Special Webinar: Progress and Future Prospects toward Deploying GEN IV reactors as Advanced Nuclear Energy Systems
Generation IV International Forum: 20th Anniversary Celebration

Patricia Paviet
So good morning, everyone. I see 5:30 a.m. for me. So, we are going to start this special webinar event, celebrating the 20th anniversary of the GEN IV International Forum. I am Patricia Paviet. I am a group leader at the Pacific Northwest National Laboratory and I am the chair of the GIF Education and Training Working Group. I am very pleased and very honored to introduce and moderate this webinar hosted by GEN IV International Forum, which global scope is progress and future prospects towards deploying [ph] these GEN IV reactors as advanced nuclear energy system.

From its inception 20 years ago, as a breakthrough concept, for sharing international programs on GEN IV reactor system until today, the GEN IV program fueled by governments and private sector investment has made considerable progress in collaborative research and developments.

I'm very happy to have a very talented and distinguished international panel featuring the current and former chair of the GEN IV International Forum. We will hear all the panelists giving some welcoming remarks, concluding remarks, and also the chair will share their experience as the chair of GEN IV international feedback. They will give some feedback and also they will provide some insights for the future deployments of these GEN IV reactor system. During the webinar, you the audience, can participate also and ask some questions in the question pane and also, I would like everybody to know that this webinar is recorded and will be available in the future.

So now, I'm very pleased to introduce all the panelist to you and I am going to start with the honorable Mr. Bill Magwood, IV, who is the Director-General of the Nuclear Energy Agency. Prior to joining NEA, he was commissioner at the US Nuclear Regulatory Commission and prior to that he was Director of the civilian nuclear energy program in the US at the Department of Energy. This is you, Bill, who had this fabulous idea to create, to have the vision for the GEN IV International Forum. So, thank you for that, Bill. And you were the first chairman between 2003 and 2005.

Our second speaker today will give also some welcoming remarks. Dr. Hideki Kamide, who is the Deputy Director General for Fast Reactor and

Advanced Reactor at the Japan Atomic Energy Agency. He is also a fellow of the Atomic Energy Society of Japan. He is the current chair since 2019.

I will then invite Ms. Diane Cameron, who is the head of the Nuclear Technology Development and Economic Division at the Nuclear Energy Agency to give some introductory remark on GEN IV International Forum. She was a GIF member for the policy group representing Canada. After these introduction, we will start our first panel decision and I will have four chairs joining Mr. Magwood and Dr. Kamide. We will have Dr. Yutaka Sagayama from the Japan Atomic Energy Agency, is the Taskforce Leader for Fast Reactor Development, Dr. John Kelly who is past President of the American Nuclear Society, and he was also the Chief Technology Officer and Deputy Assistant Secretary for Nuclear Reactor Technologies at Department of Energy. He was a chair between 2013 and 2015.

From France, we will have Mr. Christophe Behar who is Director for Energy at Fayat Group. He was Vice Chair for GIF between 2010 to 2015 and Chair early 2016. Mr. Francois Gauche, Vice President of CERCA and Supply Chain for Framatome who is also from France. He was the chair between 2016 and 2018.

Finally, the concluding remarks will be given by Dr. Fiona Rayment from the UK. She is the Chief Science and Technology Officer for the National Nuclear Laboratory. She has served on numerous International Advisory Panel and she is a GIF member on the Policy Group for the United Kingdom.

Patricia Paviet
So, without any delay, I am going to give the floor to Mr. Magwood for his welcoming remarks. Thank you.

Bill Magwood
Thank you very much, Patricia and it’s a great pleasure to participate in this 20th anniversary celebration of GIF. It is hard to believe it's been 20 years, but I guess it has. I don't like thinking about the time that's gone by. But I am pleased to be here because I remember back when I was chair, one of the things that I did was I signed an agreement to have the NEA Service Technical Secretariat. I had no idea that 20 years later I would be in this position facilitating this kind of conversation, but here we are. It's a great pleasure to welcome all of you from around the world watching this, great pleasure to share this webinar with close colleagues and former chairs and vice chairs of the GIF and we hope that all of you enjoy and learn a lot from the conversation coming today. So, Patricia, back to you.

Patricia Paviet

Thank you so much, Bill. I would like to invite Dr. Kamide who is our current chair for the GEN IV International Forum.

Hideki Kamide
Thank you, Patricia. Dear webinar participants, thank you very much for joining us and welcome to GIF 20th anniversary webinar. Today, we will show how GIF contributed to the Generation IV reactor development and how GIF R&D [ph] accelerated such development for the carbon-free, reliable, and sustainable energy supply against the climate change. It will be done through the international collaboration inside GIF and also the cooperation with other International organizations, IAEA, OECD-NEA, World Nuclear Association and so on. And furthermore, various stakeholders including private sectors. I appreciate also our GIF members and kind support members for great work for the preparation tonight and please enjoy today's webinar. Thank you very much.

Patricia Paviet
Thank you so much, Dr. Kamide. So let's have Ms. Diane Cameron giving us some introductory remark. Thank you so much, Diane.

We don't hear you, Diane.

Diane Cameron
Thank you, Patricia. Can you hear me now?

Patricia Paviet
Yes, we do.

Diane Cameron
Okay, wonderful. Thank you for the introduction and I'll just mention by way of introducing myself that I only just joined the Nuclear Energy Agency in March of this year where I now have distinct pleasure of overseeing the Generation IV International Forum Technical Secretariat. Prior to that though I was with the Government of Canada leading on Nuclear Energy Policy and in that role I had the distinct pleasure of serving as Canada's representative of the Generation IV policy group. So, my remarks here, I've been asked to provide a bit of an introduction to Generation IV International Forum or as some of us call it 'JIF' or as some others call it 'GIF.' So if you hear any of those terms, we are all talking about the same thing. For those of you who are new to this forum, I'll provide some introductory remarks and some of it will be based on my current role and some of it will be based on reflections after serving our policy group for 7 years. Turning to the next slide, please.

So, by way of introduction to GIF, what we are talking about is a framework for international cooperation in research and development for

the next generation of nuclear energy systems. Is everyone seeing the title slide or have we moved to the next slide?

Patricia Paviet
We see the title slide.

