THE 35TH JAIF ANNUAL CONFERENCE

第35回原産年次大会

APRIL 22〜24, 2002

JAPAN ATOMIC INDUSRTIAL FORUM, INC.

(社)日本原子力産業会議

［ 第1日　4月22日(月) ］

受付開始（8:45～）

於 大宮ソニックシティ・大ホール

開会セッション（9:30-11:00）

〈議　長〉 金　井　　務　（社）日本原子力産業会議 副会長、（株）日立製作所 会長

原産会長所信表明

西　澤　潤　一　（社）日本原子力産業会議 会長

文部科学大臣所感

遠　山　敦　子　文部科学大臣

経済産業大臣所感

松　あきら　経済産業大臣政務官

埼玉県知事挨拶

土　屋　義　彦　埼玉県知事

大会準備委員長講演

末　次　克　彦　アジア・太平洋エネルギーフォーラム 代表幹事

セッション１（午前の部）(11:15-12:30)

「２１世紀のエネルギー政策と原子力」（講演）

〈議　長〉藤　　洋　作　　関西電力（株） 社長

「米国のエネルギー政策と原子力ルネッサンス」

Ｊ．コルビン　　米国原子力エネルギー協会（ＮＥＩ）理事長

「原子力と持続可能な開発」

Ｊ．ブシャール　　フランス原子力庁（ＣＥＡ）原子力開発局長

柏崎市重要無形民俗文化財「綾子舞」の公演（13:15-13:45）

セッション１（午後の部）(14:00-17:00)

「２１世紀のエネルギー政策と原子力」（講演）

〈議　長〉 秋　元　勇　巳　三菱マテリアル（株） 会長

「英国の規制緩和市場でどのように原子力発電所の新規建設を達成するか」
Ｎ．アスキュー　英国原子燃料会社（ＢＮＦＬ）社長

「欧州の原子力：現実はイデオロギーを克服するか ―原子力段階的廃止をめぐって」
Ｐ．ハ ウ ク　　欧州原子力産業会議（ＦＯＲＡＴＯＭ）事務局長

「ロシアにおける原子力事情と今後の見通し」
Ｌ．ボルショフ　ロシア科学アカデミー付属原子力安全研究所 所長、
ロシア科学アカデミー 準会員

「環境保護主義者からみた原子力」
Ｂ．コ ン ビ　　原子力を支持する環境主義者協会会長（フランス）

「２１世紀のエネルギーと原子力」（仮題）
南　　直　哉　　電気事業連合会 会長、東京電力(株) 社長

レセプション(17:30-19:00)

於 パレスホテル大宮４階「ローズルーム」

[第2日　4月２３日(火)]

セッション２ (9:00-12:00)

「大都市圏と原子力施設立地地域の課題」（パネル討論）

〈議　長〉 森 嶌 昭 夫　(財)地球環境戦略研究機関 理事長

〈基調講演〉
「地域振興から見た電源立地 －消費地と生産地の共生について－」
下平尾　　勲　　福島大学経済学部 教授

〈パネリスト〉
岩 木　　浩　　埼玉県さいたま市助役
西 川 正 純　　新潟県柏崎市長
濱 田 隆 一　　電気事業連合会 専務理事
松 田 美夜子　　生活環境評論家

午餐会（12:15-14:15）

於 パレスホテル大宮４階「ローズルーム」

〈司　会〉 西　澤　潤　一　(社)日本原子力産業会議 会長

福井県知事挨拶

栗　田　幸　雄　福井県知事

〈特別講演〉

「世界の中の歌舞伎」

河　竹　登志夫　日本演劇協会 会長

原子力映画上映（13:00～）

於 大宮ソニックシティ・大ホール

〈上映作品〉

①21 世紀の知と技　原子力研究によるフロンティアの開拓（20 分）

②人にやさしいがん治療　～放射線治療の現在～（11 分）

③原子燃料サイクルの確立を目指して　～日本のリサイクルエネルギーは青森から生まれていく～（30 分）

セッション３（14:30-17:30）

「プルトニウムのリサイクル利用をなぜ進めるのか」（パネル討論）

〈議　長〉 近　藤　駿　介　東京大学大学院工学系研究科 教授

〈パネリスト〉

内　山　洋　司　筑波大学機能工学系 教授

榎　本　聰　明　電気事業連合会原子力開発対策委員会 副委員長、東京電力(株) 常務取締役

鈴　木　達治郎　(財)電力中央研究所経済社会研究所 上席研究員

舘　野　　淳　中央大学商学部 教授

野　田　　宏　核燃料サイクル開発機構 ＦＢＲサイクル開発推進部長

Ｊ．ブシャール　フランス原子力庁（ＣＥＡ）原子力開発局長

［ 第３日　４月２４日(水) ］

セッション４（9:00-11:45）

「新しい社会経済環境下における原子力発電の貢献」（パネル討論）

〈議　　長〉中　村　政　雄　　　科学ジャーナリスト

〈基調講演〉
J．メリフィールド　　米国原子力規制委員会（ＮＲＣ）委員

〈パネリスト〉
崔　洋　祐（チェ・ヤンウ）　韓国水力原子力発電会社 社長
R．クリッチ　　エクセロン社許認可担当 副社長
S．ブロスナン　　マグノックス・エレクトリック社 エネルギー営業担当 取締役
J．フィチ　　ウエスチングハウス社 原子力プラントプロジェクト担当 上級副社長
十　市　　勉　　（財）日本エネルギー経済研究所 常務理事・首席研究員
J．メリフィールド　米国原子力規制委員会（ＮＲＣ）委員

市民の意見交換の集い（12:45-14:45）

〈ファシリテータ（司会）〉
土　屋　佳　子　　フリーアナウンサー

〈コメンテータ〉
長　見　萬里野　　（財）日本消費者協会 理事
鈴　木　康　夫　　原子力発電環境整備機構 専務理事
野　田　　宏　　核燃料サイクル開発機構ＦＢＲサイクル 開発推進部長
G．マーカス　　米国エネルギー省（ＤＯＥ）原子力科学技術局 副局長

セッション５（15:00-17:30）

「原子力技術の将来展望－新型原子炉を中心に」（講演）

〈議　　長〉横　山　裕　道　　毎日新聞社 論説委員

「新型高温ガス炉の導入戦略---アフリカン・ルネッサンスへ向けて」
D．ニコルズ　　南アフリカ・ペブルベッド・モジュラー・リアクター社 社長

「革新型軽水炉の開発」
饗　場　洋　一　　三菱重工業（株）特別顧問

「第４世代原子炉開発計画および米国の方向性」
Ｇ．マーカス　　米国エネルギー省（ＤＯＥ）原子力科学技術局 副局長

「国際革新的原子炉・燃料サイクル計画（ＩＮＰＲＯ」
全　豊　一（ﾁｮﾝ･ﾌﾟﾝｲﾙ）　　国際原子力機関（ＩＡＥＡ）原子力発電部長

「高速増殖炉サイクルシステム実用化戦略調査研究からの展望」
相　澤　清　人　　核燃料サイクル開発機構 理事

４月２３日(火)　12:30-14:00

原子力を考える若人の集い

於：ソニックシティビル棟４階「市民ホール」
主催：ACT for E^3

近年の若年層の原子力離れは、世界の原子力界が抱える深刻な問題となっている。原子力の将来にとっても、若い世代の原子力への参画は重要である。このような中で年次大会に合わせて、原子力に携わる若者、原子力に関心のある若者が自主的に集まって、原子力が抱える問題や将来について、率直に意見交換を行い、アイデアを出し合うための「原子力を考える若人の集い」が開催される。このため、当会議では、別途、討論の場所を提供し、これに協力する。

Program of the 35th JAIF Annual Conference

Main Theme: Nuclear Power in the Changing Socio-Political Environment
-- Challenges for the Future

April 22 (Monday)

Registration (8:45 -) at Omiya Sonic City - Sonic City Hall

Opening Session (9:30-11:00)

Chairperson: Tsutomu Kanai, Vice Chairman of JAIF and the Chairman of Hitachi, Ltd.

