

## MSR Study outcomes and selection of Moltex Energy SSR technology

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### The MSR Review process

The substance of the EPD Ltd Study was provided by six molten salt reactor development entrepreneurs (for details see Report) who were ready to act as reactor vendors. They provided conceptual designs and associated engineering detail. A key activity of the study was to put this information forward to Fraser Nash engineers (a team of six) for an independent review of the material provided. The level of detail provided varied between vendors, in part due to concerns over confidentiality and due to limitations on what could be sent to the UK under export license rules.

Design descriptions are published in the Report, but not full details for confidentiality reasons.

All the designs were found to be valid, which is to say that if adequately funded each proposed design could be expected to lead to a functioning fission reactor with possible routes to commercialisation.

The Fraser Nash review uncovered interesting features of the designs. The review itself was presented in a standard format for each proposal. It comprises five separate reports looking at each of the five proposals under main headings, namely Components, Safety & Environment, Operations & Maintenance, and Ability to Licence, with appropriate sub-sections. From this careful, professionally conducted review, information is presented in the Report to allow the reader to make their own comparison of the proposals.

The EPD team made their own analysis of the Fraser Nash reviews of the different reactor concepts, taking due account of the different levels of detail provided and the confidential information to which they had access and concluded that the Moltex Energy Stable Salt Reactor had clear advantages over the other concepts. This paper sets out the reasons for that choice.

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### Comparison of the reactor concepts

Five of the six reactor concepts considered shared a common base technology derived from the ORNL Molten Salt Reactor Experiment in the 1960's. That technology is to pump molten salt nuclear fuel between a reaction chamber where it achieves critical mass and therefore produces heat, and a heat exchanger where that heat is passed to another fluid and hence used to produce power. Different reactors had different specific advantages, often reflecting impressive levels of innovation, but all shared this common base technology.

The Moltex Energy concept was fundamentally different. It put molten salt fuel

into fuel tubes and fuel assemblies very similar to those used in all nuclear reactors today. No pumps, valves, heat exchangers, emergency drain systems etc. as required by the other five concepts were needed. This simple concept had in fact been considered at the very outset of the molten salt reactor program but had been rejected. This was because it relied on natural convection to transfer heat out of the fuel through the tube walls. Natural convection could not be relied on for an airplane mounted nuclear reactor – which was what the program was then focussed on - and modern computing techniques to model convection had not yet been developed. That critical decision has never been re-examined when molten salt

reactors came down to earth, until Moltex Energy did so.

The EPD team considered that this provided a number of major advantages over the five pumped fuel systems.

- the technology hurdles were substantially lower since the highly mature technology of fuel tubes and assemblies used in the Moltex Energy reactor replaced the complex and largely untested salt containment and pumping systems required for the other reactors
- the Moltex Energy team had provided credible data showing that it could be built using only existing nuclear certified steels with no need for new materials
- the fuel assemblies would likely fit within existing IAEA rules for tracking fissile materials while pumped systems would require new internationally approved rules
- the reactor did not require a completely fail safe engineered system for emergency fuel draining, the validation of which would be a major regulatory hurdle
- the reactor did not require a system for handling highly radioactive off gas from the fuel, that function being intrinsic to the fuel tube/assembly structure
- the reactor had a credible cost estimate, independent of the reactor vendor, showing a high probability of being able to match the capital cost of a coal fired power station. No other reactor concept

had provided such an independent cost estimate.

Balancing these advantages, the EPD team did consider the advantages potentially available to pumped salt reactors that would not be possible with the Moltex Energy static salt system.

The major advantage of pumped salt systems seen was the potential to continuously reprocess the molten salt fuel to remove fission products. This gives the potential to minimise the inventory of fission products, and hence the size of the radioactive hazard in the reactor. It also gives the potential to achieve very efficient breeding of new nuclear fuel in thorium based reactors. Not all the pumped salt reactors considered actually set out to achieve these potentials but the other reactors could be considered valid steps along the way.

The EPD team encourages vendors to pursue their various strategies and encourages collaboration between vendors. Molten salt presents a new fuel cycle and the fastest route to development may be a collaborative one.

