Questions and Answers
IFNEC Webinar #4
SMR Vendor Forum – An Open Discussion with Global Vendors to Review Designs and Benefits

Question	Asker Name	Answer(s)/[answered by]
1. Dear Panelists. I am Emmanuel Mulehane from the Nuclear Power & Energy Agency (NuPEA) of the Ministry of Energy (MoE) in Kenya. I have the following questions: GE-Hitachi and NuSCALE (Cost per reactor unit?Construction period?Seismic design margin?plant footprint?) 2. SMART (cost per unit? construction period?plant footprint?) 3. RITM (Cost per unit? Construction period?) 4. UK-SMR Rolls Royce (Cost per unit? Construction period?)	Emmanuel Acholla	**[Answered during session]** BWRX-300 for NOAK will be under $1B. Construction cycle will be 3 years for the first unit and expected to be lower for subsequent units. There are seismic advantages given the reactor is imbedded and the total footprint, including the Turbine building and other facitilies, is the size of a football or soccer field. **[Thomas Mundy]** The NOAK overnight capital cost estimate for a 683 MWe net (720 MWe gross) 12-module NuScale plant assumed to be deployed at a generic greenfield site in the southeastern region of the U.S. is approximately $2.5B, with a 36 month nuclear construction schedule. Seismic design 0.5g. Plant foot print approximately 30 acres within protected area boundary. **[Elena Pashina]** ROSATOM designs SMR nuclear power plants taking into account, on the one hand, the target commercial parameters that should ensure its competitiveness when compared with conventional generation sources like diesel, coal or gas, and with other SMR vendors. On the other hand, the final costs of SMR NPP both land-based and floating may vary greatly depending on: • site parameters (for example, availability of cooling water, seismic stability, soil, absence of unfavorable conditions); • regulatory requirements; • NPP configuration; • implemented business model, cost of financing; • and many other factors. We are convinced that construction time is one of the key characteristics that ensures the competitiveness of the energy solution and we work constantly on reducing it by developing the modularity concept. Construction time for the first of a kind SMR NPP

		will be approx. 4 years. Speaking about Nth of a kind, we plan to reduce it to 3 years and even to shorter period.
2. Competitive with N.gas... where?	Andrew Paterson	**[Simon Irish]** In any market that today relies on LNG. As a rule of thumb, NG from LNG is at a $4 cost basis per MMBTU to pipeline NG. In any market where foreign NG supply has national security implications. In any market where NG in a future period realizes its historic 30% to 50% p.a. price volatility.
3. And what if a country has to import the N.gas, facing energy security issues?	Andrew Paterson	**[Simon Irish]** SMR power and heat will be competitive. True energy security can only be realized by removing or eliminating the need to import any form of fossil fuel, especially NG
4. For BWRX-300, Why 10CFR52 is not adopted in US ? WHy 10CFR50 is adopted?	Krishna Kumar	**[Answered during session]** All operating units in the US utilized Part 50. This is a quicker licensing path to bring to market and supported by our customers.
5. What was the cost and schedule experience with GE's ABWR in Japan (late 90s, KK 6&7)?	Andrew Paterson	**[Answered during session]** The construction schedule was between 39-42 months and the cost was in the mid-$3,000/kW. The BWRX-300 is simpler than the ABWR, so we are confident the construction cycle and cost/kW will be less.

