Performance Audit on

Management of fuel for Pressurised Heavy Water Reactors

(Front-end of the Nuclear Fuel Cycle)

Report of the

Comptroller and Auditor General of India

for the year ended March 2007

Union Government
Scientific Departments
No. PA 19 of 2008
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Contents

Preface

This report of the Comptroller and Auditor General of India for the year ended March 2007 containing the results of the Performance Audit on 'Management of fuel for Pressurised Heavy Water Reactors (Front-end of the Nuclear Fuel Cycle)' pertaining to the Department of Atomic Energy has been prepared for submission to the President of India under Article 151 of the Constitution.

The scrutiny of records relating to implementation of Pressurised Heavy Water Reactor programme was done at Department of Atomic Energy, Heavy Water Board, Nuclear Fuel Complex, Uranium Corporation of India Limited and Atomic Minerals Directorate for Exploration and Research during May to December 2007.

The results of our audit along with recommendations are contained in this report.

Executive Summary

1. The Atomic Energy Programme of Department of Atomic Energy (DAE) contemplated that India should be able to produce all the basic materials required for the utilisation of atomic energy and build a series of atomic power stations, which will contribute increasingly to the production of electric power in the country. The share of nuclear energy as of 2002 was only 3.01 *per cent* of the total power generated in India and DAE aimed to increase this to 26 *per cent* by 2052. In pursuance of this policy, DAE set a target of 20,000 Mega Watt electrical (MWe) of nuclear power by Pressurised Heavy Water Reactors (10,000 MWe) and Light Water Reactors (10,000 MWe) by 2020.

2. The units responsible for providing inputs to sustain the Pressurised Heavy Water Reactors (PHWRs) are Nuclear Power Corporation of India Limited (NPCIL), Nuclear Fuel Complex (NFC), Heavy Water Board (HWB), Uranium Corporation of India Limited (UCIL) and Atomic Minerals Directorate for Exploration and Research (AMD).

3. There has been serious fuel crisis for the PHWRs in the country in recent years affecting nuclear power generation. We, therefore, decided to conduct a Performance Audit of '*Management of fuel for PHWRs*' to examine the reasons which led to this fuel crisis and to ascertain whether an effective system was in place to ensure adequate supply of fuel to the PHWRs so as to meet the target for power generation set out by DAE.

4. During the course of the Performance Audit, we observed that inspite of the estimated uranium reserves in India being sufficient for generation of 10,000 MWe for a 40 year lifespan of the PHWRs, since 2003-04 there had been a significant mismatch between the demand and supply of uranium. As a result, the capacity factor of the PHWRs had declined from 80 *per cent* in 2002-03 to 50 *per cent* in 2007-08 due to non-availability of fuel. The magnitude of the slowdown in nuclear power generation due to the fuel crisis had assumed significant proportions, thereby denying the nation the full benefits of clean nuclear energy to the extent of 21,845 million units valued at Rs.5986 crore.

5. DAE had not linked/ensured availability of fuel to fully address the needs of PHWR programme upto 2020. Inspite of knowledge of an impending shortage of uranium fuel, DAE went ahead and sought approval for four new PHWRs at a cost of Rs.6354 crore. This points to a significant deficiency in the planning process, which should have been adequately addressed at the time of planning for these new reactors. Further, the roadmaps for UCIL and AMD laid down by DAE had not fully addressed the needs of PHWRs.

6. NPCIL's annual demand for fuel on NFC was watered down as it was driven by expected supply rather than by projected demand. Setting watered down targets for power generation based on uranium supply rather than demand of the PHWRs led to over-reporting of performance.

7. We also observed noteworthy attempts by NPCIL in capacity addition of PHWRs and in operating certain PHWRs at a plant load factor above 90 *per cent.*

8. We observed that the HWB had taken effective measures to improve process parameters of various plants and to stockpile enough heavy water to ensure that the planned PHWR programme upto 2020 does not suffer for want of heavy water. The policy of not stockpiling uranium fuel, however, needs to be reviewed in the context of the current fuel crisis.

9. We observed that the production capacity at NFC was not commensurate with NPCIL's projected demand for PHWR fuel. While we recognise the fact that due to non-availability of yellow cake (MDU) from UCIL, the production capacity did not prove to be a constraint, the augmentation of additional capacity at NFC needed to be fine-tuned with the real requirement of fuel.

10. We observed that at UCIL, the roadmap for production of uranium resources was not commensurate with the demand for the PHWR programme. There were significant deficiencies in the strategic planning at UCIL with regard to matching the mining and milling capacity, which were avoidable, as remedial action was within the reach of DAE and was not contingent on any externalities. Resultantly, 93,472 tonnes of uranium ore was pending for milling as of March 2007.

11. Domiasiat, Lambapur and Gogi were better grade deposits and were expected to deliver significant quantity of yellow cake per annum. However, there were significant delays in opening of these mines which had adversely affected the timely supply of nuclear fuel to the PHWRs. Further, avoidable delays in filing applications for environmental clearances and preparing EIA/EMP reports were also observed which further delayed the setting up of mines. In view of importance of nuclear energy for our national programmes, DAE should lay greater emphasis on sensitisation of public and organisations like NGOs to the benefits of nuclear energy. As the extent of current intervention by DAE had not yielded the desired results and the country could not afford to continue running the PHWRs at half their capacity, some innovative decisions needed to be taken to solve the deadlock in these sites.

12. The 10,000 MWe PHWR programme planned by DAE required around 1,01,600 tonnes of uranium resources for their entire life span of 40 years. Though AMD had identified 1,07,268 tonnes of uranium resources, only 71,159 tonnes were economically viable reserves.

13. At AMD, we observed that during the IXth and Xth Plan, the pace of augmentation of uranium deposits had declined to 13,661 tonnes and 16,244 tonnes as against augmentation of uranium resources of 28,195 tonnes during the VIIIth Plan. This decline was significant in view of the fact that DAE had set a target for augmentation of 75,000 tonnes during the XIth Plan.

14. Against the target of identifying 15,000 tonnes of uranium resources during the Xth Plan in the priority areas of Gogi, Rohil and Koppunuru, only 8105 tonnes (54.03 *per cent)* had been identified by AMD, despite these sites being free from infrastructural/ environmental constraints. Further, the extent of DAE intervention had not yielded the desired results and deposits capable of hosting over 60,000 tonnes of uranium at Lambapur-Peddagattu, Chitrial and Gandi remained to be explored.

15. Though the gestation period for the extraction of uranium from other sources is only 18

months and it is a more eco-friendly process, DAE could not produce any uranium from other sources till March 2008 despite the country having an annual potential of 500 tonnes.

16. Despite existence of uranium reserves in the country to support the present PHWR programme upto 2020, India's capacity for generation of nuclear power has been compromised for want of uranium. The improved efficiency of DAE's monitoring and strategic planning from second half of the X^{th} Plan onwards has still not yielded the desired results and the demand-supply mismatch of uranium fuel continues to adversely affect the operation of the PHWRs. There is, therefore, an urgent need to further strengthen the existing planning and monitoring mechanism at DAE and in all the units involved in the front-end of the nuclear fuel cycle.

Highlights and Recommendations

Planning and Monitoring at DAE

Highlights

- DAE had not linked/ensured availability of fuel while drawing up the roadmap and laying down milestones for the construction of new PHWRs. Also, the roadmaps for UCIL and AMD laid down by DAE had not fully addressed the needs of PHWRs.

(Paragraph 3.4)

- Cabinet clearance for Kaiga 3&4 and RAPS 5&6 was taken despite the knowledge that these reactors would suffer for want of fuel and without adequately highlighting the shortage of fuel for these reactors in the Cabinet notes which led to their sanction.

(Paragraph 3.10)

Our Recommendations

1. Since it takes 10 to15 years from start of exploration programme to commencement of mining and production, DAE needs to effectively plan and monitor setting up of matching targets for all its units i.e. HWB, NFC, UCIL and AMD so that PHWRs are not stranded for want of fuel at any stage. DAE may consider monitoring the fuel availability for PHWRs in line with the comprehensive monitoring report suggested by us.
2. Before sanctioning and taking investment decisions on capital intensive new nuclear power plants, DAE needs to ensure availability/linkages of fuel while seeking approval of the Government.
3. Government may review the existing arrangement of the same incumbent holding the posts of both Secretary DAE as well as Chairman AEC.

Pressurised Heavy Water Reactors

Highlights

- NPCIL's annual demand for fuel on NFC was watered down as it was driven by expected supply rather than by projected demand.

(Paragraph 4.9)

- Due to the constraints in fuel supplies, the average capacity factors of PHWRs as a whole were consistently brought down to 72, 67, 64 and 50 *per cent* respectively during 2003-08. PHWRs operated at lower capacity and denied the nation the full benefits of clean nuclear energy to the extent of 21,845 million units corresponding to Rs.5986 crore calculated at an average tariff of Rs.2.74 per unit.

(Paragraph 4.13)

- We observed that installed capacity of PHWRs at the commencement of Xth Plan was 2400 MWe and at the end of the Xth Plan was 3580 MWe. However, the power generation decreased by 4 *per cent* during the same period (16,814 million units in 2002-03 and 16,030 million

units during 2006-07). The power generation further dwindled to 14,405 million units during 2007-08.

(Paragraph 4.17)

Our Recommendation

4. NPCIL needs to project its requirements based on its demand for running the plants at maximum capacity factor rather than on the supply capabilities of uranium to avoid under-reporting of the magnitude of the shortage.

Heavy Water Board

Highlight

- HWB had taken effective measures to improve process parameters of various plants and to stockpile enough heavy water to ensure that the planned PHWR programme upto 2020 does not suffer for want of heavy water.

(Paragraph 5.4)

Our Recommendation

5. Considering the uncertainties involved in the production of heavy water, which is vulnerable to the changes in technologies, DAE may continue the prudent policy of maintaining its strategic stock with the approval of AEC for sustaining the PHWRs in the long run.

Nuclear Fuel Complex

Highlights

- The gap between production capacity at NFC and NPCIL's projected requirement of fuel ranged from 13 *per cent* to 56 *per cent* during 2004-05 to 2006-07. Had there been sufficient inflow of MDU from UCIL or elsewhere, the PHWRs would not have operated to the full capacity due to inadequate installed capacity at NFC, which would then have been a bottleneck.

(Paragraph 6.3 & 6.4)

- NFC did not specifically demand quantities of MDU needed for operation of PHWRs at full capacity and restricted its scope of operations to what UCIL could supply. This resulted in the actual shortage of MDU being masked and not being projected adequately.

(Paragraph 6.7)

Our Recommendation

6. NFC needs to fix its target for production based on fuel bundles needed for operation of PHWRs at full capacity rather than based on supply of MDU from UCIL. This would draw appropriate attention to the capability of UCIL to deliver sufficient quantities of MDU to NFC.

Uranium Corporation of India Limited

Highlights

- The roadmap drawn by UCIL for production of uranium was not

commensurate with the demand of the PHWR programme as

- UCIL had planned exploitation of only 46 *per cent* of the requirement of PHWR fuel for the period 2001-02 to 2007-08.
- UCIL had planned exploitation of only 79 *per cent* of the requirement of PHWR fuel for the period 2008-09 to 2016-17.
- No production strategy was envisaged by UCIL beyond 2016-17 in its roadmap.

(Paragraph 7.3)

- There was an overall 26.66 *per cent* shortfall of milling capacity compared to mining capacity during the period 2002-03 to 2006-07 and UCIL had to operate its mines at a lower capacity in the range of 71 to 89 *per cent*. Despite increased demand for fuel during this period and a huge fuel crisis, 93,472 tonnes of uranium ore was pending for milling as of March 2007.

(Paragraph 7.6 & 7.7)

- The three mines at Domiasiat, Lambapur and Gogi were better grade deposits and were expected to deliver significant quantity of yellow cake per annum. The delays in opening of these mines adversely affected the timely supply of nuclear fuel for the PHWRs. Further, as the extent of current interventions by DAE had not yielded the desired results and the country could not afford to continue running the PHWRs at half their capacity, some innovative decisions needed to be taken to solve the deadlock in these sites.

(Paragraph 7.22)

- As the constraints in the better grade deposits of Domiasiat, Lambapur-Peddagattu and Gogi could not be resolved as planned, UCIL/DAE decided to re-visit the low grade deposits in Singhbhum belt, which also could not fructify.

(Paragraph 7.23)

Our Recommendations

7. UCIL needs to immediately review and redraw its roadmap to ensure that it adequately matches the fuel requirement of the identified 10,000 MWe PHWR programme till 2020.
8. UCIL needs to put exploitation of high tonnage, high grade uranium deposits of Domiasiat and Lambapur on a fast track mode to meet the acute fuel crisis.
9. UCIL should also ensure completion of all the other ongoing mining and milling projects without further slippages so as to bridge the gap between demand and supply of uranium.