Diane Cameron
Could we move to the next slide, please? So, Generation IV International forum is a framework for international cooperation in research and development for the next generation of nuclear energy systems, originally created in 2001, with originally 8 members, now 13 member countries plus the European Union through Euratom. The original motivation was a recognition of the tremendous potential that could be unlocked by Next Generation nuclear innovation, but a recognition that no single country could achieve that audacious goal alone, that it would take international collaboration on R&D to break through these new disruptive and groundbreaking technologies. Turning to the next slide.

R&D collaborations under Generation IV International Forum have been structured around six types of Next Generation nuclear technology systems. Can we turn to the next slide, please?

Patricia Paviet
We may have a delay, Diane.

Diane Cameron
Okay, here we go.

So, those six systems already collaborations have been structured around six types of Next Generation nuclear technology systems. Those are very high temperature reactors, molten salt reactors, sodium-cooled fast reactors, supercritical water-cooled reactors, gas-cooled fast reactors, lead-cooled fast reactors. These areas of R&D have been complemented by an active program of collaborations in cross-cutting areas including economics and modeling, education and training, proliferation resistance and physical protection, risk and safety, safety design criteria, and recently R&D infrastructure. All with a view to advancing four goals – four rather audacious goals. Number one, around sustainability – to develop sustainable energy sources with minimum waste streams. The second, around economics – to develop nuclear technologies that can compete on the basis of lifecycle costs and that have manageable and competitive financial risk profiles. On safety and reliability, creating technologies that have a low likelihood and degree of reactor damage and that reduce or eliminate the need for offsetting [ph] emergency response. And a fourth goal around proliferation resistance and increased physical protection against malicious acts or would-be malicious acts. All with a

view to readying technology R&D for these reactor systems for potential industrial deployment by 2030, which is now just around the corner.

Work has been progressing for 20 years and the need for next generation nuclear technology is greater today than ever. As the world faces an accelerating and mounting climate change crisis, there is a need to replace coal and other fossil fuels. There's a need for deep de-carbonization of hard-to-abate sections of the economy with non-power applications of energy technologies, for resource extraction and heavy industry. There's a need to generate clean hydrogen for the hydrogen economy. There's an increasing need for desalination technologies and markets are signaling demand for simpler, safer, more affordable nuclear power and in some cases smaller nuclear power. Small modular reactors and advanced modular reactors could play a significant role if they are ready in time. There is a window of opportunity open now and it may close in the 2030s. There's a clear possibility that clean energy technology decisions by public and private sector will be locked in within the next 5 to 15 years.

So, there's an urgency to the work of Generation IV International Forum now. In 2001, GIF members knew that international collaboration was necessary to advance nuclear innovation. This is still true. Strategic partnerships are key to success including international collaboration; but increasingly, public-private partnerships, multi-sectoral collaborations and applying lessons learned from other sectors including digital transformation, advanced manufacturing and construction, and new business models.

I'll leave you with this closing thought. Twenty years ago, GIF started with R&D. As a former member country representative on the GIF policy group, I believe it is time to plan the path forward to demonstration and deployment to reach our goals of industrial build-up by 2030 and I look forward to supporting your continued collaborations to achieve this goal. I also look forward to hearing from the distinguished panelists for today's 20th anniversary celebration. Thank you very much.

Patricia Paviet
Thank you so much, Diane, for the excellent remarks that you gave today. And we are going to start our first panel discussion now. To the panelist, I will ask only one question to each one of you – just the same question, and I will give you the floor because of the timing. So, the purpose of this panel discussion is for the panelists to share with us their experience and feedback as chair and perhaps some initiative they introduced during their tenure. They will share their point of view about GIF principal findings, prospects, and outcomes. So, I would like to start with you, Bill, if you want. Thank you so much for your remarks.

Bill Magwood
Thank you very much, Patricia, and again, it's a great pleasure to have lived long enough to see the 20th anniversary of GIF. When I think about how all this got started, it grew out of a problem that we had in the US back in those days, which was that we had been required to restart our nuclear program. The nuclear program in the US really actually stopped for one year and I had the task of rebuilding it from nothing. And when doing that, it seemed quite reasonable for us to work with other countries. And so we began to put together bilateral relationships with key countries, particularly France was one of the first, UK, Japan, and we started to do projects together. And as I was going through all this, it occurred to me that if any of these projects were successful, we would want to deploy these technologies on a global basis. So would it make more sense to have a more global approach? So, I got on the plane, I flew to France and I visited with a gentleman that many of the French colleagues remember very, very well, Jacques Bouchard, who was the head of the CEA nuclear program back in those days. And I gave Jacques my logic. And one of the things I liked about him was that he immediately understood and in fact had gone past what I said and started talking about how one would market an advanced technology. And of course we had to get the regulators involved and of course we had to do. So we quickly sort of sketched out what we need to do.

And so I went back to Washington and started planning this thing out and getting all the right permissions and we made an invitation for countries, really almost all countries to come to a meeting in Washington, DC. That was in January of 2000 actually. That's how far back this is going. And all these countries sent representatives to this meeting and we were stranded in a Washington hotel, with 1 meter of snow outside because we ran into a blizzard and so we were in this hotel for two days, talking about this subject. And as all the countries gave their presentations about what they wanted to do, we saw all these commonalities and it became very clear that we were all doing the same thing and that we were all interested in very, very similar technologies. And the logic of GEN IV, of GIF was immediately apparent. Everyone saw it right away. And so it was really about a year later that the GIF itself really came together entirely after a few discussions.

The world has changed a lot in that period and the GIF, as Diane pointed out, was a research and development for cooperative work on different projects related to technologies, materials, fuels, whatever the subject was. But it was all driven by government laboratories, government ministries and over the course of time, we've seen the shift from the emphasis of government-driven research and development to more industry-driven research and development. And that I think is perhaps the challenge going forward, which I know we'll talk a little bit more, but I think that GIF is up to that challenge. The GIF still has a strong basis of

research and development, assets held by governments in terms of facilities and science expertise that is going to be necessary to be successful to deploy these new technologies. So, I think that what the GIF has accomplished still stands the test of time and is well positioned to assist going forward. And so I think that the GIF has been a success and will continue to be a success going forward.

Patricia Paviet
Thank you so much, Bill, for your remarks. I would like to invite Dr. Sagayama. You have the floor.