Remarks :

- □ Jun-ichi Nishizawa, JAIF Chairman
- □ Atsuko Tohyama, Minister of Education, Culture, Sports, Science and Technology
- □ Akira Matsu, Parliamentary Secretary for Economy, Trade and Industry
- □ Yoshihiko Tsuchiya, Governor, Saitama Prefecture
- □ Katsuhiko Suetsugu, Chairman of the Preparatory Committee
  Secretary General, Asia Pacific Energy Forum

Session 1: "Energy Policy of the 21st Century and Nuclear Power"
(morning session: 11:15 - 12:30 Lecture Session)

Chairperson: Yosaku Fuji, President, Kansai Electric Power Co. Inc.

Speakers :

- □ "U.S. Energy Policy and the Nuclear Renaissance"
  Joe F. Colvin, President and CEO, Nuclear Energy Institute, USA
- □ "Nuclear Energy and Sustainable Development"
  Jacques Bouchard, Director, Nuclear Energy Direction, Atomic Energy Commission (CEA), France

<Folk Dance Performance: "Ayako-Mai" from Kashiwazaki City>(13:15 - 13:45)

Session 1: "Energy Policy of the 21st Century and Nuclear Power"
(afternoon session: 14:00 - 17:00)

Chairperson: Yumi Akimoto, Chairman, Mitsubishi Materials Corp.

Speakers:

- □ "How to Achieve New Nuclear Build in a De-Regulated Market"
  Norman Askew, CEO, British Nuclear Fuels, U.K.
- □ "Nuclear Power in Europe – Will Reality Overcome Ideology?"
  Peter Haug, Secretary General, Forum Atomique Europeen (FORATOM)
- □ "Status and Perspectives of Nuclear Power in Russia"
  Leonid Alexandrovich Bolshov, Director, Nuclear Safety Institute, Russian Academy of Sciences
- □ "Nuclear Power from the View Point of an Environmentalist"
  Bruno Comby, President, Environmentalists for Nuclear Energy (EFN), France
- □ "Energy of the 21st Century and Nuclear Power"
  Nobuya Minami, President, Tokyo Electric Power Co.,

Reception (17:30-19:00) at "Rose Room", 4th Floor of Omiya Palace Hotel

April 23 (Tuesday)

Session 2: "Tasks for Metropolitan Areas and Regions with Nuclear Facilities"
(9:00 - 12:00 Panel discussion)

Chairperson: Akio Morishima, President, Institute for Global Environmental Strategies

Keynote Speech: Electric Power Source Siting from the Viewpoint of Local Promotion
--Enhancing the mutual understanding between power-consuming and power-producing areas--
Isao Shimohirao, Professor, Faculty of Economics, Fukushima University

Panelists：

- □ Masazumi Saikawa, Mayor of Kashiwazaki City
- □ Miyako Matsuda, Specialist on Living Environment
- □ Ryuichi Hamada, Senior Managing Director, Federation of Electric Power Companies
- □ Hiroshi Iwaki, Deputy Mayor, Saitama City

Luncheon (12:15-14:15) at "Rose Room", 4th Floor, Omiya Palace Hotel

Chair: Jun-ichi Nishizawa, JAIF Chairman

Remarks: Yukio Kurita, Governor, Fukui Prefecture

Speech: "Kabuki on the World Stage"
Toshio Kawatake, Chairman, Japan Theater Arts Association

Session 3: "Why Plutonium Recycling?" (14:30 - 17:30 Panel discussion)

Chairperson: Shunsuke Kondo, Professor, University of Tokyo

Panelists :

- Yoji Uchiyama, Professor, Tsukuba University
- Toshiaki Enomoto, Managing Director, Tokyo Electric Power Co.,
- Tatsujiro Suzuki, Senior Research Scientist, Central Research Institute of Electric Power Industry
- Jun Tateno, Professor, Chuo University
- Hiroshi Noda, Director, FBR Cycle System Development Office, Japan Nuclear Cycle Development Institute (JNC)
- Jacques Bouchard, Director, Nuclear Energy Direction, Atomic Energy Commission (CEA), France

April 24 (Wednesday)

Session 4: "Contribution of Nuclear Power under the New Socio-Economic Environment" (9:00 - 11:45 Panel discussion)

Chairperson: Masao Nakamura, Scientific Journalist

Keynote Speech: Jeffrey S. Merrifield, Commissioner, United States Nuclear Regulatory Commission

Panelists :

- Yang-Uoo Choe, President, Korea Hydro & Nuclear Power Company
- Rod Krich, Vice President for Licensing Projects, Exelon Corporation, USA
- Steven G. P. Brosnan, Executive Director, Energy Sales and Trading, Magnox Electric plc
- James A. Fici, Senior Vice President, Nuclear Plant Projects, Westinghouse Electric Company, USA
- Tsutomu Toichi, Managing Director, Institute of Energy Economics, Japan

□ Jeffrey S. Merrifield, Commissioner, USNRC

Public Talks (12:45-14:45) at Civic Hall, 4th floor of Main Bldg.

Facilitator: Yoshiko Tsuchiya, Freelance Announcer
Commentators:

- □ Marino Osami, Director, Japan Consumers' Association
- □ Michio Suzuki, Managing Director, Nuclear Waste Management Organization of Japan (NUMO)
- □ Hiroshi Noda, Director, FBR Cycle System Development Office, Japan Nuclear Cycle Development Institute (JNC)
- □ Gail H. Marcus, Principal Deputy Director, Office of Nuclear Energy Science and Technology, Department of Energy, USA

Session 5: "To shape the future of nuclear power : Development of advanced and innovative reactors" (15:00-17:30 Lecture Session)

Chairperson: Hiromichi Yokoyama, Editorial Writer, the Mainichi Newspaper

Speakers :

