics, advances in the region, pharmaceutical, and electro mobility.

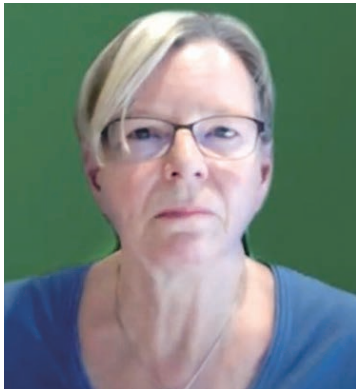
Ebrard Casaubon, Marcelo Luis

Brady, Terry

Mr. Terry Brady expressed the honor for Underwriters Laboratories (UL) to partner with the STS *forum*. As a nonprofit global safety science leader, UL embraces the responsibility to help safeguard the planet and society, by advancing safety science through open and collaborative research, standards development, and education and outreach. He stated the belief that all members agree that the future of society is linked with the advancements in science and technology, but newly accelerating technologies can create new obstacles that must be addressed together. When we recognize that progress is not without consequence, we must take deliberate action to mitigate emerging risks. Humanity is on the cusp of multiple revolutions in technology, and every one of these technologies has the potential to change people's lives for the better, but they will also reshape our society and bring unintended and unknown consequences. Mr. Brady emphasized that members must communicate their findings with various stakeholders in order to make an impact in society.

Prof. Cherry A. Murray began by applauding the STS staff for pulling off a remarkable meeting that was very smooth and interactive, and because it was online, it drew policy makers that would not have time to travel, and a more geographically diverse speaker population. Prof. Murray then raised several points on how the forum this year was different from previous forums. There is no argument that humans are using the resources of the planet unsustainably, and humanity is facing various existential crises. In order to avoid catastrophe, action and intervention are needed, and there is a need to involve the community in coproduction of solutions and preparedness for the next crisis. Forum members are not looking at sectors and tracks, this year they are all merged together into a complex whole, while observed from different perspectives in various sessions. A number of speakers mentioned the need for transdisciplinary sciences and technologies, including integrating social sciences and humanities. There were also many calls for more international cooperation in research and innovation. There was a greater sense of equity and inclusiveness and a realization that the 17 UN Sustainable Development Goals are a comprehensive and impressive vision for humankind to strive for.

Dr. Ashwani Kumar expressed his delight to be part of a conversation that will show humanity the way forward in redefining the world that is upon us; a world driven by science and technology, and driven by a common urge to survive the many common challenges. This forum has attracted distinguished people from all over the globe, who have shared their insights into the way forward for a better world, and is a major event in the calendar of common endeavors that all are engaged in. Dr. Kumar expressed his belief that science and technology, in the service of humankind, can best serve its purpose if it does not shy away from answering the complex ethical questions that challenge collective ingenuity, and challenge the vision for the future. The idea that science is and ought to be morally neutral cannot be accepted. Science in the service of humankind cannot be divorced from the intensity of human emotions. Uppermost in our minds should be the quest to harmonize the ethical imperatives with the advances in science. Dr. Kumar concluded that moments of transformative scientific advances stand out as the peaks and essence of human history, but only those who can marry these advances to human emotions will find a place of honor in the realm of human science and thought.



Murray, Cherry A.