6. What is the update on BWRX300 BORON INJECTION REMOVAL? And what is the basis for removal?"	Farid Berry	**[Answered during session]** We are finalizing the PRA and severe accident response in the next couple of months. These results will define if boron injection is needed.
7. I didn't understand Mr Ball's reference to Part 50 licensing of hte BWRX-300 in the USA. Did you mean Part 52? Design certifications are issued under part 52 --aren't they?	Ian Grant	**[Answered during session]** Part 50 will be used, not Part 52. ESBWR was certified under Part 52 and we will use that basis plus the LTRs as part of the Part 50 application. Our customers in the US support the Part 50 approach as it will be quicker to market and used by all operating units in the US.
8. To Jon Ball. Is there already a customer for the first reactor? 9. What are the physical dimensions of the reactor?"	Józef Sobolewski	**[Answered during session]** Yes - we will be submitting an ARDP proposal with multiple utility partners in the US. We will announce those customers at the appropriate time. The actual reactor vessel is roughly 4m in diameter and about 27 m in height.
10. The question for BWRX GEH. Taking into account that BWRX is a boiling reactor how do you plan to consider the public acceptance matters associated with Fukushima accident?	Artem Larionov	**[Answered during session]** The BWRX-300 base design is capable of passive cooling for 7 days without any operator interaction. We are evaluating options to increase this time window.
11. we are pump manufaturers of primary and secondary cooling system for large scale civilian nuclear applications in Europe. How can we collaborate on your SMRs BWRX-300	Suresh Kumar	**[Jon Ball]** The BWRX-300 is a natural circulation BWRX-300, so it does not use reactor coolant pump. The BWRX-300 does use feedwater pumps that are small in size compared to large nuclear reactors. Please provide data regarding your pump manufacturing capabilities and we will evaluate the suitability.
12. Wouldn't pumped in vessel recirculation enhance load/source following vs slower flow natural circulation? i can provide pumped flow in a BWR either overall, or on a per cell tailored flow basis passively with no electricity and no moving parts. this would allow faster transients and possibility for BWRX-300 uprate with the same core, improving $/MWe even further."	Carl Perez	**[Answered during session]** We prefer passive, natural circulation. We've modeled the ramp rates at 0.5% output per minute, so it pairs well with renewables. I would be happy to discuss with you separately and put you in touch with our technical experts.
13. Core thermal Power of HTR-M is 250 MW but the electrical output is 211MWe. How this high effenciency is achieved?	Krishna Kumar	**[Li Fu]** 2 reactors each with thermal power 250MWt can produce 211MWe, therefore the efficiency is about 42%.
14. For the HTR Pebble bed, if you use a higher enrichment (perhaps 12% to 15%), does that reduce reactor cost (fewer pebbles needed, smaller reactor and footprint)? Why did you choose 8.5% enrichment?	Andrew Paterson	**[Li Fu]** The enrichment is determined by the burnup. For HTR-PM, as discharge burnup is set as aroubd 100 GWd/tU, only 8.5% enrichment is required. In future, if higher burnup is permitted if fuel performance is demonstrated, higher enrichment is required, the cost of fuel can be reduced.

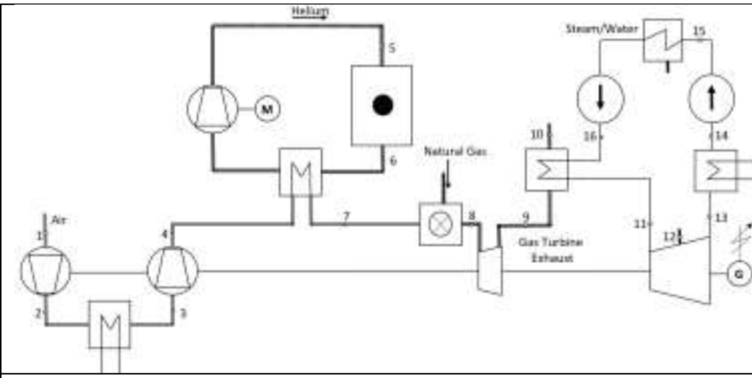
15. Question for HTR-PM. During operation, a lot of radioactive graphite is expected to appear in a bulk and dust condition. Could you explain your approach to the radioactive graphite waste management and disposal? How this process contributes to the operational expenses?	Artem Larionov	**[Answered during session]** For spent graphite management, the experience from GCR and AGR in UK, AVR and THTR in Germany, Fort St. Vrain HTGR in USA, can be referenced.
16. Why commisioning of HTR-PM is taking 5 years?	Juhyeon Yoon	**[Answered during session]** The installation is not totally finished, therefore commissioning test of primary circuit must wait, although commissioning test of supporting system is finished already.
17. Krishna Kumar HTR-PM us 250 MWthermal each reactor of the parir, but combined turbine generator is 211MW electric	Carl Perez	**[Answered during session]** Yes. The efficiency is around 42%.
18. Is the BWRX - 300 considered a FAOK or an NOAK?	Princewill Okpala	**[Answered during session]** The complete design is considered FOAK, but there are many aspects that are NOAK such as the fuel and major components, just smaller scale.
19. On the HTR-PM - would the six module plant be built in Shandong, or at a completely new site? If the latter, what sites are under consideration	Philip Chaffee	**[Answered during session]** Several sites are considered.
20. HTR-PM has 2SGs and one turbine. Don't you have flow instability problems in SGs?	Juhyeon Yoon	**[Answered during session]** Instability prblem depend on SG itself, not the coupling of 2 SG.
21. Can you give an update of the plans to build an HTR-PM in Saudi Arabia? What other markets are you looking at?	Philip Chaffee	**[Answered during session]** Recently no progress in Saudi Arabia project. There are some countries contacted.
22. For the BWRX -300, would an LCOE of less that $60/MWh and a capital cost of $1B be achievable for a FAOK or even an NOAK?	Princewill Okpala	**[Answered during session]** The FOAK will still be very cost competitive … we anticipate about $300-400M of one time (non-repeating) design and licensing costs. This is minimized versus other designs by leveraging the existing design and licensing basis of the ESBWR.
23. What would be the construction completion timeframe for the the BWRX -300?	Princewill Okpala	**[Answered during session]** The first unit can be constructed in 3 years. We are confident in that timeframe given our recent experience with ABWR with our alliance partner. The ABWR was consistently built in under 4 years, including one project at 39 months. The BWRX-300 is approximately 1/10th the size of the ABWR, so the construction cycle can be significantly reduced versus prior experience.
24. To Li Fu. Can you share the basic information about CAPEX, OPEX. If not in USD, than comparable in % to big LWR.	Józef Sobolewski	**[Answered during session]** Cost data for FOAK must be adjusted.