- □ "Strategy for the Deployment of Pebble Bed Modular Reactor - toward the African Renaissance"
  David Nicholls, CEO, Pebble Bed Modular Reactor Ltd., South Africa
- □ "Development of Innovative Light Water Reactors in Japan"
  Yoichi Aeba, Special Advisor, Mitsubishi Heavy Industries, Ltd.
- □ "Development of Generation Four Reactors and the U.S. Strategy"
  Gail H. Marcus, Principal Deputy Director, Office of Nuclear Energy Science and Technology, Department of Energy, USA
- □ "International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) "
  Poong Eil Juhn, Director, Division of Nuclear Power, IAEA
- □ "Prospects for Commercialization of Fast Breeder Reactors; from Strategic Study for Commercialization of FBR Fuel Cycle System"
  Kiyoto Aizawa, Executive Director, JNC

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Youth Forum: 12:30-14:00, Tuesday April 23 (at Civic Hall, 4th Floor of Main Bldg.)
organized by ACT for E^3

OPENING SESSION

開会セッション

第３５回原産年次大会　原産会長所信表明

西澤 潤一

議長、遠山（とおやま）文部科学大臣、松（まつ）経済産業大臣政務官、土屋（つちや）埼玉県知事、ご列席の来賓の方々、並びに国内、海外から、この原産年次大会にご参加下さいました皆様に、心から厚く御礼申し上げます。

第３５回原産年次大会の開催に当たりまして、主催者を代表いたしまして、一言、所信を述べさせて頂きます。

さて、今、日本の原子力をとりまく政治・社会環境は、電力市場の自由化、日本原子力研究所と核燃料サイクル開発機構の統合化など、まさに原子力の位置づけ、役割が問われている時代となっております。

２１世紀の重要な科学は、「ライフサイエンス」、「情報通信（ＩＴ）」、「環境」、「ナノテクノロジー・材料」、「防災」に関する科学と言われております。

人類が生きていくために、私達は、科学をより人間の生活を豊かにするものに利用し、発展させようとしてきました。振り返ってみますと、科学の目ざましい発展は、大きな成果を挙げたものの、それら全てが人類の幸福に結びついたとは言えませんでした。私達の環境が悪化してもそれに適切に対処できないなど、負の遺産も引きずっております。私達はそれらを深く認識して、２１世紀には、科学が人類社会の持続的発展に十分貢献で

きるように、取組まなければならないと考えております。

さて、２１世紀はどのような社会を目指すのでしょうか。おそらく、「人間の生活の豊かさ(即ち、クオリティ　オブ　ライフの向上)」を目標とするのであろうと思います。そのためには、私達が高度な科学を駆使し、高度な科学が日常のものとして社会に定着するように努力をしなければなりません。その時、原子力もまた、有用な技術として、社会に定着できていなくてはならないでしょう。冒頭に申し上げました２１世紀の重要な科学の中に、「原子力」という言葉は入っておりませんが、原子力の生み出すエネルギーの「質」や放射線の利用技術は、これら先端技術の基盤であり、同時にそれらとの相乗効果により、さらなる生活の豊かさをもたらすものであります。

そのためには、私達は、原子力のもつ危険性を、どのような時にも認識していなければなりません。原子力や放射線を扱う専門家や関係者は、常に心を引き締めて、不注意な事故とその後の不適切な対応などによって、一般の人々に不安を与え、信頼感を損なうようなことは、決してないように、しっかりと行動しなければなりません。私はこの機会に、原子力関係者が真摯な態度でその研究や開発に取り組まれることを、改めて要請します。このような態度が長い間にわたって浸透しない限り、原子力の有用性を一般の人々に納得してもらえることはないと考えます。

エネルギーについて考える場合には、２１世紀という超長期的なレンジ

で捉える必要があります。エネルギーの安定供給に貢献し、地球温暖化ガスを出さないという特長をもつ原子力が、２１世紀のエネルギー源として定着していくためには、そのリスクをも十分に管理できる人材を育てることが不可欠であります。特に、日本においては、原子力が必要なエネルギー源であることを、理解してもらえる土壌作りを行なわなければならないと考えます。小・中・高校生の時から、エネルギーについての大切さを認識してもらうような教育を行ない、その中での原子力の位置づけ、役割を、若い時代より理解してもらうことが重要であります。さらに、その大切さだけではなく、革新的な原子炉開発などにより、原子力のもつ魅力を引き出させて、原子力に関心を持つ多くの若者を創り出す必要があります。つまり、私達には、原子力を十分に管理、コントロールできる、優秀で倫理観のある技術者を間断無く提供していく責任があるわけです。

このように原子力の開発利用には、非常に長期で広範な取り組みが必要であります。このためには、国も長期的視点に立って、積極的に国民に訴え、主導的役割を果たしていただき、計画の実施に関しては、民間関係者が自らの責任を明確にして、国との適切な役割分担のもとに、推進していきたいと思います。

本大会の開催地であるこの埼玉県は、首都圏の一角として多くの電気を利用しておりますが、発電設備をほとんど持っておりません。エネルギーについては、消費地であると共に、通過地でもあるかと思います。即ち、それぞれの地域はその置かれた状況によって、わが国全体の機能を分担し

てきたのですが、昨今、大都市圏と地域の相互の関係に様々な課題が生じてきております。とりわけ原子力発電立地地域との間に意識の乖離が指摘されております。このような問題につきましても、将来にわたって、このような役割分担を良しとして進めるのか、電力消費地もある程度自給できる体制を整える必要があるとするのか、お互いに話し合って、より良い仕組みを作り出すことが大切ではないかと考えております。

最後になりましたが、今回の年次大会の準備委員長には、アジア・太平洋エネルギーフォーラムの末次克彦(すえつぐ　かつひこ) 代表幹事にお願いいたしました。末次さんには、ご多用中にもかかわらず、快くお引き受け頂き、大会の準備にあたり様々なご指導を頂きました。厚く御礼申し上げます。また、準備委員の方々、国内、海外の発表者、議長に感謝の意を表したいと存じます。また、お集まりいただきました皆様には、是非積極的に議論に参加され、大会を盛り上げていただきますようお願い申し上げます。

ご静聴、有り難うございました。

(Opening Session)

Address to the 35th JAIF Annual Conference
by
Jun-ichi Nishizawa
Chairman, Japan Atomic Industrial Forum
April 22, 2002

Let me first express my gratitude to Dr. Kanai, Session Chairman, Minister Toyama of Education, Culture, Sports, Science and Technology, Parliamentary Secretary Matsu of Economy, Trade and Industry, Governor Tsuchiya of Saitama Prefecture, our guests, and all of you who have come both from within Japan and abroad to participate in this year's JAIF Annual Conference.

On behalf of the organizer of the conference, please allow me to make a few remarks.

The current political and social environment for nuclear energy in Japan - including liberalization of the electricity market and the planned integration of the Japan Atomic Energy Research Institute and the Japan Nuclear Cycle Development Institute - requires a redefining of nuclear energy and its role.

Meanwhile, subjects such as life science, information technology (IT), environment, nano-technology and materials, and disaster prevention have become important scientific pursuits in the 21st century.

In order for humanity to continue to prosper, and to make our individual lives more meaningful, we, those of us here, have been endeavoring to develop and make use of the full potential of science. Looking back, remarkable results have been achieved. But not all have brought happiness to the people. We carry a negative legacy, too: We have not properly coped with the worsening environment, for example, and we must be aware of this. Sustainable development must be part of the scientific goal hereafter.

