Thorium energy

Standard Note: SN06671
Last updated: 24 June 2013
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Thorium is an element which, with the right technology, can be used as a fuel for nuclear power. It is claimed to have a range of advantages over uranium including greater abundance, lower radiotoxicity waste, safer operation and weapons proliferation resistance – although some of these are disputed.

While several significant demonstration projects have been built and operated since the 1940s, the technology is still at the research and development stage and commercial use is thought to be at least 10-15 years away (and further for more innovative plant designs). The Government "maintains an interest in the global potential of thorium" but does not see a role for it in the UK's short- to mid-term energy market. Research spending in the UK is low, although larger projects are underway elsewhere in Europe and in China, India and Japan.

Contents

1	**What is thorium?**	**2**
2	**How does a thorium reactor work?**	**2**
3	**What benefits could a thorium reactor have?**	**2**
4	**How developed is the technology?**	**3**
5	**What is the Government's position?**	**3**
6	**Research spending**	**4**

1 What is thorium?

Thorium-232 is a naturally occurring element, approximately three times more common than uranium.[1] It is not a fissile[2] material but if bombarded with neutrons it transmutes to thorium-233, an unstable isotope that then decays into uranium-233. This isotope is fissile – on bombardment with neutrons it splits, releasing energy and enough neutrons to react with other thorium and uranium atoms, producing a self sustaining chain reaction.

2 How does a thorium reactor work?

The World Nuclear Association lists seven types of reactor design which could use thorium,[3] but the most widely discussed involves dissolving thorium (and enough uranium to provide the initial neutrons) into a molten salt such as lithium fluoride to produce a liquid fuel. Such reactors are known as Liquid Fluoride Thorium Reactors (LFTR). A 2010 article in the journal Nuclear Engineering and Design provides background to how the technology works and how and why it developed.[4] Thorium cannot straightforwardly be substituted for uranium in a conventional reactor.

3 What benefits could a thorium reactor have?

A number of advantages have been claimed for thorium reactors as compared to uranium, including the following summarised from an International Atomic Energy Agency (IAEA) report on thorium:[5]

- Thorium is more abundant, widely distributed and easily exploitable.
- Produces low radiotoxicity waste and can consume existing waste from uranium-fuelled plants.
- Thorium is a better fertile material and can operate over a wider range of neutron spectra, giving a higher fuel conversion ratio.

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1 World Nuclear Association, *Thorium*, August 2012, accessed 5 June 2013
2 A fissile material is one that can maintain a chain reaction of nuclear fission
3 World Nuclear Association, *Thorium*, August 2012, accessed 5 June 2013
4 LeBlanc, D., "Molten salt reactors: A new beginning for an old idea", *Nuclear Engineering and Design*, 240(6), June 2010, pp1644-1656
5 IAEA, *Thorium fuel cycle — Potential benefits and challenges*, May 2005

- Thorium dioxide is more chemically stable and has better thermophysical properties than uranium dioxide making for better in-pile performance and easier storage and disposal.

- Intrinsic weapon proliferation resistance.

It should also be possible to build "sub-critical" reactors which are safer because they avoid the risk of meltdown.[6] However, it should be noted that the benefits are disputed. A UK National Nuclear Laboratory (NNL) independent review of thorium was much less optimistic about some of the claimed benefits of thorium listed above. It viewed reductions in radiotoxicity of waste as likely to be "modest" and stated that using the thorium cycle for disposition of plutonium would currently "present a higher level of technical risk" than conventional routes.[7] It also rejected the notion that thorium does not pose a nuclear proliferation risk:

> Contrary to that which many proponents of thorium claim, U-233 should be regarded as posing a definite proliferation risk. For a thorium fuel cycle which falls short of a breeding cycle, uranium fuel would always be needed to supplement the fissile material and there will always be significant (though reduced) plutonium production.[8]

4 How developed is the technology?

The idea of using thorium for power generation has been around since the 1940s and there have been several significant demonstration projects.[9] However practical designs are in the early stages of research and many issues remain to be resolved, particularly the question of how to handle safely and cost effectively the corrosive salts that will be used for fuel and coolant. According to the NNL (in 2010):

> It is estimated that it is likely to take 10 to 15 years of concerted R&D effort and investment before the Thorium fuel cycle could be established in current reactors and much longer for any future reactor systems.[10]