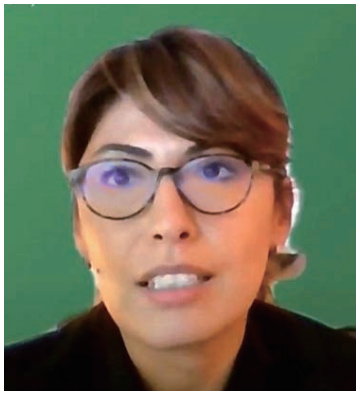
Kumar, Ashwani

Mr. Takeshi Uchiyamada expressed his condolences to the families of those whose lives were claimed by the pandemic, and his best wishes to those suffering from COVID-19, and his respect for the medical professionals tackling the disease. He reiterated that COVID-19 has brought to light various challenges, revealed our deficiencies as human beings, and impacted all areas of society. Addressing it is a major challenge common to all humankind that requires worldwide cooperation and solidarity. Mr. Uchiyamada also stated that solutions must be found to various issues, including environmental challenges and social issues. Facing such issues on a global scale, how companies can contribute are being called into question. Mr. Uchiyamada explained the various efforts that Toyota is making to redesign itself into a mobility company, based on the idea that technology must contribute to the happiness and health of people, by providing goods and services that make people happy. Amid all of this, there is a need to strengthen awareness that realizing a decarbonized society is critical to humankind's survival. The goal is to be carbon neutral, and as such vehicles running on fuels should not be a problem as long as that fuel is carbon free. Innovation is needed before these new fuels can be used normally in society. Preparing a variety of options according to the energy situation of the country or region concerned will effectively reduce CO_2 emissions on a global scale. Mr. Uchiyamada also stated that it will become more important to resolve social issues through border transcending cooperation and trust among members of academia, policy makers, and industry, and that science, technology and innovation will be key.

Dr. Maria Papadopoulou expressed her pleasure at being part of the STS *forum* and representing young leaders. She shared three viewpoints of her impressions from the forum. Firstly, the STS *forum* represents a wide and diverse, international group of researchers, innovators, academics and policy makers who share many common points, including the passion for

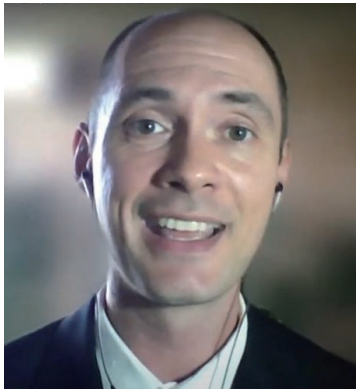
science and technology, and more importantly the desire to network and learn from world renowned leaders. Her second point is about the relationship of science and technology with policy making, in particular the concept of time. As many speakers mentioned, science and technology are not static, they are processes that are continuously evolving. With that in mind, decision making and regulations need to be flexible enough in order to understand and adapt quickly to changes, and keep up with scientific and technological progress. While this progress can bring benefits to society, it can also uncover societal challenges and issues of ethics and trust. These issues relate to her third viewpoint of individuals and citizens. Citizen engagement and trust are key to solving societal challenges, and effective communication is vital in order to be able to build this trust. Researchers need to be able to deliver simple and clear messages to citizens, while listening to concerns in order to establish a true dialogue. Dr. Papadopoulou concluded by stating her desire to see more international efforts that value the diversity of backgrounds and experiences across generations to help establish that dialogue and find innovative solutions to current and emerging global challenges.

Uchiyamada, Takeshi



Papadopoulou, Maria

Prof. Pedro Henrique Brancalion stated that at the forum, young leaders could be connected to some of the most brilliant minds of the time, and were inspired by the presentations. The interactions with laureates and leaders confirmed that high-level science and technology are a global collaborative enterprise, and members must work together to resolve common problems, but the bulk of high-level collaboration has occurred among limited groups of members. Finally, Prof. Brancalion commented that as a species humanity is great at resolving short-term demand over long-term demands. He concluded by expressing the hope that the forum can continue to advance science and technology in the coming years, that this forum can continue to be a high-level stage for discussions, and that we can



Brancalion, Pedro Henrique

overcome some of these barriers to achieve the full potential of humankind.

Prof. Serageldin concluded the 18th STS *forum* by thanking the participants, organizers and the Chairman for making the forum possible, and by sharing the Collective Statement. Finally, Prof. Serageldin explained that the 19th STS *forum* will take place from Sunday Oct 2nd to Tuesday Oct 4th, 2022.

Science and Technology in Society *forum* (STS *forum*)
18th Annual Meeting
Kyoto, Japan, October 5, 2021

Statement

1. The 18th Annual Meeting of the Science and Technology in Society *forum* took place from October 2 to October 5 live online from a base studio in Kyoto, with online participation of around 1,400 global leaders in science and technology, policymaking, business, and media from 125 countries, regions, and international organizations.

Analysis and Synthesis in Science—Earth and Commons

2. Humanity today is at a critical juncture. For a very long time, many of us believed that our economic development had been supported by a stable and resilient Earth system—our global commons. But the reality is that we have pushed the carrying capacity of this system to the breaking point. Earth's climatic, ecological, and human systems are converging towards an existential crisis for global civilization within the lifetime of children now living. To build a sustainable, inclusive, and resilient future, we must find ways to change how we live, and how we interact with the ecological systems we are all part of. We need to transform key economic systems and look for new social norms, so that we can be stewards to the global commons. Global governance is needed not only to manage the global commons, but also to assess the revolutionary changes that are coming in science and technology and how their deployment can help or harm different aspects of our lives.