The Moltex Energy reactor was seen however as ready for immediate development and deployment and great weight was attached to this given the world's urgent need for affordable nuclear energy.

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## Present outcomes and the future in UK context

Current UK energy policy was set out by Amber Rudd, Secretary of State for DECC, in November 2015. The energy mix is to be determined by market forces - and largely absent of subsidies on 'renewables', carbon capture projects, and coal-burning. This is expected to include new gas-fired power and building a small but significant fleet of large "Generation III" Pressurised Water Reactors. The UK government has also however implemented a techno-economic assessment of small modular reactors with the view to the UK becoming a global exporter of this

technology and helping drive a major expansion of nuclear energy use worldwide. It has committed £250 million to R&D in the nuclear fission area.

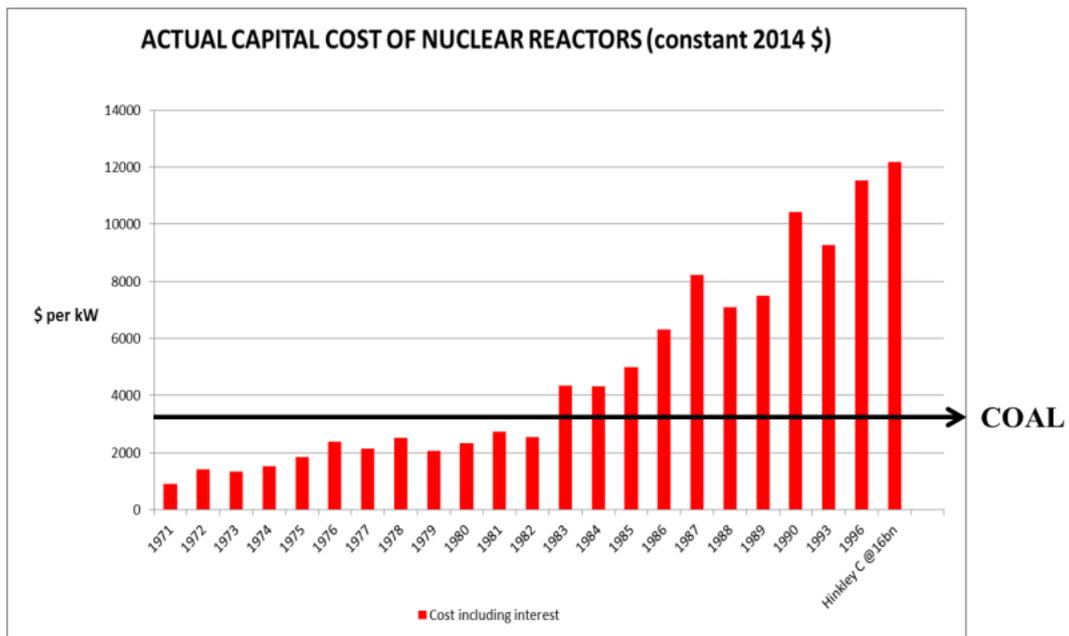
The graph below illustrates the magnitude of this challenge. It shows the construction cost of nuclear reactors since the start of the nuclear age – in constant 2014 dollars. Up until 1983 nuclear reactors were actually cheaper to construct than an equivalent, clean burning, coal fired power station. That is why

nuclear grew rapidly in the USA, and in France came to dominate power production. Then Three Mile Island and Chernobyl happened and the cost of adding new engineered systems to these reactors to make them safer destroyed the economics of nuclear power.

For nuclear to become a dominant global power source, these economics must be restored and it is the opinion of EPD that this can only be done by making nuclear energy intrinsically safer, instead of adding layer on layer of engineered safety systems. Molten salt reactors can achieve this.

The Moltex Energy reactor has a highly credible claim to be able to meet the cost requirements for massive nuclear expansion, with an independent capital cost estimate comparable to that of a coal fired power station. It has been submitted to the UK government techno-economic assessment of small modular reactors.

In 2015, the Chancellor announced that the government will hold a competition to select which small modular reactors will be developed in the UK. EPD strongly supports Moltex Energy's entry into that competition as the most credible opportunity to meet the economic challenge represented by massive expansion of nuclear energy globally.



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