House of Commons

Science and Technology Committee

Oral evidence: Delivering nuclear power, HC 626

Wednesday 23 November 2022

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Watch the meeting

Members present: Greg Clark (Chair); Aaron Bell; Dawn Butler; Tracey Crouch; Rebecca Long Bailey; Stephen Metcalfe; Graham Stringer.

Philip Dunne, Chair, Environmental Audit Committee, attended the Committee.

Questions 166 - 258

Witnesses

I: Tom Samson, CEO, Rolls-Royce SMR; and Gethin Jenkins, Head of Safety and Licensing, Last Energy.

II: Dr Ian Scott, Chief Scientist, MoltFlex Energy Limited; John Eldridge, Principal Engineer, U-Battery; and Dr Fiona Rayment OBE, Chief Scientific Officer, National Nuclear Laboratory.

III: Professor Tim Abram, Westinghouse Chair in Nuclear Fuel Technology, University of Manchester; and Laurent Odeh, Chief Commercial Officer, Urenco

Examination of witnesses

Witnesses: Tom Samson and Gethin Jenkins.

Q166 **Chair:** The Science and Technology Committee continues its inquiry into new nuclear power. We are pleased to be joined in our questioning today by Philip Dunne, Chair of the Environmental Audit Committee.

I am very pleased to welcome our first pair of witnesses. Tom Samson is chief executive of Rolls-Royce SMR—small modular reactors—which has been chosen by the Government as the UK's preferred SMR supplier.

I am delighted to welcome Gethin Jenkins, the head of safety and licensing at Last Energy, a US SMR developer. We are interested in his perspective. It might interest Members to know that Mr Jenkins was part of the team leading the generic design assessment of the UK ABWR on behalf of Hitachi for the Wylfa project, which was suspended.

Thank you both very much indeed for coming this morning.

Mr Samson, SMRs are clearly the subject of intense policy interest at the moment, but the reason that Rolls-Royce is a leading member of the consortium derives from its long-standing expertise in nuclear-powered submarines, does it not? Can you describe how the technology can be moved from that use to civilian nuclear power use?

Tom Samson: We have used our capability and know-how in engineering and manufacturing to develop a commercial nuclear reactor technology application within Rolls-Royce SMR. The know-how and experience we have built up over the last six or seven decades in our submarine defence business, where we manufacture and design propulsion systems for the submarine fleet, have given us an engineering capability and a manufacturing know-how that we have taken to one side to develop a civil commercial nuclear reactor.

It is in the same family of reactors; it is a pressurised water reactor. For a variety of reasons there are many differences between the submarine technology and the civil technology, but we have deployed our know-how, experience and expertise in creating this new domestic sovereign technology.

As you said, Chair, it gives us, for the first time ever, I think, an opportunity to export a nuclear clean energy solution at a time when nuclear has such a critical role to play globally in both energy security and net zero.

Q167 **Chair:** When is the earliest feasible time for the deployment of UK SMR if all the lights are green, as it were?

Tom Samson: Any deployment timeline has to be predicated on the assumption that we begin to execute and deploy against a commitment. The hard part is getting to that point. Assuming we get to that point towards the end of next year—the back end of 2023—which is our ambition, we believe the first unit will be on the grid probably in the early 2030s.

If we manage to accelerate and use the existing nuclear estate and try to short-cut or expedite planning processes to put the reactors on existing nuclear sites with existing supportive communities where there has been a nuclear asset for many decades, we will probably be looking at 2031 or 2032 as a feasible on-grid date.

Q168 **Chair:** Again, assuming all the lights are green, what would be the contribution to our power needs from that point?

Tom Samson: Each of our SMRs is over 470 MW. That is enough to power a city the size of Leeds, and these plants are designed to operate for 60 years, but they will probably operate for longer than that. We have seen plants that were designed to operate for 30 or 40 years operating for many decades beyond that. That is the scale for one unit. We can deploy multiple units.

Two weeks ago, we publicised a very interesting study, where we worked with the NDA to explore the existing nuclear estate in England and Wales, considering whether our existing nuclear assets—

Chair: NDA being the Nuclear Decommissioning Authority.

Tom Samson: Yes, indeed. We looked at the NDA estate and other nuclear sites that are designated for large gigawatt or are under EDF, Chinese or French control, which could readily be deployed as nuclear sites for SMR. Within that existing footprint, there is enough space to accommodate all of the 24 GW that we would need from nuclear by 2050 if we chose to deploy this technology to meet that need. We would not need any new sites beyond that nuclear estate if we were to try to get to that goal.

Q169 **Chair:** In terms of the definitions, one of our witnesses in the last session said that, strictly, in the international typology, at 470 MW this is a medium-size reactor rather than a small reactor. Is that true, and does that classification have any implications?

Tom Samson: There is no international classification. There is a nomenclature that associates 300 MW with an SMR that goes back in time to when people thought about what an SMR might be. But we are absolutely part of a modular technology solution, and the reason we are at 470 MW is that that is the biggest reactor we can produce in the factory environment that takes full advantage of a factory-built solution to avoid construction risk and allows us to develop a solution that can go from factory to site on road, without any need to stick build in the field.

That is how we get to our capacity, but there is no international nomenclature as such. We are working with the IAEA on SMR deployment and harmonisation; we are part of that programme. We are working with many companies and countries that are interested in SMR as a type, and which are not really bounded by some kind of megawatt threshold.

Q170 **Chair:** In terms of regulatory and approval processes, there is no difference between something that is below 300 and 470.

Tom Samson: None whatsoever.

Q171 **Chair:** Given that submarines are roaming the world's oceans at the moment powered by nuclear reactors built by Rolls-Royce, clearly they are capable of generating power. Some people might wonder why it takes so long to lift and shift that technology to a licensed nuclear site, which might be an easier environment than the bottom of the sea in a pressurised container. Why does it take so long to make the conversion, as it were?

Tom Samson: We have done the design work and we have the design and a technology. We are now taking that design through its evolving stages of maturity, thanks in part to the grant that we received from UKRI and investment from our shareholders. That technology is now going through the generic design assessment process with the regulator. Any new technology has to go through that process, which takes time. That is the journey we are on.

We are trying to advocate that we do a number of things in parallel so that while we are doing the GDA we commit to deploy the technology so that we can start to build the factories. This is a new technology that will require investment in factories and industrial capability, and then we can prepare the sites to host the product that we manufacture in those factories. That is what we are trying to advocate. It does not need to be done in series; we can be doing this in parallel, and we can be doing it now.

Q172 **Chair:** In terms of the essentials of the reactor, is it basically the same as the power source for a nuclear sub?

Tom Samson: The more common reference is that, of the more than 440 reactors in service in the world today, more than half are pressurised water reactors using standard enriched uranium. That is exactly the type of reactor technology we are using in our Rolls-Royce SMR.

We have chosen specifically to use proven technology, and scale it to be sized so that it can be built in a factory. Importantly, that allows us to deploy that technology today without the need for a demonstrator, because we have done a digital twin. We have created a solution that is being designed in its entirety within Rolls-Royce SMR—the same digital twinning adoption as within the Dreadnought programme, developing a digital twin to avoid the need for a prototype.

We are now taking to market a well-proven technology: the pressurised water reactor and standard fuel. Indeed, our innovation has been more focused on how we modularise and build it in a factory to try to reduce and remove as much of the construction risk as possible, which has constituted many of the challenges faced by large nuclear.

Q173 **Chair:** Do not similar considerations about the manufacturing design and the risk associated with it apply to making the power sources for the subs? I am interested in how close the relationship is between what is already done by Rolls-Royce and what is proposed to be done. Is it very different?

Tom Samson: We should not really consider the reactor in a submarine and an SMR as being an evolution of one to the other. They are very different.

Q174 **Chair:** Are they? In what way?

Tom Samson: The detail about the submarine reactor is classified; even I am not familiar with it. What I am saying is that the engineering and manufacturing knowledge and expertise that we deploy in Raynesway in Derby for, as you rightly pointed out, a much more arduous and complex environment has now been developed into a civil Rolls-Royce SMR, using that same factory manufacturing know-how to develop a civil application.

It is not a correlation or an evolution of the reactor in the submarine—there are a number of major differences—but we have deployed the know-how and capability, which is a UK skillset, to develop a new civil design.

Chair: I see. Thank you very much indeed.

Q175 **Rebecca Long Bailey:** You mentioned that there was a possibility that SMRs could be ready to supply energy to the grid by 2030. What are the current challenges in achieving that goal, and what more should the Government be doing to support you?

Tom Samson: We are really keen to move now with the Government into negotiations—to begin discussions on a structure for how we can deploy the technology in the UK. That is our ambition: to move now into that negotiation stage. That negotiation will take probably the best part of a year so that, by the end of next year, we will be in a position where we can, I hope, create a construct that we can then have a commitment from, allowing us to start building factories, preparing the sites and deploying the technology.

That is where we are now: we are hoping to move into those negotiations. We have been having discussions over the last few months with officials and we are keen to continue that momentum over the coming weeks and months.

Gethin Jenkins: There are lots of parallels between both projects. The technology that Last Energy is bringing to the UK is on the smaller end of the small modular reactors, and therefore the challenges are slightly different. I can go into them in a moment.

From the policy side, the challenges are predominantly led by the siting policy. The current national policy statement, EN-6, is very much aimed at gigawatt power stations, and it provides eight sites where the power stations could be built. It is going through an update at the moment, and that is vital for the deployment of SMRs, which have a wider application in other areas, such as in industrial clusters. That siting policy is a key challenge that needs to be overcome.

Q176 **Rebecca Long Bailey:** Thank you. Once the relevant commitments are received from Government, how ready is the supply chain to engage in the strategy?

Tom Samson: The supply chain needs a demand signal, and it is the same with skills. I have every confidence that in the UK, and globally, the supply chain can respond to this challenge, but we have to provide it with the demand signal. Talking about deployment and ambitions to build nuclear is not the same as having an actual commitment to deploy.

Part of our commitment in the UK is to look at building new industrial capability, building new factories, creating new jobs and having a capability we can then export globally. I have every confidence that the supply chain can rise to that challenge once we have the demand signal. Today, we engage with the supply chain extensively and prepare it for what is coming, but that anticipation can translate into investment and action only once we have a deployment programme against which it can start to invest and plan.

Gethin Jenkins: As I said, the Last Energy PWR-20 is on the smaller side of the small modular reactors. It has often been referred to as a microreactor: 20 MWe. That allows for the use of more off-the-shelf components and equipment that is already being manufactured and fabricated in the UK by the existing supply chain.

Our deployment model, which is fully modular, is to embrace and work with the existing supply chain. We would be able to put in long-term, sustainable orders with manufacturing and modular integration facilities, which could then build up their skills over the longer term, and then offer those skills for other technologies and sectors in the UK.

We have already had great interaction with suppliers, predominantly around nuclear clusters where existing sites are, and we are very keen to continue those discussions.

Q177 **Rebecca Long Bailey:** My last question is the $1 million question: should the Government support SMR deployment over larger nuclear power plants?

