U3A Future of Nuclear Energy

Slide No	Title	Detail
1	Black Slide	Blank Pre-Title
2	Title Pylons at Sunset	What is nuclear energy? It is energy that can be obtained from the fusion or fission of certain elements. I'm going to look at the nature of nuclear energy and power generation: where it is now, and where it might go in the future.
3	Energy Content	Why is attractive as a power source? The concentration of energy in a small mass is very attractive compared with fossil fuels.
4	Sustainable Energy	Energy The CO2/climate change issue makes it attractive too as sustainable energy sources are even worse than fossil fuels. Even if an impossibly large section of the UKs power generation were turned over to sustainable power generation, there would still be a gap needing to be filled. However, nuclear energy is seen by many as too dangerous to use and politically decisions to use it are difficult. Currently the UK has shifted from "no more nuclear power" to seeking tenders for new power stations, while Germany has decided not to build any more after the current generation is shut down.
5	Uranium Decay	How do we obtain nuclear energy? The heavy fissionable isotopes, eg, U235 are at the natural limit of element mass which can exist - they were forced into this combination originally during the violent collapse of very big stars. They have naturally continuously decayed over the billions of years since they were created. In the case of uranium, half of its mass decays to become lead in roughly 4.75 billion years. There will be a test on this slide at the end
6	Uranium Fission	However, this natural decay can be accelerated. The addition of a single neutron to a Uranium 235 nucleus causes it to break into the lighter elements barium and krypton, with the release of energy and more neutrons: these can be used to create further fissions in a self-sustaining chain reaction.
7 8	Power Station Fission Schematic	This is the process that occurs in the nuclear power stations we are familiar with. It was invented originally to create bombs, but as an energy delivery mechanism it was once thought that it could produce electricity too cheap to meter.
9	Future Power	
10	Fusion Diagram	Fusion is another option. If deuterium and tritium nuclei can be raised to very high temperatures, then they will combine to create a helium

nucleus with a large the release of energy and a spare neutron. This is the process that stars use and has been carried out at the Culham laboratory. It is at the forefront of power generation research – of

11 Culham Lab which more later.

12 Chernobyl Fission Reactors are seen as dangerous because of the hazards of radioactivity that accompany them.

What is Radioactivity/Nuclear Radiation? When radioactive elements decay, or are stimulated to decay in reactors, they release energy in the form of high speed particles and electromagnetic radiation.

Alpha particles are fast moving Helium4 nuclei. They are not very energetic and are stopped by a sheet of paper.

13 Particles and Radiation

Beta particles are high energy electrons but are stopped by a sheet of aluminum.

Gamma rays are highly energetic photons and are gradually absorbed by material they pass through. This can be many feet of lead or concrete.

Neutrons are similarly energetic and are captured by light elements as they pass through them.

Why is radiation dangerous?

The radiation particles and energy can alter the nature of other elements through the creation of other radionuclides which themselves create energetic particles through their decay. They also can alter elements and compounds, including biological systems, by ionisation which alters chemical properties and biological functions. In the latter case, the creation of free radicals within cells can be harmful leading to cell damage and or genetic modification effects. Gamma rays and neutrons are most dangerous and can easily cause damage: even low energy alpha and beta radiation can be dangerous if radioactive elements emitting them are absorbed into the lungs or gut.

14 Sievert plus The Linear No Threshold (LNT) model assumes all radiation is

Doseage

dangerous, and there is no minimum safe threshold for human beings. I.e. all radiation can cause genetic damage/cancers.

The unit of radiation dose received is the Sievert named after Rolf Sievert (1896-1966) of the Swedish Physics Institute who researched the biological effects of radiation in low doses. The Sievert was adopted as a standard unit of measurement of radiation in 1979.

15 Nuclear Stats

Why is this important for nuclear power? There are radiation hazards in the fission process which are reduced as far as possible by careful design. However, poor design, and or poor standards of operation can produce catastrophic failures although these are very rare.

16 Waste Disposal

Waste management is another issue. The Fuel Rods in reactors are altered by the fission process and new radio-active elements are formed eventually poisoning the reaction through neutron absorption. The fuel rods have to be removed the waste products separated off and the unused/re-useable U235 recovered. Similarly the structure of the reactor becomes radioactive creating problems during decommissioning of disposing of these materials.

Of particular concern in nuclear waste management are two long-lived fission products, Technetium-99 (half-life 220,000 years) and Iodine-129 (half-life 15.7 million years), which dominate spent fuel radioactivity after a few thousand years. The most troublesome transuranic elements in spent fuel are Neptunium-237 (half-life two million years) and Pu-239 (half-life 24,000 years). Nuclear waste requires sophisticated treatment and management to successfully isolate it from interacting with the biosphere. This usually necessitates treatment, followed by a long-term management strategy involving storage, disposal or transformation of the waste into a non-toxic form. Governments around the world are considering a range of waste management and disposal options, though there has been limited progress toward long-term waste management solutions.

The whole subject has high political implications mainly concerning public resistance and protest.

Is there a better way?

