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C. Frei:

Your Excellency, ladies and gentlemen, it is my great pleasure to introduce this session on the nuclear outlook and renaissance. The question is whether there is a renaissance and how it can be accelerated in the nuclear industry, given the context of the climate negotiations and the successful conclusion of last year's Paris Agreement.

We have heard that the immediate context is one where, currently, we have 67 reactors under construction; we have seen 10 reactors coming onstream last year, which compares to five in the previous year, so we are seeing another acceleration of new reactors coming onstream. We have seen seven new reactors starting to be built, and I think the question that we have to ask is, what is the bigger picture here?

My name is Christoph Frei, I represent the World Energy Council (WEC). We are in 100 countries and looking at energy issues in those countries, so on the bigger picture side, with our scenarios, we are clearly looking into a future where demand is still growing very fast. We are still seeing up to a doubling of energy demand over the next 50 years or so, and if nuclear is roughly 5% of primary energy today, we believe there is a possibility that in 50 years' time, nuclear could multiply its installed capacity by a factor of two to three.

However, it is not that simple. There is huge complexity here, and we are all talking about not only growth, but also about transition. We are talking about transition, what we at the WEC are calling a triple transition, the first being decarbonization, this massive driver to move towards decarbonization as a result of pressure from the COP movement. The second aspect is the challenging of market logic. We see market logic being challenged by intermittent energy sources, by more digital, by decentralization, by various new elements that simply challenge traditional market logic. And third, resilience. Cyber, extreme weather, and other issues that also challenge conventional supply.

Now, again, within all that, what does this mean for nuclear? We have an outstanding panel here. Please allow me to introduce people to make it easier.

We have a producer here, a world-class producer with Rosneft represented, we have a government that is looking at its own agenda, but not only internal; it is also looking at hosting the next climate summit and asking how we can keep up the momentum. We have two agencies that are at the centre of nuclear safety, with the IAEA, and that are at the centre of the nuclear outlook, as well, with the Nuclear Energy Agency (NEA) of the OECD.

I think we have a brilliant panel here, and with no further introduction, I would like to just recall the rules of this session: we want to stick to short interventions so that we can have a lot of dialogue.

For my first question I would like to go directly to Mr. Magwood from the Nuclear Energy Agency. Clearly, we have challenges ahead; we have massive growth of opportunity. What does it take to realize that opportunity; where do you see the opportunities and challenges?

W. Magwood:

Thank you for the question. It is a pleasure to be on this panel. I agree with you: it is an excellent panel and I am looking forward to the conversation this afternoon.

I think that we really have three major challenges. One is to recognize that we are in a significant transition globally when it comes to energy. The achievement of COP21 is just one indication of how things have evolved over the last two years. Not only are we in a period where we are trying to control CO₂ emissions, but we are also seeing an unprecedented increase in the availability of fossil fuels, at the same time. How the world deals with those two forces is going to be very important for the future.

At the same time, technology is changing. Renewables are becoming cheaper and more available; nuclear is evolving as well, with new reactor designs and

passive safety systems, and small modular reactors, which could possibly change the entire economics of nuclear power.

Then, on top of all that, we have what I consider to be the most serious challenge facing us, which is the complete instability of the electricity markets in many countries. This is a situation which makes it very difficult to invest in the future, because many utilities cannot earn enough revenue to invest in new technology and new plant, unless they are subsidized by governments. That is not how markets are supposed to work, and I think it is a big challenge facing us.

C. Frei:

Thank you, that is very good. Let me just build one quick question. First, you were emphasizing the opportunity offered by COP; you were saying we will run out of climate before we run out of fossil fuel, with all the big new discoveries, and you emphasized this instability of the electricity markets: can you just elaborate what you mean by instability, and what recipes there could be to solve that?

W. Magwood:

Well, due mostly to government policies in many areas of the world, electricity prices are so low today that utilities that produce electricity and invest in the future really can barely make enough money to continue operating.

In some parts of the world, electricity prices, which would normally have been more like USD 40 or 50 per megawatt, are now half that, and during some parts of the day, electricity prices actually go negative, which means that it costs utilities to produce electricity.

Those are not markets any more. And in those conditions, if you want to see utilities making investments in transmission or generation, if you want to see them invest in new research, they do not have the money; they cannot do it.

And that deprives us of the opportunity to have a market-based future, which means that the job of dealing with climate change will be that much more difficult.

C. Frei:

Thank you. I would like to move on to Sergey Kirienko, Chief Executive Officer of the State Atomic Energy Corporation, Rosatom. Clearly, we are talking about this competition between fossil fuels, the whole pressure from the climate change agenda: where do you see the biggest opportunities for nuclear to change the game? There is a transport side, an electricity side, we have a water side: where do you see the biggest opportunities?

С. Кириенко:

Роль атомной энергетики связана в первую очередь с выполнением решения Парижского саммита о резком сокращении выбросов CO₂: нужно обеспечить надежные поставки дешевой электроэнергии, что важно прежде всего для развивающихся экономик, но так, чтобы не увеличивать, а, напротив, уменьшать объем выбросов CO₂. В этом отношении потенциал атомной энергетики огромен: согласно подсчетам Международного энергетического агентства, атомные электростанции за все время их существования позволили предотвратить выброс около 56 гигатонн CO₂. Только атомные станции России каждый год предотвращают выброс 711 миллионов тонн CO₂ — примерно такое количество этого газа все автомобили России выбрасывают в атмосферу за шесть лет.

В фильме, с которого начиналась наша сессия, говорилось, во-первых, об уникальном энергопотенциале используемого вещества, а во-вторых, о том, что атомная энергетика позволяет инвестору гарантированно предсказывать цены. Важны не только цены сами по себе — я согласен с господином Магвудом в том, что сегодня они не слишком стимулируют развитие рынка: для большинства инвесторов и потребителей важно иметь

гарантию цены. Доля топлива — природного урана — в себестоимости электроэнергии составляет 4—5%, а не 60—70%, как при использовании углеводородного сырья. Можно гарантировать стоимость электроэнергии на много лет вперед, и одновременно — безопасность и надежность работы станции для генератора. Одна урановая таблетка весом в несколько граммов заменяет собой сотни килограммов угля или нефти, что позволяет спокойно накопить запасы топлива на пять лет вперед, обеспечив его устойчивую поставку. Нельзя создать на угольной станции пятилетний запас угля — инфраструктура не позволит сделать этого. На атомной же станции возможно сделать запас топлива. Таким образом, атомная энергетика вносит существенный вклад в обеспечение устойчивого энергоснабжения.