Atomic Minerals Directorate for Exploration & Research

Highlights

- During the IXth and Xth Plan, the pace of augmentation of uranium deposits by AMD had declined to 13,661 tonnes and 16,244 tonnes as against augmentation of uranium resources of 28,195 tonnes during the VIIIth Plan. This decline was significant in view of the fact that DAE had set a target for augmentation of 75,000 tonnes during the XIth Plan.

  (Paragraph 8.2)

- Out of 15,000 tonnes of uranium resources targeted for identification during the Xth Plan, the AMD Council set a target of proving expected reserves of 5000 tonnes each at Gogi, Rohil - Ghateshwar and Koppunuru in the order of priority. Against this target, though AMD could identify 16,244 tonnes during the Xth Plan, it had actually identified a total of only 8105 tonnes in these targeted areas representing an achievement of only 54.03 *per cent*, despite these sites being free from infrastructural/ environmental constraints.

  (Paragraph 8.10)

- The roadmap contained in the *Report of Nuclear Power Programme upto 2020* emphasised the need for identification and firming up of additional deposits for the Xth Plan in Lambapur-Peddagattu and Gandi. Further, AMD Council also underscored the need for activities for augmentation of uranium reserve in Chitrial for the Xth Plan. However, only limited progress could be made in these sites.

  (Paragraph 8.18)

- Shortfalls in achievement of targets in field activities of AMD were observed during the Xth Plan in airborne survey (54.75 *per cent*), geo-physical reconnaissance survey (18.46 *per cent*) and jeep survey (14.70 *per cent*).

  (Paragraph 8.29)

Our Recommendations

10. A holistic and detailed plan needs to be drawn up in respect of every potential uranium deposit indicating time frame for each activity, right from identification of a potential deposit till its handing over to UCIL for commercial exploitation.
11. All out efforts need to be made to develop economically viable deposits like Gogi, Rohil-Ghateshwar, Koppunuru, Lambapur-Peddagattu, Chitrial and Gandi.
12. AMD needs to modernise its infrastructure for achieving higher productivity in surveys and drilling.

Extraction of uranium from other sources

Highlight

- The *Report on Nuclear Power Programme upto 2020* envisaged that at least 200 tonnes per year of uranium should be recovered from other sources during the Xth Plan and an additional 240 tonnes per year of uranium during XIth Plan. The AUS Committee, in February 2007, also held that if all the uranium from other sources was extracted, it would provide 500 tonnes of uranium annually. However, till March 2008, DAE could not produce any uranium from other sources despite the gestation period being only 18 months and it being a more eco-friendly process.

(Paragraph 9 and 9.1)

Our Recommendation

13. DAE may attempt extraction of uranium from other sources in a time bound manner in order to ease the demand-supply position of uranium.

Performance Audit Report on Management of fuel for Pressurised Heavy Water Reactors (Front-end of the Nuclear Fuel Cycle)

Chapter 1 Introduction

Background

1.1 The Department of Atomic Energy (DAE) was established in August 1954. The programmes of DAE aim at using atomic energy for power generation, development of radiation technology and applications of atomic energy in the areas of agriculture, medicine, industry and research.

1.2 Atomic Energy Programme contemplated that India should be able to produce all the basic materials required for the utilisation of atomic energy and build a series of atomic power stations, which would contribute increasingly to the production of electric power in the country.

Share of nuclear energy

1.3 The share of nuclear energy as of 2002 was only 3.01 *per cent* of the total power generated in India. According to DAE, this share was likely to be increased to 26 *per cent* by 2052. In the meantime in 1997, DAE set a target for generation of 20,000 Mega Watt electrical (MWe) of nuclear power by Pressurised Heavy Water Reactors (10,000 MWe) and Light Water Reactors (10,000 MWe) by 2020. Pressurised Heavy Water Reactors (PHWRs) are dependent on natural uranium and the estimated uranium reserves in India are sufficient for generation of 10,000 MWe for a 40 year lifespan of the PHWRs.

Atomic Energy Commission

1.4 Considering the special requirements of atomic energy, the strategic nature of its activities and international and political significance, Government of India, established an Atomic Energy Commission (AEC) with full executive and financial powers, as an apex body of DAE. AEC is responsible for formulating the policy of DAE and implementation of Government policy in all matters concerning atomic energy.

1.5 The Secretary DAE heads the Department and is responsible for its day to day functioning. The Secretary DAE is also the ex-officio Chairman of AEC and is responsible for arriving at decisions on technical questions and advising the Government on matters of atomic policy. All recommendations of the AEC on policy and allied matters are put up to the Prime Minister through the Chairman, AEC.

India's nuclear power programme

1.6 Nuclear Power Programme (NPP) pursued by DAE is based on a closed-cycle approach that involves a number of ancillary operations. The operations include mineral exploration, mining, milling & processing of ore, fabrication of fuel, reprocessing of depleted uranium fuel and management of nuclear waste. These operations, as a whole, are known as the nuclear fuel cycle. Nuclear fuel cycle is divided into two parts viz., front-end and back-

end of the nuclear fuel cycle. Front-end of the nuclear fuel cycle includes mineral exploration, mining, milling and processing of ore, fabrication of fuel and production of heavy water, which is used as a moderator and coolant in the PHWRs. The back-end of the nuclear fuel cycle covers reprocessing of spent uranium fuel and management of nuclear waste.

Units involved in the PHWR programme

1.7 The units responsible for providing inputs to sustain the PHWRs are:

i. Atomic Minerals Directorate for Exploration and Research

Atomic Minerals Directorate for Exploration and Research (AMD) is the oldest unit of DAE set up in July 1949. Mandate of AMD includes identification, exploration and evaluation of uranium reserves.

ii. Uranium Corporation of India Limited

Uranium Corporation of India Limited (UCIL) is a PSU under the administrative control of the DAE. Established in October 1967, it is engaged in mining and processing of uranium ores to produce MDU[1]. This MDU is sent to NFC for further processing and conversion to nuclear fuel for the power reactors for generation of electricity.

iii. Nuclear Fuel Complex

Nuclear Fuel Complex (NFC), an industrial unit under DAE, was established at Hyderabad in 1970 to indigenously manufacture and supply fuel bundles for PHWRs for meeting the requirement of NPP of DAE.

iv. Heavy Water Board

Heavy Water Board (HWB), an industrial unit under DAE, was set up in 1989 to manage the operation of its heavy water plants. It is primarily responsible for production of heavy water required for PHWRs and other research reactors.

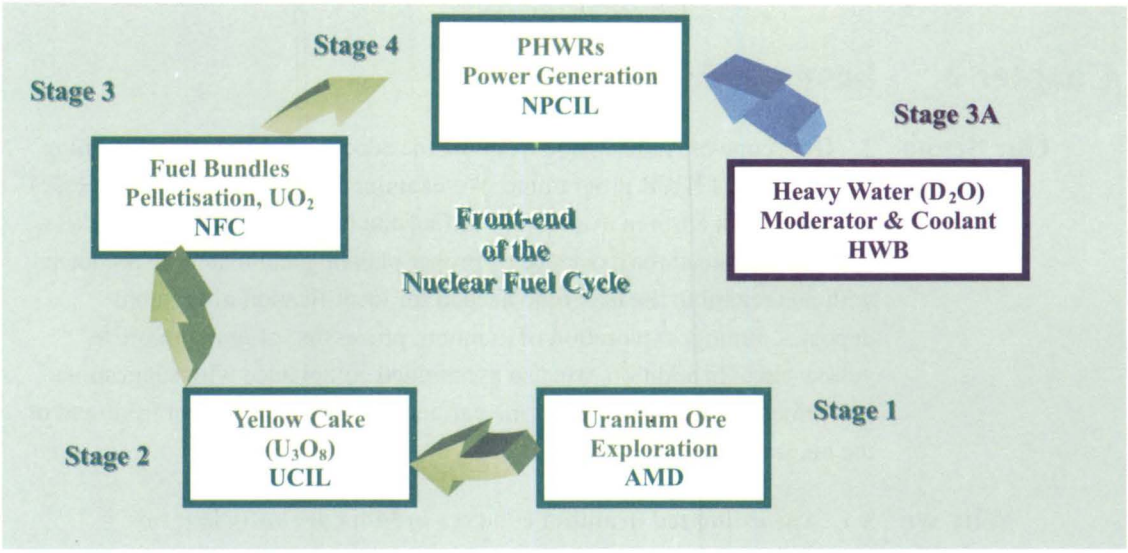
v. Nuclear Power Corporation of India Limited

Nuclear Power Corporation of India Limited (NPCIL), a PSU of the Government of India under the administrative control of DAE, is the nodal agency to undertake the design, construction, operation and maintenance of the atomic power stations for the generation of electricity under the provisions of the Atomic Energy Act, 1962.

Stages in the front-end of the nuclear fuel cycle

1.8 In order to ensure smooth functioning of the PHWRs, a steady flow of the raw material i.e. uranium and heavy water is required. The process of making available uranium for the PHWRs involves exploration and identification of the uranium ore deposits by AMD, mining and milling of the uranium ore to produce yellow cake by UCIL and production of pellets and fuel bundles by NFC. Heavy water is another raw material for the PHWRs. A flow chart of how the front-end of the nuclear fuel cycle works is given below.

[1] MDU (Magnesium-di-urinate) is also known as yellow cake and its chemical formula is U_3O_8.



1.9 Bottlenecks at any of the four stages in the front-end of the nuclear fuel cycle can jeopardise the entire PHWR programme. It takes 10 to 15 years from start of exploration to the time uranium is made available for use. Thus, planning and monitoring of the entire process is of paramount importance to ensure that the front-end of the nuclear fuel cycle runs smoothly. It is, therefore, important to ensure that besides long term planning for generation of nuclear power through PHWRs, matching targets are also set for each of these four stages in the front-end of the nuclear fuel cycle.

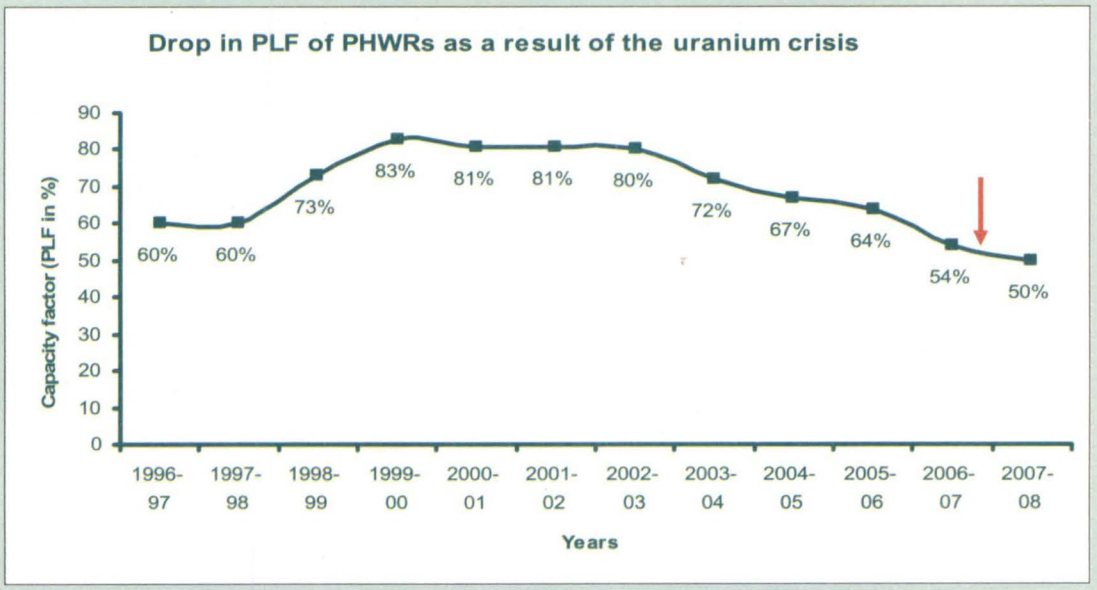
Chapter 2 Scope of Audit

Our Scope

2. Our scope of Audit was to examine the adequacy of long term planning of DAE in its PHWR programme. We examined the activities and processes in DAE which ensured availability of fuel and heavy water for the PHWRs. We also examined the existence of proper planning and matching roadmaps with due regard to the lead time needed for identification of uranium deposits, mining, exploration of uranium, processing of uranium ore to yellow cake. In addition, we also ascertained compliance with suggestions/ recommendations contained in the various Committees/AEC on front-end of the nuclear fuel cycle.

Why we examined this issue

2.1 The estimated uranium reserves in India are sufficient for generation of 10,000 MWe for a 40 year lifespan of the PHWRs. However, since 2003-04, there has been a significant mismatch between the demand and supply of uranium and the capacity factor[2] of PHWRs had declined to 50 *per cent* in 2007-08 due to non-availability of fuel (depicted in the table below). **The magnitude of the slowdown in nuclear power generation due to the fuel crisis had assumed significant proportions and this prompted us to undertake this performance audit.**



Our main objective for examination

2.2 The main objective of our performance audit was to examine whether there was an effective system in place to ensure adequate supply of fuel to the PHWRs so that nuclear power was generated as planned.