Tom Samson: I think it is not either/or. The scale of the clean energy challenge in this country, and globally, requires everything to be deployed if we are to have any hope of impacting climate change in the near term, but there is a potential for the distraction of different choices preventing us from getting to a point where we can make decisions and move forward. It is about how we get the next nuclear megawatt on the grid, because that is what will really start to benefit consumers, in terms of cost and energy security. That is what we should be prioritising. Another year, or two or three years, spent talking about it is going to affect consumers in the 2030s. It is really important that we take action now.

Gethin Jenkins: I fully agree. In order to meet the UK targets for net zero the large gigawatt projects need to go ahead. It is great to see recent announcements for Sizewell C, but the speed of deployment of some of the SMR technologies, and specifically the PWR-20 that Last Energy is bringing to the UK, and the flexibility in siting, means that it can be deployed quickly in industrial areas.

One feature of the PWR-20 is that it is air-cooled, as opposed to requiring a thermal heat sink for the water, which means it can be sited in areas where the industrial users require it, so it can get to the heart of decarbonisation very quickly, which would complement the large gigawatt power stations for energy production and electricity supply but would help widen the decarbonisation of industrial users.

Q178 **Rebecca Long Bailey:** I am sorry, but I have one more question: what are the differences in construction times for SMRs and larger-scale reactors?

Gethin Jenkins: On the basis that the modules can be assembled, integrated and tested in a factory setting, the timescales can be very quick. If the supply chain is ready and the licensing is all in place, the timescales can be as short as four or five years from now, assuming we get the green light to go ahead.

That is then scalable; you can then have more than one unit. You can start building up over time as the industrial areas or the other users may grow with the sites. You could add further modules as you go forward, for expansion, for clean tech or data centres, for example.

Q179 **Chair:** Mr Jenkins, in your answer to Rebecca about the siting of new reactors, you mentioned that for decarbonisation reasons you might want it to be close to industrial users. Were you implying that they would not be in existing nuclear licensed sites?

Gethin Jenkins: The current policy allows for nuclear development close to or on one of the eight sites that have been identified in the national policy statement. Those sites are obviously of value for SMR development and they would be good sites.

The true value proposition of SMRs would not necessarily be realised on those sites. Most do not require a large thermal heat sink, and those eight sites were originally identified for gigawatt power stations. If the national policy statement was widened or broadened to allow for deployment in other areas, it would allow the SMRs to be deployed close to the industrial users, in either behind-the-grid applications or clean tech industrial areas where they could then be the clean energy source for other industries and technologies.

Q180 **Chair:** The obvious concern about that would be the security concern. On licensed nuclear sites you have the Civil Nuclear Constabulary; you have well-established protection measures. Tell me how concerned we should be. How extensive would the security requirements be if you were to deploy these SMRs off the approved sites?

Gethin Jenkins: The simple answer is that the SMRs would still adhere to the same regulatory security requirements as any other nuclear site in the UK. A lot of nuclear sites in the UK co-exist in local communities, fairly close to areas of industrial users and residential users; so they would be no different in the requirements that we would adhere to. The opportunity with modern technologies, and designing with this from the start, is that you may be able to simplify some of the systems. If you have based a design so that security and safety is one of the fundamental objectives of the design, you can allow for some simplifications and efficiencies as you go forward. But the simple answer is it would be exactly the same as the other nuclear sites, so there should be no concerns over that.

Q181 **Chair:** Mr Samson, does Rolls-Royce have a perspective on this? Would you expect them to be deployed beyond the existing licensed sites?

Tom Samson: Yes. As I mentioned, we have done a study with the Nuclear Decommissioning Authority on the extent to which the existing nuclear estate could accommodate our size of SMR. That means we could meet all the full 24 GW without any new sites being released.

However, I think there are two things to say. As well as deploying SMRs on that existing nuclear estate, they could then become magnets for other energy-intensive users to come to those communities to access that clean, low-cost source of baseload energy. So the opportunity for data centres, hydrogen production or industrial growth to occur adjacent to those nuclear estate sites is, I think, quite key.

Equally, in the longer term we have other ideal sites such as the existent decommissioned coal-fired estate, where we could deploy SMRs to make use of the grid connection and the water sources, to produce power. That would require more medium-term planning, because you have to go through the licensing and siting laws to ensure that that could be operated as a nuclear site.

I would say they would be more medium-term growth opportunities, but the key message, I think, is that we have a nuclear estate today with supportive communities that could host all our nuclear needs and potentially attract other industrial activity to support growth in those areas to access that form of low-cost baseload clean energy.

Q182 **Chair:** If you were to use former fossil fuel generating sites, which, as you say, have grid connections, how concerned about security would we need to be in terms of hostile threats?

Tom Samson: I think the key thing with the nuclear technology and the nuclear design—and we are taking this through the generic design assessment, which covers safety as well as security—is the design features are heavily regulated and every nuclear reactor in the UK meets that threshold.

Q183 **Chair:** That is true of every reactor. I guess the question is: is there any reason to think that small modular reactors would be less of a risk or less of a concern than a large-scale reactor?

Tom Samson: I think when you get to future advanced technologies, in the next decade, where there may not be the same risks associated with some of the new technologies that exist today, it may be different; but for now, we would have to have all the same security and protection measures. We have a Civil Nuclear Constabulary that would have to be funded to protect those sites, and if you went to a coal-fired site, for example, they would require implementation of those security measures on those sites and locations to protect those nationally secure assets.

Chair: Okay, that is very clear. Thank you very much. Philip Dunne.

Q184 **Philip Dunne:** Thank you very much, Chair, for letting me join you today for this interesting discussion.

I should like to focus on the technical challenges you are both facing, and the readiness levels that you are at. You both touched on some of this already.

Mr Samson, you described the digital design having been completed. What technological readiness level does this mean the project is at? Is it complete? Does that mean it is at a 9?

Tom Samson: No, I would not say it is complete at a 9. We have been developing this technology since 2015 in Rolls-Royce, so we have got seven years of experience in developing it.

Our reactor island is the most advanced part of our technology, in terms of the expertise that, as I mentioned before, we have had in this programme, for many years. We are now taking the technology through the GDA. We are going to be entering step 2 of the GDA in April next year, and we are on track to enter that point, in which case we then start to provide detailed evidence on the safety case of our design. As well as that, we start then to build test rigs to verify and validate a number of safety features.

I would say that our PWR reactor island design is mature—I would need to go back and check with my engineering team whether it is TRL 5 or 6, but I would say it is a mature design that will continue to evolve as we complete the GDA. That is one of the benefits of going through the GDA concurrently with us maturing and finalising the design. As we complete the GDA, we adapt and adopt the design to meet the UK's requirements—

something we know very well. It is the first time the UK regulator has had a UK design by a UK engineering firm coming through that understands the UK regulatory environment. We are in very close co-operation with the ONR, and we are working closely on making sure that our design—because we understand the requirements—fully meets the UK regulatory thresholds.

Q185 **Philip Dunne:** As this is new, as you have just said, there is always scope for surprises and delay. How long is step 2 expected to take? And talk us through step 3.

Tom Samson: We are funded through to the end of step 2 with the money we have today. That will complete in August 2024—potentially earlier than that, but that is currently our plan—at which point there is a further year and a half to complete step 3.

Step 2 is a major de-risking step, because in step 2 we present the design and discuss with the regulator whether there are any showstoppers or risks or issues that the regulator is uncomfortable with. We have concluded all that by the time we get into step 2; and step 3 is then the presentation of the detailed safety case of what we have presented in step 2.

So the end of step 2 is a major threshold for us in the design validation with the regulator. We have been working with the regulator for the last two years, during phase 1. We and our consortium had the UKRI grant before we entered step 1 about a year ago. We have had a long discussion with the regulator, educating them on what technology we are bringing forward, acknowledging the understanding of the regulatory environment.

With the fact that it is a family of pressurised water reactors with standard fuel, we don’t envisage there will be any technical showstoppers in what we are bringing forward.

Q186 **Philip Dunne:** How does that timeline then play out? If you get to the end of step 2 in August 2024, do you go straight into step 3?

Tom Samson: Our plan is that during the next 12 to 24 months we will secure orders to start deploying the technology. When we are deploying the technology and we have the revenue coming in from those orders, we will then continue to complete the detailed design and site-specific design, and included in that will be the conclusion of step 3.

Q187 **Philip Dunne:** How long does that take?

Tom Samson: Step 3 should be finished some time towards the end of 2025, beginning of 2026.

Q188 **Philip Dunne:** And site identification has happened, so you then apply for planning prior to commencing step 3?

Tom Samson: We would advocate that we can identify the sites now. We have looked at the options with the NDA. We need the Government now, either with GBN or in isolation, to make a decision on which sites we could deploy the technology on, and start the process and the planning applications to consider that site for SMR deployment. There is nothing preventing that work from beginning as soon as January next year, if the Government choose to pursue that as a siting option, but the siting is tied into the project customer, the project company and the funding and siting, so there is a bunch of work to be done on how we structure a deal within which we can deploy the technology. That is part of the work we are hoping we can continue to explore with the Government during 2023.

Q189 **Philip Dunne:** Do you feel that your counterparts within the Department have the expertise to be able to keep up with the pace that you want to put them through?

Tom Samson: I hope so. They have been doing a lot of work recently on the formation of Great British Nuclear as a way to try to drive the nuclear agenda forward. With Great British Nuclear, coming with other instruments of Government, such as the Nuclear Decommissioning Authority and other elements of Government that have nuclear capability, it is absolutely realistic that if we have commitment and drive we can try to get a deal done in 2023. That is our ambition.

Q190 **Philip Dunne:** Mr Jenkins, forgive me, but I was not familiar with your company until I was preparing for this session: do you have existing plants elsewhere in the world?

***Gethin Jenkins*:** No, we don’t.

Q191 **Philip Dunne:** You have technology that you have deployed as a company elsewhere, which helps you have confidence that you can deliver against the timeline you are about to tell us.

Gethin Jenkins: The PWR-20 reactor type that Last Energy is looking to bring to the UK is the standard PWR technology, with standard fuel. The only difference is it is far smaller—so fewer assemblies. It relies on the 300 other operational units, operational experience and data to inform the design. There is nothing too novel or different about the technology itself.

The technology isn’t necessarily the challenge. We believe that the challenge is more in the deployment model and how you bring, design, plan, construct, and operate small modular reactors.

Our timelines have been described as aggressive. We are very keen to bring nuclear technologies—small modular reactors—to industrial users in the UK. With the licensing routes established and clear, we could be deploying the technology within four or five years in the UK.

The benefit of using the smaller or micro reactors is that the majority of the equipment and components can be off the shelf. Suppliers already exist in the UK. The manufacturing fabrication facilities already exist. Our timescales will be challenged by the licensing and planning consent route, which we are already embarking on, and starting discussions with regulators.

Q192 **Philip Dunne:** Where is your design, in relation to the TRL levels? It sounds as though you are unlikely to be as advanced as Rolls-Royce, because you haven't got an existing model to work from.

Gethin Jenkins: We don't have an existing operational model. We do have demo plants that are built in the US. Again, on the basis that the challenge is more on the modularisation and integration of modules, we built a demo plant that showed how the modules come together and how they move.

We are coming to the end of detailed design for the NSSS. Similarly to what Tom said, the nuclear island part is a very well-developed design, and the balance of plant are more off-the-shelf components, so they are pretty much existing anyway.

Q193 **Philip Dunne:** When do you propose to start your GDA process?