В заключение скажу следующее: уважаемый господин председатель, мне кажется, неверно сравнивать источники энергии и говорить о том, что одни лучше, а другие — хуже. Любому потребителю и любой стране нужен правильный баланс. Бессмысленно утверждать, что в какой-либо стране или в каком-либо регионе 100% электроэнергии необходимо производить на атомных станциях. В устьях больших рек, конечно, правильнее сооружать гидроэлектростанции, близ угольных разрезов — угольные, а для страны в целом нужен правильный баланс. Атомная энергетика играет важную роль в достижении оптимального баланса.

C. Frei:

If I may also follow up with one quick question: you emphasized the price reality, obviously, and I want to build on the point made previously, as well: policy stability. I think we have seen in the example of the UK, with a contract for different proposals to maintain price reality. Is that the typical type of policy that you think must be in place for nuclear? Have you seen other policies which you would say are other good examples that you would like to point to in this context?

С. Кириенко:

Согласен с Вами: речь идет не столько о политике как таковой, сколько о высокой предсказуемости. Сооружение атомной станции занимает достаточно много времени, работает она еще дольше. Современную станцию можно построить за 5—7 лет, минимальный гарантированный срок ее работы — 60 лет. Несколько лет назад наши ученые разработали сталь, которая может выдерживать нейтронный поток на протяжении более 100 лет. Современные реакторы технически могут работать более 100 лет, дальше встанет вопрос экономической целесообразности. Следовательно, нужны высокая предсказуемость, надежность поставок, гарантии поставщиков, стабильность ценообразования. В этом велика роль политиков и государств. Инструменты могут быть разными. Так, например, в случае с атомной станцией Хинкли-Пойнт правительство Великобритании гарантирует, что в случае падения цен на рынке ниже определенного уровня, окупаемость проекта для инвесторов будет обеспечиваться за счет государства. Хорошее решение.

Возможно и другое решение, которое мы реализовали в проекте атомной станции для Турции: правительство Турции не инвестирует в станцию, но гарантирует выкуп всей произведенной электроэнергии по заранее согласованной цене, которая не может изменяться на протяжении длительного периода времени. Потребителю обеспечена предсказуемая цена, инвестору гарантировано возвращение затрат. Существуют разные способы, но крайне важно гарантировать предсказуемую цену и соблюдение договоренностей.

С. Frei:

Our purchase agreement has two typical situations that help to create that stability that one would actually need in this context.

I would like to move on to Minister El Haite from Morocco. We all wonder how we can maintain a focus on the good dynamics from Paris, and obviously that is on your shoulders to some extent, but the question linked to that is this. I think that, so far, energy has not been at the core, at the centre of the climate discussion. I think Paris has tried to move that a bit closer to the discussion, and clean energy, in particular nuclear. How do you see Marrakesh looking at those issues in a constructive way?

H. El Haite:

Thank you, and thank you Sergey for this opportunity by inviting me to share the view of the Moroccan Presidency on this panel.

Let me remind you what happened in Paris. In Paris, we did not speak about decarbonization, we spoke about neutrality of emissions, and this is very important. When we are speaking about neutrality of emissions, we are of the consensus that we are going to live for the next 20 or 30 years with mixed energy. We will live with fossil fuels; we will live again with nuclear, with coal, and with renewables. And this is a very critical point.

So, now the question is not what kind of energy is better than another; the question is how can we reach emissions neutrality, to reduce the impact of climate change on all these vulnerable countries and to give answers to those people who are waiting for them?

So, how can we do that? Mr. Magwood spoke about coherency in policies, and I think this is very important. At this moment in time, there are 60 countries around the world which have already got plans to build 300 nuclear plants in the next 30 years. So I think that it is a question of how we can do that.

First, maybe I will answer by saying: do it like Morocco. We do not have fossil fuels. We used to import our fuel from abroad: 97% of our energy was brought in from abroad. We introduced a new policy, the energy policy of the country, and we built the most important solar installation in Morocco, and then we faced the

problem of the competitiveness of the renewables market, and we were obliged to phase out subsidies for fossil fuels.

We established this coherence in Morocco, but Morocco is a small village. The world has to establish this coherence. And we should know that tomorrow, maybe the reservoir of renewables will be in Africa, in countries which have no fossil fuels; the countries which have fossil fuels should maybe pay a carbon price: we should work on carbon sequestration and innovate in this area, because we are all aware that the mix of energy will be 28% fossil fuels in 2030, 23% nuclear, less than 20% renewables, and 28% coal. So this mix is here and innovation is not really about phasing out all of those technologies.

We are speaking about nuclear today, and I am very much an environmentalist, Sergey, and I will tell you that the problem with nuclear is not whether it is green or not; nuclear is a green technology. The problem which faces nuclear is the guarantee of safety and security. This is the problem. The problem which faces nuclear is also capacity building, because we are now building something like 75 or 76 installations, and by 2030, we will reach 300 installations. We need more than 400,000 people, technicians, who will deal with the new safety technologies in nuclear.

So, I think that the question may be: we have a responsibility to maintain the momentum in Marrakesh, but Marrakesh will not solve all the questions. This is a process. We need to change everything, to change the method of production, of industrialization, to innovate in finding the right solutions to safety problems, carbon emissions, etc., etc.

C. Frei:

You make very important points. I think the first one, obviously, is in relation to COP: if there should be a CO₂ price, and I think that you implied that if there was a CO₂ price, it would relax some of the other policy uncertainties, and we should not forget to mention that; it is a very important point.

I think you made a second very important point: that Morocco, having been 97% dependent on imports of fossil fuels, had a massive incentive from a security perspective to go after a renewable and nuclear agenda, and I think you have completed – if I am not wrong – one of the largest renewable projects. You look very consistently at the nuclear agenda, so I think your government has been extremely concise in going after higher security from an energy perspective.

I think the third point you make is also on the innovation side. There is so much innovation going on, and I would like to come back, perhaps afterwards, to ask the question: there is a lot of innovation going on in this sector as well – where do we see the biggest innovation?