25. How does the BWRX -300 design compare interms of its pros, when benchmarked with a Nuscale Power Module design or the UK SMR design?	Princewill Okpala	**[Answered during session]** The BWRX-300 RPV is roughly the same size as a NuScale power module, but produces ~5X the output.
26. What is the scale of contribution from heat supply from SMRs compared to electricity sales for return of investment rate and period?	Görkem Güngör	**[Jon Ball]** In locations where district heating or process heat can be utilized, the economies of a SMR can be significantly enhanced.
27. Let's hear Jon Ball's (GE) response to the point by Simon Irish that Gen III SMRs are stuck at $100 / MWh. GE says their simplified design pushes LCOE below $50 / MWh. Is one a wholesale price and the other a retail price?	Andrew Paterson	**[Answered during session]** The key to SMRs using light water technology is simplification. We've dramatically simplified the design, so we will use more than 50% less concrete and building materials per MW versus existing LWR technolgy, so that enables an LCOE below $50/MWh.
28. Nuclear does compete with NGCC, but wind and solar cannot compete with nuclear for larger cities, non? There is no room to place the solar panels and wind turbines; they are intermittent -- even if capacity were free. And transmission and storage add cost and may pose their own challenges for siting, non?	Andrew Paterson	**[Gloria Kwong]** Your statements are correct. Wind and solar power cannot compete with nuclear power for baseload generation due to their intermittency. Efficient energy storage is another challenge faced by renewable energy.
29. Mr Irish. What you want to do with spent fuel?	Józef Sobolewski	**[Simon Irish]** The IMSR operates in a soft thermal neutron spectrum and it achieves much greater thermal efficiencies for electric power generation. Consequently it generates ~50% less long term spent fuel waste by mass per MWhe compared to a Gen III system. IMSR Spent Fuel will be stored within the Reactor Auxiliary Building (inside containment) over the full life of the IMSR power plant, which is ~56 years. Terrestrial Energy is working with the Canada NWMO to ensure that IMSR spent fuel complies with protocols agreed by the NWMO for safe DGR disposal at the time when those protocols have been finally agreed.
30. Simon, you mention that the molten salt reactor would operate at a temperature of 600degC, how do you achieve a low pressure as you indicated at such an operating temperature?	Princewill Okpala	**[Answered during session]** The IMSR fuel salt has high thermal stability. It remains a fluid at atmospheric pressure to well above 1,000 C. Hence a pressurized cooling system is not required.
31. To GE Representative. Excellen presentation, very clear. Compliments !! Please, would you provide a range of expected capital cost per unit of 300 MWe ? Please, would you provide a schedule from starting construction to commercial operation?	Oscar Mignone	**[Answered during session]** The cost for NOAK will be under $1B. The timeframe to construct will be 3 years for the first unit. See my other responses for references versus the ABWR.