Breaking Silos in Education

3. In terms of human activity, our knowledge base has shown the greatest growth from the 20th century onwards. However, knowledge is in a chaotic state, just like the pieces of a huge jigsaw puzzle. Education must break down the silos of organizations, subjects, or regions so that we can create a multidisciplinary approach to deal with the complex issues of our time and cultivate our ability to overcome known and unknown challenges

and attain the double goal of solving societal challenges while nurturing human resources.

Global Pandemic

4. Pandemics have always been part of human history; still, the COVID-19-pandemic came as a surprise to the entire world, and we must continue to confront the emergence of more virulent strains. At the same time, the threat of new pandemics is always with us. It has become obvious that effective systems of global disease surveillance, rapid reporting, and early warning are essential for preventing pandemics. Quick and effective communication is key in fighting a pandemic, starting with health care providers, and among scientific experts from both academia and industry. The science community must have an open dialogue with policymakers and ensure that clear messages are communicated to the public.

5. New or recent discoveries and approaches in biology, for example, mRNA vaccines and the use of CRISPR technologies in testing, have had a major direct impact on dealing with the pandemic. While science has been critical for vaccine development, understanding viral spread, and developing treatment, there have been many challenges. The impact of the pandemic has been felt by those directly affected, the health system, and national economies, and on global interactions and supply chains. The pandemic has taught us that we need collaborative systems that work in a crisis. It has also taught us that we must confront anti-science misinformation that uses social media and other platforms to obstruct the effective deployment of vaccines and remedies.

Advanced and Precision Medicine

6. Driven by new approaches such as bioinformatics and synthetic biology, medical technology is currently making great strides. The fusion of polymer chemistry and life sciences has created new drug delivery systems, which are expected to contribute to combatting central nervous system diseases. The mRNA vaccine, a possible game changer in the fight against COVID-19, was promptly and successfully developed by bringing together the best of these advanced technologies. We must discuss the advantages and disadvantages advanced science and technology bring to human life and health and how we can deal with them.

Energy and Environment

7. The 26th UN Climate Change Conference of the Parties (COP26) will be held in Glasgow, UK next month, calling for speeding up all countries' climate change efforts. Green investment is also gaining momentum in the business community. Nevertheless, additional efforts must be made to accelerate energy efficiency, provide access to clean electricity, and decarbonize industry and transportation. In particular, radical actions will be required, including strong incentives such as forcing users to pay the full environmental cost of their energy consumption, and targeted state interventions will be needed if we are to have significant reductions in the use of fossil fuels. The impact of significant changes in energy use on economic activity must be minimized by improving the quality of energy management, expanding renewable energy, and using hydrogen systems, storage battery systems, and possibly Small Modular Reactors (SMRs).

Resilient Society

8. Across the planet, societies are currently confronted with multiple challenges including the COVID- 19 pandemic, increasingly frequent extreme weather events, and escalating degradation of the biophysical environment. While these impacts are occurring across the planet, the ways in which they manifest themselves are highly location specific. For this reason, societies must find ways to adapt and develop resilience in the face of the specific challenges they face. Building resilience at the community level will require a convergence of science, technology, and social sciences with input from and engagement with civil society.

Nurturing Talent in Developing Countries

9. We discussed the various ways in which science and technology can be encouraged, taught, and moved into practice in the often-challenging environments of the developing world. In addition to just learning and becoming excited about science, ways in which practical outcomes through business development and research opportunities can both stimulate and nurture a love of science and technology and lead to true economic benefits were explored. Universities, businesses, and other developed-world institutions should engage with young people in developing countries by providing opportunities for visits, advanced education, and collaborative endeavors that can benefit all parties.

Collaboration

10. The United Nations' Sustainable Development Goals (SDGs) are a call for action by all countries in a global partnership to combat the urgent challenges we face. But these challenges interact among themselves, sometimes in a conflicting manner, and no goal can be truly dealt with in isolation of action on the others. Global issues cannot be addressed by any single nation or institution acting alone. The 2030 Agenda for Sustainable Development cannot be achieved without strong, coordinated collaboration between governments, industry, and academia. We must continue to strengthen this collaboration within and between nations to address current and future global threats.