But before that, one point you did not refer to, and I think it is relevant to many of your neighbouring countries as well, is the whole water nexus. If I might quickly follow up on that point, on the role of desalination and nuclear in that context: have renewables played a role there, can nuclear can play a role, is that a big issue, do you see it as a strong issue in your region?

H. El Haite:

I think that is exactly what Sergey is saying. In our country, I think regions are different. In the North of Morocco, we have 1,800 millimetres precipitation. In the south of Morocco, we have less than 130 millimetres of precipitation per year, so we cannot use hydro in the South. So we are looking at how to take into account the specificity of each area and install the right technology for the area.

We are thinking about desalination in the south of Morocco. The problem was the cost. We already have seven desalination facilities in the south of Morocco, but the cost is higher than that of renewables. Renewables, with photovoltaic, are now at around 0.3 centimes each: it is very, very competitive, and I think that fossil fuel producers should think about that.

You spoke about carbon pricing. In the mechanism of negotiations, we will not be able to fix a price if we do not think about carbon in a holistic way. We should find

a way to fix a price floor, and to introduce differentiation in the price of carbon. This is why we are working together with our friends and with other countries which are interested in fixing the price of carbon to organize a forum in Morocco and to discuss together with those countries, which are sensitive and which are resisting a carbon price. Because a carbon price should be a tool to finance climate change response. There is transition, yes, but also adaptation and reducing damage.

C. Frei:

This is very interesting, and I want to move on, but I want to come back to this, as well. You talk about a bottom price, a bottom level for the carbon price, and I think the question that I would like to move on to before coming back to that question is what your objectives will be for Marrakesh. I think this will be of interest to all of us and I think we will let you elaborate later on.

But before that, Mr. Chudakov, obviously you are representing the IAEA, the agency that is best known for its work on safety, but also as a training agency for new countries coming to the nuclear agenda. What are the typical issues that a country engaged in its first nuclear construction, a country that has never had it before? They must ask lots of questions on the talent side, on the safety side, the institutional side, the governance side, the technology side. What are the typical sets of questions that you get from newcomers?

M. Chudakov:

Thank you for the question, and good evening, ladies and gentlemen.

This year, the IAEA marks its sixtieth anniversary. We now have 196 member states and 30 member states operate nuclear power, and about the same amount, as you have already mentioned, are thinking about, or are already contracting, to add nuclear power to their energy mix.

So, two countries are contracting for the first time: Belarus, where two 1,200-megawatt units have been designed, and also the United Arab Emirates, where four 1,400-megawatt units have been designed. About 25 to 27 other countries are at different stages of creating the necessary infrastructure.

That is where we are helping them, because our guidelines describe exactly what the countries should have before starting nuclear power operations safely, reliably, sustainably for many, many years, for 100 years.

Nuclear power, of course, is specific kind of power, and we should remember what happened at Chernobyl and Fukushima and the lessons learned, so that we develop the necessary infrastructure and we help countries to create this necessary infrastructure.

These are our guidelines and documents, which have 19 issues and three different phases. Phase 1 is when the country is making a knowledgeable decision; they understand what they are constructing. Phase 2 is when the country is ready for the bidding process and to begin installing nuclear power, and in Phase 3, the country is ready for operational nuclear power.

The 19 issues cover all aspects of nuclear power and include strong regulation, operations, human resources, spent fuel, red waste and decommissioning, legislation and the necessary laws, and all the other things that are necessary to help in the safe and reliable operation of nuclear power for 100 years.

To date, we have conducted 17 so-called INIRs, Integrated Nuclear Infrastructure Review missions: we assess the information about countries that are going to have nuclear power in the future. We have conducted 17 review missions in 13 countries. Some of them are already following up. Last year, we conducted three review missions, all in Africa: in Morocco, Nigeria, and Kenya. This year, we are conducting two new ones in Kazakhstan and Malaysia, and following up in Bangladesh, where we have previously conducted review missions. We are also planning one in Poland. They are not obligatory, not mandatory, but we are

happy that all newcomer countries and all countries that operate nuclear power are taking it very seriously and creating the necessary infrastructure.

This is where we can help, and we are helping these countries. We are often asked when a country is ready to operate nuclear power. We are not in a position to judge, to tell the country whether they are ready or not. But when we conduct these INIR missions, we ask countries to openly report, and developed countries which have already been operating with great experience for many years, their neighbours, can estimate whether they are ready for nuclear power. This is the real judgement of their readiness for nuclear power.

Of course, there are a lot of other problems that we help so-called newcomer countries with when they are creating nuclear power for the first time. We conduct a lot of seminars, exchange databases. We have in the INIR information system more than 3 million records, and 1.3 million are only available in INIR. We share best practices, conduct seminars, organize human resource development and capacity building for these countries, and they exchange with countries who have great experience in the nuclear industry, creating nuclear networks between technical universities and helping to develop the necessary human resources.

There are a lot of other reviews that we are conducting to help countries who are creating nuclear power for the first time to be ready for safe and reliable operation of nuclear power for many years.

C. Frei:

Just to build on this as well, you mentioned 19 issues: that is a lot of due diligence to be done before you are ready. Among those 19 issues, you mentioned a whole range of things relating to talent, technical, governance, institutional, etc. issues, and clearly you support those countries in getting over the line to be fully ready.

Which are the issues that are, in your view, the most difficult to achieve in a typical situation? What are the most difficult two or three issues that you see come up regularly?

M. Chudakov:

Generally, perhaps the most difficult is public acceptance and stakeholder involvement. We have examples where if there is no stakeholder involvement from the very beginning in the construction of the nuclear power plant, the power plant will not be put into operation, and this is a problem. So from the beginning, we ask countries which are creating their infrastructure to involve all stakeholders and to pay more attention to public acceptance. This is most important.

Then, of course, government support is very, very important. The necessary legislation, as well.

C. Frei:

So, public acceptance, government support, legislation are the key issues.

You also noted that a lot of new countries are coming to the table. When we describe our scenarios, we describe different roles as follows in a very simple way: we can imagine a world where the market dominates and the different technologies kind of come in, like the instruments are playing their own solo and there is no big orchestration of it, it is just market forces that drive certain technologies; we call this “the jazz world”. The other world is the “symphonic world”, where you have very strong directors deciding we need that price, that structure, and we want that type of technology.