Yutaka Sagayama
Thank you, Patricia. So GIF's mission is to realize GEN IV reactors which requires achieving 4 development goals. So that's shown in the slide. Slide please. This slide shows the 4 development of goals. But the first one, the important point is we are focusing on sustainability. So, this goal is already described by Diane. So, only two points I will explain. With regards to the safety, we are focusing on the evacuation-free concept very aggressively. The 4 development goals are very ambitious and novel compared to those of the GEN III and GEN III+ fast reactors so that GIF's R&D items are mainly innovative technology that is used in the GEN IV concept for all member countries. And these R&D items are technologies in the viability phase or performance phase, not demonstration phase. The multilateral R&D framework like GIF is more suitable for innovative technology compared with evolutional one. This is because the technology we are currently using or close to commercialization requires solving IT issues. We could proceed with R&D without considering IT issues. So, I think these R&D items in GIF could have progressed well.

Could I add one.

In this context when I was the chair in GIF, autumn 2010, I started creating safety design criteria in the special group SDC Task Force. That was organized in PG. Initially, many GIF members seemed reluctant but the incident of Fukushima-Daiichi accident on March 20, 2011, all GIF members became aggressive. I believe that this attempt was successful and fruited by the effort of the people involved. And of course John succeeded me. Thank you.

Patricia Paviet
Thank you so much, Dr. Sagayama. You see that we are live. Sometimes I may go too fast. So, sorry. I will give the floor now to Dr. John Kelly.

John Kelly
Well thank you, Patricia, and hello everyone. Before I begin, let me thank all of those who have supported GIF over the last 20 years, and especially

those that helped me during my tenure as chair. I really appreciate working with all the people on GIF. Let me say that when I joined GIF 10 years ago, it seemed rather confusing and Diane hit on one of the points, which was some people call it 'JIF. Well, in the US, JIF is a form of peanut butter and I didn't think it was a good idea to have an R&D program that was associated with peanut butter, because that's a negative term in the US. So, let me move on.

It took me a while to understand all the dimensions of it. And part of the reason for that is GIF has taken international collaboration and cooperation to a new level, very high level of cooperation. And as Bill pointed out, it's multilateral. So this is a very new concept, and with that comes complexity. And so it makes sense that GIF has a lot of complexity. But during my tenure, I wanted to make GIF more relevant to its members. This was accomplished by engaging with the technical experts directly, broadening our leadership team – the executive leadership team to include other members such as Korea. And we also were recruiting Australia and the UK at that time to join in. I am glad that both of those countries have now joined GIF and I understand other countries are interested in joining as well. So this is very good for Generation IV.

Near the end of my tenure we decided that the each Vice Chair should have specific responsibilities, and I was assigned the responsibilities for regulatory and safety, and that gives me a nice segue into discussions on the safety. On the safety topic, when GIF was formed 20 years ago, one of the fundamental goals, as Yutaka has just said, and I viewed as a requirement that even in a severe accident scenario there would be no need for off-site evacuation. Basically, very limited or low core damage and no significant off-site radioactivity release. Now, this can be assured, even if all the active systems are inoperable, if the decay heat can be removed. This is accomplished through passive systems. That is, that they only rely on natural processes such as gravity but these must be included in the design from the beginning. Now today, I'm happy to say that each of the concept has a different approach, but all meet this requirement. And by including passive heat removal in the design, accidents such as Fukushima are not physically possible in GEN IV systems.

Now, I think we recognize, as Sagayama said, that we needed more than just a goal, and he began the working group to develop safety design criteria. We also develop methodologies in our working group design criteria and guidelines and that work progressed under my tenure. But I think the important point that Bill mentioned was that we needed to engage the regulators. And so that was one thing that we began which was when I was the Vice Chair was to really engage with the regulator

community through the IAEA and through the NEA committee on nuclear regulatory authorities. And that was started about a decade ago.

And I can tell you that when we started the dialogue or asking to talk to the regulators about GEN IV systems, they weren't interested. They didn't see GEN IV as coming in their near future, so they had no time to devote any resources to it. But thanks in part to Bill's help and others, we got them to engage, and today the situation has changed radically given the interest in the industrial sector, commercial sector in GEN IV systems. So, I believe that the foresight that we had in putting safety first position us very well now to look at the demonstration and deployment phase with the GEN IV system. I'll turn it back to you, Patricia. Thanks.

Patricia Paviet
Thank you so much, John. I would like to have Christophe Behar from France sharing his feedback and experience.

Christophe Behar
Thank you, Patricia. Hello to everybody. It's a pleasure for me to be here among you today. I will talk, as you said, as a previous member of GEN IV forum, but as well as what I am now President of the French Nuclear Supply Chain because it was the opportunity for me to discuss with my colleagues from industry. I think that GEN IV reactor will face a strong competition with GEN III reactors, and this is probably during many years for the production of electricity.

Why? Essentially for three main reasons. First of all, the fleet of reactor which are classically used all around the world are light-water reactors. Second, producer of electricity will not invest easily in new types of reactors. And third, probably the building cost is higher than the one of light-water reactors. But on the opposite, I think that there will be some reasons which are able to push to build that type of reactor. And if I focus now to fast-neutron reactor, which I believe will be probably the main feature of GEN IV reactor, I would like to underline a few reasons why fast-neutron reactor for GEN IV may be deployed.

The first one is probably the strong help for the management of high level radioactivity waste. It means their ability to burn minor actinides. I know that many countries stopped that kind of work, but I think it's a very good task for that type of reactor and more specially for the public, the people in the street.

Second of all, I think that for the countries which already use MOX fuel for light-water reactor, as you probably are all aware. Those reactor are able to burn spent MOX fuel. Now, they are not sure it will be possible to burn spent MOX fuel in light-water reactor or not very easily or with high cost.

But those reactors are able to do that. And the third reason is uranium. When the cost of extracting uranium will become high enough and because those reactor are able to burn while producing electricity depleted uranium, spent MOX fuel as I said, and so on, they probably may be built to replace step-by-step light-water reactors.

Just a few words if I may as a conclusion. I would like to say that in my mind in a country like France, for example, GEN IV fast-neutron reactor will be deployed at first probably participate to the closed fuel cycle and waste management. It is the first reason. And second reason after, because of uranium, as I told before, they will be deployed, they will be used to produce electricity. Thank you very much.

Patricia Paviet
Thank you so much, Christophe. I would like to invite Mr. Francois Gauche to share his experienced as chair of the GEN IV International Forum.

Francois Gauche
Hello Patricia and hello everybody. I am very pleased to be with you today. When I chaired the Generation IV International Forum, I was very honored because if you see this list of countries that are around the table, we have a set of impressive national and also European research and development programs that are there. Some of the results are shared, let's say, for contribution to the forum. This is a very important point and let's say the power of research that is available at GIF, I think is impressive and is unique. And for me, we all need safe, innovative, sustainable, competitive, nuclear, which means de-carbonized energy systems to support the well-being of the world's population while fighting against climate change. And for me, GIF is a unique place for the international collaboration industry.