[2] The capacity factor at which the power plants operate is also expressed as Plant Load Factor (PLF)

Our detailed objectives for examination

2.3 The detailed objectives for our examination were:

- Whether planning and monitoring at DAE ensured availability of required inputs at every stage of the front-end of the nuclear fuel cycle so that power generation was not hampered,
- Whether DAE had established the linkage of fuel required for operating PHWRs while drawing the roadmap to establish 10,000 MWe PHWRs by 2020,
- Whether new PHWRs were planned and constructed after realistically assessing fuel availability,
- Whether PHWRs suffered for want of heavy water,
- Whether the PHWRs suffered for want of fuel bundles and whether targets for production of fuel bundles matched with the requirements of fuel for the PHWRs,
- Whether the production of fuel bundles at NFC was affected for want of yellow cake from UCIL and whether this was adequately reported,
- Whether UCIL had a roadmap to produce sufficient yellow cake to meet the needs of the identified 10,000 MWe PHWRs programme by the year 2020,
- Whether there were any delays in taking action by UCIL for establishment of mining and milling facilities at specified locations,
- Whether AMD had a roadmap for exploration of viable uranium reserves to support 10,000 MWe PHWRs for life of 40 years,
- Whether AMD efficiently explored, proved and handed over uranium resources in priority areas, and
- Whether DAE had made adequate efforts for extraction of uranium from other sources.

Our audit methodology

2.4 We discussed our audit objectives with the auditee in an Entry Conference in DAE Secretariat at Mumbai on 24 April 2007. DAE in principle, agreed with the objectives and methodology adopted in this performance audit. We conducted scrutiny of records relating to implementation of PHWR programme at DAE, HWB, NFC, UCIL and AMD during May to December 2007. Preliminary audit findings were communicated to appropriate authorities for confirmation of facts. The draft report was issued to DAE in May 2008. The comments furnished by DAE in June 2008 were discussed in Exit Conference held on 14 July 2008 at DAE and were considered while finalising the audit conclusions. On a special request by DAE, we shared the highlights and recommendations contained in the final report with DAE, which is a departure from our regular audit reporting process. Secretary, DAE also discussed the highlights and recommendations with the Comptroller and Auditor General

of India on 4th December 2008. The response of DAE is included as Annex 1. The co-operation of DAE and its various units viz. HWB, NFC, UCIL and AMD during the entry/exit conference and in the course of audit was satisfactory and the same is acknowledged with thanks.

Our detailed findings

2.5 Our detailed findings with regard to planning and monitoring mechanism at DAE, NPCIL, HWB, NFC, UCIL and AMD are in the chapters that follow.

Chapter 3 Planning and Monitoring at DAE

3. While AEC is mainly responsible for formulating the policy of DAE and implementation of Government policy in all matters concerning energy, formal and informal planning is carried out through various Committees/Plan Projects, Formulation/ Implementation Committees etc,. These include Strategic Planning Group at DAE Secretariat, Steering Committee on Nuclear Power Programme, Quarterly Review of Performance of PSUs and Review of Plan Projects, Review of status of the Projects in the AMD Council/UCIL Board from time to time, Review at the time of Plan Formulation/Mid Term Appraisal, Management Service Group etc,.

3.1 Further, DAE had set up various committees as detailed below to aid the planning and monitoring processes with regard to availability of fuel for the PHWRs.

i. DAE, in its Vision 2020 document brought out in September 1997, aimed at attainment of a nuclear capacity of 20,000 MWe by 2020.

ii. In May 2000, DAE constituted a committee for assessment of demand-supply of uranium for the X^{th} Plan. The committee submitted its report in August 2000 and concluded that the shortage of uranium raw material may arise from 2003-04 onwards.

iii. DAE constituted another committee in December 2000 to prepare an overall plan of the activities of DAE for the nuclear power programme in order to reach a target of 20,000 MWe by the year 2020 {10,000 from PHWRs and 10,000 from other reactors like Light Water Reactors (LWRs)}. *Report on Nuclear Power Programme upto 2020,* submitted in June 2001, recommended planning of activities of DAE to attain an installed nuclear power capacity of 20,100 MWe by the year 2020. The Report emphasised the necessity for matching actions on nuclear fuel cycle facilities. Moreover, it also predicted the impending demand-supply mismatch of uranium fuel for PHWRs from 2001-02 onwards.

iv. In December 2005, DAE constituted an expert committee on augmentation (AUS Committee) for putting uranium exploration and mining activities on a fast track. The Committee in its Report in February 2007 recommended various measures which, when implemented, would lead to identification of enhanced uranium resources and optimise the production of uranium from the identified resources so that the mismatch between demand and supply for the planned PHWRs could be bridged to the maximum extent.

3.2 We reviewed the various processes linked to planning and monitoring

for the availability of fuel for the PHWRs and observed the following deficiencies.

Targets set for capacity generation of PHWRs

3.3 DAE had set a target for generation of 10,000 MWe from PHWRs by 2020. To achieve this target, DAE had planned to continue construction of PHWRs from the IXth Plan to the XIIIth Plan.

3.4 We observed that there was no deficiency in planning for construction of PHWRs to meet the defined targets. We, however, observed that DAE had not linked/ensured availability of fuel while drawing up the roadmap and laying down milestones for the construction of new PHWRs. Also, the roadmaps for UCIL and AMD laid down by DAE had not fully addressed the needs of PHWRs.

3.5 Though DAE strengthened the planning and the monitoring processes in the second half of the Xth Plan after the crisis had erupted, these were belated efforts which should have been taken 10 to 15 years in advance of the projected requirement.

3.6 DAE stated in June 2008 that the decision to set up new PHWRs was consciously taken for strategic reasons so as to ensure that the skill and manufacturing base within DAE and outside did not get eroded. DAE further stated in December 2008 that:

- NPP had been periodically reviewed and redrawn and discussed at all levels including in AEC.
- It was important to recognise that the indigenous technology programme required parallel pursuit of activities related to reactors, uranium production within the country and fuel fabrication activities in accordance with the overall programme and it would be wrong to say that these were not linked.

3.7 The reply of DAE may be viewed in the light of the following:

- DAE in 1984 had targeted achieving 10,000 MWe from PHWRs by 2000 which was deferred in 1995 to 2020. However, the roadmap for achieving the target of 10,000 MWe by 2020 was drawn only in 2001 whereas the target of 10,000 MWe was fixed as early as in 1995. Even the roadmap drawn in 2001 was incomplete as it did not fully address the needs of PHWRs upto 2020. There was a gap between NPCIL's projected requirement and UCIL's planned augmentation upto 2016-17. Beyond 2017, there was no roadmap for capacity addition in augmentation of uranium by UCIL.
- Though NPP was periodically reviewed and discussed at all levels including in AEC from 2001 onwards, the mismatch continued and only got aggravated between 2002-03 and 2006-07. This indicated that the monitoring mechanisms in place were not effective enough in

addressing the issue.

- Though the need to sustain the human resources and manufacturing capacity within/outside DAE was appropriately mentioned in the AEC notes and Cabinet notes, while seeking concurrence for new reactors, DAE had not made specific disclosures that these reactors, on completion of construction, would suffer for want of fuel.

Approval for new PHWRs

3.8 We noted that DAE was aware as early as in August 2000 (based on the report of the committee set up by DAE in May 2000) that shortage of uranium may occur from 2003-04 onwards. Even the *Report on Nuclear Power Programme upto 2020* submitted in June 2001 predicted the impending mismatch of uranium demand-supply from 2001-02 onwards.

3.9 DAE sought approval for four new PHWRs viz., Kaiga 3&4 and RAPS 5&6 during 1999 -2002 at a cost of Rs.6354 crore (Kaiga 3&4: Rs.3282 crore and RAPS 5&6: Rs.3072 crore) as detailed below:

	Kaiga 3 & 4	RAPS 5 & 6
Approval by NPCIL Board	November 1999	**August 2001**
AEC approval	February 2000	**September 2001**
CCEA[3] approval	**April 2001**	**January 2002**
Administrative Sanction	**May 2001**	**April 2002**

3.10 From the table above, we observed that as of August 2000, CCEA approval and Administrative Sanction for Kaiga 3&4 was pending. For RAPS 5&6, approval of the Board, AEC approval, CCEA approval and administrative sanction were also pending. However, these projects were approved inspite of having knowledge (Committee Report submitted in August 2000) that there was going to be a fuel shortage in the future by the time these projects fructified. Thus, Cabinet clearance for Kaiga 3&4 and RAPS 5&6 was taken despite the knowledge that these reactors would suffer for want of fuel and without adequately highlighting the shortage of fuel for these reactors in the Cabinet notes which led to their sanction.

3.11 It is also pertinent that in the note submitted in July 2001 to AEC seeking approval for the perspective plan for the *Nuclear Power Programme upto 2020*, DAE had not established availability/linkages of fuel to the proposed PHWRs or made specific disclosure that there would be shortage of uranium in the future, even if the planned mining and milling facilities were taken up. Further, AEC, in August 2001, while approving NPP upto the year 2020, had also raised a specific enquiry regarding fuel availability for the proposed roadmap and the roadmap was approved with a firm affirmation from Chairman AEC and CMD, NPCIL that requisite action had been taken to accelerate augmentation of fuel related projects for the timely availability of fuel for these projects.

[3] Cabinet Committee on Economic Affairs

3.12 We are concerned that inspite of knowledge of an impending mismatch of demand vis a vis availability of uranium fuel in the near future, DAE went ahead and sought approval for new PHWRs. This points to a significant deficiency in the planning process which should have been adequately addressed at the time of planning for these new reactors.

3.13 DAE stated in June 2008 that the position of uranium inventory was satisfactory till 2000 and the Projects (Kaiga 3&4 and RAPS 5&6) got sanctioned after taking due cognisance of the inventory position and planned actions for augmenting uranium production capacity. It further contended that AEC and the Cabinet were presented with the overall plan of activities of the Nuclear Power Programme. DAE further stated in December 2008 that Kaiga 3&4 was a IXth Plan project when fuel was not a constraint and Domiasiat was in the pipeline and as a prudent measure Kaiga 1&2 were replicated. Approval in this regard was in early 2000-2001. RAPS 5&6 took due cognisance of the June 2001 report of DAE at specific behest of AEC to work out details for roadmap of NPP. The report interalia recommended physical schedule of the NPP and inputs needed for RAPS 5 to 8. After AEC's scrutiny, the proj ects were submitted for CCEA approval and audit's conclusion on 'inadequate' disclosure was not judicious.

3.14 DAE's contention that the conclusion drawn by us was injudicious needs to be viewed against a specific direction of August 2000 from DAE Committee to the effect that linkage of fuel was to be established before taking decisions to set up new reactors. However, AEC/Cabinet clearance for Kaiga 3&4 and RAPS 5&6 was taken without any specific disclosure about impending fuel shortage though DAE was aware of the same.

Monitoring

3.15 We observed from the planning and monitoring processes being followed in DAE that formal and informal monitoring was periodically done through various committees/plan project formulation/implementation committees. We also observed that monitoring was being done at the highest level, more so, in an informal manner.

3.16 While we recognise the efforts being made by DAE in monitoring the fuel crisis in PHWRs after the crisis had erupted, DAE needs to put into place, a formalised system of monitoring. Such a system could ensure that matching targets are set for all the units i.e. HWB, NFC, UCIL and AMD so as to ensure that PHWRs do not suffer for want of fuel at any stage. This is particularly important as it takes around 10 to 15 years to make available uranium from the exploratory stage to the finished fuel stage.

3.17 DAE confirmed in December 2007 and June 2008 that it was aware of the goals and targets set for uranium prospecting, mining and milling to meet the increased fuel requirements and monitoring was done at the highest level, especially in an informal manner, keeping in view the sensitivity of the programme. It further confirmed that formal and informal monitoring

was periodically done through various Committees/Plan Project Formulation/Implementation Committees. It also stated that AEC was apprised of the developments in uranium exploration and mining from time to time and as such there was no deficiency in its planning and monitoring. DAE further stated in December 2008 that from X^{th} Plan onwards to accelerate the overall programme, emphasis was on programme mode instead of project mode and the 15 year long programme was dovetailed to the 5 year planning process.

3.18 The reply of DAE is to be viewed in the light of the fact that a former DAE Secretary in the AEC meeting held in November 2006 commented (as recorded in the minutes) *"that since there was no periodic and detailed review of various materials/inputs to the nuclear power programme, Chairman, AEC could consider having a senior officer under him to carry out this task in a unified manner. Chairman AEC agreed with the need for such periodic reviews including those pertaining to inputs for the NPP. In hindsight, he stated, it did seem that if a formal mechanism had been in place, it could have probably anticipated and taken corrective actions pertaining to the mismatch between demand and supply of inputs for the nuclear power programme".* The Chairman AEC had stated in the subject meeting that a senior level Steering Committee on NPP set up by DAE in August 2001, chaired by Secretary, was reviewing the entire NPP every month to ensure that all areas of concern were addressed and that outstanding issues were kept in focus and resolved.