Digital Economy

11. It is widely recognized that digitalization has unleashed a new wave of innovation with profound implications for existing economic models and that have impacted businesses, public organizations, and personal life. Emerging digital technologies such as the Internet of Things, artificial intelligence, and Big Data will lead to further disruptive innovation, creating many benefits for consumers and businesses on the one hand, but also generating new problems and policy issues on the other. In particular, AI has a wide range of potential economic and social implications, including new forms of economy and governance. An appropriate ethical and legal framework is needed to ensure that digital technologies are designed and deployed in an inclusive and transparent manner.

12. We look forward to convening again next year in Kyoto and have agreed to hold the 19th Annual Meeting of the STS *forum* from Sunday, October 2 to Tuesday, October 4, 2022.

Board Members, Council Members & Members

Board Members

Chairman

KOMIYAMA, Hiroshi, Chairman, Science and Technology in Society *forum* (STS *forum*); Chairman of the Institute, Mitsubishi Research Institute, Inc.; former President, The University of Tokyo, JP

Executive Director

FUJIKI, Kanji, Executive Director, Science and Technology in Society *forum* (STS *forum*), JP

Directors

ANZAI, Yuichiro, Senior Advisor, Director of Center for Science Information Analysis, Japan Society for the Promotion of Science (JSPS), JP

FRIEDMAN, Jerome I., Institute Professor and Professor of Physics Emeritus, Massachusetts Institute of Technology (MIT); Nobel Prize in Physics (1990), US

GRUSS, Peter, President and CEO, Okinawa Institute of Science and Technology Graduate University (OIST); former President, Max Planck Society for the Advancement of Science, DE

HOLLIDAY, Jr., Charles O., former Chairman, Royal Dutch Shell plc.; former Chairman of the Board, Bank of America; Chairman Emeritus, Council on Competitiveness; former Chairman and Chief Executive Officer, DuPont, US

KLEINER, Matthias, President, Leibniz Association, DE

KUMAR, Ashwani, Senior Advocate Supreme Court; former Union Minister of Law & Justice; former Member of Parliament (Rajya Sabha), IN

LEE, Yuan Tseh, President Emeritus, Academia Sinica; former President, International Council for Science (ICSU); Nobel Prize in Chemistry (1986), TW

LIM, Chuan Poh, Chairman of the Board, Singapore Food Agency (SFA); former Chairman, Agency for Science, Technology and Research (A*STAR), SG

McKINNELL, Henry A., Chairman Emeritus, Pfizer Inc.; Chairman Emeritus, US Business Roundtable; former Chairman, Moody's Corporation, US

McNUTT, Marcia, President, National Academy of Sciences, US

NURSE, Paul, Director and Chief Executive, The Francis Crick Institute; former President, The Royal Society; Nobel Prize in Physiology or Medicine (2001), UK

SASAKI, Nobuhiko, Chairman and CEO, Japan External Trade Organization (JETRO), JP

SERAGELDIN, Ismail, Founding Director Emeritus, Library of Alexandria, EG

TSUNAKAWA, Satoshi, Chairman, President and Chief Executive Officer, Toshiba Corporation, JP

UCHIYAMADA, Takeshi, Chairman of the Board, Toyota Motor Corporation, JP

WALLBERG, Harriet, Professor and former President, Karolinska Institutet, SE

YAMANAKA, Shinya, Director and Professor, Center for iPS Cell Research and Application (CiRA), Kyoto University; Nobel Prize in Physiology or Medicine (2012), JP

YOSHIKAWA, Hiroyuki, President, International Professional University of Technology in Tokyo; former President, The University of Tokyo; former President, National Institute of Advanced Industrial Science and Technology (AIST), JP

Auditor

OKIMURA, Kazuki, President, Japan Research Community for Science and Technology (JAREC); President Emeritus, Japan Science and Technology Agency (JST), JP

As of October 14, 2021

Council Members

In alphabetical order of individual names
(* Board Members / ** Auditor)

ABDUL HAMID, Zakri, Chairman, Atri Advisory; former Science Advisor to the Prime Minister of Malaysia, MY

ALBERTS, Bruce M., Chancellor's Leadership Chair in Biochemistry and Biophysics for Science and Education, University of California, San Francisco (UCSF); former President, National Academy of Sciences, US

***ANZAI, Yuichiro**, Senior Advisor, Director of Center for Science Information Analysis, Japan Society for the Promotion of Science (JSPS), JP