What kind of society, then, shall we aim for in the 21st century? For me, the answer is in the expression,"richness of life", namely,"quality of life." We must work to make individual lives richer in meaningful ways. Advanced science gives us the tools to do this. To succeed, however, an appreciation of advanced science must also take root in society - an appreciation among people; acceptance of it as routine - including, of course, appreciation of nuclear science as a useful technology.

Actually, when I named topics a moment ago seen as important for the 21st century, "nuclear energy" was not among them. But the "quality" of energy generated by nuclear power and the technology to positively utilize radiation are the foundations of those other advanced sciences. At the same time, there are - or can be - synergistic effects between those areas of exploration and nuclear technology that can help advance the level of science itself, and yield the "richness" of life we all seek.

Yet nuclear energy will not be able to play its role unless we remain constantly aware of its risk. Specialists and others who deal with nuclear power and radiation must remain firm and vigilant, in order that one careless mistake, an accident or mishandling, not again cause the people to lose confidence in nuclear technology. Taking this opportunity, I urge each of you in the nuclear community to re-dedicate yourself to this principle. Without such a commitment among us, proven without exception over the long term, it will be difficult for the general public to understand and accept the usefulness what we do - the usefulness of nuclear energy.

Energy security, global warming and human-resource development are issues of the very long term - issues for the entire century we have only just begun. On each there must be action now, even as, on each, we continue to think far ahead. The long-term advantages of nuclear generation - supply stability, no greenhouse gases - are clear. For it to take root as an energy source, the long-term development of human resources necessary to successfully manage risk must be undertaken with the same perspective.

Here in Japan, I think we are required first to create a social environment where the necessity of nuclear energy is understood. And that must start with people in their formative years. Education in primary, junior-high and high schools should include energy issues and the role of nuclear energy. Students with interest and aptitude must be encouraged. We must, for example, continue the development of innovative reactors - exciting, new technology, not "yesterday's technology" - in part to inspire young people into nuclear-related careers. For our work to continue, for our accomplishments to mean something, for our hopes to be fulfilled, we must make certain that capable, ethical engineers, technicians and managers follow after us. That, too, is our responsibility.

All of this requires both a long and a broad vision. So it is essential that the government also play an active role, taking the initiative, for example, in speaking to the people of the nation. The private sector is, of course, committed to making its own responsibilities clear, to sharing roles properly with the government, and to developing and implementing the best possible programs.

We meet today in Saitama, part of the Tokyo metropolitan area. Saitama Prefecture consumes a large amount of electricity and has very few power generation facilities. It is an electricity transferring area, with its own share of responsibilities, but also a typical "power consuming" area.

Lately, in their perspectives on energy, we have seen various differences emerge between major cities and other places - especially differences in awareness between nuclear siting areas and the rest. In this kind of situation, I think it is important to create a better system through discussions. Perhaps the existing role sharing is appropriate for the future as well; or perhaps it will be necessary for electricity consuming areas to have some degree of self-supply.

Lastly, Mr. Katsuhiko Suetsugu, who is the Secretary General of the Asia Pacific Energy Forum, served willingly also, despite his terribly busy schedule, as Chairman of the Preparatory Committee for this year's conference. We are grateful for his leadership. I would like to also express my appreciation to all the members of the Preparatory Committee, to the speakers from Japan and abroad, and to all Session Chairmen. I ask you in the audience to participate in the coming discussions and help make the conference a success.

Thank you very much for your attention.

第３５回原産年次大会　遠山文部科学大臣所感

文部科学大臣　遠山　敦子

（はじめに）

原産年次大会の開催にあたり、一言御挨拶申し上げます。本大会が今回で３５回目を数え、さらに国内外から多数の御参加を得て、かくも盛大に開催される運びとなりましたことをまずはお喜び申し上げます。また、西澤会長、末次大会準備委員長をはじめ、大会開催に尽力された方々の御苦労に敬意を表します。

今や本大会は、各国の原子力の関係者が一堂に集う国際的にも著名なものとなっており、毎回、諸外国から政府関係者をはじめとする多くの方々が参加されております。また、原子力の関係者のみならず、広く地方自治体や一般市民の方々の御参加を得ることにより、原子力の研究開発利用に対する国民の理解促進にも大きく寄与されてきており、私といたしましても、これらを高く評価しているところです。

（原子力分野における行政の改革）

昨年４月に小泉内閣が発足してから１年が経過いたしましたが、その間に政府として、様々な分野にわたり「聖域なき構造改革」を進めてまいりました。　今後も、この改革への取組を一歩一歩着実に前進させていく所存でありますが、原子力についても、その例外ではなく、気持ちを新たにするとともに、引き締めて

取組んでいかねばなりません。

特に、特殊法人改革につきましては、昨年１２月の「特殊法人等整理合理化計画」において、 日本原子力研究所と核燃料サイクル開発機構を廃止・統合し、新たに原子力研究開発を総合的に実施する独立行政法人を設置することが決定されましたので、我が省としては、必要な検討を行うべく青山副大臣を座長として原子力二法人統合準備会議を開催し、より一層効率的かつ重点化を図った最良の原子力の研究開発体制の構築を目指してまいります。引き続き、皆様の御理解、御支援をよろしくお願いいたします。

（原子力研究開発の重要性）

原子力の重要性は、エネルギーの安定供給や地球環境保全などの観点から、今後もますます増大していくものと考えております。このため、原子力の研究開発に責任を有する我が省といたしましては、原子力委員会の「原子力の研究、開発及び利用に関する長期計画」に沿って、着実に原子力の研究開発を進めてまいります。

（安全確保・防災対策）

一方、原子力の研究開発を進めるためには、安全の確保が大前提です。

安全の確保には、何にもまして、原子力活動の現場において常に緊張感をもって取り組んでいくことが肝要です。この場にお集まりの関係者の方々におかれま

しては、以前にもまして安全の確保に万全を期していただきたいと考えております。

（国民の理解と教育）

また、原子力の開発利用は、国民の皆様の理解と信頼なくして進めることはできません。そのためには、すべての原子力関係者がそれぞれ、国民の安全と安心のために最大限の努力をしていくことが重要であります。

また、国としても国民の皆様に分かりやすい形で情報が提供されるよう、様々な工夫をしつつ、情報公開を徹底するとともに、国民の皆様との対話を絶やすことの無いよう引き続き努力してまいります。

さらに、エネルギーや原子力に関する教育の支援のための取組など、教育等の場においても、生徒一人ひとりがエネルギーや原子力について、自ら考え、判断する力を身につけることができるような環境整備に向けた取組を行ってまいります。具体的には、平成１４年度から新たに「原子力・エネルギーに関する教育支援事業」を創設することとし、各都道府県が新たな学習指導要領の趣旨に沿って主体的に実施する原子力やエネルギーに関する教育の充実に資するよう、副教材の作成、指導方法の研究、教員の研修、施設見学会等を支援することとしております。