32. Mr. Li, Fu and Mr. Eben Mulder, as the spherical fuel element is the fuel design that has been adapted by a few HTGR technologies, consequently, it is expected that the nuclear grade graphite demand will increase, the available potential suppliers in the market are very limited, please elaborate on the plans to secure the supply, potential suppliers and your forecast for the future market demand.	Tariq Mheidat	**[Answered during session]** Supply of graphite depends on how large the HTR market is.
33. To GE Representtive, interesting approach to "license by difference" with Large G-W. Please, would you provide the number of topical reports already approved by the Authority and the number of topical reports still missing? In time terms, are we talking of coupleof years to complete licensing?	Oscar Mignone	**[Jon Ball]** There are approximately ten US NRC licensing topical reports regarding the differences. The first three have already been submitted with the first having already gotten to the point of no open issues. All are expected to be approved by the end of 2021.
34. MOLTEX only uses the TRU's out of CANDU SNF leaving mist of the ~98% Uranium behind, and ~1%. How is that closing the fuel cycle?	Carl Perez	**[Answered during session]** We utilise the long lived actinides. The urnaium that remains has a similar radioactivity to natural uranium and as such cna be disposed of in the original uranium mines. The enrichment is below natural levels. It is very inneficient to consume in reactors and there is far far too much in the world for our energy needs.
35. MOLTEX: With a carbon credit or a Euro 25-30 / ton tax as in EU, how much would that lift the cost threshold in your forecast from $2,000 per KW toward $3000 per KW?	Andrew Paterson	**[Answered during session]** It increases the threshold significantly yes. Many others have done these studies in different markets. We assume we need to be competitive without carbon tax.
36. To GEH: do you have already fixed chain of equipment suppliers of nuclear and convetional parts?	ANDRZEJ MIKULSKI	**[Answered during session]** Yes - We have an existing supply chain and can leverage as required. However, we recognize the importance of developing localized supply chains. This is one of our core competencies and are planning on leveraging that experience to further develop supply chains where it's important locally.
37. What is the expected cost of Moltex generated power compared to renewables, in Canada for example?	Denis Crevier	**[Answered during session]** Renewable costs vary significantly across the globe and in particular across Canada. Under CAD 10c/kWh will be competitive. We expect to be below this.
38. a bit of a general Q: what would it take to have SMRs be competitive with large reactors? (and not have it be competitive only in niche markets or in situation where large reactors aren't suitable)	Sina Hajarat	**[Answered during session]** The key is simplification. Going smaller isn't enough as Simon pointed out and we agree. We've been able significantly reduce the complexity through innovation and have reduced the amount of concrete and construction materials by more than 50% per MW versus large reactors. If ~1 GW of output is

		needed, 3-4 BWRX-300 SMRs can be constructed for less cost than one large LWR.
39. To Terrestrial Representative. Molten salt reactors could create operability and maintainability issues, are these factored in in your approach to commecialization of these units? In addition, you are based your design in a R&D reactor. Would say that you are still at the prototype stage, thus, costs and schedule will not be too much representative for the market. You mentioned that large G-W reactors presented problems for construction with cost overruns and delays. However, these shortcomings were observed in Europe and USA in the last years, which are cases in which the project management failed to put everything together. How can you assure that your prototype will not run in the same risks than the large G-W reactors ??	Oscar Mignone	**[Simon Irish]** A Molten Salt reactor does have operability and maintainability complexities that could be challenges to timely commercialization. Those challenges are substantially addressed by the IMSR design – which uses a seal and replacement "Core-unit". This component contains all of the very traditional challenging "operability and maintainability" primary system components – pumps, moderator, HX – which are hence included when the Core-unit is replaced every 7 years. The sealed natured of the Core-unit avoids the maintenance challenges that are associated with maintaining primary components in operation over plant life. SMR designs today are derivatives of proven reactor systems, but none has been demonstrated as a complete final system (Rosatom's SMR's accepted). The IMSR is the same position as the rest of the market. IMSR is a derivative of a MSR successfully operated more than 4 years at ORNL, TN in the US. SMR designs today have yet to demonstrate schedule and cost performance for first plant (Rosatom's SMRs accepted). The IMSR is the same position as the rest of the market. Finally, it is important to recall the risks of schedule overrun are financial risks and that is why they get the attention they do. These risks for a $10 Bn large conventional Gen III plant cannot be absorbed by the private sector consortium as these risks are unacceptably large and threaten the business, they have destroyed nuclear business over the last 10 years. The character of cost and schedule overrun risks are different for a $1 Bn SMR project. They are manageable by a