Gethin Jenkins: We are currently in discussions with BEIS on the appropriate route for licensing for the PWR-20. I am probably reflecting more on my experience of GDA from my time in Horizon and Hitachi; the updated guidance allows for coming out of step 2 or step 3. So we are currently in discussions with both BEIS and ONR about which stage we aim to complete our GDA for. We also intended to run a site licence in parallel. Obviously, with the goal of having a site and running a project in parallel, we are having both those discussions at the same time.

Q194 **Philip Dunne:** Have you started step 1 yet?

Gethin Jenkins: No, we haven't.

Q195 **Philip Dunne:** Do you know how long that would take, for a design that hasn't yet been completed?

Gethin Jenkins: We have a fairly well-developed safety case. I should explain; the PWR-20 was designed with the UK in mind from the outset, so the codes and standards, the safety case, the documentation, the claim, argument and evidence, are all aligned to UK regulatory approaches. The safety case is well developed.

The next step is to have those discussions—either pre-licensing or early GDA—with the regulators, and agree the timescales. We would like to think we could complete it in a far shorter timescale than has been done for the large gigawatt projects, but we would like to have those discussions with the regulators first.

A lot will hang on the resources, internally, from the regulatory point of view, and their commitment to the project, and also the expectation of information in the first step.

Q196 **Philip Dunne:** Do you need a UKRI contract before you enter step 1?

Gethin Jenkins: No. The Last Energy model is that the reactor is sized and scaled so that it could be covered by private finance, so the money is there for the first number of units. We are not looking for any funding or grant investment. We obviously intend to build and operate these, so a key aspect of our requirements is to identify sites.

For any GDA project it obviously needs to be borne in mind that the overall purpose is to take it forward to a site. We would look to identify those sites and run it in parallel to try to shorten the timeframes. It really, then, teases out the value proposition of an SMR that is quick to deploy, by running the licensing and consenting processes in parallel.

Q197 **Philip Dunne:** Can I just ask about manufacturing and supply chain capacity? You have just said that you think the supply chains exist already. They exist for the existing fleet, but they are under considerable pressure through relatively limited orders and building up green labour forces in order to be able to supply capacity. In a former life, I attended Nuclear Industry Council meetings, and in every meeting the main concern was where the workforce was going to come from in future generations. Tom, can you give us your assessment of supply chain robustness, and willingness and ability to ramp up the kind of pace that you are talking about?

Tom Samson: Yes. Again, it depends on what the ramp-up is, and what rate of production we are trying to get to, but there are two factors. There is an existing international supply chain that we could look to, to manufacture some of our components. Our ultimate goal is to manufacture as much of the technology here in the UK as we can, because there is going to be a UK demand, and we want to export, and create an economic growth story, behind this technology.

We will be looking at building new factories. In fact, we have gone through a process this year of factory siting, looking at a number of sites for those new factories, and particularly our heavy pressure vessel factory that would manufacture the reactor pressure vessel and other large components.

We have other needs for factories to produce the modules, and that is more flexible. We can repurpose factories in the supply chain, as well as having the option of building new facilities to produce the modules.

Both those avenues, whether it is creation of new industrial capability in the UK or accessing the international supply chain and then ramping up to meet that demand, require that demand signal. We have confidence that we have enough knowledge of the supply chain's capabilities to reflect in our schedule the ambitions that I mentioned to Ms Long Bailey, that we could be on the grid by the early 2030s—that we would either tap into that existing international supply chain or could actually manufacture the product here in the UK. It really requires the demand signal, in terms of a commitment to deploy, for the supply chain to ramp up.

The same applies to scales. We have already started. We have gone through a huge recruitment programme this year. We secured the UKRI grant just over a year ago, of £210 million. We have brought in a commitment to £280 million of equity, to access that grant, and we have already spent a large part of that in 2022. We have grown the company. We launched from 160 people, and today we are over 500. We have made over 300 job offers this year, to grow this company, including 20 graduates and apprentices.

It is that commitment to move forward to deployment that we are pursuing that has allowed us to grow that organisation; but that organisation has to be sustained with commitments, as I mentioned before, to enter into negotiations, and has to secure commitments to start building these projects, so that we can continue to grow the scale base, not just in terms of our company but in the supply chain and those new factories. So it really comes down to chicken and egg. We have to make the commitment to deploy, to really set the path forward for the industrial capacity to ramp up.

Q198 **Philip Dunne:** Have you estimated how many jobs you would need to generate in order to complete the first project?

Tom Samson: Yes. We have looked at the jobs using tools like the Treasury Green Book, and have looked at what it will look like in the 2030s and beyond if we have a fleet of reactors in the UK and are exporting this globally. This could contribute more than 40,000 jobs in the UK alone, in terms of the opportunities to manufacture and export this technology internationally.

We have ambitions to sell 20 of these reactors internationally by the end of this decade, which would generate many tens of billions of pounds of revenue, coming into the UK, as a key export. That is the real prize, here. The real prize is for the UK to be on the world stage as an exporter of a clean energy source, through this nuclear Rolls-Royce SMR solution, manufactured in the UK and sold internationally. That is where we have to start to compete on the world stage—to create those opportunities so we can then create a really strong industrial base here that is focused not just on the UK's demand, but on meeting an enormous global demand for clean energy.

Philip Dunne: I think we might come on to exports, but perhaps I should leave it there.

Chair: We will. Thank you very much, Philip.

Q199 **Tracey Crouch:** I just wanted to probe the build aspect. You both said there are quite ambitious target times, though there are slight differences in that. Could you explain, perhaps starting with you, Mr Samson, and then on to you, Mr Jenkins, what is meant by "from investment decision to delivery"? What is included in that? Are things like testing, for example, included, and does delivery include switch on, or is that completely separate?

Tom Samson: We have done a lot of work this year on our schedule, from the first order to commercial operation date. As I said, if we get an order towards the end of 2023, or a commitment from a customer to start deploying the technology by the end of 2023, we believe we can be on the grid by 2031-32, depending on the planning, or opportunity to try to accelerate through the planning process.

That is from an order commitment to commercial operation date, so that includes all the start-up commissioning and testing. It includes the time for the first units. It also includes the time needed to build the factories and to prepare the manufacturing and the procurement of long-lead items. It then involves the work on site to prepare the site. It involves the site assembly and then the start-up and commissioning.

We are bringing to market a full turnkey solution. We are working with partners today to help us be capable to deliver that on that timeline. So that is what we call our first-of-a-fleet schedule. It is a longer schedule than our nth-of-a-fleet schedule. For nth of a fleet we would not need to build the factories, because we will have the factories up and running. We will be accessing the market in terms of product and supply chain, so that schedule would come down by at least two years in future sales of units.

Q200 **Tracey Crouch:** The 500 days target is just the build, is it?

Tom Samson: The 500 days is a target we have, ambitiously, from first nuclear concrete to commercial operation. We are much longer than that today, but in terms of moving through the production cycle and building up the factory capability, and starting to transfer that lesson, that is the beauty of the factory build philosophy: the factory makes the same product many times, and eventually we hope that our factories will be sized and capable of producing as many as four units a year, and that knowledge would then be transferring from unit to unit. So we project through our first 10 units that we would really come down that cost curve through the benefits of the lessons learned transferring from unit to unit.

That is the beauty of a factory build programme: you have the lessons learned, and knowledge and experience, in a location that is producing the same product time and time again. We have seen the benefits of that in our civil aerospace business in Rolls-Royce and our other businesses, where that factory production environment can really start to increase productivity and reduce costs by continuing to do the same thing time and again. The objective of the GDA is to get the GDA done, and then we make the same product, regardless of location, coming out of our factories.

Q201 **Tracey Crouch:** You think you need to build 10 units before you get to the 500 days.

Tom Samson: No, the projection of how we can progress towards a much shorter build cycle is somewhere on that journey of the first unit to the end unit, whether is it the fifth, sixth or seventh. We need to explore how quickly we can reduce that timeline.

Q202 **Tracey Crouch:** Mr Jenkins, you have a two-year target.

Gethin Jenkins: Yes. The time for on-site assembly, as we call it, is very limited. It is very short, on the basis that the 80 or so modules that are required for the PWR-20 are fully assembled and tested in the factory setting. The challenge there is early engagement with the supply chain and module integrators and also, from a licensing and safety case point of view, to allow the existing supply chain facilities to be inspected from a quality control point of view, to ensure that the product coming off the production line is what is needed on the site. The modules are sized so they can be transported by road, so there are no delays or time constraints in getting the modules to site. Because of the size and scale of the reactor itself, the on-site excavation works and the ground works are very limited in that sense. The actual time on site can be very short.

There are various different models that could be deployed. It could be 10 units built in parallel, or one unit could be built and it could be scaled up from there. The first unit would be where the supply chain really comes forward, and we develop those skills in the supply chain. After that, there would be efficiencies going forward from there.

Ultimately, similarly to what Mr Samson has said, the skills developed in the manufacturing and the modularisation, and bringing these together, would be a great skill and potential export, in that the energy demands around Europe and the world could be serviced from skills developed in the UK.

Q203 **Tracey Crouch:** I think in response to a question from Philip, you, Mr Samson, implied that the manufacturing would be done here and then exported, rather than the technology being exported, and the factories built in each country. Is there the same intention for Last?

Gethin Jenkins: The intention for Last Energy is to use the existing supply chain wherever possible, on the basis that the size and scale allows us to use more off-the-shelf components that are traditionally used in renewable technologies or oil and gas. If there was a competitive market we would also go to those countries where the competition allowed for those to be built.

The race is to see where we develop first. Our intentions are to develop in the UK. We have established a UK subsidiary in order to achieve that, we are engaging with suppliers in the UK and we are getting a really good response. The ability to use existing facilities is of interest to a lot of the suppliers, as they can then grow their business around an order from ourselves and service other sectors and energy providers.

Q204 **Tracey Crouch:** Did I interpret your response correctly? You hope that most things are manufactured here and then exported.

Tom Samson: That will be the case initially, but we also see the opportunity for two more steps. One is a regional hub. Where there is significant demand in certain regions, be it the middle east, Turkey, Asia or the US, we could build regional hubs to manufacture product in those markets once our production capacity is up at scale in the UK or, indeed, if there is significant demand in that territory that would justify that. In fact, we have made our technology global and scalable such that we can then replicate the factories in those new environments.

We also have an ambition that at some point in the future we could license this technology to countries where they have extensive modularisation and manufacturing expertise, particularly places like Korea and Japan. We could then offer a licensing solution as well.

Those are the future stages of our evolution. The initial focus is on how we start to build a manufacturing and product base here in the UK that we can export. We will then look to build regional hubs. Equally, we are seeing huge demand in parts of the world where in the coming years we will start to focus on building a presence. For example, the US is a really exciting market for us. We could take a 60 Hz variant of our technology to the US and build factories there, replicating a UK model for 50 Hz in the US with a 60 Hz variant. That is very much part of our ambition as well.

Q205 **Tracey Crouch:** This is my final question, because I am very conscious of the time. It builds on that answer and is about your international experiences. Are you finding any particular countries or regions that are far more engaging or where the regulatory process is a bit smoother than it is here? What can we in the UK learn from those processes?