The GIF is also very official international body, and what strikes me, it is a mixture of vivid technical exchanges at the level of the so-called project management goals, but also add sometimes to the policy group and there is also certain formalism associated with GIF. But there are other communities we need to engage with, and we tried and we launched a few initiatives starting with [Unclear] but also who have followed by [Unclear] in particular, and of course, we needed to engage with young generation and Patricia, you are well placed and know about it and so the Education and Training Taskforce which became working group after that. There was a GIF Symposium in 2018 to present, inform, and educate audiences, let's say, the young GIF community. But we felt and we had some discussions about it that we also need to connect ourselves with all the new companies, the entrepreneurs and the startups that were developing, and still are advanced reactor projects particularly in North America and in the UK. The follow-up of our discussion was the

organization of a roundtable discussion between the policy group and small modular reactor vendors back in 2019, and also international several workshop in the nuclear industry including SMR vendors and also supply chain small and medium-sized enterprises in beginning of 2020.

So, the collaboration is not only of course with other important international organizations, such as OECD, NEA or IAEA or World Nuclear Association, but we also need to engage and continue to engage with young generations and also with the private sector big companies but also all the set of new companies we can see for the last decades and I hope they will be successful – some of them would be successful in the next decade. Thank you very much.

Patricia Paviet
Thank you so much, Francois. So our last panelist, Dr. Kamide, I am inviting you to share your feedback as the chair.

Hideki Kamide
Thank you, Patricia. Sustainability is the key of Generation IV reactor systems. I talked to the sustainability of fast reactor in last year IAEA General Conference Scientific Forum. It is crucial to express that Generation IV reactors can contribute not only the carbon-free electricity production but also the reduction and high level waste of long term radioactive nuclei by actinide by burning in the fast reactor core as Behar-san noted before.

Last two years, we have approached to the people and policymakers worldwide to such chances, IAEA, Clean Energy Ministerial and NICE Future Initiative. I believe that these talks and documents throughout the world is a role of the international organizations of GIF. As for the R&D, we have launched an R&D taskforce since 2017 and had a workshop with the participants from power company, reactor vendors, and regulatory. The key issues picked up there are [Unclear] and qualification of evaluation methods and efficient communication with the regulatory in the development phase. We will enhance such activities in GIF. Thank you.

Patricia Paviet
Thank you very much. So, I think it's already 6:08 for me. It's going fast. So, I think we're going start directly our panel session 2, and we are going to look now with our panelists the prospects for deploying these GEN IV reactor systems. So as we prepare for the deployment of GEN IV reactors, how best should we proceed with the development programs worldwide? So, I will have questions for each one of the panelists. And Bill, I am sorry, I am going to start again with you. What is your view, Bill, on the role of GEN IV reactors in the frame of long CO2 energy mix? Why is GIF exceptionally attractive to foster climate change and perhaps

which sustainability after 2050. Thank you, Bill, in advance for your answer.

Bill Magwood
Thank you, Patricia. Let me also just take a moment to thank my colleagues for their comments. All contributed a great deal to the work of the GIF and it is GIF. It's not JIF, that's peanut butter. And let me just take a quick moment to also particularly recognize Dr. Sagayama. He was one of the key partners when this all began many, many years ago. It was really he and Jacques Bouchard and I that laid the ground for what became GIF, working very closely together for quite some time. And it's a pleasure to have him join us today. I think that the answer to your question is both difficult and easy to answer at the same time. Easy, because the need is clearly there. There is no question that the world needs these technologies to be successful, to be deployed in large numbers, and to be used around the world. I don't think there's any question that the world would benefit greatly from that for a variety of reasons.

The only issue is can we get it done. Can we deliver? I think there are still reasons to be concerned because the framework of research and development around the world over the last 20 years has seen a tremendous decline. If you look where we used to be back in 20 years ago. And most country's investment in nuclear research and development has plummeted, has gone down quite substantially. And it is only because the private sector has picked up the baton because there were individuals in the private sector, entrepreneurs who felt that there was a gap to be filled, that this conversation has been revived. Because just five years ago, it was very little conversation about advanced reactors because governments had largely abandoned the field. There are only a few governments who are still investing significant amounts of money in these areas but the most had stopped. And the private sector saw that and moved into the void. And now we have 70 different concepts around the world of small and advanced reactors where entrepreneurs believe they have the technology that will meet the needs of the future. And about half of those technologies are GEN IV technologies. And just think about this. So we went from a place where very little was happening, where most work on large demonstration projects had stopped in most of the countries – not all because obviously among GIF, China continued to invest quite heavily in GEN IV technologies. Russia has had some tremendous success in fast reactors, but the most of the rest had stopped. And so now we have 30-odd GEN IV development projects around the world, which is truly remarkable. And many of those are not what I consider to be the easier technology, the high temperature gas reactors which I can say are a little bit easier because the fuel now exists. We know how to make triso fuel very well. But also the more exotic, what we

saw at the time when GIF was created, the more exotic technologies like molten salt reactors.

When GIF was formed, molten salt reactors was sort of the stretch goal. It wasn't in the heart of the program. It was this ambitious idea for the long-long-term future, maybe 50 years from now. But there are companies investing money and who believe they can deploy these technologies within a decade or so. And that's a whole new world.

So I think that the prospects for GEN IV reactors are very, very good if the world is able to get them completed, deployed, regulated in a timeframe that meets the needs of the world. And if that can happen, I think that the prospects for success here are extremely high because the need is clearly there. There is no question. The question is, can we deliver and we have to prove that.

Patricia Paviet
Thank you so much, Bill. I will tell now a question to Dr. Sagayama. In your opinion, what are the R&D breakthrough needed to accelerate GEN IV deployments and the needs for the next 10 to 20 years?

Yutaka Sagayama
Okay, thank you. Technical innovation is the important point to realize or commercialize GEN IV reactors because it is important to meet 4 development goals, especially safety and the economic development goals at the same time. SFR is the most promising concept in the near future so that a lot of countries are pursuing to commercialize SFR within 2030, 10 to 20 years from now on.