Regarding adoption of programme mode approach, the reply of DAE needs to be viewed in the context that a programme is always implemented through various projects and cannot be viewed in isolation. Having an emphasis on the programme mode for implementation of the NPP does not mean that DAE could pay less emphasis on the timelines set out for it in the various projects as laid down in the five year plans, which would be essential in evaluating the success of NPP in the long run.

3.19 While DAE has initiated certain mechanisms to monitor the shortages in fuel for the PHWRs, we are of the opinion that the presence of a comprehensive monitoring report would be more helpful to AEC in taking necessary steps to avert any such large scale crisis in the future. The formal report may include the following parameters.

Comprehensive Monitoring Report for fuel availability for PHWRs

	Parameters for monitoring	Remark
1.	Total capacity of PHWRs established and planned to be established within the next 10 to 15 years both in MWe and million units (mu).	
2.	Total fuel bundles required by NPCIL to run the PHWRs at a capacity factor of 85 *per cent.* Shortages/excess stock, if any with action plan for mitigation.	
3.	Total quantity of heavy water required for operation of PHWRs at a capacity factor of 85 *per cent.* Shortages/excess stock, if any,	

	with action plan for mitigation.	
4.	Total quantity of yellow cake required by NFC to produce the required amount of fuel bundles to feed the PHWRs. Shortages/excess stock, if any, with action plan for mitigation.	
5.	Total quantity of uranium ore required to be mined and milled to produce requisite quantity of yellow cake required by NFC. Shortages/excess stock, if any, with action plan for mitigation.	
6.	Total quantity of uranium deposits to be handed over by AMD to UCIL for taking up mining. Shortages/excess stock, if any, with action plan for mitigation.	
7.	Total quantity of uranium reserves identified by AMD. Shortages/excess stock, if any, with action plan for mitigation.	
8.	Whether the reserves identified by AMD were adequate to meet the uranium fuel requirement of the already established PHWRs. Shortages/excess stock, if any, with action plan for mitigation.	
9.	Whether the reserves identified by AMD were adequate to meet the uranium fuel requirement of the PHWRs likely to be established in the next 10 to 15 years. Shortages/excess stock, if any, with action plan for mitigation.	
10.	Whether there is a chance in the immediate future or in the next 10 to 15 years of the PHWRs being starved of fuel. If so, short term and long term action plan for resolving the same.	

Such a report may be submitted to the AEC in every meeting so that the AEC is suitably apprised of these critical parameters.

Integrated approach in building up stock of raw material

3.20 AEC, in its meeting held in November 1999, held that there was a need to stockpile certain strategic nuclear materials like heavy water and nuclear fuel to insulate India's nuclear programme.

3.21 While in the case of heavy water, we observed that DAE periodically reported to AEC, the retention of excessive stocks and the projected demand-supply scenario, in the case of uranium, the impending demand-supply mismatch was not reported to AEC periodically.

3.22 DAE stated in June and December 2008 that it was prudent to maintain a strategic stock of heavy water for sustaining the PHWR programme in the long run in view of the uncertainties involved in the supply scenario. Considering the distinct factors involved in the production of heavy water and uranium, no comparison of stockpiling of uranium and heavy water could be made. It further contended that on the production front for uranium, extensive focused and effective monitoring at different levels, including by AEC, was undertaken periodically.

3.23 DAE's contention that stockpiling in case of heavy water was necessary due to uncertainties involved in the supply scenario and the situation in case of uranium was completely different is to be viewed in the light of the fact that availability of uranium is also clearly contingent on various foreseeable and unforeseeable factors, which have to be accounted for while planning for exploration, mining and milling. Hence, the policy for stockpiling of fuel and reporting for the same needs to be reviewed; more so, in view of the adverse impact the lack of fuel has had on the current

functioning of PHWRs.

3.24 Despite existence of uranium reserves in the country to support the present PHWR programme upto 2020, India's capacity for generation of nuclear power has been compromised for want of uranium. The improved efficiency of DAE's monitoring and strategic planning from second half of the X^{th} Plan onwards has still not yielded the desired results and the demand-supply mismatch of uranium fuel continues to adversely affect the operation of the PHWRs. There is, therefore, an urgent need to further strengthen the existing planning and monitoring mechanism at DAE.

Structure of DAE/AEC and its role in monitoring

3.25 The Secretary DAE, as head of DAE, is responsible for operational issues relating to its day to day functioning. Besides, the Secretary DAE is also the ex-officio Chairman of AEC and in this role, is responsible for arriving at decisions on technical questions, advising the Government on matters of atomic policy besides critically monitoring and directing DAE on important operational issues.

3.26 With regard to the availability of fuel for PHWRs, we observed that the Secretary DAE is directly responsible for managing and ensuring adequate fuel for PHWRs, whereas Chairman AEC is required to monitor and direct DAE on the course of action to ensure that PHWRs are not starved for fuel due to management failures at DAE. Considering the fact that the posts of Secretary DAE and Chairman AEC are held by the same person, the chances of ownership of failures and consequent remedial action thereon get diminished. Thus, we are of the opinion that having a single person as head of both DAE and AEC may lead to a conflict of interest.

3.27 While we recognise the need for such a dual structure at the nascent stages of our nuclear power programme, the maturing of the nuclear power production units has necessitated a re-look of this dual structure particularly when the country is going through a huge nuclear fuel crisis inspite of the availability of sufficient uranium resources.

Our Recommendations

1. Since it takes 10 to15 years from start of exploration programme to commencement of mining and production, DAE needs to effectively plan and monitor setting up of matching targets for all its units i.e. HWB, NFC, UCIL and AMD so that PHWRs are not stranded for want of fuel at any stage. DAE may consider monitoring the fuel availability for PHWRs in line with the comprehensive monitoring report suggested by us.
2. Before sanctioning and taking investment decisions on capital intensive new nuclear power plants, DAE needs to ensure availability/linkages of fuel while seeking approval of the Government.
3. Government may review the existing arrangement of the same incumbent holding the posts of both Secretary DAE as well as Chairman AEC.

Chapter 4 Pressurised Heavy Water Reactors

4. PHWR is a nuclear power reactor that uses natural uranium as its fuel and heavy water as a moderator and coolant. NPCIL operates 15 PHWR units with an overall installed capacity of 3800 MWe as of May 2007. The main objectives of NPCIL are to maximise power generation and profitability from nuclear power stations and to increase nuclear power generation capacity in the country, consistent with the available resources in a safe, economical and rapid manner and in keeping with the growth of energy demand in the country.

Roadmap for capacity building of PHWRs

4.1 The plan-wise capacity build up of PHWR programme by NPCIL was as under:

Plan Period	**PHWR capacity addition in MWe** (figure in bracket indicates cumulative capacity)	
	As per DAE's Report on Nuclear Power Programme upto 2020 of June 2001	As per DAE's XIth Plan proposal
Upto end of VIIIth Plan	1520	1620
Capacity addition in IXth Plan (1997-2002)	880 (2400)	880 (2500)
Capacity addition in Xth Plan (2002-07)	1000 (3400)	1080 (3580)
Capacity addition in XIth Plan (2007-12)	1440 (4840)	880 (4460)
Capacity addition in XIIth Plan (2012-17)	3440 (8280)	3500 (7960)
Capacity addition in XIIIth Plan (2017-22)	1000 (9280)	2100 (10060)

4.2 We observed that over the years, NPCIL had made noteworthy attempts in the capacity addition of PHWRs as NPCIL was able to establish PHWR capacity of 3580 MWe as of March 2007 as against capacity of 3400 MWe of PHWRs aimed at the end of Xth Plan in the roadmap in Report on Nuclear Power Programme upto 2020.

4.3 NPCIL had also been effective in setting up PHWR plants and it appears capable of attaining the installed capacity of 10,060 MWe by 2017, provided DAE ensured availability of requisite nuclear fuel and heavy water required for the PHWRs.

4.4 We observed that while NPCIL was effective in capacity addition planned for it by DAE, DAE failed to ensure adequate fuel supply to NPCIL through its other units, which resulted in low capacity operation of PHWRs.

4.5 DAE stated in December 2008 that till around early nineties, when

reactors were taking much longer time to construct and were operating at a low capacity factor, uranium (yellow cake) stockpiles had grown, the carrying cost of which was commented upon by Audit. This input interalia contributed to new uranium mine projects being closed. Today reactors were constructed fast and could operate at high capacity factors and inspite of best efforts at all levels in Government of India (including Cabinet Secretariat and PMO) development of uranium mines had got delayed primarily due to factors external (mining lease, law and order issues, forest clearance, environment clearance, etc.) to DAE .

4.6 The reply of DAE needs to viewed in the light of the fact that though we had commented on the carrying cost of stockpiled uranium in a different context, DAE should have taken its decisions based on technical reasons and the needs of the NPP, considering the fact that it takes 10 to 15 years from the start of exploration programme to commencement of mining and production. The best efforts referred to by DAE in developing the uranium mines and setting up of committee under the Cabinet Secretary (in March 2007) were belated and have not yielded the desired results as yet. DAE, as the implementing department of the Government of India for the NPP, needs to effectively address these factors referred by them as being external to them.

Roadmap for fuel availability for PHWRs

4.7 *Report on Nuclear Power Programme upto 2020* of June 2001 depicted annual and cumulative requirement of PHWR fuel from 2001-02 to 2021-22. As against the requirement, the roadmap envisaged augmentation of uranium only till 2016-17.

4.8 Analysis of demand supply position during the period 2001-02 to 2021-22 revealed that there was a gap (shortage) of 30 *per cent* between the projected requirement of NPCIL and the envisaged augmentation in the roadmap despite proposed action plans. NPCIL, in June 2002, had intimated these reduced requirements from 2002-03 to 2020-21. Even as per this reduced requirement, NPCIL had forecasted a demand-supply mismatch for PHWR fuel, indicating a deficit in Xth Plan (2002-07), surplus in XIth Plan (2007-12) and again deficit in XIIth Plan (2012-17) and XIIIth Plan (2017-22) based on three anticipated scenarios[4], where first year of production of mine and milling plants was likely to be commenced in different locations.

4.9 We observed that while NPCIL had made realistic projections in its long term planning, its formal demand on NFC was based more on the availability of uranium rather than on the requirement of fuel for the PHWRs at its maximum capacity, to enable it to generate optimum nuclear power. Thus, NPCIL's annual demand for fuel on NFC was watered down as it was driven by expected supply rather than by projected demand. We are of the

[4] Scenario-1: Turamdih W in 2006-07; Domiasiat and Lambapur in 2008-09.
Scenario -2: Turamdih W in 2006-07; Domiasiat and Lambapur in 2008-09, Gogi in 2009-10 and Sikar in 2010-11.
Scenario -3: Turamdih W in 2005-06; Lambapur in 2007-08; Domiasiat in 2008-09, Gogi 2008-09 and Sikar in 2009-10.

opinion that such suppression of requirement may have had an adverse impact on timely planning and decision making.

4.10 DAE stated in June 2008 that setting up of nuclear power stations and opening of new mines for augmentation of supplies required long gestation periods. While claiming that with improved technological expertise, the gestation period of power plants had been reduced, it attributed delays in the execution of mining projects to various external factors and the enormous time needed for activities such as land acquisition, rehabilitation, mining lease, surface rights, local/central statutory environmental clearances, law & order and resistance of local people. It further contended that efforts for augmentation of uranium supply were part of a continuing process and the roadmap for the PHWRs itself envisaged these very efforts and claimed that a robust mechanism of monitoring these at the level of Cabinet Secretary and the involvement of the nodal central and state Government machinery was in place. Further, DAE stated in December 2008 that NPCIL's demand on NFC cannot overlook the supply of MDU by UCIL and there was no attempt to conceal the shortage of fuel.

4.11 The reply has to be viewed against the fact that the mechanism of monitoring the activities at the level of Cabinet Secretary was started belatedly only in 2007 whereas the roadmaps for PHWRs contemplating proactive actions and the need for stepping up the activities relating to uranium mining and milling were drawn way back in June 2001. From the governance point of view, setting watered down targets leads to inadequate number of warning signals being thrown up, which could impact timely remedial action.

Capacity factor of PHWRs

4.12 During 1996-99, we observed that NPCIL operated its PHWRs with an average capacity factor in the range of 60 and 73 *per cent.* The PHWRs as a whole were operated with higher capacity ranging from 83 to 80 *per cent* during 1999-2003. In fact, during 2002-03, NAPS-2 was operated at a capacity factor as high as 96 *per cent,* KAPS 1 at 98 *per cent* and RAPS-4 at 97 *per cent,* indicating increased efficiency in operation.