Tom Samson: I would suggest two things. Our regulatory process is world recognised as one of the highest regulatory standards. It is a good thing for us to be in the GDA, with the ONR, the Environment Agency and Natural Resources Wales as environmental and nuclear regulators. If we get through that process, that is a high watermark and a good signal to other markets that they can replicate that.

We are promoting nuclear harmonisation and standardisation, through the IAEA, to make it easier for other countries to try to align their regulatory expectations so that it is easier for us then to export a technology into a new market.

We see lots of opportunities on the global stage. Our main competitors are American companies. They have huge support from the US Government in those countries. We are trying to encourage the UK Government to recognise that we now have a domestic, exportable, sovereign nuclear solution and should be exploiting that for energy diplomacy purposes on the world stage. We have strong support from UK Export Finance and FCDO.

We need to do more to advocate for British technology in those markets. I am going to a reception this afternoon for the President of South Africa, who is in the country. Those are the types of conversations where, collectively, industry and Government should be advocating opportunities for greater trade, as we can export a technology that has great demand, particularly in a place like South Africa and in many other countries. When we turn up to those conversations alongside Government, it makes a very compelling proposition.

Gethin Jenkins: Last Energy has engaged with regulatory processes in the UK, Poland and Romania. There are lots of similarities across all three. The ONR, EA and NRW processes, guidance and approach are very well regarded in those other countries.

In a way, establishing licensing in the UK is also a very good export for Last Energy, as we can use the assessments that have been done in the UK in other countries where they have not developed nuclear recently or do not have procedures or processes that are as well developed. That is being developed both through the IAEA and through inter-regulatory discussions between all parties. It is worth saying that the UK regulatory processes are very well regarded globally, hence our focusing on the UK.

Q206 **Graham Stringer:** To get the benefit out of small modular reactors, you need to put them nearer to where the energy is going to go. You have mentioned that sites are under discussion. How many sites do you think that you will need?

Tom Samson: I go back to my earlier comment that the study that we have done with the Nuclear Decommissioning Authority identifies that, within the existing nuclear estate in England and Wales, there is sufficient space to accommodate 24 GW of our SMRs, which is the amount of nuclear that it is our ambition to deliver by 2050. We would not need any new sites to be categorised as nuclear to meet that ambition if we met it with a purely Rolls-Royce SMR solution.

Q207 **Graham Stringer:** I am sorry—I misunderstood what was said before. You are saying that you would not need extra sites.

Tom Samson: Not beyond the nuclear estate that exists in the country today. We may have an ambition to deploy technology on other sites such as coal sites or other industrial sites in the future, but that is not needed to meet the current demand for nuclear in this country.

Q208 **Graham Stringer:** Did you want to say something, Mr Jenkins?

Gethin Jenkins: I go back to the point that I made at the start. The eight sites that are currently identified in the UK are very suitable for both gigawatt and small modular reactors. Not opening up other sites or allowing deployment close to industrial users does not realise the true value proposition of the small modular reactors, which can be deployed in areas close to industrial users using air cooling, away from water bodies, to allow for the deep decarbonisation of some very industrial areas—for example, data centres and steelworks. Although the eight sites are a great starting point, it would be wise to look at other areas. I understand that the national policy statement is being updated to reflect that between now and 2025.

Q209 **Graham Stringer:** Mr Samson, you mentioned that the American Government were giving a lot of support to the American nuclear industry. In the proposals that you have at the moment to hit the 24 GW target, how much taxpayers' money will go into that project?

Tom Samson: It is really for the Government, through GBN, to decide how it intends to deliver those 24 GW. We would say that we see a need for Government support for the initial units, as we build up our business. Ultimately, if the Government have a desire to try to keep nuclear off the Government's balance sheet by finding a way for this to be financed, with offtakers to come forward, that is certainly an opportunity that we see in the future. Customers could sign up to a PPA, we could bring in private capital, debt and equity, and we could have a nuclear IPP that operates to sell power to commercial or private companies. That is further down the line. To begin with, we need to take advantage of the Nuclear Energy (Financing) Bill, CfDs or other forms of Government support to be able to start deploying the technology in the short term.

Q210 **Graham Stringer:** That is a comprehensive answer, without giving a figure. Do you have any idea what the public subsidy—or the cost directly to consumers—would be, whichever form of financing is used, whether it is contracts for difference or a regulated asset base?

Tom Samson: The form of subsidy you allude to is measured only when you know what the market pricing would be. One thing that we can say this year is that the market volatility as a result of our exposure to imported gas is significant. What we are doing with nuclear is isolating ourselves from that volatility and providing a very robust benefit to consumers by having nuclear power.

Our goal is to provide a cost-competitive solution to our customers, be it through the CfD or through the RAB. We believe that we have a very cost-competitive solution that we can bring forward. Our first units will probably have an LCOE of around £75 a megawatt-hour. As we go through the cost curve, it will come in significantly below that. Today, wholesale prices are around £200 to £300 a megawatt-hour, given the current crisis. That crisis does not show any signs of letting up any time soon. That is why we would emphasise the urgency of starting to build more nuclear capacity, because that is how we can start to protect and isolate ourselves from those externalities that are affecting the market today.

Q211 **Graham Stringer:** What about taxpayers' support for R&D? Do you have a figure for that?

Tom Samson: We have received a grant from UKRI of £210 million, for which we went through a process. That began many years ago, when the Chairman was at BEIS. We competed for that grant and were successful in securing it, and we are the beneficiary of it today. Again, that is innovative funding to enable us to develop a UK capability that, as we talked about before, we can not only deploy in the UK but also export.

We have already received grant funding to the tune of £200 million to £250 million. We do not expect to have any more grant funding coming into this solution. Indeed, we are now ready to come to market. That is why we are looking for commitments, so that we can start to sell the product and start building it. Our future is then based on revenues, as an enterprise that is securing sales to grow and sustain our business.

Q212 **Graham Stringer:** I understand that the target cost of the fifth SMR is £1.8 billion. Is that right?

Tom Samson: It is very difficult to talk about specific costs without discussing the scope, the site and a bunch of other factors. I would say that our initial units will be in the order of £75 a megawatt-hour. As we go down the cost curve, that number will come down significantly. We may end up at less than £2 billion per unit, as you say, but that needs to be considered in the realms of what other costs, such as site costs or other costs that the customer has to fund, are involved in that.

Q213 **Graham Stringer:** Does that include the cost of the construction of the factories?

Tom Samson: No. The cost of the construction of the factories is a cost that would sit on our balance sheet as a company. We would have to make the choice between whether we have a significant enough demand signal to invest in factories and whether we have to buy the product from the supply chain. The factory cost is a cost that would be invested in by our shareholders.

Q214 **Graham Stringer:** Can I ask you a very general question? It is not on this specific issue. The commitment to net zero has given a boost to the nuclear industry. Do you think that that is accurate? Do you think that that is true?

Tom Samson: I think that the industry has been boosted in 2022 by the recognition and realisation that energy security is of critical national importance to the UK. That has been the more prominent promotion of nuclear in the last 12 months. It was already recognised as an integral part of net zero. In fact, there is now widespread acknowledgment around the world that, without nuclear, we will never get to net zero. That was already the case, but this year we have seen a much greater emphasis on the importance of nuclear from an energy security perspective, not just in the UK but in places like central Europe, the

Nordic region and Estonia. That is what is driving an acceleration of and an increased appetite for this type of technology.

Q215 **Graham Stringer:** That is a fair point. Without net zero and the war in Ukraine, what do you think that the future of the nuclear industry would have been?

Tom Samson: The other thing that I would say in that regard is that the next crisis that is on our horizon in this country, I would suggest, is capacity. We have not built baseload generation capacity in this country, other than Hinkley Point C, for many decades. Most of the capacity we rely upon today—the coal plants and the CCGT plants that we built in the '90s—is coming to the end of its life. Most of the nuclear estate is coming to the end of its life. By 2030, access to baseload capacity in the electricity market will be a very sparse commodity.

We need to be thinking today about how we replace that and provide a baseload backbone to this country's grid as we increase the dependency—and rightly so—on more intermittent renewable. Regardless of net zero and the war in Ukraine, we should be building nuclear capacity to maintain a strong, stable and reliable backbone and baseload. On top of that, you get the net zero benefits and the energy security benefits.

Q216 **Chair:** I want to follow on briefly from Graham's question about funding. As you say, Mr Samson, you got £210 million about a year ago. That followed £18 million from the industrial strategy challenge fund. Mr Jenkins has been critical of that. In its written submission to us, Last Energy said, "excessive Government funding for early stage development activities" can crowd "out … entrants and innovation," and that having a preferred supplier may limit the field. Would you elaborate on that a little?

Gethin Jenkins: Certainly. The point that we were trying to make was, hopefully, not overly critical. In order to meet the net zero targets, there are various different technologies and deployment models that are not mutually exclusive and that are all needed and necessary, even to a point where they could share the same sites. The deployment model adopted by Last Energy is one of private finance. The reactor size and scale is such that it keeps the costs to a point that is more accessible, so there is more appetite for private finance. That allows for a more streamlined deployment model in between the design, planning, construction and operation, essentially avoiding any of the interfaces or challenges that have beset the larger projects, where funding was withheld or costs and timescale overran. It was offering an alternative and, we believe, quicker model, using private finance in order to take it forward.

Q217 **Chair:** By any token, £210 million is a lot of money. Your view is that that need not have been spent and that you could have had a more diverse field. Mr Samson, would you be able to proceed without that?

Tao Samson: No. I think that the scale of this challenge and the importance to UK industry of having a domestic solution requires Government intent to support the development of innovative new technologies to try to exploit a capability that we have in the UK, as I mentioned before, that could then be part of a huge global market. I make no apologies for the fact that we have benefited from Innovate UK's support to create a UK technology solution.

Q218 **Chair:** You have benefited from it, but was it necessary? Mr Jenkins thinks that we may have been able to do without it. Is it the case that Rolls-Royce, with its many decades of skilful ability to lobby and to extract funds from the Government, if I can put it in that way, has extracted successfully £210 million that we could have not deployed yet still be having this conversation?

Tom Samson: As you know, the challenge fund was a process we competed for. We were successful in that process. The national capability that we offer as a nuclear submarine designer and manufacturer is quite a unique capability. The Government could have chosen not to support that, in which case we probably would not be sat here today with a solution.

We are not trying to solve this 20 MW at a time, as the gentleman from Last Energy is doing. This is a utility-scale response to a global climate crisis. We are bringing forward a solution that is scalable globally. At this stage, you cannot get there entirely with private capital. We have been able to raise £280 million of equity on the back of the UKRI grant. Equally, we are still dependent on the Government to give us the green light and the path forward to deploy the technology. We are still at the mercy of the Government in terms of how we can make this a reality—all technologies are, whether it be on siting or on the funding solution. The Government have a role to play.

It is really important that we recognise that, while this is grant funding, it is creating a very important UK capability that will build economic growth, build exports, create jobs and continue to put the UK in a really great position in a space around clean energy at such a critical time on the world stage. We should be taking advantage of that to move forward.

It is interesting that Last Energy would be critical of that approach, given that most of the things that they are describing here are an imitation of what we are doing. They are following in our footsteps. I offer that up as a suggestion to show that we are actually leading the way.