		private sector consortium. The ability to manage deployment risks is going to be critical for commercial success.
40. You could passively pump Condensate & Feedwater as well as, plant cooling water, you would have full plant operational passive cooling independent of electrical power."	Carl Perez	No comments from our panel.
41. What are the prospects of using these technologies as a carbon free option in heavy industry applications such as steel, glass, ceramic where these require very high tempertures? Would using it to produce hydrogen then burn it after one of the only choices?	Mike Hassaballa	**[LI Fu]** Hydrogen produced from high temperature gas cooled reactor is one of the solution for carbon free option. **[Simon Irish]** There are two options for Gen III and Gen IV SMRs to supply the very-high-temperature industry market: 1 – Use of "topping heat" from electric heating to achieve 1000 C plus supply 2 – Generate hydrogen first and combust it in oxygen (NOX free) or air. This is a derivative method to supply clean heat. **[Eben Mulder]** We have designed our pebble bed HTGR with an inlet/outlet temperature of 250/750 °C subject to well-known code case. The thermodynamic flow path can be easily changed in the existing design to allow for an outlet temperature of 900 °C. That would enable HyS or S-I processes for hydrogen production. We know that electrolytic hydrogen production on a large scale unfortunately, is not economically feasible. As I have indicated during the Q&A session, we can quite easily produce a combined cycle that produces an outlet temperature of 1200 °C. Please look at the schematic below:

		
42. Fluor Corporation, which maintains a controlling interest in NuScale Power, has reduced its annual investments into NuScale project since 2017 and started looking for investors. Do you expect any difficulties in project financing?	Artem Larionov	**[Thomas Mundy]** Fluor remains a strong supporter of NuScale and is committed to our work to bring America's first NuScale small modular reactor power plant online in Idaho by 2027. Fluor continues to provide its Engineering, Procurement, Fabrication, and Construction (EPFC) expertise for this first project. Fluor is able to reduce its annual investment in NuScale because NuScale continues to acquire additional private investment that provides working capital for our program operations. This private investment is supported by the U.S. Department of Energy (DOE) cost share award funding that NuScale has received to date in excess of \$300M. Currently, NuScale has invested over \$950M in our technology development and licensing, which includes this DOE support.
43. The cost of TRISO fuel is twice higher than the traditional fuel cost, which affects the competitiveness of HTGRs compared with LWR. How do you expect the cost (on \$/MWh basis) of TRISO fuel to change in the future?	Tariq Mheidat	**[Answered during session]** The cost of TRISO fuel is drastically being addressed by improved methods of manufacturing. Furthermore, the fuel utilization is much better than LWRs (165 GWd/t vs 50 GWd/t). Eventually cost of TRISO fuel will be reduced through sheer demand.
44. With respect to NuScale, can you explain if the reactor Design Certification review is excluding approval or "finality" on certain design issues? If so, what are those, and what impact may that have on early deployments?	rob sweeney	**[Thomas Mundy]** The U.S. NRC has excluded certain elements of the NuScale design from the scope of its approval under the Design Certification until greater design detail is provided. These few elements will be addressed by NuScale either prior to, or with NuScale's support as part of our customer's combined operating license application seeking U.S. NRC approval to construct and operate a NuScale power plant. None of these elements are expected to impact early deployments.

45. In HTR-PM, how do you control feedwater flow rates to two SGs. In your SGs, you do not have levels, because your SG is an once-through SG. During long term operation, coolant inventories in two SGs can be dfferent, I mean the boiling boundary, inside in your SGs., and you can not measure the level.	Juhyeon Yoon	**[Answered during session]** HTR normally use once-through steam generator. The flow rate of feed water is proportional to thermal power. No water level as in PWR steam generator.
46. How would a newcomer country, which is considering HTGRs, diversify and secure its nuclear fuel supply of the HALEU? keeping in mind the limited HALEU producers around the world.	Tariq Mheidat	**[Answered during session]** It is foreseen that regional fuel factories will arise as the demand increases. These manufacturing units are also modular and can be simply duplicated.
47. What is the $/kWe of KLT-40S and RITM-200?	Juhyeon Yoon	**[Elena Pashina]** FNPP Akademik Lomonosov is the world first floating nuclear power plant. It is very important to understand, that the deployment of the first-of-a-kind of any technology is always more expensive than the Nth of a kind. For example, FOAK project includes the expenditures for the technology development that significantly affects its cost. The cost of the optimized version of the floating NPP will be considerably lower due to another type of the reactor, improved layout design, the learning curve and other factors. ROSATOM designs SMR nuclear power plants taking into account, on the one hand, the target commercial parameters that should ensure its competitiveness when compared with conventional generation sources like diesel, coal or gas, and with other SMR vendors. On the other hand, the final costs of SMR NPP both land-based and floating may vary greatly depending on: • site parameters (for example, availability of cooling water, seismic stability, soil, absence of unfavorable conditions); • regulatory requirements; • NPP configuration; • implemented business model, cost of financing; • and many other factors.
48. Question for Ms. Pashina - could you also provide some pricing points for the various SMRs on page 7 of your presentation? Thank you…	Amjad Ghori	**[Elena Pashina]** ROSATOM designs SMR nuclear power plants taking into account, from the one hand, the target commercial parameters that should ensure its competitiveness compared with conventional generation sources like diesel, coal or gas, and with other SMR