（核燃料サイクルの意義）

核燃料サイクル技術は、資源の有効活用に貢献することによって、エネルギーの供給安定性を一層向上させる技術であります。その中でも高速増殖炉サイクル技術は、将来のエネルギーの有力な選択肢を確保する観点から着実にその開発に取り組むことが重要であり、その研究開発の場の中核として、高速増殖原型炉「もんじゅ」の早期の運転再開を目指します。

（原子力科学技術の重要性）

原子力科学技術は、非常に大きな可能性を秘めており、これを強力に推進してまいります。特に、加速器科学については、原子核・素粒子科学、生命科学、物質・材料科学など広範な研究分野の新展開を目指して「大強度陽子加速器計画」を着実に進め、世界最高のビーム強度を持った加速器を効率的に建設することとしております。また、未来のエネルギーの選択肢の幅を広げる核融合の研究開発については、国内の大学、研究機関等による研究開発を推進するとともに、ＥＵ、ロシア等との国際協力の下、国際熱核融合実験炉（ＩＴＥＲ）計画に主体的に取り組んでまいります。

また、放射線の利用は、国民生活の向上に大きな役割を果たしてきており、今後とも、安全確保に十分努めつつ、医療、工業、農業等幅広い分野での利用の普及を図るとともに、より幅広い利用の可能性を探るための研究開発を進めることが重要です。

（核不拡散対策）

これらの研究開発にあたって、我が国は、原子力基本法に則り、厳に平和利用に限って推進してまいりました。即ち、核不拡散条約（ＮＰＴ）を締結し、国際原子力機関（ＩＡＥＡ）の保障措置の下で核物質等を厳格に管理し、我が国のプルトニウム利用等に関して国際社会の理解を得てきました。また、包括的核実験禁止条約（ＣＴＢＴ）もいち早く批准し、国際監視制度の整備に取り組んでおります。

我が国は、今後とも国際的な核不拡散体制の維持・強化に積極的に取り組んでまいります。また、ロシアの余剰核兵器の解体に伴って発生するプルトニウムをロシアの高速炉で燃やす実験に、核燃料サイクル開発機構が協力し、成果を挙げているところであり、我が国は、今後ともこれまで培ってきた平和利用技術を最大限生かして、ロシアの余剰プルトニウムの処分に協力することとしております。

（産業界との連携）

また、原子力の研究開発を進めるに当たっては、その成果が実用化に結びつき、産業分野において十分に活用されて、国民生活のより一層の向上に役立つものであることが重要です。引き続き、産業界の皆様と十分に連携を取りつつ原子力の研究開発を進めてまいりますので、皆様の御支援、御協力をよろしくお願いいたします。

（むすび）

２１世紀において、地球社会が持続的な発展を目指すには、エネルギーの安定確保と地球環境保全を両立させることのできる原子力を抜きには考えられません。また、エネルギー利用以外の分野でも、原子力は、基礎から応用にわたる幅広い科学技術の発展や国民生活の質の向上、産業界への貢献の可能性を秘めております。

米国においては、昨年５月、ブッシュ政権発足に伴って新エネルギー政策が発表され、この中で原子力開発利用を積極的に推進する政策への転換がうたわれる等、原子力を巡る国際的な状況は変化しつつあります。

我が国においても、このような原子力への期待と内外の新たな状況にしっかりと応えられるよう、今日この大会に御参加いただいている皆様方とともに、全力を挙げて取り組んでまいる所存です。今後とも、より一層の御尽力、御支援を賜りますようお願い申し上げます。

最後に、本大会が実り多き大会となることをあらためて祈念いたしまして、私の所感とさせていただきます。

第３５回原産年次大会

平成 14 年 4 月 22 日

大会準備委員長

アジア・太平洋エネルギーフォーラム

代表幹事　末次克彦

２１世紀の我が国原子力の課題と展望

１．　２１世紀の原子力

２．　世論調査に見る日米の差—その意味

３．　原子力の構造改革

４．　競争化時代と原子力

ご紹介いただきました末次でございます。大会準備委員会はどういうテーマを、何を論点にご議論していただくのがよいかを考える会合です。準備されました５つのセッションと市民の意見交換の集い、原子力を考える若者の集いのプログラムをご覧になりましても、大会の開催場所が電力やエネルギーの大消費地である「さいたま」にお願いされたことからもお分かりいただけますように、２１世紀と言う新たな時代における原子力エネルギーをめぐる諸問題を地方と中央、民間と政府、産地と消費地などといった対置概念や対極観でなく、社会はネットワークとして成り立っているという原理，原点に帰って考えたい、というのが大会を準備した人々の「心」であります。準備委員長に私のようないわばノンフィクションのエネルギー・エコノミストをあてられたのもそうしたところからきていると思います。したがいましてこの準備委員長の報告もファジーなバックグランドミュージイック（ＢＧＭ）のようなものとして気軽にお聞き頂きたいと思います。

1．２１世紀の原子力

21 世紀のエネルギーの風はどこに向かって吹くのかにつきましては本大会にご参加いただきました世界の優れた原子力専門家の諸先生からもご示唆いただけると思いますが、わが国での認識としましても、風は省エネ、自然エネ、再生リサイクル、環境共生（廃棄物削減)、安全性、分散型などいわゆる持続的社会開発の路線に向かっています。その中で原子力をどう位置ずけたらよいでしょうか。この持続的社会開発路線には人類社会の経済的福祉のニーズを量的に満たす機能に欠けるところがあり、原子力は化石燃料主体から自然・再生エネルギーに傾斜する持続的開発路線へのシフトのつなぎ手として、同時に新たなエネルギーミックスの中核として有用な機能、役割を持つと考えられます。

こうしたグローバルな潮流やニーズに加えて、日本社会には 21

世紀においてもエネルギー供給におけるセキュリティ機能が必要であり、原発は化石燃料依存度をふやさない、あるいは減らすという点でエネルギーセキュリティ機能があります。（図１，２，３）

その機能は化石燃料の価格高騰、供給中断時に発揮されますが、平常時における電源間の競争力でも原子力はバックエンドコストを含めて充分競争力のある安定電源となっています。（図4，5，6）社会が原発のこうしたセキュリテイ機能を評価することは原発に対する民間投資を維持促進し、公的補助をも可能にしますが、同時に地球温暖化防止に役立つ炭酸ガス（CO_2）を排出しない有効な電源であることを計量的にも明示し、社会的に再評価することが不可欠であります。（図8）

原子力の CO_2 抑止効果を評価することは原発が市場を通じて CO_2 ゼロエミッションのプレミアムを受け取れる可能性があることを示しています。そのプレミアムは相対的なコスト競争力の強化、排出権取引における排出権の取得などであります。

原子力発電は重量にして化石燃料発電の５万分の１あるいは10万分の１の少ない燃料で年間同じ量の電力を生産します。廃棄物の量も原子力発電は化石燃料発電の約400分の１である。問題となって

いる高レベル放射性廃棄物の量は使用済み燃料を再処理すれば、それをしない場合の３％に減る。(図７，９) このように核燃料サイクルによって廃棄物削減が可能であることも原子力の21世紀性を示しています。高レベル放射性廃棄物に含まれる放射性の半減期の長い核種を質量とも減らすための技術研究開発の展望を開き、自然界、環境系における原子力廃棄物の位置付けについて社会的理解を得ることが依然大きな課題であります。こうした地球環境や廃棄物をめぐって原子力発電の機能が充分発揮されるメカニズムの形成について、本大会のいくつかのセッションで論議される事になっています。