When promoting SFR cooperation, it may be necessary to have a cooperation mechanism that goes beyond the conventional framework of GIF R&D. For example, to create a mechanism to protect R&D knowhow, it means to make more specific R&D group. So, another point is to achieve the sustainability goal we need fuel recycling by using fast reactors, but the fuel cycle R&D has delicate political elements, so it may not be suitable for GEN IV cooperation framework unfortunately.

Bill explained, SDGR [ph] or such kind of idea is one idea. In addition to this, I'd like to make another suggestion. The maintenance criteria will be important for GEN IV reactors in addition to safety design criteria. So advanced in-service inspection criteria, particularly important for GEN IV systems with opaque coolant and/or high temperature shutdown condition. My suggestion is that GIF should support to realize GEN IV reactors not only in GIF country, but also worldwide. The deployment timing of GEN IV reactor will depend on the decision in each country, of course, but safety design criteria and maintenance criteria as a world standard will be very beneficial to each country. GIF should take on this role. Thank you.

Patricia Paviet
Thank you so much, Dr. Sagayama. I would like to turn now towards Mr. Francois Gauche. Francois, what are the opportunities of GEN IV reactors in the small modular reactor markets. Do you see any opportunities for non-electric application?

Francois Gauche
Thank you, Patricia. I am not sure I will have the time to answer completely. For me, there is a growing understanding worldwide that is of course not uniformly distributed. Nuclear energy will be needed in a massive manner to fight against greenhouse gas emissions. Is it feasible to say that all the needs will be covered by existing mature technologies? Of course not. So I am convinced that there is room for Generation IV systems since they can provide the additional features that were mentioned in particular, on sustainability, safety, and competitiveness. Looking ahead and preparing for the next generation of technology is not only a possibility. This is a duty we have with regard to the next generations of people since as you know the development times for nuclear systems can be very long. The R&D at the laboratory is not sufficient. The demonstration is a key step. We can already see several projects that are based on Generation IV technologies, that are being developed in the world. Some of them at the stage of construction or even start-up phase, not to speak about existing experimental reactors.

When I look at the map of small modular reactors of micro [Unclear] projects in the world, I see something very dynamic, mini projects that use GEN IV technologies. Inside the GIF, we can also mention projects that were shared together and that are, technically speaking, they belong to the SMR category. So, advanced reactor systems of limited size, up to 300 electric megawatt can be the path forward towards demonstration of GEN IV concepts. I am convinced that before 2030, several such projects will come to light in the world and show the complementarity between existing mature technologies and GEN IV concepts. Thank you, Patricia. I give you the floor now.

Patricia Paviet
Thank you so much, Francois. So now, Dr. John Kelly, we are in the post Fukushima era and we would be interested to hear about how could we rebuild and keep the confidence and acceptance of the public. Also, as chair of the GIF Education and Training working group, I am interested to hear about how can we engage the younger generation with the future leaders of tomorrow and how could we communicate positively about this GEN IV reactor system?

John Kelly

Well, thank you, Patricia. I too think that the outlook for Generation IV commercial demonstration and deployment is particularly good and getting better every day. Right now, China is doing hot functional testing of the HTR-PM which will be the first demonstration of this new generation of reactors. And the US it has launched a major reactor demonstration program that promises to demonstrate two of the GEN IV reactor technologies. And with this worldwide interest in innovation to combat climate change, I see GEN IV reactors as well situated in the future marketplace. Now, one thing that's been mentioned and is really something that's evolving is this view of reactors to move from beyond just electricity production to also other non-electric applications. And with that comes the idea that in the past, light-water reactors basically supplied electricity and they hoped that people would use that electricity. Now, our innovation is looking at the commercial needs to de-carbonize and bringing nuclear technology to those needs. So, it's really a different view of how nuclear can contribute to de-carbonizing not just electricity, but industrial processes as well.

Now, let me say that in order to have successful deployment and demonstration of GEN IV reactors, we were going to need several factors. We've heard about the climate driver. Public acceptance can be very important as is financing, technology, etcetera. So, let me talk about public acceptance. And I am not an expert in the social sciences but I know from personal experience that at least people, I am talking about people in the US, know two things. One thing is that climate change will be bad. And number 2, maybe nuclear power can be part of the answer. And so that debate has opened up. And so very important for us as we engage in this debate, be clear and have honest communications with the public on the role that nuclear power can play. Now for the general public, GIF itself needs to take a more public-facing attitude and be willing to go out to public forums to talk about GEN IV and why it is so important to the world's future. We've thought to ourselves a lot. We need to be outward-looking. And with innovation being part of the solution in people's minds to combat climate change, I think our message will be well received because it's so easy to point to all the innovation within GEN IV. And for the young generation and those considering a career in just science and technology, we need to provide those opportunities for them to have successful careers both professionally and personally in nuclear science and technology. Many young people have told me that they went into nuclear field in order to save the planet and we need to help them in that quest. Given the concerns about climate around the globe, this will be an issue that I believe will be around for a long time. It's not just a 2020 decade problem. It's going to be a long, long time.

And so, we need to be thinking about those young people, school-aged children, and we need to introduce nuclear and science and technology education very early in the process of education. In US, we've launched

such a program – video training programs that are distributed to about half the schools in the US that introduce nuclear science from children that are just beginning school to those that are graduating and going to college. And we've been discussing these programs with our international partners and on the importance of really teaching the early people, early students in their education about nuclear, and with that I'll turn it back to Patricia. Thank you.

Patricia Paviet
Thank you so much, John. Christophe, you touched a little bit about that in your first remarks. What are the opportunities with GEN IV reactors for closing the fuel cycle and improving waste management.

Christophe Behar
Sure. Thank you, Patricia. So you are right. I introduced those points in my first talk. Now, I would like to give one more perhaps explanation into two main points. First one is the kind of resume of my first talk, is no deployment of GEN IV feed very soon. Second point is, then as I explained before, they will be used at first for high-level waste management, and when uranium will be a rare resource. To answer your question, in my opinion, what are the principle issues to tackle? The first one I think is the cost. I do believe that the cost of electricity produced by GEN IV reactor is higher now to the cost of electricity produced by light-water reactor. So the cost has to be one of the most important thing, that is to decrease the cost of course.

The second one is safety. You know, I've heard many times in France GEN IV is a very good marketing name. And when I asked why, they told me because you move from generation to generation because you increase safety. So, GEN IV reactor will be more safe than GEN III reactors. That's why in my opinion we really need to work very deeply on safety to be able to demonstrate that those reactor are safer than the reactor which are in use. Thank you.