		vendors. On the other hand, the final costs of SMR NPP both land-based and floating may vary greatly depending on: • site parameters (for example, availability of cooling water, seismic stability, soil, absence of unfavorable conditions); • regulatory requirements; • NPP configuration; • implemented business model, cost of financing; and many other factors.
49. For Ms. Pashina - what site(s) are you looking at? How fixed are the FOAK plans in Russia?	Philip Chaffee	**[Elena Pashina]** Rosatom is considering several locations for the first land-based SMR NPP in Russia. The sites are very different which shows that the project can address a wide range of customer demands. The main target for this year is to determine which would be the best site for NPP. We in Rosatom pay great attention to SMR development and we think that we have sufficient in-country market size for serial SMRs production to be able to export a tried, tested and reliable technology. • SMRs are part of Russian Energy strategy – 2035 • SMRs are one of the key tracks of a Comprehensive R&D program of Russian nuclear industry • Special purpose office responsible for FOAK project within ROSATOM was established with participants from Rosatom major subsidiaries • Full government support for FOAK projects implemented in Russia • SMRs became one of ROSATOM key business areas Rosatom is considering several locations for the first land-based SMR NPP in Russia: in the Urals, in the Arctic regions of Yakutia and the Baim deposit in Chukotka. We plan to commission FOAK SMR NPP in Russia by 2027.

50. To Prof. Li Fu, Understood. My question is how do you correct long term accumulated inventory difference in two SGs, because of slightly different flow rate differnce to two SGs in HTR-PM.	Juhyeon Yoon	**[Answered during session]** Auotmaic control of pressure in each SG outlet, control the flow rate of each SG according to the power of each reactor. Then it is.
51. Charles McCombie Arius and ERDO: to all speakers -especially Tom Mundy of NuScale : What happens with the spent fuel if there is no take back. The challenges of nuclear power have always been safety + costs + waste. All speakers are addressing costs. What about the others - especially waste and spent fuel?"	Charles McCombie	**[Answered during session]** The Moltex Stable Salt Reactor can consume any spent oxide fuel waste. The more spent fuel available, the bigger the commercial opportunity for Moltex. **[Thomas Mundy]** NuScale's plant design incorporates proven, safe and effective used fuel management systems and provides space on site for interim dry cask storage of used fuel until, for example in the U.S., a long term disposal solution is made available.
52. Since HTR-PM is among first SMRs underconstruction, then what are major issues led to project delay (the operation date is further delayed to 2021)?what are lessons learnt that other vendors shall consider based on Chinese vendor's experieince?	Tariq ALSHAKETHEEP	**[Answered during session]** Fabrication of the components.
53. Question to SMART. Considering your cooperation with US DoE do you have any plans to participate in design review in NRC?	Artem Larionov	**[Answered during session]** Currently we don't consider NRC review. Later we might go to CANADA for general design review.
54. To SMART. What is your implementation schedule for your project in Saudi Arabia?	Artem Larionov	**[Answered during session]** Now KHNP and KAERI are discussing business model for SMART implementation in KSA. I'm sorry for not providing it's fixed schedule now.
55. To Dr. Kang - Are there plans to build a first-of-a-kind SMART plant in Saudi Arabia or Korea? If so, where and when? And what other markets are you looking at selling into?	Philip Chaffee	**[Answered during session]** Now KHNP and KAERI are discussing business model for SMART implementation in KSA. I'm sorry for not providing it's fixed schedule now. We are cooperating with Jordan, Czech, and Philippines to deploy SMART.
56. Normally SMRs thermal power is upto 3ooMWE, So how the SMART falls under SMR domain?	Krishna Kumar	**[Answered during session]** thermal power 365 MW, electrical power around 110 MWe
57. Mr. Eben Mulder, as the spherical fuel element is the fuel design that has been adapted by a few HTGR technologies, consequently, it is expected that the nuclear grade graphite demand will increase, the available potential suppliers in the market are very limited, please elaborate on the plans to secure the supply, potential suppliers and your forecast for the future market demand.	Tariq Mheidat	**[Eben Mulder]** We are in contact with several nuclear graphite suppliers in the US. Based on historical evidence we are specifically targeting a medium grain graphite. Long term supply is not a problem. Once again supply will be driven by demand. What we have also found is that graphite companies have merged and broken up several times. Fortunately, graphite and its manufacturing is well understood today.