BLANCO MENDOZA, Herminio, President, IQOM, Inteligencia Comercial; former Minister of Trade and Industry, MX

CHUBAYS, Anatoly B., Special Presidential Representative for Relations with International Organisations, Russian Federation; former Deputy Prime Minister of Russian Federation, RU

CHUCHOTTAWORN, Pailin, Deputy Minister of Transport, TH

COLOMBANI, Pascal, Vice-Chair, French Strategic Council for Research; Honorary Chairman, VALEO SA, FR

COLWELL, Rita R., Distinguished University Professor, Center for Bioinformatics and Computational Biology, University of Maryland; Professor, Johns Hopkins Bloomberg School of Public Health; former Director, National Science Foundation (NSF), US

DIJKGRAAF, Robbert, Director and Leon Levy Professor, Institute for Advanced Study (IAS), US

DIRKS, Nicholas B., President, The New York Academy of Sciences (NYAS), US

DUSZYŃSKI, Jerzy, President, Polish Academy of Sciences (PAS), PL

FLANDRIN, Patrick, President, French Academy of Sciences, FR

***FRIEDMAN, Jerome I.**, Institute Professor and Professor of Physics Emeritus, Massachusetts Institute of Technology (MIT); Nobel Prize in Physics (1990), US

FUCHS, Alain, President, Université PSL (Paris Sciences & Lettres), FR

***FUJIKI, Kanji**, Executive Director, Science and Technology in Society *forum* (STS *forum*), JP

***FUJIMORI, Yoshiaki**, Chairperson of the Board of Directors, Oracle Corporation Japan; Senior Executive Advisor, CVC Japan, JP

GROS, François, Honorary Permanent Secretary, French Academy of Sciences, FR

***GRUSS, Peter**, President and CEO, Okinawa Institute of Science and Technology Graduate University (OIST); former President, Max Planck Society for the Advancement of Science, DE

GUTFREUND, Hanoch, Executive Committee Chairperson, Israel Science Foundation; Professor Emeritus, Physics, The Hebrew University of Jerusalem, IL

HAMAGUCHI, Michinari, President, Japan Science and Technology Agency (JST), JP

HANDOKO, Laksana Tri, Chairman, National Research and Innovation Agency (BRIN), ID

HARA, George, Chairman, The Alliance Forum Foundation; Special Adviser, Cabinet Office of Japan, JP

HASHIMOTO, Kazuhito, President, National Institute for Materials Science (NIMS), JP

HASSAN, Mohamed Hag Ali, President, The World Academy of Sciences (TWAS); President, Sudanese National Academy of Sciences (SNAS), SD

HAUG, Gerald H., President, The German National Academy of Sciences Leopoldina, DE

***HOLLIDAY, Jr., Charles O.**, former Chairman, Royal Dutch Shell plc.; former Chairman of the Board, Bank of America; Chairman Emeritus, Council on Competitiveness; former Chairman and Chief Executive Officer, DuPont, US

HÜTTL, Reinhard F., former Vice President, acatech - National Academy of Science and Engineering, DE

ISHIMURA, Kazuhiko, President, The National Institute of Advanced Industrial Science and Technology (AIST), JP

JOHNSON, Ray O., Chief Executive Officer, Technology Innovation Institute; former Senior Vice President and Chief Technology Officer, Lockheed Martin Corporation, US

KAJITA, Takaaki, President, Science Council of Japan (SCJ); Nobel Prize in Physics (2015), JP

KAZAO, Yukihiko, Director General, Science and Technology in Society *forum* (STS *forum*), JP

KIRLOSKAR, Vikram S., Vice Chairman, Toyota Kirloskar Motor Private Limited (TKM); President, Confederation of Indian Industry (CII), IN

*__KLEINER, Matthias__, President, Leibniz Association, DE

KOANANTAKOOL, Thaweesak, Advisor and former President, National Science and Technology Development Agency (NSTDA), TH

*__KOMIYAMA, Hiroshi__, Chairman, Science and Technology in Society *forum* (STS *forum*); Chairman of the Institute, Mitsubishi Research Institute, Inc.; former President, The University of Tokyo, JP

KRISHNAMOORTHY, Shankar, Executive Vice President in charge of Strategy & Innovation, Industrial Development, Research & Technology, and Procurement, ENGIE, IN

*__KUMAR, Ashwani__, Senior Advocate Supreme Court; former Union Minister of Law & Justice; former Member of Parliament (Rajya Sabha), IN