Q219 **Chair:** Let us suppose that you get to where you want to be in having deployable technology that is available. Why does it need the UK Government to buy it? If it speaks for itself, are there not countries around the world that could buy it? Why does it need the UK Government?

Tom Samson: Our challenge on the world stage, in a country like the UK where we have an ambition to have 24 GW by 2050 and are committing to new nuclear with Hinkley Point C and Sizewell C, is that when I go to a country to offer to sell them my technology, the Government there say, "Where is your deployment in the UK? Why are your Government in the UK not advocating, supporting and deploying the technology to help them in their own transition to clean energy?" That barrier of having an identifiable project in the UK becomes a real issue for us when we try to sell this technology on the world stage. We are asking for support to begin the deployment in the UK so that we can then actively compete on the world stage.

Chair: We have covered a lot of ground. There is more we could go into, but we need to move on to our next panel of witnesses. Thank you very much to Gethin Jenkins and Tom Samson for joining us here today.

Examination of witnesses

Witnesses: Dr Ian Scott, John Eldridge and Dr Fiona Rayment OBE.

Q220 **Chair:** As they take their seats, let me welcome the next panel of witnesses. We are very pleased to have Dr Fiona Rayment, who is the chief scientific officer of the National Nuclear Laboratory. She is also chair of the Nuclear Skills Strategy Group and has a particular perspective on skills shortages, which have come up already.

We also have Dr Ian Scott, the chief scientist at MoltexFLEX Limited, which is a Canada-based developer of molten salt reactors, and John Eldridge, the principal engineer at U-Battery, which is a UK-based consortium, owned by Urenco, that is developing a high-temperature gas reactor design.

Thank you very much, all of you, for coming. Dr Rayment, can you set out for a lay audience how advanced modular reactors differ from previous generations of reactors?

Dr Rayment: Advanced modular reactors are based on a family of six types of technology. Some are fast reactor systems and some are thermal reactor systems. We have sodium fast reactors, lead fast reactors and gas fast reactors. We also have molten salt reactors, high-temperature and very high-temperature gas reactors and supercritical water reactors. That is the family of advanced reactors. They are not like water reactors. They are not PWRs or BWRs, which you talked about previously.

A lot of these reactors can be scaled. You can have micro systems, small systems and large systems, depending on what the requirements are. A number of these reactors have been researched for a whole number of years—for decades—internationally. Many countries have demonstrated the technology to a demonstration level, but not to a commercially deployed level. None of these reactors is currently deployed commercially anywhere in the world, but a number of them have been demonstrated. A number of demonstrators are still running.

Q221 **Chair:** What has been the barrier between their demonstration and their deployment?

Dr Rayment: A lot of this comes down to what infrastructure you need to support and decisions that were made in the past about the nuclear technologies of choice. Internationally, a number of countries chose the LWR technology, so a number of light-water reactor technologies—either PWR or BWR—were deployed, with the associated fuel cycle that supports that. That meant that a number of advanced reactors were not considered any further at that stage because these technologies were more mature and able to go to market.

Here in the UK, we chose the gas technology. We had our Magnox stations and our advanced gas reactor technology, and we went through a whole programme of building a fleet, first the Magnox fleet and then the AGR fleet. We did not need to do any more at that point in time, other than continue to make sure that we were aware of what was happening elsewhere in the world.

We ran a number of demonstrators here in the UK. Specifically, we did quite a lot of work on high-temperature reactors, through the Dragon technology. We had our own demonstrator here in the UK years ago. We have had a couple of sodium fast reactors at Dounreay, the DFR and the PFR, and we have had a supercritical water reactor as well. We have done a lot of this research ourselves. There is a key thing here about capability that we have to be able to take forward, but the decisions were commercial. It was about what was mature at that moment in time and, basically, what was happening on the world stage.

Q222 **Chair:** When do you expect to see advanced modular reactors supplying electricity to the grid?

Dr Rayment: If you made the decision today to take forward advanced modular technology—some technologies are more mature than others—the earliest would be the late 2030s, in my view. Some of the technologies I have talked about are probably later. We are probably talking about the '40s, maybe even into the '50s. It really depends on the technical maturity of the technology.

Q223 **Chair:** Which technologies are available for deployment earliest?

Dr Rayment: Some of my colleagues may not agree, but my view is that in this country the high-temperature gas reactor is the most mature technology, not just because of the technology itself but because of the capability that we have in the UK. We understand how to regulate gas reactor technology and have done so for decades. We have designed a whole variety of different types of gas reactor. We understand a lot of the technology challenges that come with gas reactor technology—for example, graphite irradiation.

We understand the fuel cycle associated with gas reactor technology because of what we have done with Magnox and AGR in the past. That, combined with the fact that there are a number of demonstrators in existence in the world that are demonstrating the technology just now, makes me think that that technology is probably the most mature of all of the technologies so far. There are others that are quite close behind. It then comes back to how much investment can go into it to get it to market faster.

Q224 **Chair:** May I ask Dr Scott and Mr Eldridge briefly to give an indication of where their technology is in the deployment timeline? We will start with Dr Scott.

Dr Scott: Can I start by correcting your introduction of me? MoltexFLEX is not a Canada-based company. MoltexFLEX is a UK company. Moltex Energy was founded in the UK. It has been developing two technologies—a fast spectrum reactor and a thermal spectrum reactor, as Fiona mentioned. The fast spectrum reactor was unsuccessful in the UK AMR competition. As a result, that technology and its intellectual property were transferred to our Canadian company, which now operates independently.

Chair: I see.

Dr Scott: MoltexFLEX is a UK company, and we hope very much to be able to develop that technology in the UK.

Q225 **Chair:** Very good. Thanks for clarifying that.

Dr Scott: As for when, our target is to have a full-size demonstrator reactor operating by 2029 and the first fleet, which would be a plant with capacity of around half a gigawatt, operating by 2031-32. We believe that that can be done much more quickly than is conventionally believed because of the fundamental simplicity of the technology and the lack of supply chain challenges. We are much more aggressive in our target for doing this than is the norm within the UK.

Q226 **Chair:** We will go into a bit more detail on that. Mr Eldridge, can you give your position on this timeframe?

John Eldridge: I appreciated Fiona's introduction, because in a way she touched on my history. I actually worked on the Dragon reactor. It was an awfully long time ago, but it was part of my training. I confess that I was very attracted to the concept even then, as a very raw beginner in the profession. Yes, the U-battery is a high-temperature gas reactor, and, yes, the grandfather is the Dragon.

We have had the benefit of some half a dozen applied and evolving examples running to date, including reactors working in Japan, China and so on. In fact, we, too, are looking at a 2029 or 2030 first deployment. We are looking at a demonstration unit by that time and a commercial-size application probably a couple of years afterwards, although we are still looking at what the benefit is.

We have the benefit of those 60-odd years of evolution and development of the programme and technology, and we are going with that. We are taking a very conservative approach on our technology. Everything we are focusing on is about being able to deliver this thing. You had quite a lot of conversations earlier, with your previous panel, about tooling up in factories and the supply chain and being able to minimise the time on site. That is certainly one of the key areas we are focusing on.

Chair: Very good. I am very grateful.

Q227 **Stephen Metcalfe:** Good morning, everyone. Obviously, there are a number of different technologies around. I would be interested in your view on where the advanced modular reactors fit into the Government's overall plan to deliver new nuclear. What should be the split between gigawatt, small modular reactors and so on? Will the timescale be impacted by what the proportions of those individual technologies are?

Dr Rayment: I can see a portfolio approach for nuclear. There are four phases. Phase one is gigawatt; phase two is SMR; phase three is AMR; and phase four is fusion. That trajectory is on a long timescale.

At the moment, gigawatt and SMR are very much about dealing with our energy security challenges, replacing the existing baseload and enhancing it in the electricity requirements going forward—the 24 GW challenge currently in play.

The current UK energy mix is 18% electricity and 82% everything else. We are talking about how to decarbonise the other really difficult to decarbonise sectors. For example, what do we do with aviation fuel, cement, concrete and ammonia manufacture? There is also a whole debate about the hydrogen economy at the moment.

I think that AMR fits into that very interesting area at the moment about how to decarbonise some of the other difficult parts of that energy mix. Some of these AMRs could help with process heat—industrial heat—and that could be used for other derivatives like hydrogen, ammonia and things like sustainable aviation fuels. You can see that is a longer trajectory.

In addition, you can have AMR producing electricity. A nuclear reactor makes heat and then you decide what you want to do with that. With our current fleet, we take the heat and make electricity with it. In the late 1950s, we had co-generation at Calder Hall. We produced heat for the Sellafield site at the same time as putting electricity to the grid.

We have an opportunity here to be more flexible. I think that is where the AMR fits in. It is about how you decarbonise some of these other difficult to decarbonise parts of the grid and help to deal with the current timeline in place in meeting net zero by 2050.

John Eldridge: I absolutely endorse the overall picture as Fiona has put it. Certainly, within the small U-Battery HTGR we envisaged supporting the foundation industries, where there is a dependency on gas at the moment for their process heating.

If electricity production is required, we can do that, but, frankly, the main thing is processing; that is where we see the major benefit. It is easy with the numbers we have in mind. There are about 500,000 jobs associated with the foundation things—ceramics, glass, steel, cement, chemicals and so on—which are dependent on these things.

Our picture was of a plant being deployed, more likely alongside existing facilities, supporting them, taking over and enabling them to expand with carbon-neutral power.

Q228 **Stephen Metcalfe:** Presumably, heat is very difficult to transport, hence it has to be co-located with the industry that requires the heat. Do you see planning that aspect being a barrier to that? While the ambition may be fantastic, is it deliverable?

John Eldridge: You have used the word "barrier". It is probably more a challenge. What we have been hearing today is the realisation that things have to change.

We have been finding in the past few weeks that the interest and demand in the market is changing; it is rising. We were talking to what you would consider to be the usual suspects—people who are close to existing sites, and so on. There are certain refineries and others that we are talking to, but we are finding now that people who are nowhere near existing sites are putting up their hands and asking to talk about providing carbon-neutral. Of course, it is a challenge, but I do not think it is a barrier.

Dr Scott: I have every support for what my colleagues have said about the importance of industrial heat. That is an area where all the advanced reactors are a meaningful solution because they have an output temperature of about 700° C to 750° C. A PWR is about 300° C. That high-temperature heat is much more useful.

I would add another important point for advanced reactors. We are moving into a world where renewables will be, in many ways, the dominant source of electricity specifically, and potentially energy more generally. Renewables are intermittent, as you all know, and we are already reaching a stage in this country where at times renewables provide all the electricity for which there is any demand.

As we increase the spread of baseload generation—gigawatt-scale PWRs and small modular PWRs—those technologies are intrinsically difficult technically to flex in their output. It is even more difficult economically, because obviously if you are not making electricity you are not making any money.

The potential for advanced reactors is their ability to flex much more easily and more economically. When the wind is blowing well and you have demand you can easily shut down the output. If you do not have that and you simply have baseload, you have to shut down either the baseload power plants, which is really difficult, or your renewables, which is unattractive. The importance of advanced reactors in enabling high renewables and an efficient grid is often not talked about enough. They really can do it.

Q229 **Stephen Metcalfe:** It is clear that the Government have chosen the high-temperature gas reactor as its reactor of choice. Is that purely and simply because it is at the highest level of technological readiness?