21 世紀のエネルギーを取り巻く潮流から見てまた原子力は化石燃料と対立するものではなく、共に新世紀のニーズに向けて共生を図る時代に入り、この道を切り開くプログラムが求められています。その 1 つの課題は、軽水炉発電所を新増設し、低廉な夜間電力を使って高効率の電気分解装置で水を電気分解し、脱炭素型の水素製造をすること、また新たに高温ガス炉を開発導入し、その高温熱を化石燃料の改質源に使い、水素の生産を効率よく行う等、原子力発電と化石燃料の利用とを水素の生産に結び付けたの実現を図ることが望まれます。(図 11) 新たなエネルギーコンビナートの実現を図ることが望まれます。

このような21世紀のエネルギー供給システムの要請に合致する第四世代原子炉の開発と高速増殖炉を含めた核燃料サイクル路線の新しい組み合わせについて、官民が協力してビジョン、シナリオを産み出すことが望まれます。

2.世論調査に見る日米の差—その意味

米国では原子力発電所の計画外停止頻度が目立って減っています。（図３）９０年代初頭は年間の原子炉１基あたり停止回数が３．７~３．８と多かったのが、近年は１．３~１．５へと大幅に改善しているのです。世界第一位の発電量は９０年代は増え続け、２０００年は石油換算で２億トンを突破しました。米国の世論調査（ＮＥＩなど）によりますと原発支持率、つまり原発は安全且つ有用と思う人々の比率は９０年の４０％が２００１年調査では６５％へと上昇しています。（図２）９９年３月のギャラップの世論調査では原発増設が必要と考える人は５６％で、必要なしの４１％をかなり上回っています。昨年のブッシュ政権の新エネルギー政策発表後のＣＮＮの世論調査でも原子力発電の拡大が必要と思う人が４９％で、必要ないの４６％を上回りました。ＡＢＣニュースの調査も増設賛成は９０年の２２％が２００１年６月には４２％に増えたと報道しています。

米国では原発のトラブル回数の減少や順調な運転が総じて原発のパブリックアクセプタンスを高めていると言えます。これを反映して原発技術をコンベンショナルテクノロジー（Conventional Tech）とみなす意識変化が進み、原子力運転専門会社が登場、原子力発電プラントの売買が最近2年間で１０サイト１５基にのぼるなど、原発のルネッサンス現象がみられます。ただ、米国でも使用済み燃料の永久廃棄物処理地の立地については立地候補州の反対で立ち往生を続けています。

一方、わが国日本も日米欧の原子力発電上位5カ国のなかで９０年代の原子力発電量の伸びがトップであり、設備利用率も７２~３％から８２~３％へと漸増、原子力発電所の事故、故障、異常事象などトラブルの報告件数も９０年の３５件が２００１年には１５件へと大幅に減って順調な操業を続けています。（図 12，13）

しかし世論調査による原発の安全性認識や発電所建設への賛否は、図のように米国の動向とは全く逆に悪化しています。社団法人エネルギー・情報工学研究会議の世論調査（０１年１１月）によれば、原子力発電所の安全性を確保できると考える人の割合は８９年の５６％が２００１年には４７％まで減り、逆に安全性は確保できないと思う人の割合は８９年の４０％が２００１年には４２％に増えています。総理府の世論調査では原子力は安心であるとした人の割合

は９０年調査より９９年９月調査の方が４４％から２５％へ大きく減っています。

このように日本では原子力発電のパーフォーマンスが大幅に改善しているにもかかわらず、安全性に関する疑念、懸念は逆に高まるという米国とは全く逆の現象が起きていて、これが我が国の原子力プロジェクトにおける停滞の主な要因であることは間違いないと言えます。

また地球温暖化防止対策で我が国政策は、原子力発電の CO_2 削減効果を認めましたが、CDM（クリーン・デベロップメント・メカニズム）や CO_2 排出権取引に原発を組み込むメカニズムの開発は進んでいません。我が国の CO_2 排出量はこのままでは増え続け、当面、原発の CO_2 削減効果を定量化し、それを社会常識に変える作業が緊要ではないでしょうか。（図８）

日米のこの逆転現象は何故起きているのでしょうか。この１０年軽水炉の細管破断事故、高速増殖炉・原型炉もんじゅや再処理施設の火災、ＪＣＯの事故、さらに虚偽報告、データ改ざん事件などが起き、マスメディアがこれらを大々的に報じたことなどが、もともとメディア報道に対して敏感で、過剰反応する国民の体質が世論調査のねじれ現象の背景にあります。先日新聞紙面で対談した芥川賞作家の荻野アンナ女史も言っていましたが、我が国はメディアの報道

を通じて原子力発電にかかわる事故などが大事（だいじ、おおごと）なのか、些事（さじ）なのかの判断がつかないようになっております。国民もメディアもいわば原発過敏性症候群にとりつかれている状態であると言えるでしょう。このため原子力プロジェクトは地方政治の案件にはなっても、自治体や議会で論議をつくした決定や執行ができず、住民投票などに決定を依存する傾向を強めています。原発プロジェクトはこうした地方の状況により一層、地方と中央政府の資源配分の取引の材料となっているのではないでしょうか。

このことはまた、地方が国益を中央政府に代わって代理執行する機能分担の考え方が曖昧になっていることをも意味しており、我が国の政治システムのあり方にも一石を投じています。今大会の基調テーマを「政治・社会変化の中の原子力」としたのもこうした社会現象をよく論議したいという狙いからで、セッション 2 や市民との意見交換の集いなどでよく論議されることを期待しています。

3．原子力の構造改革

21 世紀の原子力を展望するにあたって、この分野でも構造改革を構想することがまず必要と考えられます。構造改革とは何か。それ

は守るべきものは更に一層磨いて守り、改めるべきものは改めるということであり、更に停滞した状況に対処する為、原子力産業界自体が内部改革、意識改革をすること、それが原子力の構造改革でありましょう。

この20年、核燃料サイクルの拡充、高速増殖炉の開発、核融合研究などいわばあれもこれもの原子力長期計画路線をひた走ってきました。しかし原子力を巡る政治社会そして経済の状況は、一転してあれも困難これも困難という停滞状況に陥っています。ウラン探鉱への公的投資は断念せざるをえなくなりました。高速増殖炉の開発も一体高速増殖炉はいつ使えるのか、使うのか、はっきり見えなくなってきています。

核融合の開発もまだ目途がつきません。

プルトニウム・ウラン混合酸化物燃料（MOX）の利用をめぐる混乱も、その安全性は既に内外で検証されているとか、我が国のプルトニウム需給バランスを守るのに必要だとか、ウランリサイクル上必要であるなどの論理よりも、地方対中央の配分争いのなかに埋没しつつあるところから起きているのではないだろうか。こうした状況そのものは、民主主義のために支払わなければならない必要なコストなのか、それとも我が国社会の意思決定力の欠如なのかを判定する必要があります。