Clearly, we see from where we stand with our own scenarios, we see that typically, those countries that are closer to the symphony world have much greater success with nuclear.

I am very keen to have your observations on where you see your markets, perhaps, Mr. Kirienko, where do you see your markets going? Do you see a

regional trend; do you see a structural trend? Where is your market going with new projects?

М. Чудаков:

Предложение, которое мы сделали нашим партнерам, распространяется на всех. Было бы неправильно предлагать одни условия странам Азиатско-Тихоокеанского региона, и совершенно другие — нашим партнерам на Африканском континенте. Мы действительно считаем, и госпожа Эль Хайт об этом говорила, что главная проблема в атомной энергетике — это проблема безопасности, которая решается одним способом: через обеспечение референтности. Чтобы гарантировать полную безопасность, мы должны предложить партнерам только решения, уже проверенные у нас. Это первое.

Второе: мы считаем, что такие страны, как Россия, Франция, США, Япония, несут особую ответственность. Это страны с полным технологическим циклом в атомной энергетике, которые должны не только пользоваться благами атомной энергии, но и обеспечить доступ к ней всем остальным партнерам, с гарантиями экономической целесообразности и безопасности. Мы считаем очень важным формирование такого интегрированного предложения. Оно адресовано всем заинтересованным сторонам, но в первую очередь — странам, которые только начинают развивать атомную энергетику: мы понимаем, что они выдвигают особые требования. Сегодня во второй половине дня мы с господином Магвудом, представляющим Агентство по ядерной энергии ОЭСР, подпишем соглашение о подготовке кадров. Это принципиальный вопрос. Атомная станция строится долго, но подготовка квалифицированного специалиста, которому можно доверить ее эксплуатацию, занимает еще больше времени, и начинать ее надо на ранней стадии.

Предложение должно включать в себя не только строительство атомной станции. Мы должны помочь нашим партнерам сформировать необходимое законодательство, организовать подготовку кадров, оказать помощь в разработке необходимых стандартов и требований, обеспечить уровень безопасности и качества работы подрядчиков, которые займутся локализацией в соответствующей стране. Мы должны гарантировать поставку топлива после строительства станции — если потребуются, то на протяжении всего жизненного цикла. Если станция будет работать сто лет, мы должны быть готовы с самого начала подписать контракт на поставку топлива в течение ста лет. Мы обязаны оказать содействие в таких сферах, как переработка отходов, вывод станции из эксплуатации, хранение, и гарантировать завершение жизненного цикла станции.

Такое комплексное предложение сегодня должен получить любой наш партнер. Меня очень радует, что в последнее время почти все наши переговоры начинаются с подписания договоров о подготовке кадров и соглашениях об оказании российской стороной содействия национальным надзорным органам. С самого начала подписываются соглашения о строительстве исследовательского центра и научно-исследовательского реактора, который служит для отладки требований безопасности и подготовки кадров, и лишь затем мы приступаем к строительству самой станции. Этот подход представляется нам самым правильным. Комплексное универсальное предложение можно адаптировать к потребностям любого партнера. Кому-то нужны малые мощности для изолированных районов — это тоже вопрос референтности.

Сегодняшний день начался с очень приятного события. Я приехал сюда с торжественной церемонии спуска на воду нового атомного ледокола, оснащенного уникальной энергетической установкой. Это инновационный реактор нового поколения, мощность каждой его реакторной установки составляет 200 мегаватт. Речь идет не только о доступе к арктическим

богатствам, в том числе углеводородам, к Северному морскому пути, но и о референтности. Последняя позволит нам предлагать партнерам станции малой и средней мощности, которые помогут осуществлять, например, опреснение воды или гарантированную поставку электроэнергии в районы, где нет большой энергетики, куда дорого и сложно завозить углеводородное сырье. Мы должны предоставлять возможность индивидуальной настройки в сочетании с базовыми требованиями. Следует быть готовыми удовлетворить все потребности тех, кто начинает развивать атомную энергетику. Необходимо комплексное предложение. Мы считаем это принципиально важным обстоятельством.

C. Frei:

I think you bring up three key issues. You emphasized again how important talent development is. You also point out that an integrated way of looking at fuel-cycle management must be a part of any strategy. And I think, lastly, you started looking at the innovation side, that we have said we want to come back to, and it is probably a good moment to do so.

Before getting to the innovation side, I just want to invite anybody who has a question, please just raise your hand if you have a question, and I am happy to take questions as well. If you do not, I am full of questions, so I can always go on, but I am happy to take questions.

I think one area where we would like to delve a little bit deeper on the innovation side is: there are so many innovation areas when it comes to nuclear, and I think we have spoken about policy innovation, we can talk about finance innovation, but before doing so, perhaps we can look at technology innovation. There are so many aspects. Just on the technology side, you have mentioned the small nukes, the smaller designs; the fuel cycle in itself is probably an innovation, or can be an innovation; we can touch on thorium or fusion, but among those, probably the

biggest resonance is around the revival of small nuclear and the importance of small nuclear.

Can I invite you to elaborate? Mr. Magwood, can I ask you to perhaps elaborate, and I am happy to have other comments from anybody who wants to chime in. Where do you see small nuclear today, why have they failed in the past, and what is different now?

W. Magwood:

Well, as you have indicated, small nuclear has been discussed many times in the past, and generally the issues have been more about the financial model than the technology.

In the most recent crop of new small modular reactors, the vendors who are approaching this issue have understood this history and understood this past, and have been working hard to try to avoid the pitfalls that their predecessors fell into.

The technologies that are being presented to customers today have not yet been certified by regulators, so they are still new. But they also do not represent a major departure in technology. They are still mostly light water reactors, the same basic design philosophy as existing reactors, but they have features which are very, very novel.

For example, one technology which is likely to be the first to be certified in the United States is called NuScale technology. This technology is composed of very small units, 50 megawatts each, whereas a large central station is typically 1,000 or 1,500 megawatts. It enables the customer to buy one module at a time, so that perhaps initially, they will operate one module of 50 megawatts, then as their power needs grow, they add another module, and another module, until they add up to 600, for a complete 12-pack arrangement.