17 Public Protest

Fusion may be the answer if it can be made to work on a commercial scale. It has been successfully demonstrated at Culham laboratory, and currently a larger scale fusion reactor is being built through the International Thermonuclear Experimental Reactor ITER project in France. It is funded 46% by the EU and 9% each by India, China, Japan, S Korea, Russia and the USA. There is every expectation that when completed in 2020 the system will work to produce 500MW of power for at least 500 seconds, for 50MW put in. However, this power will just be dissipated as waste steam. It will pave the way for the 15% larger DEMO a demonstration plant in 2033 that will continuously produce 2-4GW of power which will be harnessed to produce electricity on a semi-commercial basis. In turn this will be followed by PROTO, a prototype fully commercial generation plant somewhere around 2050 – not for us then, nor will they stop the lights going out as they threaten to do in the UK shortly. (newspaper Article)

18 ITER

19 ITER

20 ITER

Of course not everyone thinks this is a good idea!

So is there an alternative to fusion reactors which are a long way off, and fission reactors which are seen as dangerous now and for the long term future?

21 ITER Protest

22 Nuclear Options

23 Berzelius

Thorium is a naturally occurring slightly radioactive element **Th** atomic number 90. It was discovered in 1828 by the Norwegian mineralogist Morten Thrane Esmark and identified by the Swedish chemist Jons Jakob Berzelius and named after Thor the Norse god of thunder. Thorium 232 is about 3 to 4 times more abundant than uranium and has a half-life of 14.05 billion years. It decays naturally into radon gas, radium and actinium. It is extracted as a by-product of rare earth metals extraction. The US has 2300 tons of it in underground storage.

Unlike Uranium 235, Thorium is not fissile, but can be persuaded to become a fissile isotope of uranium fairly easily. If Thorium 232 gains a neutron, it becomes Thorium 233 which decays naturally into Protactinium 233 and then into Uranium 233, a non-naturally occurring isotope of Uranium. Another neutron will cause the Uranium 233 to fission releasing energy and further neutrons to transmute more Thorium.

24 Thorium Reaction

This is not new. Much research has been done, and working reactors developed in the U.S., U.K., Germany, Brazil, India, China, France, the Czech Republic, Japan, Russia, Canada, Israel and the Netherlands.

Currently the Chinese and Indians are spending a lot of money on the design of commercial Thorium Reactors, and in August this year the Norwegians started a small commercial reactor designed in conjunction with the Japanese to prove the concept. While this reactor uses conventional fuel/oxide fissile materials, most interest is in Thorium reactors that use a molten thorium salt mix in a Liquid Flouride Thorium Reactor LFTR as the fission process.

Why use Thorium and why molten salt reactors?

> There is much less nuclear waste—up to two orders of magnitude less, eliminating the need for large-scale or long-term storage. "Chinese scientists claim that hazardous waste will be a thousand times less than with uranium. The radioactivity of the resulting waste also drops down to safe levels after just a few hundred years, compared to tens of thousands of years needed for current nuclear waste to cool off.
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> Once a Thorium reactor is started up [it] needs no other fuel except thorium because it makes most or all of its own fuel. Because it is non-fissile, it can also be used with fissile material, such as uranium and plutonium, as a nuclear fuel.[1]

25 Norwegian Thor Reactor

> Since a LFTR core is not pressurized, it does not need the expensive high-pressure reactor vessel for the core of light water reactors. Instead, there is a low-pressure vessel and pipes (for molten salt) constructed of relatively thin materials. Also due to low operating pressure, a much smaller containment structure is needed compared to light water reactors, up to 1,000 times smaller.

26 Molten Salt Reactor

> Since all natural thorium can be used as a fuel, and the fuel is in the form of a molten salt instead of solid fuel rods, expensive fuel enrichment and solid fuel rods' validation procedures and fabricating processes are not needed, greatly decreasing LFTR fuel cost.
>
> Comparing the amount of thorium needed with coal, CERN, estimates that one ton of thorium can produce as much energy as 200 tons of uranium, or 3,500,000 tons of coal. Coal, as the world's largest source of carbon dioxide emissions, makes up 42% of U.S. electrical power generation and 65% in China.

27	Chinese Bid	Weapons-grade fissionable material (^{233}U) is harder to retrieve safely and clandestinely from a thorium reactor;
28	Thorium advantages	Thorium produces 10 to 10,000 times less long-lived radioactive waste; Thorium mining produces a single pure isotope, whereas the mixture of natural uranium isotopes must be enriched to function in most common reactor designs. The same cycle could also use the fissionable U-238 component of the natural uranium, and also contained in the depleted reactor fuel; Thorium cannot sustain a nuclear chain reaction without priming,[29] so fission stops by default in an accelerator driven reactor.

Where do I think the future of nuclear power is going? In the short term gas and coal will remain the largest energy source because they are cheap and easy. The politics of climate change and carbon dioxide reduction is weakening as the true price of sustainable energy becomes apparent. George Osborne does not like the high cost to taxpayers of the green energy levy as it is unpopular and harms industry. The building industry is starting to react against the law that all new houses must be carbon neutral by 2016. (Newspaper Clip).

I believe that many more uranium reactors will be built because programmes are already in place worldwide – China has 17 in operation and 19 planned. India intends to generate 25% of its electricity with nuclear explouiting its Thorium reserves. There are currently 60 fission reactors being built world wide.

The UK is dragging its feet as always, but even here some very expensive reactors will be built for us by the French and the UK taxpayer will support the French taxpayer in consequence. Trade unions are worried that EDF will subcontract reactor50% of construction at Hinckley to the Chinese!

If Thorium reactors to be built by the Indians and Chinese prove successful then they may rapidly become the nuclear power of choice.

		If fusion reactors become practical after 2050 then they will solve our energy needs for the foreseeable future;
		In any event, nuclear energy, in the absence of some new physics, is here to stay.
29	TINA	
30	Black Slide	Questions?