4.13 Thereafter, due to the constraints in fuel supplies, the average capacity factors of PHWRs as a whole were consistently brought down from 80 *per cent* in 2002-03 to 72, 67, 64 and 50 *per cent* respectively during 2003-08. This had resulted in the PHWRs operating at lower capacity[5] and denying the nation, the full benefits of clean nuclear energy to the extent of 21,845 million units[6] corresponding to Rs.5986 crore calculated at an average tariff of Rs.2.74 per unit[7].

[5] Discussed in detail in paragraph 4.16 of this report.
[6] Even though in 1999-2000 the capacity factor touched 83 *per cent*, we have taken 80 *per cent* as an achievable target as was achieved in 2002-03 before the capacity factor for the PHWRs was pegged down intentionally due to shortage of fuel.
[7] Calculated on the average of the notified basic tariff rates during that period.

4.14 While accepting the facts, DAE stated in January 2008 that due to mismatch in demand and supply of fuel for PHWRs since 2003-04, these were being operated at lower levels to conserve fuel.

DAE stated in June 2008 that the decision to set up PHWRs without linking the fuel requirement and its subsequent operation at lower capacity may appear to be faulty from a purely commercial point of view. DAE further stated in December 2008 that the decision to operate PHWR at lower capacity factor was specifically taken to deal with the mismatch in fuel. The journey through the technology denial regime warranted continuing the NPCIL roadmap to avoid diversion of skill/resources. The rationale behind calculating total production that would have been possible based on the production pattern of a particular year is not justified. This can only be a theoretical exercise which leads to misleading conclusions. The reactors were operated at lower capacity factors to match the fuel supply during the years 2003-04 to 2007-08 and this had resulted in reduced power generation which cannot be construed as loss as observed by Audit.

4.15 DAE's contention that the PHWRs were operated at a lower capacity factor to conserve fuel is only an afterthought as DAE was aware that there would be a fuel crisis way back in 2000 itself. Despite this, it continued to operate the PHWRs at a higher capacity till 2002-03 and the PLF was gradually brought down from 2003-04, only after the crisis had set in. As regards the quantification of the value of power not generated, we have only calculated a *'ballpark'* figure based on average tariff rates notified during that period, so that the scale of the fuel crisis could be conveyed.

Power generation of PHWRs

4.16 The details of installed capacity, generation target, achievement, and capacity factor for the PHWRs during the period 2002-03 to 2007-08 is given below.

Year	Installed capacity (MWe)	Generation Target (mu)	Achievement against target (mu)	Capacity factor (in *per cent*)
2002-03	2400	13748	16814	80
2003-04	2400 July 03:2450	13388	15337	72
2004-05	2450	14322	14423	67
2005-06	2450 Sep 05:2990 Jan 06:3040	13539	15479	64
2006-07	3040 Aug 06: 3580	17624	16030	54
2007-08	3580	20163	14405	50
Total		**92784**	**92488**	

4.17 We observed that installed capacity of PHWRs at the commencement of the Xth Plan was 2400 MWe and at the end of the Xth

Plan was 3580 MWe. However, we observed that the power generated decreased by 4 *per cent* during the same period (16,814 mu in 2002-03 and 16,030 mu during 2006-07). Therefore, inspite of a capacity addition in PHWR of 1180 MWe, the power generation decreased. This trend not only continued but also got aggravated in the first year of the XIth Plan as the generation dwindled to 14,405 mu during 2007-08. This also fell short of the target of 20,163 mu by 29 *per cent*.

4.18 DAE stated in June 2008 that the actual overall nuclear power generation exceeded the target at the end of the Xth Plan. The reply of DAE has to be viewed in the light of the fact that inspite of capacity addition during the Xth Plan, the target for power generation set was itself not realistic as it was based on capacity factors much lower (54 *per cent* to 80 *per cent*) than the maximum capacity factor (85 *per cent)*.

4.19 We are of the opinion that setting watered down targets based on uranium supply rather than demand of the PHWRs leads to over-reporting of performance for power generation. Such significant deficiencies in target setting would mask the real performance and would impede timely corrective action.

Our Recommendation

4. NPCIL needs to project its requirements based on its demand for running the plants at maximum capacity factor rather than on the supply capabilities of uranium to avoid under-reporting of the magnitude of the shortage.

Chapter 5 Heavy Water Board

5. HWB is primarily responsible for production of heavy water, which is used as a moderator and coolant in PHWRs. HWB operates six heavy water plants at Baroda, Tuticorin, Kota, Thal, Hazira and Manuguru commissioned between July 1977 and December 1991. Operating life of a heavy water plant is 25 years at 100 *per cent* capacity. Thereafter, it can operate at 75 *per cent* capacity for another five years.

5.1 The long term strategy of demand and supply of heavy water was being reviewed by the HWB and AEC from time to time based on the then existing projected scenario of PHWRs. AEC, in its meeting held in November 1998, among other things, also decided to continue operation of all the Heavy Water Plants at the achievable capacity levels for their respective life cycle periods and creation of additional storage capacity for holding surplus stocks of heavy water in the interim period.

Projections for stock levels of heavy water

5.2 *Report on Nuclear Power Programme upto 2020* projected that the stock levels of heavy water would fall below the requirement from 2014-15 and there would be considerable shortage by the year 2021.

Measures to improve performance

5.3 We observed that in view of the above, HWB had taken various measures to improve the performance of heavy water plants in the X^{th} Plan period. This included continuous improvements in feed parameters, process intensification, upgradation of operating procedures, innovative modifications and technology upgradation etc,. In addition, HWB had taken various measures for enhancing production as well as reduction in energy consumption as given below:

- The overall capacity utilisation of heavy water plants increased to 113.40 *per cent* in the X^{th} Plan from 92.92 *per cent* in the IX^{th} plan.
- Implementation of energy saving schemes such as Vapour Absorption Refrigeration, Variable Speed Drives, Strong Base Anion Beds, Ammonia Absorption Refrigeration etc., which resulted in cumulative savings of Rs.700.30 crore due to reduction in energy cost during IX^{th} and X^{th} Plan.
- Despite a 43 *per cent* increase in Price Index, HWB succeeded in pegging down the cost of production per kg of heavy water from Rs.15,662 in 1997-98 to Rs.12,419 in 2006-07.
- Due to sustained operation with improved process parameters in the heavy water plants, coupled with the annual reduced make up requirement of operating reactors, HWB converted the envisaged deficit of heavy water forecasted in the *Report on Nuclear Power Programme upto 2020* to a surplus by 2021 as projected by DAE to AEC in November 2006.

5.4 Thus, HWB had taken effective measures to improve process parameters of various plants and to stockpile enough heavy water to ensure that the planned PHWR programme upto 2020 does not suffer for want of heavy water.

Our Recommendation

5. Considering the uncertainties involved in the production of heavy water, which is vulnerable to changes in technologies, DAE may continue the prudent policy of maintaining its strategic stock with the approval of AEC for sustaining the PHWRs in the long run.

Chapter 6 Nuclear Fuel Complex

6. The Natural Uranium Oxide (UO_2) as well as Depleted Uranium Oxide fuel bundles for all PHWRs constructed and operated by NPCIL in the country are produced and supplied by NFC. PHWR fuel bundles are produced in three steps-production of UO_2 powder starting from MDU supplied by UCIL, production of high-density UO_2 pellets from UO_2 powder and finally production of fuel bundles using zircaloy tubes and components with UO_2 pellets.

6.1 NFC was set up in 1970 with an initial capacity of 100 tonnes of PHWR fuel bundles, which was subsequently increased in 1986 to 225 tonnes. In 1989, the capacity was further enhanced to 300 tonnes. By the year 1997, NFC had an installed capacity of 600 tonnes of PHWR fuel.

6.2 To produce enough fuel bundles for the envisaged establishment of 10,000 PHWR capacity by 2020, DAE laid down the roadmap for NFC in 2001. This included establishment of New Fuel Fabrication facility viz. NFC 2 and NFC 3, each with installed capacity of 600 tonnes per annum (tpa). These plants were to be set up during X^{th}-XI^{th} and XI^{th}–XII^{th} Plan periods respectively. As against this, NFC took up an augmentation project for expansion of the existing 600 tpa to 850 tpa only in the X^{th} Plan, which is scheduled for completion in 2008-09.

Production capacity

6.3 We observed that the production capacity of 600 tonnes at NFC was not commensurate with the NPCIL's projected requirement for PHWR fuel (for the power plants operating at 85 *per cent* PLF) during 2004-05 to 2006-07. The gap between production capacity at NFC and NPCIL's projected requirement of fuel ranged from 13 *per cent* to 56 *per cent* during these three years.

6.4 We also observed that had there been sufficient inflow of MDU from UCIL or elsewhere, the PHWRs would not have operated to the full capacity due to inadequate installed capacity at NFC, which would then have been a bottleneck.

6.5 While we recognise the fact that due to non-availability of MDU from UCIL, the production capacity did not prove a constraint, the fact remained that augmentation of additional capacity needs to be fine-tuned with the real requirement of fuel by the PHWRs.

Restriction of demand - masking of real requirement

6.6 The power plants at NPCIL were operated only at the capacity factor of 80 *per cent,* which was gradually brought down to 50 *per cent* in 2007-08. The actual deficit for uranium with reference to the projected demand (had the power plants operated at 85 *per cent* PLF) of NPCIL was in the range of 7 to 62 *per cent* during the period 2002-07.

6.7 We observed that due to the shortage of uranium, NPCIL reduced its demand for PHWR fuel, instead of making demand for the actual amount required. Consequently, NFC also did not specifically demand quantities of MDU needed for operation of PHWRs at full capacity and restricted its scope of operations to what UCIL could supply. This resulted in the actual shortage for MDU being masked and not being projected adequately by NFC.

6.8 DAE stated in June 2008 that NFC fixes its annual targets for production of fuel bundles based on the actual annual demand of NPCIL and availability of MDU supplied by UCIL and NFC was able to meet the actual annual requirements of NPCIL.

6.9 The reply of DAE needs to be viewed in the light of the fact that as NPCIL reduced its demand from NFC, the actual requirement of PHWR fuel bundles was not adequately requested for. Further, as a result of this suppressed requisition and under-reporting, the scope for taking timely corrective action to address the shortages of MDU at UCIL were reduced.

Our Recommendation

6. NFC needs to fix its target for production of fuel bundles based on fuel bundles needed for operation of PHWRs at full capacity rather than based on supply of MDU from UCIL. This would draw appropriate attention to the capability of UCIL to deliver sufficient quantities of MDU to NFC.

Chapter 7 Uranium Corporation of India Limited

7.1 UCIL is engaged in mining and processing of uranium ores. After joint inspection of the deposits identified by AMD, AMD hands over the uranium deposits to UCIL for evaluation and commercial mining and milling to produce MDU. AMD had handed over 27 deposits of uranium located in various parts of country having an estimated reserve of 93,259 tonnes of uranium to UCIL during 1966 to 2007. Out of this, majour reserves of uranium were from the Singhbhum belt where UCIL is operating all its present mining and milling plants. These deposits were handed over by AMD to UCIL during 1966 to 1989.

Roadmap for augmentation of uranium resources

7.2 *Report on Nuclear Power Programme upto 2020* of June 2001 depicted the roadmap for augmentation of uranium resources and annual and cumulative requirement of PHWR fuel from 2001-02 to 2021-22.

7.3 We observed that the roadmap drawn had the following deficiencies:

- UCIL had planned exploitation of only 46 *per cent* of the requirement of PHWR fuel for the period 2001-02 to 2007-08.
- UCIL had planned exploitation of only 79 *per cent* of the requirement of PHWR fuel for the period 2008-09 to 2016-17.
- No production strategy was envisaged by UCIL beyond 2016-17 in its roadmap.

The shortage of 54 *per cent* (2001-02 to 2007-08) and 21 *per cent* (2008-09 to 2016-17) was not addressed in the roadmap though AMD had handed over sufficient proven reserves to UCIL for meeting the PHWR requirement upto 2020. Thus, the roadmap drawn by UCIL for production of uranium was not commensurate with the requirement of the PHWR programme.

7.4 DAE, in June 2008, stated that at the time of preparation of Nuclear Power Programme Report, based on the resources available, the strategy for production of uranium upto 2016-17 was planned. Further, some of the resources identified by AMD were small in size and it would not have been feasible to set up uranium mining and processing plant at every location. DAE further stated that AMD was involved in exploration of targets having higher grade uranium like Gogi, Wahkyn, Chitrial and Koppunuru between 1999-2000. It was anticipated that AMD would hand over these economically viable resources to UCIL. However, there were delays in taking up these projects warranting a decision to reconsider mining of low grade uranium in Singhbhum belt. DAE also stated in December 2008 that it was not feasible to set up mining/milling plant at every such location as apart from viability, other aspects of transportation of radioactive waste, disposal of tailings, public perception etc., needed to be addressed. Entire in-situ reserves identified were thus not mineable and hence the comparison/requirement of PHWR with reference to in-situ reserves would

be flawed. The percentages worked out by audit on 'under exploitation' were not apt.