しかし原子力の研究開発は大切であり、どれを取り、どれを捨てるかという取捨選択が必要になってきています。核燃料サイクルの実現の必要性を再確認しつつ、実施についてのスケジュールの組み直しもひとつの選択肢であります。長計路線に問題があるとすれば、それはいったん立てた開発計画を現状維持しようという傾向が強く、リスケジュールを含めて大きな取捨選択が出来にくくなっているという点ではないでしょうか。（図 9，10）

原子力の専門家集団は透明性を基本とする社会とさらに積極的に対話し、相互交流をよくして、原発過敏性症候群の下で広がりつつある原子力と社会とのギャップを埋める努力を強める必要があります。その為にも原子力の開発は日本社会においては 21 世紀の潮流に合致していることを原子力の専門家集団が自ら改めて確信し改めて確信し、社会に対する説得力を強めることが緊要であります。

４．競争化時代と原子力

電力の競争化時代の到来は原子力産業の側及び原子力発電を巡るもろもろの規制政策の両面で新たな改革が必要なことを示唆しています。

米国は９０年初、停滞から脱出のため原子力発電を巡る規制政策を

緩和し、民間原子力関係企業の改革努力にもより設備利用率を７０％から９０％への改善が実現しました。原発の定検の量と質両面の見直しを実施しています。日本も原発の安全操業が確保され、かつ電力競争化時代にも適合できる安全規制政策、原子力発電サイト許認可プロセスの新たなモデルを早急に作りだす必要があります。

原子力発電の新たな立地や既存サイトでの増設などを巡る広範な許認可プロセスの簡素化も課題となりました。このような改革を行っても安全確保はできるということについて明快なメッセージを社会に発することが緊要であります。民も官もこうした変化に対し、一段と積極的に対処することが望まれます。

電力の競争化時代はコスト意識の変革を迫ります。原子力のバックエンドを巡り米国、英国、フランスなどはその多くを政府部門が担うという政策法論理をとってきましたが、我が国は発生者責任の原則に立ち、電力会社が独占体制であったという意味合いも含めバックエンドを担当し、必要なコストは料金に算入してきました。この従来の体制が肥満なコスト構造をもたらし、官と民の役割分担についても曖昧さをそのままにして来たとしたならば、競争の時代への移行はそうした点を再点検し、明確にする契機と言えましょう。

競争化は市場シェアの変動と電力小売価格の変動、なかんずく価格水準が下がる可能性があります。それにより電源および販売部門の

コストダウンが迫られ、電源間の競争も激しくなります。また競争化に伴う分散型エネルギーシステムの台頭により原子力、火力などの電源のみならず送配電及び販売コストを全て含めたいわゆるネットワーク電力の競争力が問われて来ます。

こうした市場環境の中では、未知数なコスト要因、あるいはコストを削減しにくい要因が多いか、大きい電源はコスト構造の見直しや変革を断行し、競争力を確保しなければなりません。電力経営全体の中でそれらの電源の位置付けも再検討しなければなりません。
原子力発電にはバックエンドコストの不確実性があります。現状では再処理のコストにも未知数なところがあり、バックエンドの事故発生確率もわからないところがあります。原子力発電は今後減価償却の進展や設備利用率の更なる改善に伴うコストの減少が期待される一方、４－５０年後の将来、再処理工場が廃止される時の解体費用など、コストに未算入の要素もあり、そうした未知数の要因を早急に出来るだけ確定する必要があります。
その必要なコストを試算し、電気利用者から税として徴収し積み立てておくか、料金に入れるのか。どういう形で積み立てておくのか。そのコスト負担をどのように世代間で分担するのか。そのシナリオを用意し、社会的合意を得る必要があります。

今大会ではこの競争化と原子力の関係については、セッション４

で充分議論をしていただきたいと思います。

このように21世紀の原子力の課題と展望をめぐりまして多くの論点がありますが、もっとも重要なことはこの際、原子力産業界自身が確信をもつことだろうと思われます。

ご清聴ありがとうございました。

以上

21世紀の原子力の課題と展望

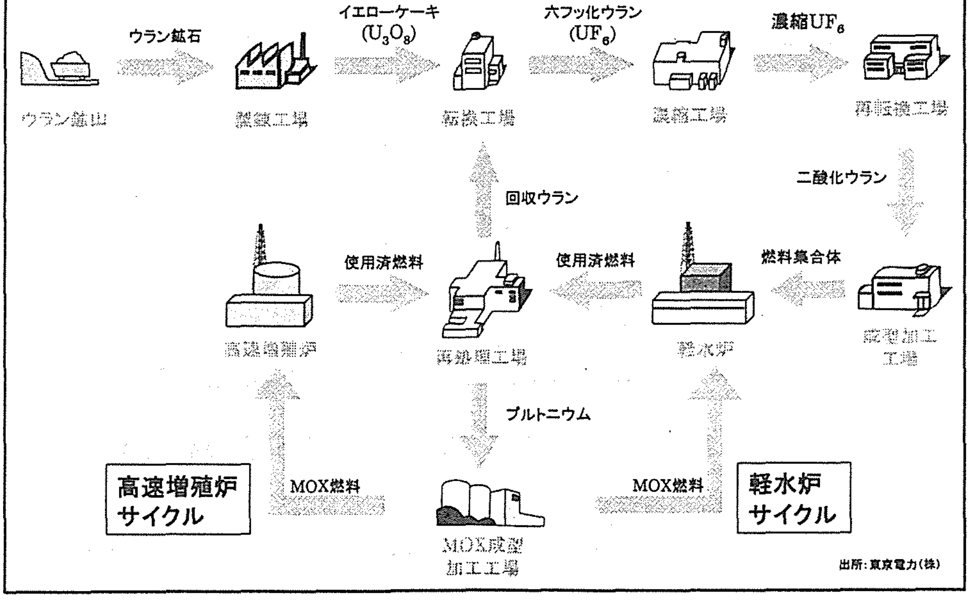
第35回原産年次大会

平成14年4月22日
さいたま市大宮ソニックシティー

準備委員長
アジア・太平洋エネルギーフォーラム (APEF)
代表幹事　末次克彦

原子燃料サイクル

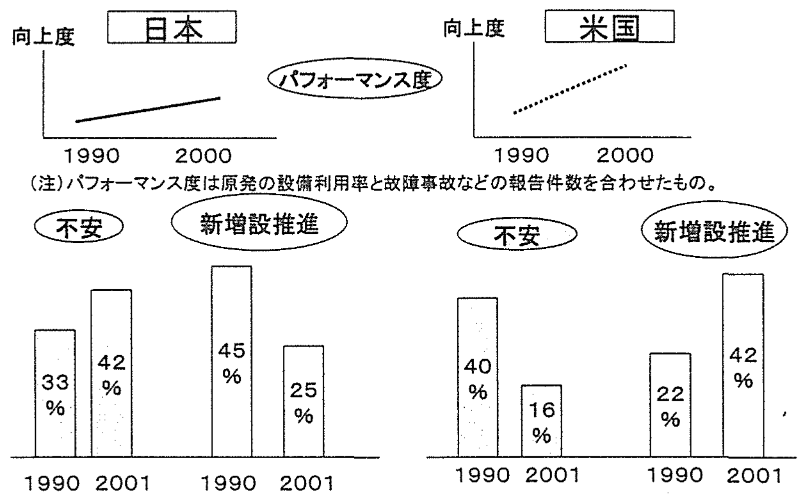
図1



出所:東京電力(株)

