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ENERGY REVIEW - NUCLEAR WASTE AND DECOMMISSIONING

Issue

The way forward on dealing with waste and decommissioning in the context of any new nuclear build.

Recommendation

That you agree the proposed language on decommissioning and waste and agree to advise the Prime Minister accordingly. The proposed language has been discussed with HMT at official level and is attached at Annex A. We will continue to work with HMT in the coming days to refine the language but we do not anticipate that it will change substantively. This language:

- Affirms that the owner/operator of a new nuclear power station should cover the full costs of decommissioning
- Establishes that the owner/operator of a new nuclear power station should cover the full and equitable waste disposal cost attributable to new build through an explicit charge covering both the fixed and variable components of the expected level of waste generated over the expected life of the plant. This charge will be set using the best available information following the first round of work on the implementation of the CoRWM recommendations.
- Outlines the process and timetable for better estimating the costs involved and for working with industry and other experts to finalise the mechanism for the private sector to cover these liabilities.

That you note the cost estimates for nuclear decommissioning. That you note that these estimated costs are subject to some uncertainty, although we are comfortable that our estimate is of the right order of magnitude provided that the regulatory regime does not change significantly. The estimate would be refined further through the process provided for in the Review.

That you note the cost estimates for nuclear waste management. That you note that these estimates are highly uncertain and depend on follow up work to the CoRWM recommendations. Further clarity on costs will not be possible until it has been decided, in the follow up work to the CoRWM report, whether to build a deep underground repository, a site has been selected and extensive geological assessments have been completed. Peter McDonald has sent a separate submission on the Government Response to the CoRWM recommendations. New build waste management cost estimates would also be refined further through the process provided for in the language we propose to include in the Energy Review.

That you note that the clear assumption is that the owner/operator should pay the full costs of decommissioning and the full and equitable cost of waste management attributable to new build (covering both the fixed and variable components of the expected level of waste generated over the expected life of the plant).

REDACTED MATERIAL

Timing

It would be helpful to get a steer from you by Wednesday 21 June, so that we can prepare the necessary material for the next meeting of the EE(O) committee on 26 June.

Argument

The Government has a legal obligation laid down in European legislation stemming from the EURATOM Treaty to ensure that decommissioning and waste management are carried out safely. For this reason, if insufficient provision is made by the owner/operator, the Government would need to meet the unfunded costs of decommissioning and/or long term waste management in order to ensure safety[i].

Measures should be put in place to transfer as much of the risk as practicable to the private sector and minimise any contingent liability which might fall to Government. The Energy Review should establish the principle that the owner/operator of any new nuclear plant should be required to meet the full costs of its subsequent decommissioning and the full and equitable cost of waste management attributable to new build.

However, due to uncertainties in the cost estimates for both decommissiong and waste management, it will not be possible to arrive at detailed arrangements to implement this principle in time for the Review conclusions. Uncertainties exist

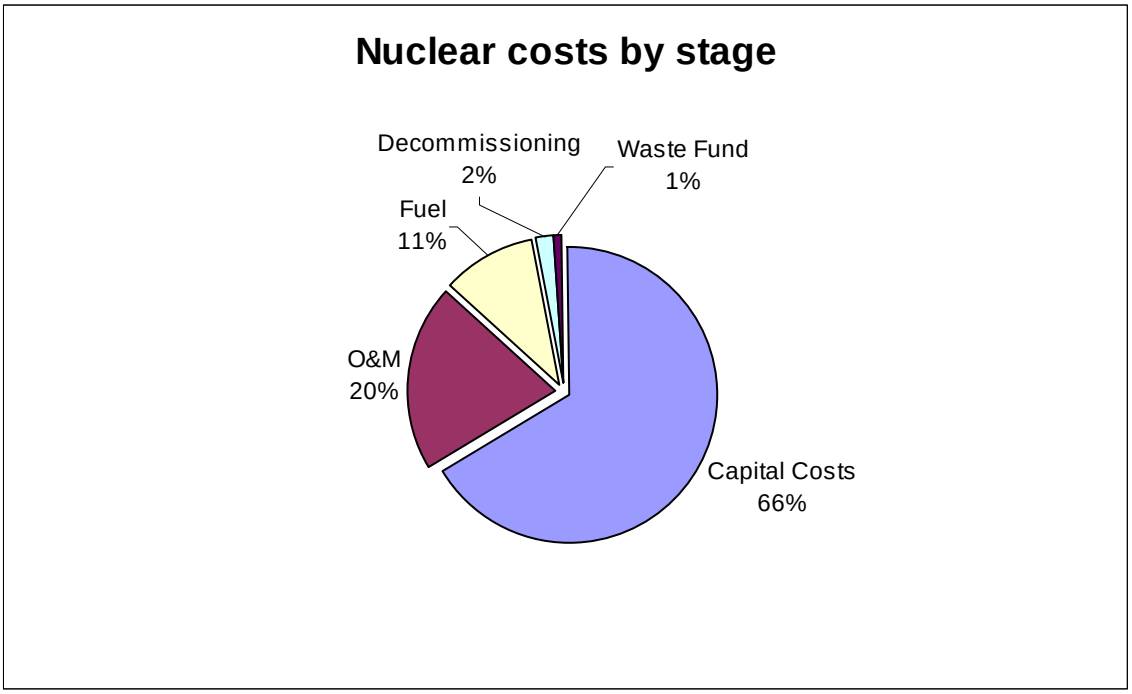
[i] Estimates of what the full costs of decommissioning and waste management might be are included in the relevant sections below. In a worst case scenario, the liability risk to HMG could be the full cost.