7.5 The percentage of shortfall highlighted by us is a comparison between the roadmap drawn by UCIL for augmentation and the projected requirements of fuel by NPCIL for operation of PHWRs during 2001-02 to 2016-17 at 85 *per cent* capacity factor. As regards the in-situ reserves, as per DAE, any reserve less than 3000 tonnes is considered as uneconomical but is not ruled out for exploitation. The fact remains that there was significant gap between the requirement of PHWRs and the planned availability of fuel, which was not adequately addressed in the roadmap. This points to a significant deficiency in the long term planning for augmentation of uranium resources by UCIL and DAE.

Mismatch in mining and milling capacity

7.6 We observed that against the installed mining capacity of 8,55,000 tpa at four mines viz, Jaduguda, Bhatin, Turamdih and Narwapahar, UCIL had only one mill at Jaduguda with installed milling capacity of 6,27,000 tpa. Thus, there was an overall 26.66 *per cent* shortfall of milling capacity compared to mining capacity during the period 2002-03 to 2006-07. As a result, 93,472 tonnes of uranium ore was pending for milling as of March 2007.

7.7 We further observed the following:

- Due to mismatch in milling and mining capacities, UCIL had operated its mines at a lower capacity in the range of 71 to 89 *per cent* during 2002-07 despite increased demand for fuel during this period and a huge fuel crisis.
- Further, an opencast mine at Banduhurang which was ready to produce 1600 tpd ore from October 2006 and 2400 tpd from April 2007 onwards remained unexploited for want of augmentation of milling capacity by UCIL.
- Though UCIL was aware of the increased need of fuel requirement of NPCIL in June 2001 itself, it embarked upon a project for the capacity augmentation of Jaduguda Mill from 2090 to 2500 tpd, only in September 2006, which was slated for completion by March 2008.
- Though installed capacity of PHWRs increased from 2500 MWe in 2002-03 to 3580 MWe by 31 March 2007, there was no augmentation in the milling capacity by UCIL during the corresponding period.

7.8 The above position suggests significant deficiencies in the strategic planning process. As remedial actions were within the reach of DAE and were not contingent on any externalities, we are obliged to conclude that the situation was avoidable.

7.9 DAE stated in June 2008 stated that due to continuous operations, the

production capacity of Jaduguda and Bhatin mine was scaled down. It further stated that expansion of Jaduguda mill was underway. Thus, there was no mismatch in planning of milling capacity.

7.10 The contention of DAE regarding no mismatch between mining and milling capacity does not discount the fact that due to delay in augmentation of milling capacity, 93,472 tonnes of uranium ore was pending for milling as of March 2007, when the PHWRs were starved for fuel.

Delays in decisions to open mines/mills

7.11 As per the identified roadmap, DAE/UCIL had proposed the mining and processing plants projects at Domiasiat, Lambapur and Gogi in the Xth Plan. However, we observed that none of the above projects were completed in the Xth Plan and were instead rescheduled for completion by 2012 at revised costs as discussed below.

Domiasiat Mining and Milling Project

7.12 Domiasiat Uranium Mining and Milling Project is located in the district of West Khasi hills in Meghalaya. AMD had completed the detailed exploration work[8] in this deposit in 1992. DAE emphasised the need to take up the development of Domiasiat mining project in a concerted manner to ensure quick and efficient development of the project, as it considered the ore to be of better grade. UCIL Board, in March 2004, approved the mill and mining projects with a production capacity of 1500 tpd at an estimated cost of Rs.788.49 crore, which was revised to Rs.1036.90 crore in the updated DPR with enhanced production capacity.

7.13 We observed that though an expenditure of Rs.3.20 crore was incurred by UCIL as of March 2007, the project activities had not commenced even after expiry of more than 15 years from the time of completion of detailed exploration in 1992 due to delays as detailed below.

- UCIL took 12 years in preparation of the DPR[9] from the date of completion of detailed exploration of the deposit in 1992. It further took over two years in preparing the revised DPR.
- The EIA/EMP[10] Report was prepared in 2006 after 14 years from the date of completion of detailed exploration of the deposit in 1992.
- UCIL also took over three years in obtaining environmental clearances from Ministry of Environment and Forests (MoEF) due to submission of incomplete application and procedural delays.
- Delay in obtaining the approval of mining plan from AMD due to non-issue of precise area certificate by the State Government. The approval of Mining Plan was awaited as of December 2007.

[8] In the absence of a clear date of handing over of the deposit by AMD to UCIL, the date of completion of the detailed exploration work has been taken as the stage from which the site was available to UCIL for further exploitation of the deposit.
[9] Detailed Project Report.
[10] Environmental Impact Assessment/Environmental Management Plan.

- Delay in land acquisition for the project due to resistance from local population and NGOs. The approval for land acquisition was awaited as of December 2007.
- Delay in obtaining mining lease from State Government. The approval for mining lease was also awaited as of December 2007.

7.14 DAE stated in June 2008 that despite UCIL's continuous efforts, the project could not be started due to lack of adequate support from the State Government. Successive State Governments could not take effective action to curb opposition by some local segments, including NGOs with a distinct agenda, and efforts by UCIL for setting up the project came to a dead end.

7.15 However, the fact remains that UCIL could file the mining lease application with the Government of Meghalaya only as late as in October 2001 after a delay of nine years from the date of completion of exploration in 1992. This was one of the most significant reasons for the delays in this project so far. This delay is even more significant as other mining and milling activities were shelved in the Singhbhum belt during this period in anticipation of the opening of the Domiasiat mine. Though UCIL had stepped up its efforts from 2004 after the crisis had erupted, as of June 2008, even the financial sanction of DAE for the project was awaited. This raises doubts on the commencement of production from this better grade mine even from the rescheduled date of 2012.

Lambapur Mining and Milling Project

7.16 AMD handed over the Lambapur–Peddagattu deposits to UCIL in 2001. UCIL Board, in June 2003, approved the setting up of mining and milling plant at Lambapur at a total cost of Rs.506.98 crore. The cost was revised to Rs.558.42 crore due to change in processing site from Mallaparam to Seripally as there was a Supreme Court Judgement, in case of two other drinking water reservoirs, against setting up of chemical industry within 10 km radius.

7.17 We observed that though an expenditure of Rs.4.21 crore was incurred by UCIL upto March 2007, no activities had commenced/ progressed both at the mine and mill, even after an expiry of more than six years, due to delay in obtaining statutory clearances from various agencies viz., MoEF and Government of Andhra Pradesh.

7.18 DAE stated in June 2008 that though all clearances were available, UCIL had no option but to await the decision of National Environmental Appellate Authority on the verdict against the clearance of MoEF for the mine. The delay, therefore, could not be attributed to UCIL as far as this site was concerned.

7.19 The reply of DAE may be viewed in the light of the fact that the *Report of Nuclear Power Programme* envisaged in June 2001 that there would be commencement of uranium mining at Lambapur from 2006-07.

The project had, however, been delayed considerably and was rescheduled for completion by 2012.

Gogi Mining and Milling Project

7.20 UCIL proposed to undertake the Uranium Ore Mining & Milling Project at Gogi in April 2003 so as to complete the project in March 2007. We observed that the project had not commenced in Xth Plan and was in fact dropped after the mid-term appraisal, as detailed exploration was not completed by AMD.

7.21 DAE stated in June 2008 that delay in establishing economic viability of this deposit was mainly attributable to the erratic nature of the ore body. Further, factors relating to land, law & order, people's perception etc., were externalities beyond the control of DAE

7.22 Considering the fact that these three mines i.e. Domiasiat, Lambapur and Gogi were better grade deposits and were expected to deliver significant quantity of yellow cake per annum, the delay in opening of these mines had adversely affected the timely supply of nuclear fuel to the PHWRs. Further, as the extent of current interventions by DAE had not yielded the desired results and the country could not afford to continue running the PHWRs at half their capacity, some innovative decisions needed to be taken to solve the deadlock in these sites.

Revision in implementation of projects

7.23 As the constraints in the better grade deposits of Domiasiat, Lambapur-Peddagattu and Gogi could not be resolved as planned, UCIL/DAE decided to re-visit the low grade deposits in Singhbhum belt, which had been ignored earlier by it. UCIL/DAE, therefore, decided to:

- Open the Bagjata Mine in June 2002, so as to treat the ore from this mine at the existing Jaduguda Mill;
- Establish a milling plant at Turamdih to process the ore from Turamdih and Banduhurang mines;
- Open the Mohuldih Mine in March 2004; and
- Set up uranium mining and milling project at Tummalapalle in March 2006.

7.24 We observed that the corrective decisions taken by DAE/UCIL after submission of the original Xth plan proposal and mid term appraisal during the second half of the Xth Plan also did not yield the desired results as discussed below.

Bagjata Mining Project

7.25 AMD had conducted the exploratory mining at Bagjata till 1990. UCIL decided in June 2002 to open the Bagjata mine in view of the increase in requirement of uranium. The project was approved by DAE in March 2005 and was scheduled for completion by March 2008. We observed that there was a delay in completion of project activities due to

delay in land acquisition and resistance from the local people.

7.26 In reply, DAE stated that land acquisition could not be completed because of encroachments. Besides, there were law and order issues and UCIL would now be commissioning the project by October 2008.

Mohuldih Mining Project

7.27 AMD handed over Mohuldih uranium deposit to UCIL in 1989. Considering the sharp increase in the requirement of uranium, UCIL Board, in March 2004, approved setting up of mining project at Mohuldih at a cost of Rs.90.32 crore to be completed by 2008.

7.28 We observed that DAE took 23 months in issuing the administrative and financial sanction in March 2007 due to delay by UCIL in submission of documents and obtaining various statutory clearances.

7.29 DAE, in December 2007, attributed the delay in taking up the project to the receipt of environmental clearance for the project only in March 2007.

7.30 The reply has to be viewed against the fact that DAE took nearly seven months to file an application for environmental site clearance, from August 2004 to March 2005. Further, DAE took another 14 months from June 2005 to August 2006 for the submission of formal application for the environmental project clearance.

Tummalapalle Mining and Milling Project

7.31 AMD completed detailed exploration work at Tummalapalle in 1992. UCIL abandoned the site in the middle of 1998 due to not getting encouraging results. To meet the growing demand of uranium, UCIL Board, in March 2006, approved the proposal for setting up Uranium Mining and Milling Project at Tummalapalle at a cost of Rs.1029.57 crore.

7.32 We observed that though this project had a sizeable reserve and no major external constraints were foreseen in commencing the project activities, UCIL took more than three years in obtaining statutory clearances and financial sanction from various agencies from 2004 to 2007.

7.33 In reply, DAE stated in June 2008 that at Tummalapalle, the uranium recovery in laboratory tests was not encouraging. However, in view of the pressing need for uranium, the issue was re-visited during 2003-2004 and the project work at the site had started thereafter. The fact remains that DAE could issue financial sanction for setting up of uranium ore mine and mill only in September 2007 despite completion of exploratory mining in 1992.

Turamdih Milling Project

7.34 UCIL Board, in June 2002, decided to reopen the processing plant at Turamdih at the estimated processing capacity of 3000 tpd ore to be supplied from the reopened Turamdih and Banduhurang mine and granted approval to the updated/modified DPR of Turamdih processing mill at a

cost of Rs.343.26 crore.

7.35 We observed that the mill had not been commissioned as of August 2007 due to delays in completion of project site activities.

7.36 In reply, DAE stated that the delay was due to problems in acquisition of land and contractors not completing the major packages in time. It further stated that despite continuous pursuance by UCIL and the intervention of the monitoring committees, there were delays due to factors which were beyond the control of UCIL/DAE. In December 2008, DAE further stated that the matter of delay is being actively addressed.

7.37 DAE's reply is to be viewed in the light of the fact that its stated efforts have not resulted in commercial production from the mill as of December 2008 though this was scheduled for March 2006. Due to delay of more than two years, the ore from Banduhurang Open Cast Mine, which was ready to produce 1600 tpd of ore from October 2006 and 2400 tpd of ore from April 2007 onwards, remained unexploited. Resultantly, the commitment of enhanced production and supply of uranium for the NPP could not be met.

Our Recommendations

7. UCIL needs to immediately review and redraw its roadmap to ensure that it adequately matches the fuel requirement of the identified 10,000 MWe PHWR programme till 2020.
8. UCIL needs to put exploitation of high tonnage, high grade uranium deposits of Domiasiat and Lambapur on a fast track mode to meet the acute fuel crisis.
9. UCIL should also ensure completion of all the other ongoing mining and milling projects without further slippages so as to bridge the gap between demand and supply of uranium.

Atomic Minerals Directorate for Exploration & Research

8. DAE's goal is to achieve self-sufficiency in uranium resources in order to support natural uranium based nuclear power reactors (operating, under construction and future). DAE, in its *Vision 2020* document of September 1997, had stated that AMD was confident of finding sufficient economically exploitable uranium deposits for 15,000 MWe of PHWR. Since it takes 10-15 years from start of exploration programme to commencement of mining and production, it was indicated therein that proper planning was necessary for strengthening the prospecting programme.