Chair: Dr Rayment is nodding.

Dr Rayment: I think it is for a number of reasons, some of which I have already highlighted.

When you start to think about what you want to do in terms of capability in the UK, there is something in looking at what we already have. We have an understanding of how you make fuel for these types of systems. We have an understanding of the fuel cycle and the spent fuel management of these types of systems. We understand how you regulate gas systems. We have a design capability in gas reactor systems. We have done research and development for decades on these systems, too.

When you look at that in the round, together with the fact that the technology is pretty mature in comparison with the other systems, that is a compelling argument in terms of where you would like to take these things forward, together with the story around the application. If the story around the application is process heat and, as Ian says, you are talking about needing between 600° C and 800° C, the high-temperature reactor can provide that capability for you.

John Eldridge: In a way, that is linked to the last point you raised about whether it is a barrier. To me, the big sell on this one is that it is intrinsically safe. It is everything around the fuel, which I know you will talk about later. It means that, essentially, you have a very simple machine. If there is any possible problem—we have looked at every conceivable one—you will not get an incident. It is the sort of situation where you could imagine deploying this. I know you will talk about this later, but it comes back to the fuel, and it was something that was developed here as well.

Q230 **Stephen Metcalfe:** That is a useful clarification. If the technology is fairly mature and we understand it and have the research, what are the barriers to bringing it forward more quickly? There are demonstrators in place. I think you referred to the 2040s, which seems a fair time away. Is there any way we can shorten that period, and what do we need to tell the Government to do that?

Dr Rayment: To clarify it, when I talk about the 2040s I am referring to commercial plant. If we are talking about first demonstrator, I think we could have it in place by 2030 if we make decisions today. That demonstrator would be doing two things.

First, it would be demonstrating the application. Can we make the hydrogen and process heat? Can we do what we need to do? Secondly, it would be demonstrating a particular type of technology and design and taking that forward.

That demonstrator itself could end up being the prototype; it could end up being first of a kind. Some vendors are saying that that is exactly what they would like to do.

As for what Government can do to help with that acceleration, a lot of things are happening in this space, which we really appreciate. A fuel enabling fund has been set up; a nuclear enabling fund has been set up. Thank you to BEIS for doing that. We think that is really helpful.

We believe that the creation of Great British Nuclear will help in the whole programme of driving new nuclear build going forward, and the advanced reactors factor into that space.

More research and development is still needed on some specifics, including the fuel, the materials and, if you move away from high-temperature reactors and look at some other systems, probably the coolants as well. Therefore, there will be an ask around continuing to get that level of maturity it needs to take it forward.

The final point I make is about site permitting and getting some work in place up front in parallel to start looking at sites that are not nuclear sites at this moment, and the opportunity in taking forward some of these advanced systems on industrial sites for the future.

Dr Scott: May I add an answer to that question because it is a really important one?

If indeed the UK Government have made the decision that their choice for advanced reactors is the high-temperature gas reactor—it does look that way at the moment—there is a consequence: all the eggs will be in that one basket.

There is an argument, which I put forward very strongly, that the UK should be creating an enabling environment to allow multiple technologies to compete in this country. The high-temperature gas reactor may turn out to be the winner, but the salt reactors may turn out to be the winner.

Molten salt reactors face a specific headwind in the UK, which is that opinion formers in nuclear generally do not like them; they think they are very long-term propositions. I have to say that is not the view outside these shores. Molten salt reactors are seen as one of the lead potential technologies. That was why our first technology went to Canada. It could happen with our second technology if the UK makes the decision to focus on one technology. It is a decision that has consequences.

John Eldridge: We try to avoid the word "aggressive". We are taking a pragmatic approach to how quickly we can deploy this. We have said 2029. We have said that we would require two years on the site. We are looking at that very hard, but that is what we are declaring at the moment.

We are confident with the technology. Fiona mentioned fuel. I feel the eyes of my colleague Tim on my back. He is the expert. He will tell you about where we are with the fuel on this and why there is that level of confidence.

Mr Dunne mentioned the TRLs. It is significant for us that our highest TRLs are in the core itself as it gradually works out there. We are looking for a ready deployment. We suggest that we go for a small demonstration unit. All that is doing is to confirm—not to demonstrate that it works—the model we will be using for what we call the commercial variant, which is slightly bigger.

Q231 **Dawn Butler:** You mentioned research and development and how you would need to get to a certain level of maturity. What does that actually look like in practical terms?

Dr Rayment: A number of these reactor systems still have a level of technical uncertainty associated with the fuel that will go into the system: the reactor materials of construction and how they behave in an irradiation environment and the coolants that are used either to keep the reactor running at a particular temperature or to transfer heat from the core itself to outside the system.

Research and development is required to reduce that technical uncertainty. A number of international R&D programmes are in place at this moment doing exactly that. For example, the UK is currently engaged in the Generation IV International Forum, which looks at the six technologies I talked about; research and development is happening in that space. My view is that some continued research and development in this space over the next few years will enable those technical uncertainties to be removed and that maturity to be enhanced going forward. That is where I think we are at.

To do that, you need to be able to have access to demonstrator technology for some of that research and development, and you need to make decisions about whether you do some of that yourself in the UK or you access international programmes where there are already demonstrators in place.

If I go back to the high-temperature gas reactor, for example, a number of countries have demonstrators already working. Japan has a high-temperature test reactor that is being used to demonstrate a lot of these technical uncertainties.

Q232 **Dawn Butler:** How do we work with our international counterparts? What are the current working arrangements? Is there a technology transfer of information on a regular basis?

Dr Rayment: At a multinational level, through the Generation IV International Forum, we have agreements through system-seeing arrangements for very specific technologies. We are currently party to the high-temperature gas reactor programme and the sodium fast reactor programme. We share some of that information in that programme and in return we get access to all the data from the other parties who are part of that programme. That is one example.

We have bilaterals in place with other countries. A UK-US action plan has been developed between the US DoE and BEIS and we work specifically on technologies to that effect. For example, we look at fuel and fuel cycles associated with some of these systems, and we do some work on some of the reactor technologies. That is another example.

Discussion is currently happening with the Japanese Government through METI and BEIS about the arrangement that could be in that space, too. The NNL is working with its equivalent, JAEA, in looking at what that relationship might be.

We are trying to build a really good partnership with countries and experts that have that capability, through people, research infrastructure or money for programmes, and we are bringing what we have to the party to try to accelerate that learning and get to the market faster.

Q233 **Dawn Butler:** You mentioned some of the interventions that might be needed by Government to enable you to do all of that. Is there anything else? What are your top three things that you would like the Government to do to help?

Dr Rayment: No. 1 is that advanced reactors are all around everything else beyond electricity—the difficult to decarbonise parts of the grid. Part of that is thinking about industrial sites. We need to think about site permitting and how we start to take that forward in a national policy statement, if we are really serious about deploying these systems for the 82% of the energy grid that is still difficult to decarbonise.

As for No. 2, I suggest we continue on the R&D journey and drive the international partnerships that we have, making best use of the data and experience we have with some of our international partners in taking that forward and trying to accelerate technical maturity in a faster timeframe.

No. 3 is to make a decision on what we need from a demonstrator, whether that needs to be in this country or whether it is using international capability from elsewhere. Maybe there is something in between in how we deal with that. Making a decision on that and working that through would be key.

All these things will then enable whatever technology is chosen to be taken forward in a faster timeframe. That would be my view.

John Eldridge: This is pragmatic; we are bringing this down a little bit here. As a unit, we are talking with our colleagues in Japan, and quite a bit of the technology that we are deploying in U-Battery is based directly on the Japanese model.

We are trying to avoid the expression "R&D" and use "test and development". We are deliberately trying to proceed pragmatically, going down what has already been delivered. The focus has been on getting the fuel in and out of this reactor so that we endeavour to avoid some of the problems that have occurred with the Magnox and AGR fleets.

We have built a prototype based as a modular unit. That is sitting up in Whetstone in Leicester. You are more than welcome to have a look at that small-scale unit as a demonstration of what a small high-temperature gas reactor would look like in reality. That has proved to be extraordinarily good and useful. You can imagine that regulators, our insurers and any number of other people—local politicians and so on—have been over that.

I absolutely endorse everything that Fiona has said, but we are proceeding with that pragmatic approach and taking what we already know.

Dr Scott: To give a very quick answer to your question, the right access to the regulator. The money we will look after ourselves. That is the very short answer.

The key point—here I would disagree to some extent with Fiona—is that electricity is possibly the most important market in energy. Right now, prices are going up and they will stay up unless we do something about it.

The FLEX reactor is designed to be extremely simple. It has literally no moving parts. It operates for 15 years with no operative intervention, and its capital cost has been estimated by two separate, independent nuclear companies. If you put that into a levelised cost calculation, what comes out is a cost of about half of what gas-powered electricity used to cost before Ukraine happened. It is down to about £30 per kWh. This can transform electricity. I think that in many ways that is the big opportunity here. From MoltexFLEX's point of view, our mission has always been to bring down nuclear costs far enough that it will replace coal and gas everywhere in the world, not just in rich countries that can afford expensive electricity. That is what we are aiming to do; that is the target.

Q234 **Aaron Bell:** That leads nicely to the economics of AMRs. Dr Scott, the

Government have put £170 million into the advanced nuclear fund to support the research, but how should the commercial deployment of AMRs be funded in the UK? Would the RAB model or contracts for difference be suitable? You just said that you would look after the money, which sounded very encouraging, but how do you think they should be funded?

Dr Scott: The reason we can look after the money is that the first of a kind plant, which would be a 30-module power plant, 500 MW, would be highly profitable, so getting investors to invest where they can get their money back and more from the first plant is a huge enabler in being able to get money. That is what we absolutely aim to do.

One of the big political risks for us is that the electricity market is being somewhat distorted at the moment. Two years ago, Bloomberg New Energy Finance did a study that predicted that by 2030, for half of the day, wholesale power prices would be below £5 per MWh because renewables would be producing at that level. They would all have strike prices; they are making all their money from the strike price, not from wholesale, so you need some mechanism to sell the electricity at its real value into the market. Right now, that market is in flux, which is a great opportunity to get the electricity market reform right so that it rewards flexible generation, in particular, for its value. The current market probably would not do that.

Q235 **Aaron Bell:** Would your company be prepared to work on a strike price basis on that very first one?

Dr Scott: We would be prepared to, but if you have a strike price you have absolutely no incentive to operate flexibly, because you will get the same price whether the electricity is valuable or not.

What we really need is a mechanism, which could be based on the capacity market mechanism, whereby you are rewarded for selling your electricity when it is needed. The current structure does not work very well, but could easily be made to work well and would enable industry competitively to deliver that.

Q236 **Aaron Bell:** I ask because obviously on a larger scale what we are doing now at Sizewell is going back to the RAB model, having gone the strike price route and contracts for difference at Hinkley Point. The feeling is that because of the risks involved firms are not prepared to go on a strike price basis now, but you are suggesting that AMR firms might be. Obviously, there are some improvements we can make to the whole structure, but you think that firms would be prepared to invest on the basis that they will get an agreement price and all the risk sits with the firm rather than the Government.