because the CoRWM recommendations on waste management will not yet have been formally published and followed up, because the practical and legal considerations surrounding a mechanism have not been fully explored with industry and regulators, because regulatory change in the future could affect the costs and because there is limited relevant past experience on which to base estimates.

Establishing the mechanism to implement these principles will be matters to be settled with potential developers and regulators through the process provided for in the proposed language drawn up with officials from HMT. HMT strongly prefers not to define any funding mechanism at this stage because of the uncertainties mentioned above.

Background on costs

Decommissioning and waste costs will be an important though relatively small proportion of total new build costs. The graph below shows the levelised cost of nuclear power, i.e. average cost per megawatt hour over the life of the plant.



The majority of nuclear costs are capital, reflecting the complexity of the construction of the plant. By contrast, the fuel cost is low.

Decommissioning makes a minimal contribution to the overall cost figure representing around 2% of the overall project life costs. This small percentage reflects that decommissioning costs occur a long time in the future and are

discounted. At the time that the decommissioning costs emerge, they will be significant. However, adequate provision can be made to cover them.

Figures on decommissioning costs in this chart reflect the cost of annual contributions which are in turn based on an estimate for decommissioning costs of c. £636m per EPR[ii] reactor in 2006 money values. The estimated cost of decommissioning assumes that from the start of the plant's operational life, an annual contribution of £7.5m is made into a fund. The fund is assumed to grow at 2.2%. Therefore at the end of the operating life of the plant (assumed to be 40 years) the fund will have accumulated to £485m based on total contributions over the period of £308m. Decommissioning is assumed to take 25 years and begins at the end of the operating life of the plant and finishes 65 years after the start of plant life. Therefore whilst a portion of the fund is being spent, the balance is continuing to grow at 2.2%. At the end of the 25 year decommissioning period the decommissioning spend totals £636m and the fund has been drawn down to zero. Assuming that the regulatory regime stays the same, we are comfortable that the cost figure for decommissioning is of the right order of magnitude. How this number was arrived at is explored further in paras 18-21.

Long term waste management also makes a minimal contribution to the overall cost figure representing around 1% of the overall project life costs. As in the case of decommissioning, this small percentage reflects that long term waste management costs occur a long time in the future and are discounted.

The figure for the cost of long term waste management used in this chart reflects the cost of annual contributions which are in turn based on an estimate for waste management costs of c. £276m per reactor. This estimate is uncertain – it assumes the cost of a combined geological repository is £25billion for legacy wastes. The Chair of CoRWM, Duncan Mckerron, has estimated costs as between £10bn and £30bn depending on which solution is decided on, a site chosen and extensive geological surveys conducted. We have taken a figure towards the upper end of this spectrum. CoRWM estimate that a 10GW new build programme would add c. 10% to the repository volume and the variable cost element of the repository is assumed to be 70%. On this basis the cost of waste management for a new reactor is estimated to be £276m (25bn x 70% x 10%). Similarly to decommissioning, an annual contribution of £4.3m is made to a fund over the operating life of the plant. The fund size at the end of plant life is £276m assuming a 2.2% growth rate. The waste spend is assumed to incur at the end of plant life. Waste costs are explored further in paras 26 - 29.