58. Thank for good presentation. NuScale has very small containment vessel but has a large Reactor Building where all 12 NPMs are loaded. The volume of NuScale reactor building is about 3.5 times larger than that of the containment building of 1000MWe PWR. NuScale NPM is much simpler than NSSS of 1000MWe PWR, but 16 NPMs and same auxiliary systems are needed to produce 1000MWe. What is the key driving factor to secure economic feasibility of NuScale compared with large PWR ?	Keung Koo KIM	**[Thomas Mundy]** NuScale's SMR maximizes the economic benefits from: design simplification, repetitive factory fabrication of the NuScale Power Module™ (the entirety of the NSSS and containment in a single module), application of modular construction techniques, and minimization of the need for nuclear qualified equipment and instead greater use of less expensive commercial grade equipment to present a competitive cost in comparison to large nuclear. The overnight capital cost for a NuScale 12-module facility deployed in the U.S. is about $3,600 /KW. An industry report examined the economic advantages of the substantial modularization of the NuScale design and the use of off-site manufacturing of the modules and found: • Total capitalized cost of a 12-module NuScale plant (683 MWe net output) is approximately 38% of the reference 4-loop PWR (1147 MWe net output), representing a reduction of nearly $4 billion. • Accounting for differences in power output, the capitalized construction cost per unit of power for the NuScale plant is 62% of the 4-loop PWR ($3,466/kW versus $5,587/kW).
59. Dr. Kang, when do you expect to deploy and begin initial SMART reactor construction? What do you see the overnight costs to be for the initial Saudi project?	rob sweeney	**[Live answered]**
60. To Prof. Li Fu for HTR-PM, Thank you for your explanation. If you control two SG flow rates as you explained, one SG can have a higher flow rate than the other for a time being, and later this situation can be reversed. This situation is what I mentioned as a instability in the first question between two SGs.	Juhyeon Yoon	**[LI Fu]** The flow rate of SG is mainly determined by the feedwater pump, the balance of pressure at the outlet of SG and the adjustment of flow rate in each SG is not so difficult.
61. To X-energy. In the process of new product development, especially in nuclear energy, the core thing is existing of sustainable funding. Please, indicate availability of long-term financial resources for you.	Artem Larionov	**[Eben Mulder]** We are very fortunate to have a committed investor. In support of his vision the US DOE has been incredibly supportive in nurturing and promoting this Public-Private Partnership. This I believe will not only provide long term support for this technology but indeed will help restore the US supply chain capabilities in the nuclear arena.
62. Dr. Mulder. If it is such a safe reactor, then why 400 meters of safety zone.	Józef Sobolewski	**[Eben Mulder]** It is typical in the nuclear business to assume that during fuel manufacturing a certain number of TRISO particles would fail and that a certain amount of so-called tramp uranium would be in the matrix graphite.

		The reason for selecting 400 meters is simply because the site fencing is at 400 meters. We have been developing an in-house capability to estimate the so-called mechanistic source term expected to be in the helium circuit at any time during operation. Should this source term be released into the environment, without taking any credit for the helium pressure boundary it has indeed been found in preliminary estimates that all regulatory limits are observed at 50 meters from the core!
63. I think that the PBMR was abondoned by South Africa?	Djillali KHELFI	**[Eben Mulder]** It was indeed. There was no technical reason though. It happened during a time of changing administrations and the incoming administration had a much bigger interest in using all available resources to build soccer stadia for the 2010 Soccer World Cup than caring about the looming electricity shortage… Interestingly enough a recent RFI has gone out for 2,500 MW of nuclear new-build. Figure that…
64. To Rosatom Representative. Thank you, very comprehensive presentation. Congrads! It has confirmed Rosatom has already implemented SMRs for different applications, based on proven design. What is about cost efficiency of the RITM design, comparing with gas plant cost?	Andrey Yuzhakov	**[Elena Pashina]** ROSATOM designs SMR nuclear power plants taking into account, one the one hand, the target commercial parameters that should ensure its competitiveness when compared with conventional generation sources like diesel, coal or gas, and with other SMR vendors. On the other hand, the final costs of SMR NPP both land-based and floating may vary greatly depending on: • site parameters (for example, availability of cooling water, seismic stability, soil, absence of unfavorable conditions); • regulatory requirements; • NPP configuration; • implemented business model, cost of financing; • and many other factors.
65. to Eben Mulder - it was striking that the list of HTGRs that you showed had many that were shut down early - e.g. Dragon, Fort St Vrain, AVR, THTR, PBMR. How would you summrise the reasons for these cases?	Charles McCombie	**[Eben Mulder]** Yes, DRAGON and AVR were experimental reactors that have run their course. The AVR was decommissioned after 21 years of successful operation. Both Fort St. Vrain and the THTR were demonstration reactors. Fort St. Vrain had a bunch of technical issues but provided an immense amount of insight into both the technical and regulatory areas, both being extensively used to inform our modern-day approach. The THTR went into operation in 1986, a