Dr Scott: I think they would. If you do your strike price mechanism, you have to deliver baseload, which in our case is our cheapest energy. After that, you can go into flexibility when the mechanism to reward that exists, but certainly a strike price at the sort of level we are talking about for wind would make it a very investable proposition.

Q237 **Aaron Bell:** And for your company, Mr Eldridge?

John Eldridge: We are in a completely different game. Ian mentioned 500 MW. We are talking about 10 or 20 MW, perhaps 50 MW—that sort of order—hence, if you think about the basic economics, we do not go near that. We are talking potentially about people being off grid who need that process heat. If you do need power again it is because you want to be independent. We tend to look at the wholesale number as it stands there.

We know that we can compete on wholesale, but competing with the 500 MW, the 100 MW and the giga-scale is just a nonsense; we would not go near that as a technology.

The key for us is that we have an intrinsically safe plant, and that obviously has a scale. We are not sure exactly where that line is drawn. It might be 150 MW. My colleague sitting behind me, Professor Abram, can confirm that, but we tend to think of something slightly inboard of that as a deployable commercial unit that is intrinsically safe and that would be competitive on wholesale for you and your individual plant or your immediate need.

Q238 **Aaron Bell:** In funding the commercial deployment of that plant, when you get to the stage, what would your company be looking for? Would you be looking for the security of an RAB model, or do you hope to get investors to underwrite the risk?

John Eldridge: I am being a bit careful here because it is way outside my zone of competence, but the answer is that it is more the latter—what you just said about investors—and that is beginning to happen around us now. Forgive me; I am dodging that.

Q239 **Aaron Bell:** I quite understand. Dr Rayment, what are your overall thoughts about the way we fund the deployment of AMR?

Dr Rayment: Among all the companies I have been speaking to, there is a whole scale of what people are after. In terms of investment, a number of companies just now are saying that they have private investors who can come to the party and put money into the technology. Then, you have some basically saying that they would like to get some sort of Government help for the first of a kind. The challenge there is around the fact that, as we have already heard, first of a kind does cost more money up front. For investors to take on that risk up front for first of a kind is quite challenging, but once you get to the third and fourth plant there are further opportunities from that point of view. There is definitely a conversation about that.

As we continue to look for more and more private investment, the whole conversation on green taxonomy will start to come in again at some point. I urge the Government to go back and think about the construct there. What are we having in terms of green taxonomy and energy for the UK? If we go down that line, where does nuclear fit into that?

Q240 **Aaron Bell:** My final question follows on from what you are saying about first of a kind and so on. Does the UK still require a more diverse range of operators to have a bit more competition to ensure we get AMR to the grid sooner? If so, how can we incentivise that?

Dr Rayment: Competition is a good thing. We have an excellent operator in the UK through EDF Energy. It has operated the plants that we have in the UK for many years and has done it very well, so congratulations for that. We used to have Magnox that did the same thing.

We have tried to bring competition into the mix. We had experience of bringing in Horizon and NuGen in the past. We were not successful with that.

I think that as we go down a model of different sizes of system—large, small and advanced—we will start to find that different operators are better for different types of system and the market will start to enable that.

The challenge in getting new utilities here is around the capability that we have in the UK and the skill associated with that. We have a massive skills challenge in nuclear skills and skills for nuclear. We need to accelerate the development of those skills in the short term.

It is good to have competition. Having other utilities in place could happen. Having these different types of system in place will help to drive that, because you require different companies that are starting to deal with co-generation in comparison with just dealing with electricity in future.

Q241 **Chair:** I have one final quick question to Dr Rayment on skills. We have multiple prospective demands for nuclear skills in the various technologies we are talking about. From your purview, as someone who is particularly interested in skills, have we cracked it? Can we provide the skills that are needed, or is there a continuing problem?

Dr Rayment: I should probably say that I am the immediate past chair of the Nuclear Skills Strategy Group.

As for skills, we are cracking it. I separate out nuclear skills and skills for nuclear. Skills for nuclear—project management skills and construction skills—can come into nuclear and work in a heavily regulated environment and go elsewhere. That is the massive demand side that we have. We need to grow that by a very significant amount. That is 80% of our challenge. We probably need at least to triple that amount in the next decade for what we are trying to achieve. That is massive.

The competition is with other large infrastructure projects, not just nuclear, but we are really good in this country in creating skills and doing it quickly as long as the demand signal is there. That is the challenge.

On nuclear skills—nuclear physicists, engineers and the people who operate plant—we have a bit more time to bring them in. It is 20% of the challenge, so not as many, but it takes time to develop that skill base. We need to continue to support what we are doing in universities through centres for doctoral training and driving higher apprenticeships and other things like that to pump-prime that talent pipeline and make best use of it. We are starting to do that. We just need to continue to focus on it, but if the demand signal is there people will come to universities and the like and will want to do these jobs. We have seen that in the past.

Chair: I am very grateful for that perspective, as well as your contribution on the technologies. I thank Mr Eldridge, Dr Rayment and Dr Scott for their evidence.

Examination of witnesses

Witnesses: Professor Abram and Laurent Odeh.

Q242 **Chair:** I invite our final panel of witnesses to join us at the table.

Laurent Odeh is chief commercial officer at Urenco, which is an international supplier of nuclear fuels. It operates uranium enrichment plants around the world.

Professor Tim Abram is Westinghouse chair in nuclear fuel technology at the University of Manchester. I think I am right in saying that Professor Abram is the UK's representative on the IAEA technical working group on gas-cooled reactors.

Thank you both very much indeed for giving evidence today. I think you have heard some of the previous questions and answers that we have put. Crucial to all of this is fuel. Perhaps Professor Abram can give us a primer on what materials are used to fuel nuclear reactors now and in the future.

Professor Abram: Perhaps he could—it might be a bit long.

In the interest of full disclosure, may I say that I am also head of engineering for U-Battery, which my colleague John was just representing, and director of the Rolls-Royce university technology centre at Manchester. We do most of Rolls-Royce's R&D work in support of the naval nuclear propulsion programme. I just want to get everything very clearly out there.

You are right that nuclear fuel is at the heart of the reactor. It is the source of all the energy and the source of all the danger. If you take the nuclear fuel out of it, the nuclear reactor is just an empty pot essentially.

The source of everything that we want out of the reactor is also the source of all the danger. It is composed of a fissile material, almost always uranium. The isotope in question is uranium 235. Sadly, only 0.7% of natural uranium—the stuff we dig out of the ground—is this fissile isotope, and almost all reactors operating today require a higher proportion than 0.7%. That is where the good folk at Urenco are able, with their very advanced technology, artificially to increase the fraction of this fissile isotope, typically up to 4.95%.

Interestingly, for the advanced modular reactors you were discussing earlier, that 5% limit will probably not be enough; we will need to go higher. The important upper limit in that context is one imposed by the International Atomic Energy Agency, which is 20%. That is the key number. The agency has determined that 20% and above is material that is potentially weaponisable. Now it is not. If you have 20% material you can make a bomb out of it, but the higher you go the more dangerous it is, and 20% is the number that it has determined to be the limit. While it is very likely that for future reactors we will go higher than the current 5%, which is a somewhat arbitrary limit, nobody will go higher than 20%. The rules change above that; you need lots of people with guns. That is a world nobody wants to go into.

Chair: That is a very helpful introduction. We will go into some more detail with questions from my colleagues, starting with Rebecca Long Bailey.

Q243 **Rebecca Long Bailey:** What support, if any, is needed from the Government to secure future supplies of uranium to meet demand?

Laurent Odeh: I will just give you a brief introduction of what Urenco is and how it operates.

Urenco is a company that was founded 50 years ago under the treaty of Almelo. It is partly—one third—owned by the British Government, the Dutch Government and German utilities E.on and RWE. What we do in Urenco, as Tim said, is enrich the natural occurrence of uranium to a level that can enable fuel production and be irradiated in reactors.

Natural uranium can be found in a lot of places in the world: in Kazakhstan, Canada, Africa and Australia. There is a high occurrence of natural uranium in the world, but the only countries that can enrich uranium are Russia, the UK, under the treaty of Almelo—so we have capacity in the UK, the Netherlands, Germany and the US—France and China.

There is enough uranium in the world, but there are very limited capabilities to enrich that uranium. Why? Because we have a unique technology—the centrifuge technology—by which we can increase it from 0.7% up to 5% today. Those are the licences we have.

We are developing new fuels for the future. We have two elements of advanced fuels. One is what we call NEU-plus for the existing fleet of reactors that, without being too technical—that is Tim's world—want to increase the burn-up and the cycle of the fuel in the reactor and increase efficiency.

If we move down the path of advanced modular reactors we will need a much higher level of enrichment. We are doing the preparatory work for that, but as a private company, at the moment, there is no market. A lot of design is being discussed. I think the latest count of the IAEA is about 76 different designs. We do not know which will be the winner. We do not know when the market will mature or will eventuate.

We find ourselves in a bit of a chicken-and-egg exercise where reactor developers need the fuel to prove their technology, and fuel developers need to have enough demand to be able to make the necessary investment in a category 2 facility, which requires significant investment. That is the work we are doing at the moment, so we are expecting the Government to help us along that path.

Q244 **Rebecca Long Bailey:** To be clear for people watching at home, if we were to source uranium we would have to rely on global supply chains, but we have our own uranium enrichment capability here in the UK.

Laurent Odeh: Yes. The UK is one of the only countries in the world that has an onshore enrichment capability. There is depleted uranium in the UK as well, but at the moment uranium is mined in Kazakhstan, Canada and Africa. Those are the main countries where you can mine uranium, but in terms of the critical path in enriching uranium the UK has that capability. In the north-west of England we have a facility in Capenhurst, close to Chester, where we employ about 840 people, plus almost 50% more contractors.

Q245 **Rebecca Long Bailey:** Professor Abram, is there anything you would like to add?

Professor Abram: Only to underline the point Laurent made about the availability of uranium. Please do not be under the illusion that it is a very rare mineral; it is anything but. It has about the same isotopic abundance in the earth's crust as tin, zinc or other stuff. We often find it when we are prospecting for other minerals. There is a lot of uranium in the earth's crust and, as Laurent said, it is available in a wide range of countries, including many that are politically very stable and easily accessible, like Canada and Australia. There is not any significant concern about uranium availability. I think that is the take-home.

Q246 **Rebecca Long Bailey:** More generally, what are the strengths and weaknesses of the UK's uranium supply chain, and how can the weaknesses be overcome?

Professor Abram: To start with the positives, the great strength is Urenco. It really is the jewel in the UK's crown in terms of the nuclear fuel cycle. Laurent can close his ears at this point, if he wants to. Its technology is genuinely world-leading; it is very good.

Our weakness, probably, is that the next step in the chain is taking that enriched uranium product and manufacturing it into nuclear fuel. That is currently done at a site called Springfields, to the west of Preston in north-west England. Most of Springfield's business is involved in manufacturing fuel for our advanced gas-cooled reactors, the AGRs. As I am sure you are all very well aware, three of those stations have already closed; another two will close in 2024, and the remaining two will close in 2028. Therefore, that fuel business based at Springfields has a very precarious future. If you put aside our very small naval nuclear fuel manufacturing site that is run by Rolls-Royce, that is our only fuel manufacturing site in the UK.