Decommissioining costs and liabilities explored

[ii] It is likely that any nuclear new build reactors in the UK would be of Pressurised Water Reactors (PWRs). The two leading designs are the Westinghouse AP1000 and the Areva EPR.

The Energy Review team commissioned consultants, Ernst and Young, to explore the costs of decommissioning. In the event that new nuclear reactors are constructed in the UK, it is likely that they will be of a light water design, most likely a Pressurised Water Reactor (PWR), but a Boiling Water Design (BWR) is also conceivable.

The available data sources point to a central estimate for the decommissioning of a PWR in the range of £250m - £350m per GW (in 2006 money values). Ernst and Young have made a number of prudent adjustments to include a contingency for possible estimating errors. They suggest that decommissioning costs would be in the range of between £300m and £420m per GW (in 2006 money values). Taking a value at the upper end of this scale of £400m per GW in 2006 money values gives a contingent liability of £636m per EPR reactor. For full details on how these costs were arrived at, see Annex 2.

The decommissioning cost estimates are based on reactor vendor own estimates and assertions, actual data from decommissioning reactors (of earlier generations) and third party academic or research studies. The uncertainties in the estimates reflect the fact that no-one has practical experience of decommissioning the new designs of nuclear reactor, nor are they likely to for at least 50 years. In addition, Government, through controlling the regulatory environment under which decommissioning takes place, has the power to significantly influence the costs and timescales of clean up. Discussions with the NDA suggest that the UK's regulatory regime is amongst the most stringent in the world and it is unlikely that requirements would be strengthened significantly. The final actual costs of decommissioning will vary from country to country and plant to plant due to differences in public policy and plant design.

As demonstrated in the earlier pie chart, it is estimated that decommissioning costs, when discounted, would represent only c. 2% of the total project life cost of a nuclear power plant. Discussions with industry players show that they are relatively unconcerned about remaining uncertainties in the exact figures because they are confident about the order of magnitude. Industry suggests that they are comfortable with paying the full costs of decommissiong and can make adequate provision to cover these costs.

In contrast, it is of greater concern to Government that decommissioning cost estimates are robust. This is because of the risk that Government could face a contingent liability (estimated as up to £636m for an EPR reactor) for meeting the costs of decommissioning if, for whatever reason, an operator fails to make adequate provision. At the time when decommissiong costs occur, they will be significant, even though the discounted cost is relatively small.

The risk to Government would be minimised if the Review establishes that decomissioning costs should be covered by the owner/operator. Risks will also be minimised if the further work provided for in the Review language sets out a robust and transparent process whereby Government (with the NDA) will work with industry and independent experts to develop a framework which ensures costs are forecast accurately, adequate funding provision is made, and risks to the taxpayer are minimised. This is what the language worked up with HMT and attached at Annex 1 aims to achieve.

The clear assumption is that owner/operators should pay for the costs of decommissioning in full. However, in advance of the detailed work provided for, we see a benefit in retaining flexibility and not ruling out any options. For example, the Government might consider a cap on operator liability that would limit the risk to the owner/operator in the event of a change in the regulatory environment. Without a cap, operators would bear the risk of a significant increase in decommissioning costs towards the end of the asset cash generating life due to regulatory change over which they have no control.

There is a case for Government not taking the regulatory cost risk, given that other sectors of the economy (e.g. oil or water companies) face similar risks. Moreover, our assessment is that the need for such a cap is very slim. Nevertheless, retaining flexibility in the wording is a sensible precaution. We propose that the possibility of a cap on decommissiong charges would not be raised in or alongside the Energy Review. However, neither should the language close the door to this option entirely.

Waste costs and liabilities explored

The Chair of CoRWM has estimated the cost of a deep geological repository for legacy waste at between £10bn and £30bn. This repository would need to be built whether or not there is a decision in favour of new nuclear build. We have taken a figure of £25bn from the upper end of this scale. CoRWM estimates that a 10GW new build programme would add 10% to existing waste stocks. The variable component of the cost of building a repository is assumed to be 70%. On this basis the cost of waste management for a new reactor (if EPR) is estimated to be £276m (25bn x 70% x 10%).