		pretty unfortunate year from a timing perspective as it also was the year that Chernobyl happened. The main cause for the THTR's premature closure is seen as a political decision as Germany developed a particularly strong anti-nuclear sentiment during that era. The PBMR on the other hand had all these lessons to learn from and had strong support from the German specialists to develop the technology. The South Africans developed the fuel fabrication, and everything was ready to go when a administration change happened. As indicated higher up the 2010 soccer world cup effectively ousted the PBMR in its competition for resources. During the PBMR era all Universities in South Africa collaborated on various aspects of the PBMR. In my School alone we have trained and educated 150 Masters and PhD students in Nuclear Technology… It was a dream project for skills development and training… We are fortunate that an entrepreneur in typical US style recognized the opportunity and the rest, as the saying goes, is history.
66. For all SMR vendors:What market prospects could your design expect if you anticipated a capital cost of $16000 per kilowatt-installed as some Australian modelling has asserted?"	Oscar Archer	**[Eben Mulder]** We have developed a very functional cost model for both the Xe-100 reactor and its TRIS-based pebble fuel. After extensive work over the past 10 years I am becoming more and more convinced that we can be competitive with n. gas in the US! I know this sounds like a very bold statement. We have recently been awarded an ARPA-E GEMINA award to show how far we are from a positive outcome in this regard. Watch this space…
67. Are you aware of IAEA Milestones Approach (mentioned by our Korean presenter). Do you see this support to ~Members States as improving the prospects for SMRs deployment.	Milko Kovachev	**[Eben Mulder]** The most important ingredient to any of the SMR technologies will be: "A paying customer." That is the challenge…
68. Do the panelists believe that organisations such as WANO and INPO are engaging sufficiently with the SMR vendors so that guidance to future operators is developed in parallel with the design and licensing processes? For example there is a WANO NUAWG (new unit assistance working group) which has representatives from current construction projects but not (as far as I'm aware) SMR projects.	Alastair Crawford	**[Gloria Kwong]** None of the panelists had responded to this question, however, PETER PROZESKY, CEO of WANO, did indicate that SMRs have a different risk profile and it is difficult to know whether WANO will develop a specific set of processes related to SMRS.

69. Akira Tokuhiro, Dean and Professor, Ontario Tech University, Canada. Will we have enough young generation nuclear engineers well-versed in SMRs to realize the future of nuclear engineers? There are very few universities that teach SMR engineering and design. I would urge SMR vendors to take an interest in Universities. Thank you.	Akira Fitzsimmons	**[Eben Mulder]** Prof. Tokuhiro, in my humble opinion the drive for this young generation should come from the utilities signing new-build contracts. That will spark the need for succession planning. In turn that will lead to experimental facilities being built, theoretical expansion and methods development initiatives, supply chain growth, etc., etc.
70. Question to all vendors- do you see the need to cooperate in substantial public outreach effort to educate populations of especially democratic countries on how SMRs overcome all objections to nuclear power & thus will have major impact to achieve carbon neutrality?	Kalev Kallemets	**[Eben Mulder]** If I think of the particularly poor job that scientists and engineers are doing in selling these technologies, I can only hope that help will come from the PR and journalistic communities. Yes please, help us to put this in simple, understandable nomenclature for general consumption. **[Thomas Mundy]** NuScale is prepared and has been working with local and national outreach efforts on educating the public about commercial nuclear power.
71. All. To everyone who compares small reactors with large ones and treats large ones as opponents. It cannot be expected that anti-nuclear movements, by eliminating large reactors, will create space for small ones."	Józef Sobolewski	**[Thomas Mundy]**NuScale's SMR based power plant technology has a safety case, features, performance and capability not found in current large nuclear plants, which have been mainly used for baseload electricity production. Some of the features include: scalability, ability to run in island mode, ability to "black start", no need for "1E power", an unlimited coping period, ability to provide first responder power, high resilience to natural and man-made events, ability to provide highly reliable power, and ability to extensively load follow to name a few. Because of these differences, we don't view or treat large nuclear plants as opponents, but complimentary to the overall need for resilient and flexible zero carbon energy.