KUROKAWA, Kiyoshi, Chairman, Health and Global Policy Institute; Professor Emeritus, National Graduate Institute for Policy Studies (GRIPS), JP

*__LEE, Yuan Tseh__, President Emeritus, Academia Sinica; former President, International Council for Science (ICSU); Nobel Prize in Chemistry (1986), TW

*__LIM, Chuan Poh__, Chairman of the Board, Singapore Food Agency (SFA); former Chairman, Agency for Science, Technology and Research (A*STAR), SG

LIU, Peng, Managing Director, Sinocity Investment Limited, CN

MATSUMOTO, Hiroshi, President, RIKEN; former President, Kyoto University, JP

MAZUR, Eric, Balkanski Professor of Physics and Applied Physics and Dean of Applied Physics, Harvard University; Past President, The Optical Society, US

*__McKINNELL, Henry A.__, Chairman Emeritus, Pfizer Inc.; Chairman Emeritus, US Business Roundtable; former Chairman, Moody's Corporation, US

*__McNUTT, Marcia__, President, National Academy of Sciences, US

MURRAY, Cherry A., Deputy Director for Research, Biosphere2 and Professor of Physics, University of Arizona; Benjamin Peirce Professor of Technology and Public Policy and Professor of Physics, Emerita, Harvard University, US

NOYORI, Ryoji, Director-General, Center for Research and Development Strategy (CRDS), Japan Science and Technology Agency (JST); Nobel Prize in Chemistry (2001), JP

*__NURSE, Paul__, Director and Chief Executive, The Francis Crick Institute; former President, The Royal Society; Nobel Prize in Physiology or Medicine (2001), UK

**__OKIMURA, Kazuki__, President, Japan Research Community for Science and Technology (JAREC); President Emeritus, Japan Science and Technology Agency (JST), JP

PARIKH, Sudip, Chief Executive Officer, American Association for the Advancement of Science (AAAS), US

PETIT, Antoine, Chairman and CEO, National Center for Scientific Research (CNRS), FR

RIZA, M. Sc., Hammam, Principal Expert Engineer, Research Organization in Assessment and Application of Technology (OR-PPT), National Research and Innovation Agency (BRIN), ID

ROBERTS, Richard J., Chief Scientific Officer, New England Biolabs; Nobel Prize in Physiology or Medicine (1993), UK

RUBBIA, Carlo, former Director General, CERN; Professor, Gran Sasso Science Institute (GSSI); Nobel Prize in Physics (1984), IT

*__SASAKI, Nobuhiko__, Chairman and CEO, Japan External Trade Organization (JETRO), JP

SATOMI, Susumu, President, Japan Society for the Promotion of Science (JSPS), JP

*__SERAGELDIN, Ismail__, Founding Director Emeritus, Library of Alexandria, EG

SIRILERTWORAKUL, Narong, President, National Science and Technology Development Agency (NSTDA), TH

THOMPSON, Herbert Hugh, former Chief Technology Officer, Symantec Corporation, US

TOKURA, Masakazu, Chairman, KEIDANREN (Japan Business Federation); Chairman of the Board, Sumitomo Chemical Co., Ltd., JP

*__TSUNAKAWA, Satoshi__, Chairman, President and Chief Executive Officer, Toshiba Corporation, JP

*__UCHIYAMADA, Takeshi__, Chairman of the Board, Toyota Motor Corporation, JP

*__WALLBERG, Harriet__, Professor and former President, Karolinska Institutet, SE

__WALPORT, Mark__, former Chief Executive, UK Research and Innovation (UKRI), UK

__WINCE-SMITH, Deborah L.__, President & Chief Executive Officer, Council on Competitiveness, US

*__YAMANAKA, Shinya__, Director and Professor, Center for iPS Cell Research and Application (CiRA), Kyoto University; Nobel Prize in Physiology or Medicine (2012), JP

*__YOSHIKAWA, Hiroyuki__, President, International Professional University of Technology in Tokyo; former President, The University of Tokyo; former President, National Institute of Advanced Industrial Science and Technology (AIST), JP

__ZEHNDER, Alexander J.B.__, President and Founder, Triple Z Ltd.; Member, Board of Trustees, Nanyang Technology University; former President of the ETH Board, Swiss Federal Institute of Technology (ETH), CH

__ZERHOUNI, Elias A.__, former President of Global Research & Development, Sanofi SA; former Director, National Institutes of Health (NIH), US

As of October 14, 2021

Members

AUSTRIA
- AVL List GmbH

BELGIUM
- Solvay S.A.