This is a different financial model. So, instead of laying out billions and billions of dollars upfront, the initial investment is actually much more modest and much

more manageable, and this is particularly important, I think, for smaller countries that have less of a power need than, say, for a large central station. But it could also be important for more remote areas in countries like Russia or the United States, where you may not have direct access to large natural gas pipelines that are very popular, of course, with the low natural gas prices. Or perhaps you are in an area where the wind resources are not very advantageous, or solar is not a good option. So, as you start to go through your options, and especially as you are starting to move away from coal, these small nuclear plants present a major opportunity.

This is now being explored by people around the world. We have to wait and see how successful this will be, but I can tell you that there are a lot of people who are very enthusiastic about this; they think this is going to be a game-changer for nuclear. And from a regulatory standpoint, as a former regulator, I do not see any showstoppers. I do not see any major significant issues that cannot be overcome by the regulatory community to assure safety.

As a matter of fact, the small reactors have features that can enable them to be safer, even, than the newest technologies coming into the market today, because of the fact that they have inherent passive safety features.

So, this is a very exciting new development and is something that a lot of countries are watching very closely.

C. Frei:

I happened to see the NuScale two weeks ago: you can almost hold it in your hand, the central piece is so small, it is actually astounding.

Now, my takeaway is that you very strongly emphasized the importance of the financial model of this change: of course, it is a modular buildup. But I think there are two aspects: the other side of it is it is much quicker to build. Anyway, so the value of it – you mentioned that it can take three to five years to get a permit,

depending on the country, and if you can get the value quickly through the whole financing complexity, is that the key argument?

Can I have other thoughts on small nuclear and other areas of innovation that you think are critical? Can I invite anybody who wants to comment?

M. Chudakov:

If I can just give some examples of small reactors from my own experience, because I was a director of a small reactor, the Bilibino Nuclear Power Plant. This was a four-unit, 64-megawatt thermo, and half of the power was going to the electricity production of each unit, and half for the heating of the tower. But it was the warmest tower in the northern part of Russia, maybe the warmest in the northern part of the world.

Also the example of energy security: at the end of the 1990s, there was a problem with payment for electricity production, and there were also problems with delays in fresh fuel deliveries. I was happy as director, because I could see the fresh fuel in the whole reactor, and I understood that there was enough for me for two or three years, exactly what I said here, this is a good example of energy security.

C. Frei:

Madam Minister.

H. El Haite:

I am really confident listening to all of you: you are all nuclear producers and I am Minister for the Environment, so maybe I have to play my role and remind you that we did not hear you and or listen to you enough during the negotiations on climate.

I would like to remind you also that the world is changing and policies are changing, because of climate change. I think that it would be very helpful for

everything that we are preparing in those negotiations if we were to hear more about you and about your innovation, because the only thing we hear about is fear. We were in France a few days ago, and you are aware that Mrs. Ségolène Royal's policy is to phase out nuclear by 2030, because still we have this fear of nuclear around the world. If you discuss with all those ministers and those people who are conducting the negotiations, I think that it is very important that with your knowledge, with your know-how, you come to Marrakesh – I invite you to come to Marrakesh – because we will have an innovation salon or village, and explain to the world, explain to the parties, what the situation is now, how we are moving on innovation, where the game-changing innovation is coming.

Up until now, we have received only renewable energy, solar, wind energy, etc., but no nuclear, so I think that it would be very helpful for us to hear more about nuclear.

C. Frei:

If I might take you up on that point, I am sure that I can say almost on behalf of the panel that the energy community is certainly willing to be in Marrakesh, and I would almost turn this around and say we have not been invited so far to be present. I think it is increasingly recognized that from a global governance perspective, it is amazing to see the extent to which the G20 now has the energy ministerial element, that the UN now has a development goal on energy, that suddenly there are energy components in most government mechanisms, yet that is not the case when it comes to energy in the climate discussion.

Would that not be an opportunity – and I am probably putting you on the spot here, but that is not what I mean to do – to actually do that, find a mechanism to which the energy sector as a whole can contribute to a climate negotiation?

H. el Haite:

You know, you ask me what we are doing to maintain the momentum. We have prepared a global agenda of action, and we are trying to maintain that as a champion. I am a champion, with Laurence Tubiana, for maintaining this agenda of action.

We have 75 coalitions around the world. The sectors have to create their own coalitions. I think that nuclear should create this kind of coalition and come with innovation to speak at this kind of meeting, because we are discussing the decisions of tomorrow; tomorrow we will make decisions around the energy mix, we will make decisions around carbon pricing, we will make decisions around incentives and the phasing out of fossil fuel subsidies, etc., and you should be there: nuclear should create its own coalition.

We have a forum on June 23 and 24, and Mr. Kirienko is invited to this forum. I think that you should be more present to engage in discussions.

C. Frei:

I am sure the point has landed very well: I am sure you will have a lot of presence.

I want to emphasize again at this moment that there is no formal way in which energy expresses itself, there is usually a side-event type of situation, and I think you will find that I can talk on behalf of many who find that a very frustrating process, because it is very intangible in its outcomes. But I think I just want to use the opportunity to land that point, on behalf of the many who have expressed it.

We were talking about innovation, though, and I think obviously in Russia, you have just made unveiled one innovation: you mentioned the 200-megawatt unit that you have in an icebreaker, but I think there are many other small nuclear examples, and I think you have referred to the city and gold mine type of example. Where do you see, from a Russian perspective, the small nuclear

technologies, and perhaps also from a climate perspective, where do you see the first evidence for more demand for those?

М. Чудаков:

Я согласен со всем, что было сказано о малых атомных станциях, но главная проблема в области инноваций — это комплексный подход. Необходимо предложить линейку мощности — малая, средняя, большая. Атомная станция должна поддерживать маневрирование в сети, чтобы не только обеспечивать базовую нагрузку, но и работать в комплексе с возобновляемыми источниками энергии, такими как ветрогенераторы и солнечные панели, которые сильно зависят от сезонных колебаний и погоды.

Но главное — это гарантии безопасности атомной станции и отсутствие воздействия на окружающую среду.

Я согласен с господином Магвудом: никаких технических непреодолимых препятствий для обеспечения безопасности работы самого атомного реактора нет, и опыт Фукусимы ясно свидетельствует об этом. При помощи достаточно простых технических средств можно построить атомную станцию, соответствующую всем так называемым постфукусимским требованиям. Это означает, что такая станция, если бы она стояла в 2011 году на месте Фукусимской станции и подверглась землетрясению максимальной силы и удару сверхнормативного цунами, была бы полностью безопасной. Пуск первого такого блока, относящегося к поколению 3+, состоялся на Нововоронежской станции в конце мая этого года.