8.1 Uranium reserves are categorised as Reasonably Assured Resources (RAR) and Inferred Uranium Resources (IUR). As of September 2007, the estimated total uranium reserves in India (RAR and IUR) were about 1,07,268 tonnes. The 10,000 MWe PHWR programme planned by DAE required around 1,01,600 tonnes of uranium resources for their entire life span of 40 years.

Low pace of augmentation of uranium resources in the IXth & Xth Plan

8.2 We observed that during the IXth and Xth Plan, the pace of augmentation of uranium deposits had declined to 13,661 tonnes and 16,244 tonnes as against augmentation of uranium resources of 28,195 tonnes during the VIIIth Plan. This decline was significant in view of the fact that DAE had set a target for augmentation of 75,000 tonnes during the XIth Plan.

Low augmentation of economically viable uranium resources

8.3 Against the requirement of 1,01,600 tonnes of uranium resources, though AMD had identified 1,07,268 tonnes, only 71,159 tonnes were economically viable reserves. However, even out of this, UCIL could not exploit significantly viable reserves like Domiasiat and Lambapur-Peddagattu due to various local problems, despite these sites being handed over to UCIL by AMD 8 to 15 years back.

8.4 We further observed that out of 1,07,268 tonnes of identified uranium reserves, AMD had not proved and handed over 9936 tonnes of uranium reserves, though these were identified by AMD over 10 to 38 years back.

8.5 AMD stated in July 2007 that these small deposits could not be exploited independently since they were not economically viable resources. DAE further stated in June 2008 that the isolated deposits with less than 3000 tonnes were generally considered uneconomical but they were not ruled out for exploitation.

8.6 Replies of AMD and DAE are to be viewed in the light of the fact that to meet the current crisis, UCIL had to re-visit the sites it had previously

sidelined on account of economic non-viability of the deposits. Thus, onus rested with AMD to accord highest priority to locate high tonnage and economically viable deposits.

Roadmap for exploration activities upto 2020

8.7 The *Report on the Nuclear Power Programme upto 2020* had specified financial milestones till 2020 for AMD. However, we observed that no physical milestones for exploration activities beyond Xth Plan were laid down.

8.8 DAE replied in June 2008 that AMD has a clear long term roadmap for the exploration in major uranium provinces[11] across the country. DAE further stated in the reply that roadmap beyond a period of five years for survey and exploration does not help in any way as the successive stages of exploration only leads to narrowing down the target areas.

8.9 However, since exploration of a deposit spans a ten year period, the fact remains that based on its various survey activities till the preparation of *Report of Nuclear Power Programme upto 2020*, it could have identified the specific uranium sites for future exploitation, which was not done.

Targets and achievements of AMD

8.10 Out of 15,000 tonnes of uranium resources targeted for identification during the Xth Plan, the AMD Council set a target of proving expected reserves of 5000 tonnes each at Gogi, Rohil-Ghateshwar and Koppunuru in the order of priority. Against this target, we observed that though AMD could identify 16,244 tonnes during the Xth Plan, it had actually identified a total of only 8105 tonnes in these targeted areas representing an achievement of only 54.03 *per cent*, despite these sites being free from infrastructural/ environmental constraints, as discussed below.

Gogi deposit

8.11 Against a target of augmenting expected uranium reserves of 5000 tonnes in 2001 and handing over of Gogi deposit to UCIL for commercial mining activities by 2003, AMD had proven 3818 tonnes in the area. It could also not hand over the reserves for commercial exploitation as exploratory mining was taken up only in March 2007 on recommendation of the AUS Committee.

8.12 DAE stated in December 2007 that mining activities could not be taken up at Gogi, as the exploration activities by AMD were not complete. Exploration in adjoining areas at Gogi was in progress and additional reserves would be added.

Rohil - Ghateshwar deposit

8.13 This deposit was discovered in 1973-74. Inspite of observations of the AMD Council that commercial viability of the Rohil deposit was considered to be more economical than Gogi and there were no environmental issues, as of March 2007, AMD could identify uranium resources of only 3047 tonnes against a target of 5000 tonnes. We also

[11] Proterozoic and Phanerozoic Mahadek Basins

observed that these identified uranium resources were not handed over to UCIL for exploratory mining till July 2007 due to delay in evaluation of the reserve. This resulted in increase in lead-time in development of Rohil uranium deposit.

8.14 DAE, in its reply, stated that deeper drilling in such areas was a technological challenge warranting high tech instruments like deviation control device and borehole cameras and efforts are on to procure state of the art drilling rigs and deviation and drift control devices during XIth Plan.

8.15 The fact remains that inspite of identification of this deposit in 1973-74, AMD could not meet the technological challenges and develop the deposit, even though the same was mandated by AMD Council to be developed by 2004.

Koppunuru deposit

8.16 Out of the target of 5000 tonnes of uranium resources, AMD had proved only 1240 tonnes at the end of the Xth Plan. AMD Council had assessed that 13 meters of drilling resulted in establishing, on an average, one tonne of uranium. Based on this, in order to identify the target of 5000 tonnes in Koppunuru area, 65,000 meters of drilling was required to be done during the Xth Plan. However, we observed that drilling of only 9443 meters had been carried out and no drilling was carried out beyond 2003.

8.17 DAE stated in its reply in June 2008 that in respect of Koppunuru, 3 to 4 meters were to be drilled for one tonne of uranium. Even taking this yardstick into account, AMD should have completed drilling of 15,000 to 20,000 meters, against which it had carried out drilling of 9443 meters only. However, during the XIth Plan, AMD had now planned to undertake drilling of 20,000 meters in the area.

8.18 Over and above the three priority deposits at Gogi, Rohil-Ghateshwar and Koppunuru discussed above, the roadmap contained in the *Report of Nuclear Power Programme upto 2020* emphasised the need for identification and firming up of additional deposits for the Xth Plan in Lambapur-Peddagattu and Gandi. Further, AMD Council also underscored the need for activities for augmentation of uranium reserve in Chitrial for the Xth Plan. However, as discussed in the succeeding paragraphs, only limited progress could be made in these sites.

Lambapur-Peddagattu deposit

8.19 Though this belt had a potential of hosting 30,000 tonnes of uranium resources, as of 2001, AMD could prove and hand over an area containing estimated reserve of only 6450 tonnes (Lambapur 1450 tonnes and Peddagattu 5000 tonnes) to UCIL. Further, we observed that AMD did not take up any activity to firm up the balance reserves and fix targets for the Xth Plan despite a directive to this effect in the *Report of Nuclear Power Programme upto 2020.*

8.20 AMD stated that no targets were laid down in the Xth Plan in Lambapur-Peddagattu due to law and order problems. DAE further stated in June 2008 that the department had been making every effort from time to time to address the issues involved in the activities of AMD at the highest level and had been able to make progress as a result thereof.

Chitrial deposit

8.21 Inspite of high potentiality of 30,000 tonnes of uranium resources in this deposit, we observed that no specific targets were laid down during the Xth Plan.

8.22 DAE replied in June 2008 that AMD could not fix targets due to security issues and environmental clearances and it had made the best efforts to tackle the same. However, as the strike rate for drilling was very high in this area (AMD could identify 5800 tonnes by drilling just 6871 meters), the fact remains that limitations in obtaining timely environmental clearances and tackling security issues hampered the exploration activities of AMD in this area.

Gandi deposit

8.23 As per the *Report on Nuclear Power Programme upto 2020,* AMD was to identify 15,000 tonnes of uranium reserves from identified priority areas, which included Gandi. However, we observed that no targets were laid down by AMD Council for identification of uranium reserves from Gandi during the Xth Plan.

8.24 DAE replied in June 2008 that exploration was suspended for want of MoEF clearance and efforts were on for obtaining clearance for subsurface exploration in Gandi-Madyalabodu area.

8.25 While we acknowledge the efforts made by DAE in addressing the constraints at Lambapur-Peddagattu, Chitrial and Gandi, the fact remains that the extent of intervention had not yielded the desired results and deposits capable of hosting over 60,000 tonnes of uranium remained to be explored.

Targets for handing over of proven reserves to UCIL not set

8.26 We further observed that though AMD Council had been setting targets for augmentation of uranium reserves, no targets for handing over of proven reserves to UCIL were set till the Xth Plan. As the ultimate aim for AMD/UCIL was the handing/taking over of proven reserves for exploitation, setting targets and monitoring the achievements thereof could have reduced the extent of delays in handing over 23,184 tonnes of uranium reserves in seven of the 27 reserves handed over to UCIL.

8.27 DAE replied in June 2008 that as and when deposits were completely established, joint evaluation was conducted with UCIL and entire data was provided to UCIL for further planning and for undertaking commercial exploitation. Joint evaluation of the established deposits with UCIL was an integral part of AMD's Action Plan of the activities in this regard and was

also monitored regularly with a view to increase the resource base.

8.28 The reply of DAE is to be viewed in light of the fact that the importance of setting targets for handing over proven reserves to UCIL was also clearly highlighted in the AUS Committee report of February 2007 which laid down a target of handing over 30,000 tonnes of proven uranium resources to UCIL during the XIth Plan.

Shortfalls in achievement of targets in field activities

8.29 The exploration activities of AMD are carried out through various field activities like reconnaissance survey[12], detailed survey, evaluation study and exploratory mining study. Finally, a joint evaluation of the deposit is carried out by AMD and UCIL subsequent to which the deposit is handed over to UCIL. On analysis of targets and achievements in respect of field activities, we observed shortfalls in achievement of targets in field activities of AMD during the Xth Plan viz., airborne survey (54.75 *per cent*), geo-physical reconnaissance survey (18.46 *per cent*) and jeep survey (14.70 *per cent*).

8.30 Regarding shortfall in airborne survey, DAE stated in June 2008 that remedial action had already been in process.

Low productivity of drilling activities

8.31 We observed that the productivity per drill in AMD had been as low as 0.24 in 2004-05 in the Eastern Region, the highest being 20.38 in 2006-07 in the South-Central Region.

8.32 DAE stated in June 2008 that drilling productivity was dependent on type of drilling rigs, terrain, infrastructure facilities, weather conditions, social conditions and a number of other factors. It further stated that AMD had only mechanical rigs (compared to the hydrostatic rigs which were now available in the international market). DAE in December 2008 stated that in the XIth Plan there were two major projects viz. Augmentation of uranium resources through contractual drilling & Air borne and Geophysical surveys for survey over four lakh line kilometres, for which Cabinet approvals had been received and these projects would spill over to XIIth Plan.

8.33 The reply of DAE is to be viewed in the light of the fact that in the first meeting of Council of Management of AMD, held in 2006, Chairman, AEC had observed that the productivity per drill was low and higher targets needed to be set. Further, as per the XIth Plan working documents of DAE and reply of DAE given in June 2008, 75000 tonnes was targeted for identification by drilling 7,80,000 meters in the XIth Plan. However, in the reply of December 2008, DAE has now stated that these projects will spill over to XIIth Plan and so will the identification of 75000 tonnes.

[12] Reconnaissance survey includes techniques like jeep, air borne and geo-physical reconnaissance survey.

8.34 We are of the view that AMD needs to address the issue of modernising their drilling rigs so that productivity in drilling is improved.

Our Recommendations

10. A holistic and detailed plan needs to be drawn up in respect of every potential uranium deposit indicating time frame for each activity, right from identification of a potential deposit till its handing over to UCIL for commercial exploitation.

11. All out efforts need to be made to develop economically viable deposits like Gogi, Rohil-Ghateshwar, Koppunuru, Lambapur-Peddagattu, Chitrial and Gandi.

12. AMD needs to modernise its infrastructure for achieving higher productivity in surveys and drilling.

Chapter 9 Extraction of uranium from other sources

9. Research & Development work for recovering uranium from other sources was started in 1968 in Bhabha Atomic Research Centre. Based on this study, DAE erected a Pilot Plant for the recovery of uranium from other sources and the first product was obtained in May 1993. The *Report on Nuclear Power Programme upto 2020* had forecasted the mismatch between demand and supply of uranium in its report in June 2001 and had emphasised the need for tapping uranium from other sources for bridging the gap. It envisaged that at least 200 tonnes of uranium per year should be recovered from other sources during the Xth Plan and an additional 240 tonnes per year during the XIth Plan. The AUS Committee, in February 2007, also held that if all the uranium from other sources was extracted, it would provide 500 tonnes of uranium annually.

9.1 We observed that DAE could issue financial sanction for the establishment of two extraction plants for recovering uranium from other sources only in September/October 2005, i.e. after almost four years of the recommendation of the Report. Further, though the gestation period for the extraction of uranium from other sources was only 18 months and it was a more eco-friendly process, DAE could not produce any uranium from other sources till March 2008.