Further clarity on costs will not be possible until it has been decided, in the follow up work to the CoRWM report, whether to build a deep underground repository, a site has been selected and extensive geological assessments have been completed. **REDACTED NAME** has sent a submission to you separately on the Government's response to CoRWM which recommends that the NDA be given responsibility for implementing a long term waste management solution.

The draft framework language envisages a scenario where operators are obliged to manage all waste (including spent fuel) on site for the life of a plant. It is likely that Government would then take responsibility for disposing of the waste when the plant closes. The clear assumption is that owner/operators would be expected to pay an explicit charge covering both the fixed and variable components of the expected level of waste generated over the expected life of each plant

As demonstrated in the pie chart above, waste disposal costs, when discounted, are estimated to represent only 1% of the total cost of building, operating and closing a nuclear power plant. Discussions with industry players suggest they are comfortable with managing ongoing waste during the operational stage of a plant's life (for example, on-site storage, and managing these costs within operation and maintenance expenditure) and paying to cover the fixed and variable costs of the expected level of waste generated over the life of the plant.

The major area of uncertainty lies around final disposal. Operators are clear that there is a great deal of uncertainty over the costs of the solution for final disposal and when any repository would become available. They would like more clarity over the quantum of any contribution to the fixed costs of final disposal.

Owner/operators point out that the final waste management solution will be decided and delivered by Government. Most of the costs of building a repository are not linked to accommodating new waste and would be necessary anyway in order to deal with the UK's existing waste legacy. Owner/operators of any new nuclear plant have no scope to influence the scale of the costs, or reduce the risk of any cost overruns caused by, for example, construction delays.

The proposed language, developed with HMT, sets out the principle that new build operators should make a payment to reflect the full and equitable cost attributable to new build, with a promise of follow up work to develop a mechanism to achieve this. The language also foresees that the level of the charge to owner/operators will be set using the best available information following the first round of work on the implementation of the CoRWM recommendations. The charge would not change during the planned life of the reactor.

We need to ensure that any arrangements are compatible with State Aid rules. Our initial assessment is that a mechanism could be designed in such a way as to be compatible with these rules but we will continue to work to ensure that State Aid concerns are addressed.

Further work, provided for in the proposed language, is also necessary to understand whether primary legislation would be required to implement whatever mechanism is decided upon.

REDACTED NAME
Energy Review Team

Annex 1: **Language for the Energy Review on Nuclear Waste and Decommissioning**

Satisfactory arrangements will need to be agreed on dealing with the costs of decommissioning and waste from nuclear new build. Government will need to be satisfied that participants in nuclear new build have put in place an appropriate structure to deal with these costs. It is important that proposals are sufficiently robust, particularly given that in order to comply with its international obligations for nuclear safety Government must bear the responsibility for the management (or disposal) of radioactive waste and spent fuel in the event that no other party is able to discharge those obligations.

Government intends to engage with industry and other experts to develop arrangements for managing these costs based on the principles set out below. The first step will be for Government (with the support of the NDA) and industry to have a common understanding of the likely costs of waste and decommissioning. However, given that this will not eliminate the uncertainty of these costs, proposals from industry participants will need to clearly set out how the project will be capable of meeting all the costs, even in challenging downside scenarios.

In the case of waste disposal costs it is recognised there will need to be an agreement as to how to share the burden between the existing waste legacy and the cost arising from nuclear new build.

<u>Principles: The Risk Management Framework</u>

<u>Decommissioning:</u>

- There should be an upfront assessment of decommissioning costs
- Full responsibility for decommissioning costs to be retained by the private sector operator(s)
- Appropriate protection given to the public sector regarding credit risk and reduced reactor life.
- The framework should be robust though time.
- These principles will form the basis of arrangements which will apply equally to all new build operators and reactor types.