China is currently actively pursuing research into thorium reactors, as this Telegraph article explains.[11] India, Japan and Norway are also actively seeking to develop the technology, partly because of their large domestic reserves of thorium.[12] Elsewhere however, relatively few funds are being devoted to this area of research, particularly in the present economic climate. The Parliamentary Office for Science and Technology published a POSTnote in 2008 on Future nuclear technologies, which includes a short section on thorium.[13]

5 What is the Government's position?

The Government's current position on thorium reactors was given by John Hayes MP, the then Minister of State for Energy, on 13 February 2013. In a written answer to a question from Andrea Leadsom MP he stated that DECC "maintains an interest in the global potential of thorium" and highlighted the early stage assessment commissioned by that department

6 Nguyen, T., "A meltdown-proof nuclear reactor may alleviate fears", *Smart Planet*, 14 March 2011, accessed 6 June 2013
7 NNL, *The Thorium Fuel Cycle*, August 2010
8 *Ibid.*
9 World Nuclear Association, *Thorium*, August 2012, accessed 5 June 2013
10 NNL, *The Thorium Fuel Cycle*, August 2010
11 Evans-Pritchard, A., "China blazes trail for 'clean' nuclear power from thorium", *Telegraph*, 6 January 2013
12 *Ibid.*
13 Future nuclear technologies, POSTnote 317, November 2008

from the National Nuclear Laboratory.[14] This reaffirmed the view expressed earlier in that month in the House of Lords by Baroness Verma, Parliamentary Under-Secretary of State for Energy and Climate Change:

> **The Lord Bishop of Hereford**: My Lords, is the Minister aware of the All-Party Parliamentary Group on Thorium Energy's meeting, only about 10 days ago, with academics, people from industry and national nuclear laboratories? Encouragement was given at the meeting to using thorium for mixed fuels with uranium, which has the long term potential to allow nuclear waste to be used as an asset and a fuel and not just a liability.
>
> **Baroness Verma**: My Lords, the right reverend Prelate is right to raise the work done on thorium. We maintain an interest in the global potential of thorium and have, for the longer term, commissioned a wider analysis of nuclear fuel cycle scenarios which are open to the UK, among which is the reactor design fuelled by molten thorium salts. However, previous studies show that there are still significant risks to resources to develop thorium fuel to commercial deployment. In these difficult economic times, we need to concentrate on potential technologies that compete for the same investment but may have a sounder outcome than thorium currently does.[15]

DECC has commissioned a wider analysis of nuclear fuel scenarios open to the UK, including molten thorium salts.[16] It is not seen as having a part to play in the UK's short- to medium-term energy market.[17] A report into building new nuclear from the House of Commons Energy and Climate Change Committee (published in March 2013) has a short background section on thorium and included evidence from the Weinberg Foundation, a not-for-profit organization promoting thorium-fuelled molten salt reactors.[18]

6 Research spending

Research spending is currently quite low. For example, as of June 2013 the Engineering and Physical Research Council (EPSRC) only has one grant open directly in this area, consisting of a sustainability assessment of the technology and valued at just over £215,000. EPSRC's total expenditure for 2011/12 was over £800 million.[19] Other projects, such as the European Spallation Source project which is part-funded by a 5 million Euro EU grant (of which 0.6 million Euro are held by the University of Huddersfield),[20] should be expected to contribute to our understanding in this area.

The UK's Thorium Energy Amplifier Association (ThorEA) published a report in 2009 which estimated that the total cost to the public sector of funding their proposed AESIR (Accelerator Energy Systems with Inbuilt Reliability) programme which aims to design, build and demonstrate a prototype accelerator system would amount to £300 million over five years, which would be intended to leverage £1.5-2 billion from the private sector.[21]

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14 HC Deb 13 February 2013 c700W
15 HL Deb 4 Feb 2012 c8
16 HC Deb 13 February 2013 c700W
17 HC Deb 10 January 2012 cc136-7W
18 Energy and Climate Change Committee, *Building New Nuclear: the challenges ahead*, 26 February 2013, HC 117 2013
19 EPSRC Annual Report and Accounts 2011-2012, p34
20 University of Huddersfield, *Professor Robert Cywinski* (profile), accessed 6 June 2013
21 ThorEA (2009), "Towards an Alternative Nuclear Future: Capturing thorium-fuelled ADSR technology for Britain", p26