Patricia Paviet
Thank you so much, Christophe. Dr. Kamide, my question to you regarding the second panel session. How can we make GEN IV reactors extremely competitive in the market, and how can we develop a better and smarter connections with the private sector?

Hideki Kamide
Thank you, Patricia. I believe nuclear can assist and support the variable renewable energy so as to extend both with a carbon-free energy source to a large value of energy mix because of the long-term and the stable energy source of nuclear. Generation IV reactors has higher temperature of operation than in conventional power reactors. This high temperature is important and allows higher efficiency of heat utilization, like heat

storage using molten salt heat tanks, industrial heat use including the hydrogen production. Such non-electric application of nuclear heat, we call it NEANH, can provide higher flexibility of nuclear and contribute to grid stability including the frequency stability so as to compensate the variable renewable energies. Such flexibility will fit the market demand and contribute to the higher economy of Generation IV reactors.

As you can see, this graph shows matrix of non-electric applications of nuclear heat. We have six types of reactor systems like sodium-cooled fast reactor and very high temperature reactor and so on. In the middle, each of the system can have three level of the reactor scale – large power reactor, SMR, and micro reactor. The right hand side is the application like hydrogen production, seawater desalination, and so on. These matrix can provide a wide spectrum on the discussion table for non-electric heat applications. We will be able to discuss cross-cut of R&D issues and also the regulation issues. We will have a special taskforce for NEANH and also the plan forum on GIF Industry 2022. I hope that many of the participants from industry, power companies, reactor vendors including SMR for better collaboration. One of the idea for efficient development was proposed by a member of regulatory last year, GIF Workshop. It is a possibility to carry out the experiment of code qualification and validation by developer together with the regulators. Such cooperation also contributed to the better understanding of Generation IV reactor characteristics for the regulators. Thank you.

Patricia Paviet
Thank you so much, Dr. Kamide. So, I would like to thank the panelists for the two wonderful sessions that we have, and I would like now to invite our audience to ask questions. It's very important so that you – that I don't see right now participating also and you may have some more questions for our panelists. So let me look at my chat box and I have one question and I will ask John or Bill, if you want to answer. What issues are challenging but have not been properly addressed.

Bill, I don't hear you.

Bill Magwood
Sorry about that. That's a very interesting question. I think certainly there's a lot of technical issues that need to be addressed but I think that from a research and development standpoint, the single-most important issue will be materials. What materials will be needed to make some of these advanced concepts economically viable and are there materials that might be accessible to us that haven't gone through the validation process. So, perhaps one thing that the GIF can begin to look at is how to accelerate the adoption of new materials in GEN IV systems. This is something that came up a long time ago, particularly as we were looking at high temperature reactors in hydrogen production, and we saw many,

many opportunities from these materials particularly as temperatures went higher and higher. And so, I think if there were a way of quickly using these materials, getting these new high temperature materials into use as quickly as possible, I think that would contribute a great deal to the whole GIF agenda.

Patricia Paviet
Thank you so much, Bill. John, would you like to add something here?

John Kelly
Let me add just a couple of thoughts. First, financing of a nuclear project is one of the barriers that we have to overcome. We expect government to help on demonstration phase, but really to get to deployment phase we are still looking at financing as being a major impediment. It's currently an impediment for our Generation III reactor deployments in different countries. That said, how do we get over that? Well, reducing the capital cost is the key and we do that through innovation in the technology, but also perhaps having designs that are smaller so that by small, we have lower capital cost. That's one of the drivers for the small modular reactors. And I agree with Bill that the materials are going to be the key to achieving lower capital cost. Because Generation IV reactors by themselves typically have higher temperatures, so their thermal to electric efficiency is higher, which gives them an advantage if the capital cost is the same. If we can get lower capital cost, we can have a significant cost advantage. But getting the capital cost competitive is going to be important.

And then how do we do that? I think GEN IV can't do it alone, and I think we recognize that we needed to form partnerships with industry people, because we need to have that user and supplier, and eventually the technology onboard so that we understand the markets much better. And this can help then drive the innovation within our program. Now I'll turn back to Patricia, maybe there are some additional questions.

Patricia Paviet
Yes. Thank you. Maybe another panelist would like to add something to Bill and John's answer. Opening the floor. So, let me look at the next question. Bill, you are always famous so I see that it's again for you.

If it was to be re-done now, what would you definitely keep and what would you change in the GIF creation? It's tough, isn't it?

Bill Magwood
That's a tough question. The audience is challenging us today. One thing that I would definitely keep is the very broad group of countries we brought together. I think the largest group of countries that have serious R&D programs and technology expertise that you can put together and

cooperate, I think we would keep that. Something that I might change – maybe two things. One, and someone, I forget which panelists mentioned this, it might have been Kamide, I forgot who it was, but someone mentioned the codes and standards. We did not have a focus on the practical issues like codes and standards and I wish we had. I think that if GIF have had 20 years ago a much more practical focus on deployment, and that would have meant looking at codes and standards, it might have been able to not just simply pave the way for GEN IV systems but it might have made a big difference for nuclear overall because there really was this group of countries with the expertise that they had, might have been in place to really begin to get our arms around how to harmonize codes and standards and how to advance that aspect of work. So that's one thing in hindsight which we had taken on.

A second thing which was not possible at the time because it was a political issue for us, and that is really focusing on how we were going to get to demonstration. The GIF by design on purpose avoid discussions about demonstration of any of the GEN IV concepts. That was very clearly part of the political deal for this to go forward. But in hindsight, I wish we had been able to get past that. Because what my personal experience is that if you are doing research without the discipline, trying to get to a demonstration, then it's hard to focus the work. It becomes very diffused and it moves in all kinds of different directions because you are not mission focused.

So, I wish in hindsight if GIF had had the discipline of a demonstration at the end of the day, to act as a discipline, to focus the research, to make it more practical, to prioritize and to move in that direction. I wish we'd been able to do that. I know we weren't going to be able to 20 years ago but that's one thing I wish we would have been able to do. I think it would have made a big difference.

Patricia Paviet
Thank you so much, Bill, and you are totally right. This is what I say always to the students or people working with me. Nuclear energy, we need to have a goal something at the end. We want to demonstrate. That's what we like to do. So thank you so much, Bill. I have another question for Dr. Kamide.