Waste:

- Delivering and paying for a long term waste management solution for legacy waste is a responsibility that falls to the public sector. Government will develop a long term waste management solution which will factor in waste from new build.
- There will be an assessment of how new build affects the cost of delivering the national waste management solution.
- The private sector will pay an explicit charge covering both the fixed and variable components of the expected level of waste generated over the expected life of each plant.
- The level of this charge will be set using the best available information following the first round of work on the implementation of the CoRWM recommendations:
    - Charging basis will reflect the full and equitable cost that is attributable to new build.
    - Charge for each operator would not change during the planned life of the reactor
- It is expected that the commercial structure of waste disposal agreements will meant that participants operate plant in a way that seeks the optimal balance between performance and waste generation.
- Appropriate protection given to the public sector regarding changes in reactor life and other factors
- Provision and decommissioning of interim storage over the life of the plant would be the responsibility of the operator.
- The framework should be robust through time
- These principles will form the basis of arrangements which will apply equally to all new nuclear build operators and reactor types.

Indicative Timetable:

- Before the end of 2006: Government will establish the composition, function and responsibilities of a group that will be set up to explore the options for a mechanism based on the waste and decommissioning risk management framework principles above.

Decommissioning

- By mid 2007: the group will consult with industry in order to establish an outline decommissioning risk management mechanism.
- Ongoing: assessment of decommissioning costs of specific reactors.

Waste

- Before the end of 2006: a timetable will be set out to take forward work on a waste risk management mechanism. This will reflect the timetable for implementation work arising from the Government's response to the CoRWM recommendations. A robust cost assessment of the preferred solution for legacy waste will provide a baseline against which the additional costs of waste from new build can then be developed.

ANNEX 2: DECOMMISSIONING COST ESTIMATES

Background

It is likely that, in the event that new nuclear reactors are constructed in the UK, they will be of a light water design, most likely a Pressurised Water Reactor ("PWR"), but with a Boiling Water Design ("BWR") also being conceivable. The two leading designs of PWR are Areva's 1,590MW EPR, and Westinghouse's 1,100MW AP1000.

Both designs are developments of predecessor reactors. Whilst the EPR is under construction in Finland, neither has yet reached an operational stage, nor have many of their predecessors yet reached an advanced stage of decommissioning.

Consequently, information with respect to the potential costs of decommissioning these new reactor variants has to be drawn or interpolated from proxy data. The main sources of such information are:

a. Reactor vendor own estimates and assertions
b. Actual data from decommissioning reactors (of earlier generations);
c. Third party academic or research studies

It must also be noted that the final actual costs of decommissioning will vary significantly from country to country and plant to plant due to differences in public policy and plant design. There is a lack of specificity or disclosure of many of the key assumptions that underpin estimates, and hence it is considered critical to treat with caution single value estimates stated by a number of the sources.

Vendor Estimates

Both Areva and Westinghouse have given public presentations which have included statements regarding the anticipated costs of decommissioning their new reactor designs, and Areva's submission to the Energy Review (page 17) also refers.

REDACTED MATERIAL

Decommissioning Experience

Few large scale commercial PWR reactors have reached advanced stages of decommissioning, however there are examples in the US where work is substantially complete, and the radiological decommissioning has been completed to NRC satisfaction. Two key examples are Yankee Maine (a 900MW PWR) and Trojan (a 1,155MW PWR).

In both cases the nuclear facilities have been dismantled, but other structures remain, and in the case of Yankee Maine, certain wastes remain on site in a packaged form in newly engineered facilities as a consequence of the unavailability of Yucca Mountain. (Hence the stated costs cannot be treated as being for a complete Greenfield decommissioning.)

In both cases, the stated costs are those incurred to-date, plus those yet to be incurred on completion of physical dismantling, but exclude all those costs associated with Spent Fuel storage on site.

Costs disclosed are as follows:

Site	Disclosed costs	Estimated (2006 mv)	Links
Maine Yankee	US$440m (2001 mv)	£360m per GW	www.maineyankee.com
Trojan	US$300m (1997 mv)	£220m per GW	http://egov.oregon.gov/PUC/meetings/pmemos/2005/030805/reg4.pdf

Third Party Studies

A number of studies have been performed, including academic and industry body work, as well as analysis being performed by brokers such as Morgan Stanley to assess the level of provisioning being made by European utilities operating PWRs.

The more recent or more comprehensive of these studies are summarised in Appendix A.

As referred to earlier, there are a range of assumptions and approaches that may underpin the data in these studies, and many of these will not be explicit or visible. Further, much of the data represents expected costs of decommissioning activities that will be performed in the future, and hence can not be treated as empirical historical data.