9.2 DAE, in June 2008, attributed this delay to various technical apprehensions and concerns associated with the process of recovery of uranium from other sources. It, however, indicated considerable progress in addressing these concerns and stated that the XIth Plan was poised to witness considerable extraction of uranium from other sources. DAE also stated in December 2008 that technology and equipment for extraction of uranium from weak phosphoric acid have been demonstrated. Other concerns on source rock, environment sanctions etc., raised by the fertiliser companies though addressed in the Cabinet Secretary level meetings, continue to crop up. In view of the sensitivity of the issue, the commercial concerns of the fertiliser companies as well as the source of rock phosphate overpower and delay the progress. The time bound manner of action suggested by Audit will have to reckon this aspect.

9.3 The reply of DAE may be viewed in the light of the fact that DAE itself had envisaged recovery of at least 200 tonnes of uranium from other sources during the Xth Plan, which has not been achieved. We are only recommending that in view of the current fuel crisis, DAE cannot afford

further delays in recovery of uranium from these sources.

Our Recommendation

13. DAE may attempt extraction of uranium from other sources in a time bound manner in order to ease the demand-supply position of uranium.

(RAJ G. VISWANATHAN)
Principal Director of Audit,
Scientific Departments

New Delhi
Dated: 19 December 2008

Countersigned

(VINOD RAI)
Comptroller and Auditor General of India

New Delhi
Dated: 29 December 2008

Annex 1

DAE's response to the highlights and recommendations of the performance audit report on *"Management of fuel for PHWRs (Front-end of the Nuclear Fuel Cycle)"*.

DAE's replies dated 3rd December 2008

"It is important to recognise that this indigenous Technology Programme requires parallel pursuit of activities related to reactors, uranium production within the country and fuel fabrication activities in accordance with our overall programme. It would be wrong to say that these were not linked. NPP has been periodically reviewed and redrawn and discussed at all levels including in the Atomic Energy Commission (AEC).

(Dealt with in paragraph 3.7 of this Report)

Till around early nineties, when Reactors were taking much longer time to construct and were operating at a low capacity factor, uranium (yellow cake) stockpiles had grown, the carrying cost of which was commented upon by Audit. This input interalia contributed to new uranium mine projects being closed. Today reactors are constructed fast and can operate at high capacity factors and inspite of best efforts at all levels in Government of India (including Cabinet Secretariat and PMO) development of uranium mines has got delayed primarily due to factors external to DAE. (Mining lease, law and order issues, forest clearance, environment clearance, etc.).

(Dealt with in paragraph 4.6 of this Report)

It should also be recognised that to sustain technology, there must be continuity of work. Leaving a lot of gap between successive projects would lead to skills and other resources getting dissipated on other activities leading to an irreparable loss in the technological capability built so painstakingly. While this has to be the major factor in sustaining reactor construction programme, addition of fuel fabrication capacity can be done with a lesser gestation period and this has in fact been factored in building fuel fabrication capacity taking into account both augmentation in uranium availability and the requirement as has been observed by Audit.

(Dealt with in paragraph 3.7 of this Report)

A Steering Committee on Nuclear Power which includes all DAE institutions involved in implementation of NPP (NPCIL, NFC, UCIL, AMD and HWB included) has been holding regular meetings every month since August 2001 to review and define necessary corrective measures. All Heads of Units and Secretary, DAE participate in these meetings.

(Dealt with in paragraph 3.18 of this Report)

With the mine development projects on which UCIL is already working, it would be possible to reach the uranium production capacity nearly sufficient to meet the requirements of 10,000 MWe PHWR Programme. To expedite actions, DAE is being supported by a Committee chaired by Cabinet Secretary in which all concerned Departments of Government of India as well as concerned State Governments participate.

(Dealt with in paragraph 4.6 of this Report)

All recommendations made by Audit are already in place for quite some time. In case there are any

new recommendations, we will be happy to take them on Board.

On the highlights, our para-wise comments are as under:

Planning and Monitoring at DAE

The conclusion that DAE had not linked/ensured fuel availability while drawing up the roadmap and laying milestones of new Pressurised Heavy Water Reactors (PHWRs) is not correct. The roadmap in fact addressed this very critical issue. Right since 1984 till to date, the PHWR component has been kept at 10,000 MWe, and reckoned with reference to the in-situ resources. June 2001 report on "Nuclear Power Programme upto 2020", at the specific direction of the AEC addressed this very issue. Mismatch occurred due to the long gestation involved in opening of mines for reasons beyond the control of the department and the technological improvement/schedule in setting up reactors by NPCIL. The roadmap recognised the mismatch and recommended action for augmentation. Exploration, mining and processing of fuel for NPP handled by AMD, UCIL and NFC which form the fuel cycle also formed a part of roadmap for the PHWR programme.

(Dealt with in paragraph 3.4 of this Report)

The decision to operate PHWR at lower capacity factor was specifically taken to deal with the mismatch in fuel. The journey through the technology denial regime warranted continuing the NPCIL roadmap to avoid diversion of skill/resources. The rational behind calculating total production that would have been possible based on the production pattern of a particular year is not justified. This can only be a theoretical exercise which leads to misleading conclusions. As already mentioned in the earlier reply submitted in June, 2008, the reactors were operated at lower capacity factors to match the fuel supply during the years 2003-04 to 2007-08. This has resulted in reduced power generation and this cannot be construed as loss as observed by the Audit.

(Dealt with in paragraph 4.15 of this Report)

Kaiga 3&4 was a IXth Plan project when fuel was not a constraint and Domiasiat was in the pipeline and as a prudent measure Kaiga 1&2 were replicated. Approval in this regard was in early 2000-2001. RAPP 5&6 took due cognizance of the June 2001 report of DAE at specific behest of AEC to work out details for roadmap of NPP. The report interalia recommended physical schedule of the NPP and inputs needed for RAPP 5 to 8. After AEC's scrutiny, the projects were submitted for Cabinet Committee on Economic Affairs (CCEA) approval. Audit's conclusion on 'inadequate' disclosure is not judicious.

(Dealt with in paragraph 3.14 of this Report)

As to the recommendations by Audit on effective planning, monitoring, the long gestations/investment decisions with fuel linkages, it is reiterated that from Xth Plan onwards to accelerate the overall programme, emphasis was on programme mode instead of project mode and the 15 year long programme was dovetailed to the 5 year planning process. Thrust areas were identified and emphasis laid on such activities for establishing a strong indigenous NPP. These, interalia, included establishment of fuel linkage for PHWRs (uranium exploration, mining and fuel fabrication). Investment decisions have taken note of the fuel scenario.

(Dealt with in paragraph 3.18 of this Report)

Pressuried Heavy Water Reactors (PHWRs)

NPCIL's demand on NFC cannot overlook the supply of MDU by UCIL. Further on the operation of

reactors with reference to fuel availability, the ye ar 2002-2003 was historic for NPCIL to demonstrate the technological robustness of the NPCIL's progra mme. During mid term review, it was decided that NPCIL should operate, on an average, at a plant load factor of about 70% to remain commercially viable and at the same time build up fuel inventory for new reactors. As a part of this strategy, reactor cores operating at lower power were modified to maximize energy output from a given amount of fuel. This enabled sustaining operation of all nuclear power stations. With above actions, PHWR generation during the X^{th} Plan was 78,466 Million Units (mus) as compared to a target of 72,621 MUs (finalised in the year 2000). The generation targets were met for the first four years of the X^{th} Plan period. There was a shortfall in the fifth year i.e. 2006-07 and in 2007-08.

(Dealt with in paragraph 3.7 and 4.18 of this Report)

In the above context, the recommendations made by Audit on NPCIL's need to project its demand and not on supply to avoid under reporting on shortage is not appropriate as there is no attempt to conceal the shortage of fuel.

(Dealt with in paragraph 4.9 and 4.19 of this Report)

Heavy Water Board (HWB)

The contention of Audit in drawing a parallel on heavy water and uranium stock is not correct given in the background in which the two inputs i.e. uranium (shortage) and heavy water (surplus) are placed and in the context of submissions made before AEC on Heavy Water Plant operations.

(Dealt with in paragraph 3.23 of this Report)

Nuclear Fuel Complex (NFC)

The installed capacity of NFC was sufficient to meet the demand projected by NPCIL during 2002-03 to 2006-07. NFC production target is fixed annually based both on demand by NPCIL and supply by UCIL. It cannot be fixed on demand alone. This in no way masks the shortage of MDU from UCIL or fails to draw attention of UCIL/DAE on the short supply.

(Dealt with in paragraph 4.9 and 6.7 of this Report)

Uranium Corporation of India Ltd (UCIL)

For the NPP, strategy for production of U_3O_8 based on the resources available upto 2016-2017 was planned by UCIL. It is not feasible to set up mining/milling plant at every such location as apart from viability, other aspects of transportation of radioactive waste, disposal of tailings, public perception etc., need to be addressed. Entire in-situ reserves identified are thus not mineable and hence the comparison/requirement of PHWR with reference to in-situ reserves would be flawed. The percentages worked out by audit on 'under exploitation' are not apt.

(Dealt with in paragraph 7.5 and 8.5 of this Report)

As to the roadmap, the background for closure of Turamdih mine, decision to revisit Singhbhum belt, delayed opening of Domiasiat, Lambapur-Peddagattu and the constraints thereon needs to be appreciated. Projects in hand with UCIL are commensurate with the PHWR programme beyond 2016-17.

(Dealt with in paragraph 7.3 of this Report)

On Domiasiat Project, despite recent meetings at MoS (PMO) and Cabinet Secretary level including visit to Meghalaya and addressing the health and radiation concerns in the last six months, the project

is yet to be approved. On the Lambapur-Peddagattu, the matter is pending before the National Environmental Appellate Authority. On Gogi, exploratory mining is on. Ore body has been reached and feasibility of constructing the mine/mill with all ancillary requirement of land, mining lease etc. is being examined. The other mines i.e. at Bagjata, Mohuldih in Singhbhum, Tummalapalle in Andhra Pradesh are on track.

(Dealt with in paragraph 7.13 to 7.37 of this Report)

As to the recommendation by Audit, it is stated that on the roadmap, the in-situ reserves identified are adequate for the 10,000 MWe PHWR programme. The innovative decisions to break the deadlock putting exploitation of high grade uranium in Domiasiat/Lambapur on fast track as recommended by Audit may please be elaborated. On the delay in the milling plants, the matter is being actively addressed.

(Dealt with in paragraph 7.22 of this Report)

Atomic Minerals Directorate for Exploration & Research (AMD)

Exploration for uranium is sequential process which is carried out through three different stages, spanning over a period of 8 to 10 years for an area. Exploration programmes are mainly based on existing knowledge and past experience whereas during actual exploration, a lot of data is generated which adds new dimensions to the exploration programme. Calculations based on one parameter without reckoning the geological variation are not correct. During the X^{th} Plan period, AMD has actually proved 16,244 tonnes as against the target of 15,000 tonnes of U_3O_8. Exploration activities are spread across the country and the contention of audit that the reserves were to be proved from only three deposits viz. Gogi, Koppunuru and Rohil is not correct. Based on the results in the identified areas, the activities were diversified and other important areas were taken up for exploration so as to achieve the target of identifying additional 15,000 tonnes of uranium resources.

(Dealt with in paragraph 8.2 and 8.10 to 8.18 of this Report)

In Chitrial with only 10 sq. km. out of the 50 sq km area covered by subsurface exploration, a reserve of 5800 tonnes U_3O_8 has already been proved. Papers for obtaining permission for exploration in another 50 sq km area of Chitrial area falling in sanctuary area is pending with Hon'ble Supreme Court. In Rohil, exploratory mining is on and in Gandi, MoEF clearance is awaited.

(Dealt with in paragraph 8.13, 8.22 and 8.25 of this Report)

In the XI^{th} Plan there are two major projects viz. Augmentation of uranium resources through contractual drilling & Air borne and Geophysical surveys for survey over four lakh line kms, for which Cabinet approvals have been received. These projects will spill over to XII^{th} Plan and are aimed to identify 75,000 tonnes of uranium and locate fresh deposits in the 14 Proterozoic zones in the country. Technological advancements by way of procurement of state of the art hydrostatic drilling rigs with deviation/drift control mechanism besides developing and acquiring Time Domain Electro-magnetic System envisaged in the project are underway.

(Dealt with in paragraph 8.33 of this Report)

Extraction of uranium from secondary sources

On Secondary Sources for uranium concerns on the process, technology and equipment for extraction of uranium from weak phosphoric acid have been demonstrated. Other concerns on source rock, environment sanctions etc., raised by the Fertiliser companies though have been addressed in the

Cabinet Secretary level meetings, continue to crop up. In view of the sensitivity of the issue, the commercial concerns of the fertiliser companies as well as the source of rock phosphate overpower and delay the progress. The time bound manner of action suggested by Audit will have to reckon this aspect."

(Dealt with in paragraph 9.3 of this Report)