Следует не только обеспечить безопасную работу атомной станции, но и решить важнейшую проблему атомной энергетики — накопление отходов. Нужен новый технологический цикл, в котором отработанное топливо будет использовано в производстве нового топлива для быстрого реактора. Мы

считаем, что следующий шаг — это переход к быстрым реакторам, позволяющим использовать уран-238, количество которого составляет 99,3% от количества всего урана на планете. Существуют огромные отвалы, которые сегодня являются отходами, но завтра могут стать ценным сырьем. При сжигании топлива в реакторе реализуется лишь несколько процентов его энергетического потенциала. Основная же часть этого потенциала остается в отходах, которые тоже можно использовать.

Это напоминает ситуацию с нефтью, изначально служившей только для производства керосина — до того, как придумали двигатель внутреннего сгорания. Бензин считался отходом производства керосина, его выливали в воду и не знали, что с ним делать. После изобретения двигателя внутреннего сгорания обнаружилось, что это самый ценный продукт переработки нефти. С каменноугольными смолами — та же история: до второй половины XIX века они считались отходами производства кокса. После появления современных химических технологий выяснилось, что это ценнейшее сырье. Все инновации, о которых говорилось, должны сформировать новое отношение к тому, что сегодня считается отходами.

На наш взгляд, следующий цикл подразумевает строительство быстрых реакторов с натрием или с тяжелым металлическим теплоносителем — например, свинцом. Быстрый натриевый реактор в прошлом году был запущен у нас на Белоярской станции. Успешно идут испытания нитридного уран-плутониевого плотного топлива, которое показывает хорошие результаты в реакторе, запущен завод по производству МОКС-топлива для быстрых реакторов. Мы считаем, что эта технология может быть предложена на рынке к 2025 году, то есть максимум через десять лет. Ее коммерческая привлекательность — это другой вопрос: она будет зависеть от стоимости выбросов CO₂, природного урана, хранения и переработки отработанного топлива, словом, от многих факторов. Однако

ТЕХНОЛОГИЧЕСКАЯ ГОТОВНОСТЬ МОЖЕТ И ДОЛЖНА БЫТЬ ОБЕСПЕЧЕНА В ТЕЧЕНИЕ ДЕСЯТИ ЛЕТ.

C. Frei:

You emphasized again the importance of getting a hold on the waste issue, and obviously there we actually have solutions, with fast breeders, fast neutron reactors on the one hand, and then the MOX solutions, but those have not advanced as rapidly in the past as one would wish.

Can I ask for opinions on what has been the higher priority? Perhaps from the agencies, do you think that there is a broad consensus on those solutions that are promoted? Is there an interest from the signals that you are getting on the fast breeder and MOX type of contexts?

M. Chudakov:

Of course, many countries are interested in them. There are two items that we are creating. Firstly, we are creating new fuels. As Sergey Kirienko said, the fuel itself, like a phoenix, it is created from itself. And if one kilo of uranium can produce about 50,000 kilowatt hours, if you use processing to create fast reactors, in fast reactors you can multiply it by 50 more. It will be 2.5 million kilowatt hours.

The second part is that we are minimizing high-level waste. We are burning transuranium, so-called minor actinides there. We are burning them there in the fast reactors, and minimizing. Transuranium itself and minor actinides, we can minimize by a factor of 200, by 200 times. That is why many countries are interested in it, and we are organizing a cooperative research project uniting different developed countries which are thinking about this project. This is our goal, and we are going to organize meetings and conferences on this topic.

By the way, next year, Russia is hosting the Fast Reactor Conference in Ekaterinburg, and it will visit the BN-800 Fast Reactor there, which was put into operation last year.

That is also a very important topic for us.

C. Frei:

Mr. Magwood?

W. Magwood:

I would combine a couple of things, because you asked a very important question, which is: is there a broad consensus on all these things?

I think it is fair to say that there is not broad consensus on anything, really, in the world today. There is a great deal of diversity of thinking in lots of different directions.

With regard to Mr. Chudakov's comment, I think if you ask the scientific community what they think about this, you would get to see a pretty healthy consensus about the future of fast neutron reactors and advanced recycling, particularly if it can be done in a proliferation-resistant manner. I think there is a great deal of interest in that, for the reasons that he explained.

But I think that the challenge that we see today with these issues of technology and energy – as you pointed out, energy is not at the forefront of the climate discussion, as it really should be – is because energy is so important, it is by nature political.

I think we have transitioned to where it is not just political, it has become ideological, and that makes it very, very difficult to have fruitful discussions internationally on a wider range of issues, including this issue of fast reactors: this is something that both the IAEA and the NEA are working to try to correct, but we see a lot of forces that really do not want these conversations going forward, and this has become a very ideological and very political matter, when it

really should be something that is discussed technically, and then countries can make their decisions based on their own needs.

I think that that is what we need to get back to: that is where we used to be, but in recent years, the politics have taken over.

C. Frei:

I think that was an important clarification.

We have our first question from the room. I am happy to take a few questions, and let the panel respond. Yes, please. Can you please introduce yourself, and questions, please, no statements.

С. Солженицын:

Степан Солженицын, компания McKinsey.

Мой вопрос касается экономики. Допустим, поставщик атомной технологии убедил руководство какой-либо страны в том, что это безопасно, что к технологии будет прилагаться соответствующая инфраструктура — но заказчика волнуют деньги. Он знает, что на стадии строительства эта технология обходится дорого, и его волнуют простые экономические соображения: а вдруг произойдет перерасход денежных средств и график строительства не будет соблюден? Кто примет на себя риски? Как может поставщик технологии успокоить заказчика?

C. Frei:

The first question. I am happy to take other questions, a few questions: if there are other questions, please be courageous.

No other questions to answer, just brief points, actually, I think we have seen several examples where costs have been doubled, projects have gone nine years over construction time, the risk falls back on the commissioner: how do you

deal with that? You have to proactively question. First, Mr. Kirienko. I am sure the agency also has a view on that.

С. Кириенко:

Я считаю, что у заказчика должна быть возможность выбора из различных вариантов. Современные модели контрактов отличаются крайней гибкостью.