John Kelly
Patricia. This is John. I'd like to add one thought. One thing that we did in GIF was to assume that we would have the appropriate testing facilities available. And over time we've seen that the available facilities have become very, very limited. Those that were planned haven't been completed. And this is especially important for the materials science that Bill was talking about before, that you need to have fast neutrons in the right environment in order to test materials, not only for fast reactors but

to do accelerated testing on materials for other applications. And we've sort of gotten on the bandwagon of using accelerated facilities to do that which are which are useful, very useful but we still need those fast-neutron reactors for testing purposes. And that's one thing that GIF I don't think put enough emphasis on was those facilities. And one thing you asked about, what could we get rid of? Well, it's difficult to say that we didn't do anything, but I think the idea that there is something called 'proliferation risk' is something that the world community really hasn't bought into. We all understand the concerns of proliferation, but they are not unique to GIF. And so I think, emphasizing the security and physical protection, material control, these are things that are tangible and things that we can do in order to minimize the probability of a proliferation. Anyway, that's one thing that I think was emphasized very early on that probably today there's a different perspective about that. Thank you.

Patricia Paviet
Thank you so much, John. So, I feel obliged to ask the other panelists. Would you like to share also some view? No? So, now I am going to Dr. Kamide. Dr. Kamide, do you expect other countries joining in? Other member countries to join the GEN IV?

Hideki Kamide
GIF welcome to join the countries who is going to develop their Generation IV reactors really within the development program inside their country. And GIF has a mutual beneficial contribution together and such a collaboration will enhance the development of Generation IV reactors. So, we are very welcome to the new member countries, who is a really watching on to the development of Generation IV reactors. Thank you very much.

Patricia Paviet
Thank you very much, Dr. Kamide. I have a question for Christophe. Christophe, how do we bring the cost and the build time down? How do we ensure the investors and taxpayer that the project will not become overbudgeted and will run over time?

Christophe Behar
So, this is a general question, right?

Patricia Paviet
Yes.

Christophe Behar
Nothing especially for GEN IV reactor. I can answer to that. First, standardization is very important. Second, we have to move very fast on the learning curve. That is, a curve where when you build more and more reactors, the same reactors, of course, you decrease your cost. We can

estimate these up to four to six reactors for light-water reactors. Having said that, we face some problems. What is the major problem? Major problem is nuclear safety authority. Because depending on the country, the nuclear safety authority may ask different things. So, it's very difficult if you only build your reactor outside the country worldwide to decrease your cost very fast by standardization or by learning and moving down through the learning curve.

That's why what I said – standardization and moving down because building several reactor, 5 or 6 is important, but you have to do this under the same nuclear safety authority.

Patricia Paviet
Thank you, Christophe. Someone else would like to add something about how to bring down the cost and the times to build reactors. No? So, let's go to the next question for Mr. Francois Gauche. How can we better involve the licensing aspects and regulators in the GIF organization?

Francois Gauche
Actually, I will follow up on the remarks made by Bill and by Christophe. I think we should have at some point in time a target to come up with a kind of unified international framework for licensing including codes and standards. This is very ambitious to say it like that and in some cases it is not necessarily wanted by some countries and so on. But I think if we really follow the argument that at some point in time we really need massive nuclear energy to fight against climate change. At some point in time, we need that. As Christophe mentioned, it is not possible to bear the cost of new licensing including the design changes that come out of that, that are very disturbing to the different projects each time we want to install design in a new country.

And this I think it was said, could be I think by Bill, you mentioned that, it could be the place we need to do so. And I must say, the work has already started since it was the initiative led by Sagayama-san on the safety design criteria. So, it was first a taskforce of sodium-cooled fast neutron reactor experts trying to exchange on very specific concepts on safety of those reactors and so on. Then they came up with a unified document. Then they said, "Okay, we are going now to guidelines." Then, "Oh, by the way, can we share this document with regulators?" As it was said at the beginning, it was very difficult to involve the regulators. But in the end I remember at least for the French case, this document was reviewed by the expert IRSN as you know, it was even discussed inside the policy group of these.

So bit by bit, I think GIF could continue to position itself on this subject with a view to coming up at some point in time. Maybe it will take long to have international regulation on that.

Patricia Paviet
Thank you, Francois. Do we have another panelist who would like to add something for the licensing aspect? I see your hand and Dr. Kamide.

Hideki Kamide
Let me add one more thing. We have started from the SFR for the safety design criteria and now we are expanding to other reactor system, renewable HTR and recently lead-cooled fast reactor, LFT safety design criteria was going to the review by IAEA started, and also the vHTR also and MSR also with some discussion for the safety design criteria. This is expanding to all of the reactor system and it will contribute to the deployment agree...

Patricia Paviet
Thank you, Dr. Kamide. John?

John Kelly
Yes, so GIF has made I think a good start in this area. But as Francois said, it takes a while. And as Bill indicated, we needed to get to the codes and standards and really there's the codes and standards by organizations such as ASME but there's also the codes and standards that are accepted by the [Unclear] members. And I think GIF recognizes that each country has different national laws related to nuclear safety and each country can't expect GIF to change their laws. But below the legal level is the working level, the operating level. I think this is where GIF through the safety design criteria guidelines for the different systems can play an important role. Because it again is a starting point to have those discussions with each of our national regulators. So, if behooves each of the GIF members to be establishing that relationship with their regulatory authorities in their countries and begin to transmit all of the concepts, ideas, to the regulator. So the regulators begin to take Generation IV regulation seriously because they have a lot of work to do to put in place regulatory frameworks, guidance, and other documents so that as licensees come forward, the regulator is prepared for the review and approval of those designs. If they wait, there will be a huge disconnect. So, I think we are doing the fundamental work that provides that opening of the door with our national regulators to begin to help them move towards establishing in each country, what's needed for the demonstration and deployment of GEN IV reactors.

Patricia Paviet
Thank you, John. Yes, Bill, please.

Bill Magwood
I'll try to make three quick points and kind of a different inference. First, something is happening right now. Due to John Kelly’s efforts when he

was Chair, the NEA Committee on Nuclear Regulatory Activities has engaged in this discussion about advanced reactors. And one of the first really important products is about to be released. So I'll give a little preview of this. A document that represents the collective wisdom of many of the regulators involved and our work are coming out with two reports, looking at the safety aspects of sodium fast reactors, both from a regulatory standpoint in terms of operations and access scenarios, things like that but also looking for fuel and how the fuel might be approved in the future. So, very important guidelines where the countries have come together, the regulators have come together and taken common positions on how these things should be approached. So, it's a very, very important step towards international agreement on licensing GEN IV reactors.