CANADA
- Fonds de recherche du Québec
- National Research Council Canada

CHINA
- Huawei Technologies Co., Ltd.
- SHANGHAI GUOANG INDUSTRY CO., LTD.

FRANCE
- ENGIE*
- TotalEnergies

GERMANY
- German Academy of Sciences Leopoldina
- Robert Bosch Stiftung GmbH
- German Research Foundation (DFG)

INDIA
- Biotechnology Industry Research Assistance Council (BIRAC)
- Godrej Industries Limited
- State Bank of India
- Tata Consultancy Services Limited
- Toyota Kirloskar Motor Pvt. Ltd.

ITALY
- National Research Council (CNR)

JAPAN
- Ajinomoto Co., Inc.
- Chugai Pharmaceutical Co., Ltd.
- Daiichi Sankyo Company Ltd.
- Daikin Industries, Ltd.
- Fujitsu Limited
- Hitachi, Ltd.
- Horiba, Ltd.
- IHI Corporation
- Japan Innovation Network*
- JEOL Ltd.
- KANEKA CORPORATION*
- KDDI Corporation
- Kobe Steel, Ltd.
- Mitsubishi Electric Corporation
- Mitsubishi Heavy Industries, Ltd.
- Mitsubishi Research Institute, Inc.*
- Mitsui Fudosan Co., Ltd.*
- Murata Machinery, Ltd.
- NEC Corporation
- Nichicon Corporation
- Nippon Telegraph and Telephone Corp. (NTT)
- Nissan Motor Co., Ltd.
- Nomura Holdings, Inc.
- The Okinawa Electric Power Co., Inc.
- Osaka Gas Co., Ltd.
- Oracle Corporation Japan
- Panasonic Corporation
- REMOTE SENSING TECHNOLOGY CENTER OF JAPAN*
- Shimadzu Corporation
- Sompo Holdings, Inc.*
- Sumitomo Chemical Co., Ltd.
- Takeda Pharmaceutical Co., Ltd.
- Takenaka Corporation
- Tokyo Electron, Ltd.
- Tokyo Gas Co., Ltd.
- Toshiba Corporation
- Toray Industries, Inc.
- Toyota Motor Corporation

MALAYSIA
- Malaysian Industry-Government Group for High Technology (MIGHT)

NETHERLANDS
- Elsevier
- Royal Dutch Shell

OMAN
- Saud Bahwan Group

RUSSIA
- Fund for Infrastructure and Educational Programs (Rusnano)
- R-Pharm

SAUDI ARABIA
- Saudi Aramco

SINGAPORE
- NIPSEA Management Company Pte Ltd.

SOUTH AFRICA
- Department of Science and Innovation (South Africa)

SWEDEN
- VINNOVA

SWITZERLAND
- ABB
- Kudelski Group*
- Philip Morris International Management S.A.

TAIWAN
- Taiwan Semiconductor Manufacturing Company, Ltd. (TSMC)
- VIA Technologies, Inc.

TURKEY
- Arçelik A.Ş.

U.K.
- Anglo American plc.
- British American Tobacco Plc.
- Cytiva

U.S.A.
- World Resources Company

American Associates of the STS *forum* (AA-STS)
- Bristol-Myers Squibb Company
- Gordon and Betty Moore Foundation
- The Henry Luce Foundation*
- IBM
- Intuitive Foundation*
- The Simons Foundation*
- Thermo Fisher Scientific
- Underwriters Laboratories Inc.

* New members 2020, 2021

As of October 15, 2021

STS *forum* 2021 – 18th Annual Meeting Summary
Issued by Hiroshi Komiyama
Edited by Science and Technology in Society *forum* (STS *forum*)
Sanno Grand Building 419, 2-14-2 Nagatacho, Chiyoda-ku, Tokyo 100-0014, Japan
Tel: +81-3-3519-3351

Lead Sponsor

Sponsors

STS *forum* (NPO)
Sanno Grand Building 419, 2-14-2 Nagatacho, Chiyoda-ku, Tokyo 100-0014, Japan
Tel: +81-3-3519-3351 Fax: +81-3-3519-3352
https://www.stsforum.org/