Первый и самый простой вариант — контракт с фиксированной стоимостью: в случае ее увеличения риски принимает на себя подрядчик. По этим контрактам мы работаем в ряде стран, иногда подрядчик несет убытки. Возьмем, например, атомную станцию в Бушере: ее начали строить по чужому проекту, затем она попала под бомбежки. В итоге объект взялись достраивать мы, но не уложились в контрактную цену. Проект оказался для нас нерентабельным, но важным в репутационном отношении: мы доказали, что всегда выполняем свои обязательства.

Второй вариант: фиксируется стоимость не сооружения, а киловатт-часа электроэнергии. Эту модель мы применяем в Турции, а также в Финляндии, в рамках концепции «Манкала», которая выглядит очень интересно: заказчиками выступают не энергокомпании, а потребители электроэнергии. Иными словами, промышленные потребители электроэнергии скооперировались, чтобы инвестировать в атомную станцию. Их интересует не стоимость сооружения, а гарантированное получение определенного количества киловатт-часов по фиксированной цене. Риски берет на себя подрядчик, но зато мы точно знаем, что вся электроэнергия, которая будет произведена на этой станции, куплена заранее, у нас не возникнет проблем с ее продажей.

Третий вариант: подрядчик выступает в качестве инвестора. Во многих случаях мы настолько уверены в рентабельности проектов, что готовы вкладывать в них деньги. Например, в той же Финляндии мы являемся еще

и акционером, причем не мажоритарным: нам не требуется управление проектом, и наша доля составляет чуть более 30%. Но для нас это интересно, поскольку мы уверены в том, что уложимся в установленные сроки и в установленную сумму. Заказчик же получает дополнительную гарантию, так как мы разделяем с ним риски. Для нас создается возможность получения дохода не только от продажи атомной станции, но и от продажи электроэнергии. Важно и то, что такие проекты являются долгосрочными.

В других случаях дело обстоит так: мы построили станцию, пожали руки партнерам, перерезали ленточку, и все разошлись. В проектах, связанных с продажей электроэнергии, мы работаем вместе с партнерами в течение многих лет, можем осуществлять поставки топлива и сервис, что для нас крайне важно и интересно.

Итак, моделей, гарантирующих защиту интересов заказчика, много, и каждый заказчик должен иметь возможность выбора. Поставщику же нужно проявлять гибкость и уметь подстраиваться под конкретного заказчика.

C. Frei:

Any brief comments on the same issue?

W. Magwood:

Well, just very briefly, I would say that the risk that we see in nuclear projects is largely a consequence of the inexperience of those building them. Nuclear plants are like anything else: the more you do, the better you get at it, and for contractors that have not built a new nuclear power plant in say, 10, 15, or 20 years, the risks in the project are just going to be higher. It is just the nature of life. But if you go to a contractor that has built multiple plants over the last decade, and have a lot of people with experience in managing the projects, then

the chances are you can talk to them about a fixed-price contract or something like that.

So I think you have to recognize that a lot of the issues we have seen in recent years on the large cost overruns is really a factor of the lack of building programmes in many countries, and the fact that they simply do not have the experienced project managers, experienced subcontractors, to make sure they can build their project on price and on budget and on schedule.

As for those who have been doing it consistently over years – and there are several in the world that have been doing that, including our colleagues in Rosatom – you will see successful projects.

C. Frei:

I think we have touched on a lot. A very brief question, then I think we will bring it back to the big picture, but please, yes, one quick question there.

M. Концеров:

Добрый день!

Мой вопрос обращен к господину Магвуду. Здесь говорилось о будущих технологиях. Какие технологии, на Ваш взгляд, станут применяться в будущем, и что нужно сделать уже сегодня, чтобы оказаться в этом будущем?

C. Frei:

Speeding up innovation: what must be done?

W. Magwood:

Let us see: how much time do we have?

I would say first, the most important thing is that we have to regain our vision for the future. If you do not have a vision for the future, you will never make the investments; you will never make the effort to try to achieve anything.

It was interesting, we were passing by one of the exhibits and there was a little picture of Yuri Gagarin, and whenever I see him, I always think about those days in the early 1960s, when people were thinking about space as this great frontier; we were going to do these wonderful things; we were going to go to the Moon, go to Mars. You do not hear people talking about that much any more, because I think in many parts of the developed world, we have lost our vision.

So I think, for innovation to be successful, to really do big, important things, we have to get back to thinking that the future is going to be better than it is today, and that it is worth making an investment to make that happen. Unless we get back to that, both as individuals and as societies, to making those investments, then everything we do will be very small, and the future will not be as bright as it could be.

C. Frei:

That was a beautiful shift to take it back to the big picture, and we have only a few minutes left, but I think we have gone to the big picture in a few areas; we have probably been speed flirting with the issues more than going into any depth, which is not possible in a session like this.

But I would still like to bring it back. I know all of you probably have your scenarios in the way you look forward in terms of the nuclear future, and you probably have high scenarios and low scenarios, in a specific country or for your constituents or your customers.

I think when you look at your high and low scenarios, clearly you want to move the low to the high, for most of you.

What is the biggest differentiator? First of all, what are those scenarios, briefly, if you can lay them out? I would like to start perhaps from the other side this time,

so what are those scenarios in a 2030, 2040 type of horizon, and what would it take to take the low scenario to the high scenario, perhaps? Let us start with William Magwood.

W. Magwood:

I think the biggest differentiation between the low scenario and the high scenario is how serious we are about climate change.

If we are really serious about it, if we really want to address CO₂ emissions, and we do not want to just talk about it, then you will see nuclear play a significant role.

The International Energy Agency, a sister organization to the NEA, projects that, under an economic scenario, to meet the 2 degrees Celsius target, nuclear would have to increase by 2.3 times of what it is today. That is the equivalent of about 500 new nuclear power reactors. That is what would be necessary to meet the climate goals, and if we are not serious about reaching the climate goals, then we will not see those reactors being built.

C. Frei:

A clear point.

M. Chudakov:

In the IAEA, we make a projection every year up to 2030 and 2050, and last year's projection shows 2% in the low case and 70% in the upper case for 2030. The lower case is just replacement of nuclear power plants that are decommissioned, because up to 2030, the same projection shows that up to 150 gigawatts will be dropped from operation because of the age of nuclear power plants, and should be replaced.