Conclusions

In summary, the differing sources of data can be summarised as follows:

Source	Indicated cost £m/GW(2006mv)	Adjusted estimated cost £m/GW(2006mv)	Comments
REDACTED MATERIAL			
PRECEDENT			
Yankee Maine	360	360	Spent Fuel still on site in new facilities
Trojan	220	220	Spent Fuel still on site in new facilities
THIRD-PARTY STUDIES			
Morgan Stanley	311		Average of a wide range
OECD	220+	135 - 270	
US DoE	250+	250 - 300	

These figures have not been increased to reflect any additional contingency or risk margin, but the source figures may include some such provision.

On this basis, it is considered reasonable to conclude that the available data sources point to a central estimate for the decommissioning of a PWR in the range of £250m - £350m per GW (in 2006 money values). However, these estimates are unlikely to include much provision for estimating and other contingency, and consequently a prudent assumption would be to increase the range by a factor of 1.2 to reflect that contingency, and to accommodate some of the potential differences in precise interpretation and assumption base. This would give rise to a range of between £300m and £420m per GW.

On the assumption that each new reactor operates for either 40 or 60 years, at an average load factor over life of 85%, and with the undiscounted cost spread across actual generation hours, the effective cost per MWh of generation would be:

Assumed cost/GW	£/MWh – 40 year life	£/MWh – 60 year life
250	0.84	0.56

300	1.00	0.67
350	1.17	0.78
420	1.41	0.94

Applying a 2.5% discount rate to the total decommissioning costs over the 40 or 60 year lives reduces the £/MWh cost to a prospective:

Assumed cost/GW	**£/MWh – 40 year life**	**£/MWh – 60 year life**
250	0.31	0.13
300	0.38	0.15
350	0.44	0.18
420	0.53	0.21

APPENDIX A

Estimated Reactor Decommissioning Costs

Source	Reactor type	Cost estimate	Comment	2006 mv cost estimate
"Decommissioning Nuclear Power Plants: Policies, Strategies and Costs" – OECD/NEA 2003	PWRs – range of countries	Average U$320/GW, with range of U$200m – U$400m for larger reactors	Expressed in July 2001 money values, reflecting 19 reference PWR reactors	£220/GW average, with range of £135m - £270m
Dominion Energy for US DoE, 2004	4 designs, including AP1000	U$416m for 1,150MW unit	Quoted as 2003 money values, does not include full demolition, but achieves de-licensing in US	£250m/GW (though likely to be higher for total demolition)
Bayliss and Langley	Average PWR - USA	U$368m	1998 money values to licence termination NEI study of 60 PWRs from 500MW to 1,095MW, with and without full disposal and site remediation	£265m (assuming average size of 750MW)
	Average BWR - USA	U$420m	1998 money values to licence termination NEI study of 30 BWRs from 540MW to 1,140MW, with and without full disposal and site remediation	£300m (assuming average size of 800MW)
	Various reactors	Eur275M – Eur600	1997 – 2000 UNIPEDE study, covering 12 countries (10 in Europe), assumed 1998 money values	£230m - £500m (no reference MW)
US Uranium Info Centre	Average reactor	U$325m	1998 money values, range between U$280m and U$612m (described as being reduced estimates based on experience)	£235m (range of £200m - £440m, with no reference size)
Morgan Stanley research	European fleet	Eur260m – Eur800m per GW installed	Based on disclosed provisions of E.On, RWE, Electrabel, Fortum and CEZ, generally 2004 money values.	£190m - £590m per GW
	PWR	Eur110m – Eur1.1bn per GW installed	Based on data from 21 sites. Average of Eur396m, in 2001 money values	£311m per GW (average)

Notes to APPENDIX A

1. Bayliss and Langley data extracted from their book Nuclear Decommissioning, Waste Management and Environmental Site Remediation". Oxford: Elsevier, 2003.
2. Cumulative inflation factor for USA between 1998 and 2006 is 1.22, and between 2000 and 2006 is 1.15 (US Department of Labor statistics, http://data.bls.gov/cgi-bin/cpicalc.pl)
3. Cumulative inflation factor for Europe between 1998 and 2006 is 1.16, between 2001 and 2006 is 1.10,and between 2004 and 2006 is 1.03 (ECB European inflation data)
4. US$ translated at 1.7, Eur€ translated at 1.4.
5. 'US Uranium Info Centre' not found
6. Morgan Stanley *Nuclear Prospects*, Sept. 2005