Laurent Odeh: I can only thank Tim for his nice words about Urenco. Yes, the UK benefits from Urenco being here. The UK also benefits from the existence of the Springfields site and Westinghouse.

When we take natural uranium, we mine it and then there is one step necessary between mining and enriching: conversion. You need to add fuel so that you have a gas; then you can enrich the gas in the centrifuges.

The current world energy crisis is creating a spotlight on the fuel cycle. The UK is uniquely positioned to have all the chains in the fuel cycle: conversion, enrichment and fabrication. We should not undermine that competency. Not only do we do that for the UK market, but we also export it. Urenco sells to 50 different customers in 21 different countries. We are the leader after Rosatom. Rosatom, at the moment, is being disqualified. There is this capability that we can not only use and leverage for the domestic market in the UK but export.

Q247 **Rebecca Long Bailey:** Forgive me for not understanding the technical details, but what is the average shelf life of a piece of nuclear fuel that is used for a reactor before it becomes nuclear waste?

Professor Abram: Once you have made it, the shelf life is, I would say, infinite; it is measured in tens of thousands of years. Using it in a reactor depends on the reactor. In a typical light-water reactor, they operate in 18-month cycles. The fuel sits in the reactor for three of them—so, about four and a half years. Its energy has then been depleted to the point where it is no longer providing useful amounts of power and it is permanently discharged.

Q248 **Chair:** Professor Abram, would it be a problem if we had no manufacturing capability in the UK for nuclear fuel?

Professor Abram: That is a very good question that probably requires a more complete answer than I am capable of giving. I will have a go.

Nuclear fuel manufacturing—I take the entire piece; all the stages involved in that—conveys two distinct advantages to the UK. One is it is a valuable economic activity. Clearly, it is one that we make quite a bit of money on. The other is that it bestows upon us a level of energy independence that we do not need to discuss any further. We are well aware of that.

It is absolutely true that uranium is not indigenously sourced. Uranium is easily sourced, as I have said already, from countries where there is no serious prospect of us not being able to get hold of it. A long time ago, when I first started in the industry and everything was controlled by the CEGB, we used to maintain strategic supplies—very large amounts of stored uranium. Those days are long since gone because there is no need to do it.

Laurent Odeh: We heard from previous panels about reactor developers, reactor development. Those reactors will have a life of 60 to 80 years. They will need fuel for those 80 years. When we think about energy dependency—Tim touched on it—it is important to think about, "Okay, I'm going to invest that much money in the reactor. How am I going to fuel it?" Developing those skills and capabilities is a good mitigation to shock us into thinking about something happening that we were not foreseeing in developing the whole chain and leveraging the existing capabilities.

The problem is when you stop something. We have seen that with the deployment of the nuclear fleet. You have the supply chain, you have the skills and then you stop and those skills disappear. Then you have to rebuild it again. It is quite critical for the UK to consider the entire supply chain. Again, it has a lot of assets already in-country that should be leveraged.

Q249 **Chair:** Conversations with previous panels included the degree of Government intervention, whether through the financing of new nuclear programmes or the financing of research and development. You heard our exchanges. From what you said, Mr Odeh, should the Government take a view on what it needs to do to secure UK manufacturing capability?

Laurent Odeh: My short answer would be yes, absolutely. Why? At the moment, those developments are still at the start. We have been talking about it for years but you heard about the timeline—are we talking about the 2030s, 2040s? You need to be able to build those capabilities within that timeframe and supply those reactors going forward.

As we do not have a market yet, it is difficult for a private company to make the investment without knowing the size of the price in the market. The way we have been positioning it is to say, "We need a kick-start. We need the support to be able to build, for example, the fuel bank because today we don't know which of the reactors will be the winners and will be able to get licensing going forward."

If the reactor developers need some certainty on the availability of the fuel, the concept of a fuel bank, we have enough visibility to make the necessary investment in different capabilities—because today our centrifuge can enrich to that level—but we do not have the security credentials, we do not have the licensing, we do not have all the necessary ancillary systems to make that happen. This is a significant investment and we need to have some kind of certainty about the market size required for us to make those investments.

Q250 **Chair:** Briefly, Professor Abram, do you agree with the analysis that the Government should take a view on the UK manufacture of fuel?

Professor Abram: I would like to think that the Government took a view on it, yes. Absolutely, I stand behind everything that Laurent said. From the enrichment side, it is not so much that there is a technology need, because there isn't. Urenco are perfectly capable of taking that technology and designing a plant to produce the more highly enriched material.

It is a classic market failure. The Urenco board, I think, would not be open to the idea of, "Build it and they will come." They want some financial certainty.

If you move downstream to fuel manufacturing, if we look beyond AGR and ask ourselves, "Are we going to be able to continue to manufacture nuclear fuel indigenously?", for the large light-water reactors that you discussed earlier, that is a challenge. The market tends to be dominated by very large, existing incumbent players that have very close links to the reactors they sell. For example, the big players are Westinghouse, Framatome in France and Tecnatom in Russia.

There is an interesting opportunity. You were talking in the last session about advanced modular reactors. The dominance of incumbents there does not exist; there are no incumbents. This offers a very interesting opportunity for the UK to get in at the beginning when there are no gigantic players already.

Chair: Thank you very much. That is very enlightening.

Q251 **Aaron Bell:** Thank you both for coming.

I want to ask about a couple of relatively recent developments and how they have affected the UK's enrichment and fuel manufacturing industry. First, what impact has the Russian invasion of Ukraine had? Russia represents about 20% of global enrichment. Is it good news that we are getting more business? Are there any interventions we have had to make to ensure we have security of supply?

Laurent Odeh: What happened on 24 February created a market imbalance. We were moving from a world where there was significant oversupply in the enrichment market to a world where you have the biggest player that is disqualifying itself. We have seen a different dynamic. We have seen people self-sanctioning, saying, "We will no longer deal with Russia." That is the decision we made as Urenco; we terminated our contract with Russia. People came to us to say, "We need additional enrichment services. Can you help?" We are absolutely looking at helping people in eastern Europe heavily reliant on Russian fuel. The Russians were selling the reactors and the fuel that comes with those. So there was a high reliance on the fuel.

If we start thinking about potential expansion, we are moving from a world where there is ample capacity but the biggest player is disqualifying itself. It creates in the western world a shortage of capacity. Before we are able to make those investments in additional capacity, we need to ensure that we have the right policy framework—at the moment, there is nothing disqualifying Russia from delivering the fuel—and that we have enough support from our utility customers through long-term contracts.

You cannot increase enrichment capacity by flapping fingers. It takes a long time in the making. We have learned from experience. We built an enrichment plant in the UK, starting in 2010 and ending in 2015[1]. We had to impair that site a couple of times because we were somehow anticipating demand.

At the moment, we are creating opportunity. We are having numerous discussions with policy makers and utility clients. Yes, we stand ready to supply the world and the western world. We believe that is our duty, as a company, because there are only two enrichers in the western world. It is our duty to be ready, but we need enough visibility to do so.

Q252 **Aaron Bell:** Urenco would have been disappointed by EDF's decision to use French fuel manufacturers for Hinkley Point C. To what extent does that put the future of your business at risk?

Laurent Odeh: I will not comment on past decisions made by a significant client of ours. We are dealing with 50 different customers in 20 different countries.

Q253 **Aaron Bell:** Of course, but looking specifically at the UK—

Laurent Odeh: Looking specifically at the UK, we are a significant supplier to EDF globally. Urenco is a significant supplier to EDF and we intend to continue that. Simone came to Capenhurst last week. I am going to Paris after this meeting to meet them. We work closely with EDF. Decisions made in the past are decisions that were made in the past. We are looking forward to the future.

Q254 **Aaron Bell:** With regard to Sizewell C, EDF have said they are looking to eliminate the use of freshly mined uranium and do more recycling. How well set up is Urenco to work with that? Do we have the recycling

[1] Witness correction: When Mr Odeh referred to a site being built in the UK, he meant to refer to a site in the US.

facilities in the UK to generate potentially the fuel for Sizewell? Have any agreements been signed for fuel for Sizewell C yet?

Laurent Odeh: I will not comment on specific deals. What I can say is Urenco is capable of enriching reprocessed uranium. We can do that in our facility in the Netherlands. We have the technology and we can also easily instal it in the UK if there is a market need to do so.

The big problem for reprocessed uranium is you need the first step before that, which is conversion. That only takes place in Russia. At the moment, as we do not allow transport of UF6 from Russia to any of our sites, we are unable to do that enrichment of the processed uranium, but we have the technical capabilities to do so. If there is a market need, we are willing to consider additional investment there.

Q255 **Aaron Bell:** Are you looking at how you can replace that Russian capability with something in Europe?

Laurent Odeh: Our utility customers are responsible for delivering the UF6 to our sites. We know our utility customers are looking at potential options. At the moment, for reprocessed uranium, only Russia is able to provide those services.

Q256 **Graham Stringer:** You have answered most of my questions. The one area we have not really approached is the future for thorium as a fuel. Can you give the pros and cons?

Professor Abram: Thorium is not in and of itself a fuel. It is not a fissile isotope. The isotope in question is thorium-232. That is not fissile, but if you pack it around the core of a reactor it will absorb neutrons and it will transmute from thorium-232 into uranium-233. That is fissile; uranium-233 does not occur in nature but it is every bit as good a fissile material as uranium-235. It is possible to take thorium and pack it around the core of a reactor and make it into a fuel material.

The nuclear fuel industry in every country in the world, as we speak today, is based essentially on a uranium fuel cycle. That is not to say that an equivalent fuel cycle based on thorium could not be brought into existence. Today, we do not have any industrial capability to do that.

In addition, in order to kick-start such a cycle—I am referring to my earlier point about thorium not being fissile—you would have to use a uranium fissile source to create that first fissile material from thorium. From a global long-term perspective in relation to global energy supplies, it is a very good thing that thorium exists. It may very well come to be an economically viable fuel in the future—probably not today.

Q257 **Graham Stringer:** Simply because there has not been the investment; there is nothing inherently difficult about it.

Professor Abram: No. It is a little more difficult because, as I said, it is not in and of itself a fissile material; you have to create fissile material from it. Having done that, you have the possibility of either recovering that uranium-233 by reprocessing and manufacturing that into new fuel. Or it is possible to operate, as the German high-temperature reactors used to many years ago, thorium and uranium fuel in tandem. The difficulty there is that that only works from a reactor physics point of view if the uranium is quite highly enriched—above that 20% limit that I was referring to before. Things like that were possible to do in the 1970s; they are very much frowned upon today.

Q258 **Graham Stringer:** You may not know the answer to this, but I hope you do. Why have the Indians and Chinese invested in thorium plants?

Professor Abram: Two different reasons: China is investing in everything. You point to a nuclear technology that they are not investing in. They are spread betting. If you had their financial resources, you would probably do the same.

India, in common with Norway, is sitting on vast thorium reserves. It is very geographically specific in their case. Even today, even in India, their nuclear power programme is predicated on the uranium fuel cycle.

Chair: That concludes this session of the Committee. I am very grateful to Professor Abram and Mr Odeh for joining us today and to all our witnesses. In our next session in this inquiry, we will be looking at the place of nuclear in the green taxonomy, which came up today. To all of our witnesses, thank you very much.