I absolutely agree with William that in order to follow the COP21 decision, we need to follow the upper scenario, and reach at least 70% up to 2030. This

means that we should put around 20 units into the grid every year. Last year, we did 10 units, and these 10 units were mainly in China; eight in China, one in Russia, one in Korea. But to follow the scenario of COP21, we need about 20 units every year.

Also, the future is, of course, fusion. I visited Cadarache a few months ago, an international thermonuclear energy reactor where the developed countries have been working together to create this fusion, clean sun energy resulting in red waste. There are a lot of sources of energy, and this is just water. They are already promising 25 to 27 in 10 years – we should remember, this is an experimental reactor, do a cold reaction in 500 seconds, eight minutes, and to show that the output is 10 times more than the input. That is the main goal.

After this, it will take maybe 20, 30 years to develop commercial reactors in different countries. Now they are not doing it, because it is not proved that they can do a cold reaction, but theoretically they can do it, it is just technically, it depends on the technical aspect.

So I believe that somewhere in 55, 60, maybe in 70 years we can get clean fusion. We should not stop. We should work on the fission reactions in order to get new materials, new methods, new reactors, to work with red waste, with spent fuel: we should continue, because one thing helps another, and new materials especially.

C. Frei:

Your point is actually a double point: climate is one, but keep going on the innovation side, also focus on fusion is the other point. You have a very heavy burden on your shoulders, because there is a lot of pressure from COP to look at those issues in much greater depth.

You probably have two hats now, the COP hat, so what is it that you see it as a good, as an up scenario from the COP side, and from the Moroccan side as well.

H. El Haite:

I would like to say, when I am looking at the solutions and trying to do my job to enhance and maintain the momentum, I try to be concrete. And I think, concretely, that nuclear is a key issue for climate change.

The only thing is, I am wondering if there is a federation of nuclear; I'm sure it exists. We need this association of nuclear people, first to speak with NGOs, because in the climate meetings, nuclear and NGOs are not so friendly, you know? I think that you first have to develop a strategy of communication, of sharing your know-how with the NGOs, with the parties. You should try to become a member of the climate change discussion, if you really want to be a key issue and solution to the climate issue.

I know that the market for nuclear is expanding and I know that many countries already have installations, but when we prepared our agenda, we prepared an agenda for all of the coalitions, for carbon pricing, carbon trading mechanisms, but we did not have climate change and nuclear in the agenda.

I think that this is a point that you should maybe try to find a way to make central, because if the problems of safety are resolved, and if innovation is in the rendezvous, I think that it can accelerate achievement of the COP21 Paris Agreement objective.

C. Frei:

A very strong point: I think that one has to get organized and get the word out at the COP.

At the risk of sounding argumentative, I want to make the point that it is probably not a nuclear point that we are making here, actually. My organization is not a nuclear organization. Many of the points that we as an energy organization would make are very closely aligned with the points that the nuclear industry would make as well.

I would actually say with the broad energy points, we have NGO agreement to a large extent: it is about policy stability, policy predictability, and I think that is the keyword as well for this session.

And that is not an innocent word: it has to be well formulated, there are a lot of facets behind that, because at the same time we have to go through a transition, but the transition has to be managed in a way that allows capital to actually find its place.

Last word from Mr. Kirienko on the issue of the upper and lower scenarios.

С. Кириенко:

Я считаю, что даже при наихудшем развитии событий в ближайшие годы потребуется построить больше атомных станций, чем существует на сегодняшний день. Об этом говорит и тот факт, что развивающиеся страны часто делают выбор в пользу атомной энергетики. Любая страна, желающая обеспечить быстрое развитие, нуждается в надежных и экономически эффективных источниках энергии, и в каждой такой стране принимаются программы, связанные с атомной энергетикой. Ее доля в энергобалансе варьируется в зависимости от страны, но так или иначе, атомная энергетика — важная часть любой растущей экономики.

Еще одно обстоятельство: решения о запуске атомных электростанций все чаще принимают страны, обладающие огромными запасами углеводородов. Ясно, что в Марокко нет других источников энергии. Однако строительство атомных станций предпринимают Объединенные Арабские Эмираты, Саудовская Аравия, Бразилия, Россия и ряд других стран, у которых с углеводородами все хорошо. А значит, даже при реализации пессимистического сценария нам придется построить больше атомных станций, чем есть на сегодняшний день.

На мой взгляд, следует уделить первостепенное внимание принятию единых норм, требований, стандартов, а также обеспечению безопасности,

о чем говорили мои коллеги. Здесь большую роль могут сыграть МАГАТЭ и Агентство по ядерной энергии ОЭСР.

И все-таки самое главное — это образование. Атомная отрасль держится не на ископаемых источниках и не на основных фондах, а на профессионализме и интеллекте людей, поэтому в первую очередь нужно вкладываться в образование.

C. Frei:

It is going to be very difficult to try to summarize, but I think we have had a very rich discussion here.

I am going to take three points that I feel stood out particularly strongly.

The first was really about policy. It is clearly not just about talking about climate change, but actually making the necessary measures happen, and COP is the major policy issue, the CO₂ price is probably the major policy issue, but then, in the absence of that, bridge-building can be done through PPPs or through contracts, for instance, and there are other policy models. I think the policy side is the first point.

The second point, I think, is the innovation point. And I think on the innovation point we have heard a lot about small nuclear, and it is not just because of the technology, the commoditization of technology that this is interesting, but clearly because the modularity and also the shortening of the value to get to first operation makes this a much more feasible route into nuclear than perhaps the traditional designs. We have heard about MOX, about fast breeders, again; we have heard: do not give up on the fusion side. We have not heard about thorium today, thorium could be another one. There are so many innovation areas that we could have covered, clearly innovation is going on, do not give up on the fusion, and focus in the mid-term probably on small nuclear as the quick win on this one.

The last point: I think there are a lot of new players, there are some players going out, but there are a lot of new players coming in, and I think what we have heard clearly is that yes, talent is important, yes, legislation is important, but the key issue is acceptability. I think also working from a COP perspective, it is those who perhaps do not buy in that are going to be a critical part.

With that, I would like to thank you again for this very rich discussion, a great panel, and I invite you to join me in thanking the panel, thank you.