Also, I think is important to point out that many, not all, and this is a problem but many regulators have taken substantive action to prepare themselves to license these technologies. And they haven't done it together. They are doing it separately for most part, and we're working on that as you heard but there are several that have taken very, very substantive action. So, if these technologies were to show up in, say, 5 or 10 years, there's a handful of regulators will be ready to deal with it and are ready now to take on the task of licensing these technology. So, it's not – I don't want to leave the impression that we are completely unprepared. We're not as prepared as we should be but there are regulators who are prepared to deal with this.

And finally, if you wanted me to start telling GEN IV stories, I could spend the entire 1-1/2 hour on GEN IV stories. But I will share just one and that is that this is not something that was oblivious to us years and years ago. And probably the second or third formal GEN IV meeting which was held in Toronto as a matter of fact, we invited three of the world's top regulators to come talk to us about this. And Andre-Claude Lacoste from ASN in France, Linda Keen who was the Head of the Canadian Nuclear Safety Commission, and I forgot the American. He's going to kill me. John, help me out.

John Kelly
When was this, 10 or 20 years ago?

Bill Magwood
This is really embarrassing. I am having a senior moment here. He's going to call me and he's going to give me a hard time because I can't come up at the moment.

But the three of them got together and they engaged in Generation IV International Forum, and we had very, very substantive conversation and we were hoping that they were going to work with us, but in the end they

ran off and created the MDEP [ph] instead. So, they didn't engage with us because they were much more interested in current technologies.

So I just wanted to reflect this. This was a conversation 20 years ago. But at the time the regulators really weren't ready to engage in advanced reactors because as someone said earlier, advanced reactors were still seen as the long, long term future. But that's changed because now advanced reactors are seen much more as coming quickly and that's why we see regulators really beginning to engage.

John Kelly
Bill, it's probably Dale Klein but I'm not sure.

Bill Magwood
No. it was – he was the one that was born in Cuba. He's going to kill me.

Patricia Paviet
We will protect you.

It will come back. Because time is running fast and we have so many question, thank you to the audience to be so willing to participate. One question for Dr. Sagayama. Will advanced reactors help alleviate the nuclear waste concern?

Yutaka Sagayama
Of course, fast-neutron reactor is very convenient to burn actinide or such kind. So, it has a very high potential to decrease the waste. But in this case we need to pursue the recycling technology also together. So, this is a very difficult point to collaborate with a lot of countries. And in GIF probably in the initial stage we discussed with France and US and Japan how to proceed these technologies, but actually it is not so successful to do in GIF. So, I would like to talk about another point. For example, so many members discussed how to proceed the code and standard, for example, and R&D program in GIF. But basically in GIF R&D structure is multilateral collaboration scheme. This is not so convenient to do some specific issue. It means for examples structural standard, for example. We get together so many countries and so many countries have own standard in each country. But to harmonize, to make a new standard to get together, this kind of approach is not so successful because so many countries have each country's experience and history.

So like safety design criteria or such kind of criteria, this is a principle. So, it is not so difficult to make. So we look to make a new principle, to create a new principle. And with regard to the standard, we permit some difference in each country's standard. Like such kind of approach is more convenient. So, your question, so waste management or to decrease the waste, in this case some kind of technology we can proceed. But totally it

is not so easy to make such kind of total R&D inside of GIF. This is my impression.

Patricia Paviet
Thank you so much, Dr. Sagayama. As we approach almost 90 minutes, I feel sorry that we cannot answer all the questions. You would be amazed to see all the questions and I apologize, and I thank you very much for all these very interactive and lively discussion. I would like to give the floor now to Dr. Fiona Rayment who prepared some concluding remarks for us. Thank you so much, Fiona.

Fiona Rayment
Thank you, Patricia. Thank you all. So, the first thing to say is that GIF is not peanut butter. That is JIF, and so we are all kind of like very familiar with that now. After 20 years, the GIF family of the six types of reactor are as important today as they've always been; nuclear being a fundamental requirement for reduction of carbon dioxide emissions, and we've heard the importance of electric and non-electric applications. The goals of sustainability, safety and reliability, economics, proliferation resistance and physical protection created over 20 years ago are as important today. The model of collaboration is working and the talent and expertise that has been restored in the field of advanced nuclear technology is here to stay. For Generation IV, smaller reactors may be the first entrants of the Generation IV into the market. But whatever the technology or size, Generation IV should address the entire fuel cycle. Generation IV will play a role not just in carbon dioxide reductions but also contribute to other sustainability challenges. Clearly, there is more to do for nuclear in the areas of public acceptance and waste and a more public-facing attitude will be important for Generation IV International Forum going forward.

So for a JIF or a GIF, there you go, I said it myself. It's not peanut butter. For a GIF future, the private sector is advancing Generation IV technologies now. Deployment of Generation IV in countries with market-driven economies will need government and private sector partnerships for success and financing will be a key area of focus. Collaboration model for the GIF future is required that will fully embrace innovation, and demonstration will be a key step in driving these systems to market deployment.

The potential route to decarbonization of not just electricity but also industrial processes and heat and beyond. Large, small, and micro systems, all Generation IV, have the applicability in terms of taking this forward. We heard about the NEANH program in terms of actually focusing on the non-electric applications.

There's a real opportunity to bring and engage the next generation of people with the next generation of reactors, and there is a willingness to deal with climate change with this new generation of people. And so, therefore, nuclear can contribute heavily to that. We've heard about areas to overcome, some of the technology challenges, materials, financing, and economics, and working with licensing authorities, for example, on codes and standards. We've heard about what to keep and what to change. A key concept that we must keep is our broad country collaboration. We probably need more focus on demonstration going forward and how to enable that. I could cover so much more, but I don't want to basically go over old ground again. All that remains for me to say is congratulations to GIF and to the GIF chairs for a successful 20 years and to enabling Generation IV future. Thank you.

Patricia Paviet
Thank you so much, Fiona. Now, I would like to applaud and thank all the panelists today. I hope you had really enjoyed this webinar. Thank you so much for our panelists for being there for us. I would like to thank the people backstage who prepared all this webinar. Without them, it would not have been this success. I give you a wonderful – not in 20 years, let's meet again in 5 years to see where we are. Thank you again. You stay safe. We did it. And I wish you a very good day or a very good night wherever you are. See you soon. Bye, everyone.

Yutaka Sagayama
Bye. Thank you.

Bill Magwood
Bye. Thank you.

John Kelly
Thank you, everyone.

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