図2

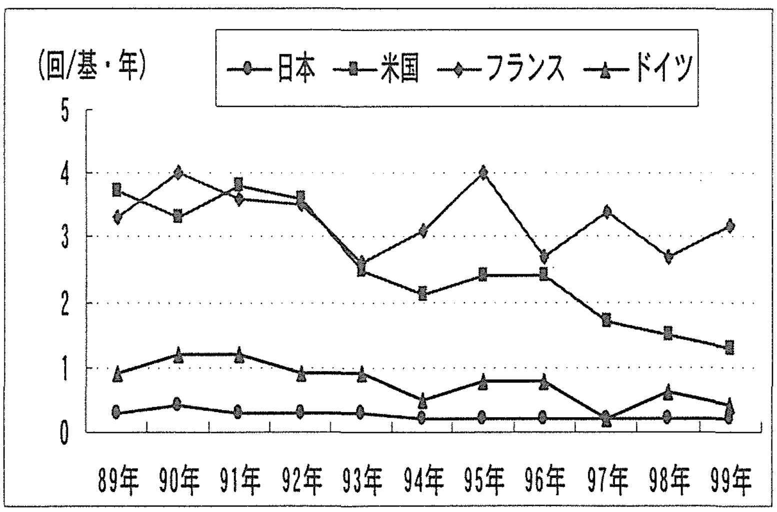
原子力発電に関する世論調査：日米比較



出所：日本：「ｴﾈﾙｷﾞｰ・原子力に関する世論調査と国際比較」（ｴﾈﾙｷﾞｰ情報・工学研究会議、2001年11月実施）
米国：「原子力発電に関する世論調査結果」（ＡＢＣニュース世論調査、2001年6月実施）よりAPEF作成

図3

主要国の原子力発電所の計画外停止頻度の推移



出所:国際原子力機関（ＩＡＥＡ）
"Operating Experience with Nuclear Power Stations in Member States in 1999" よりAPEF作成

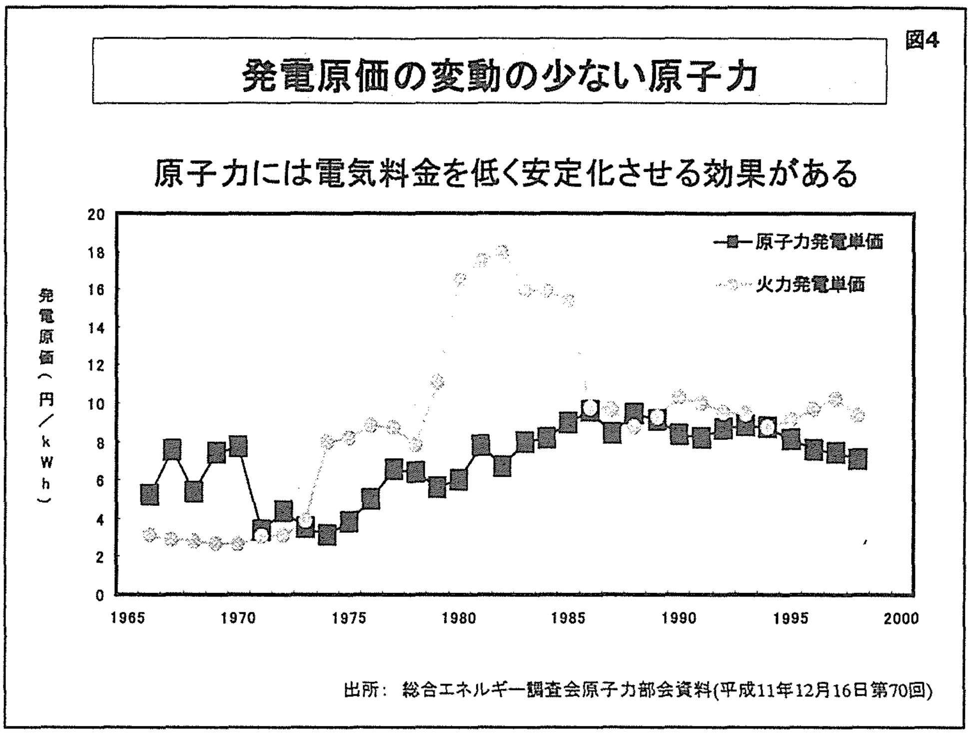
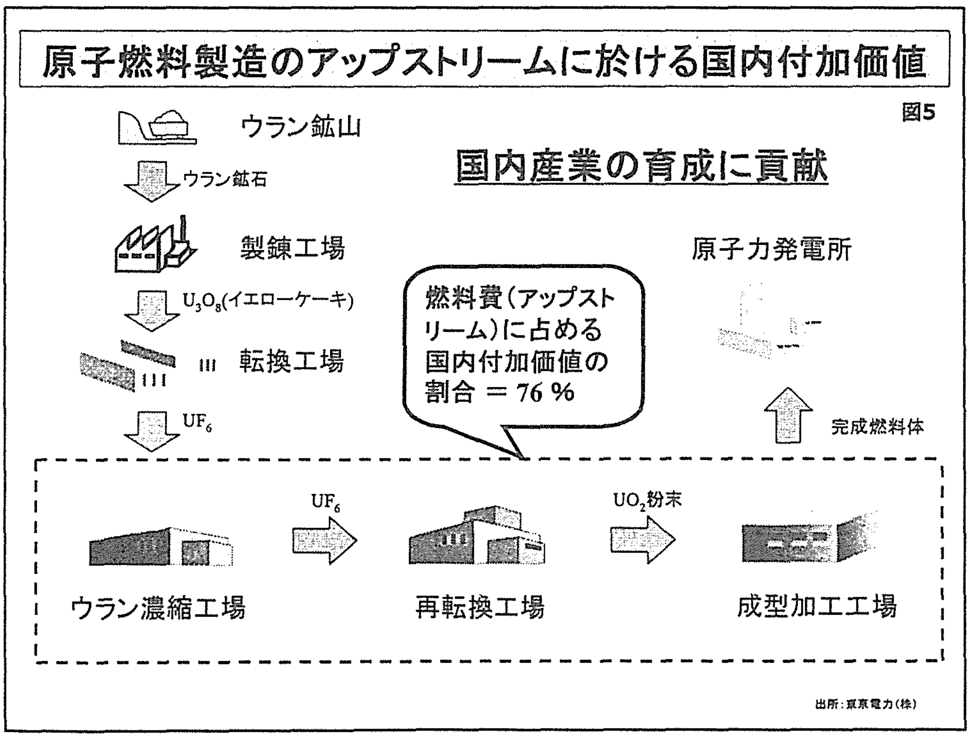
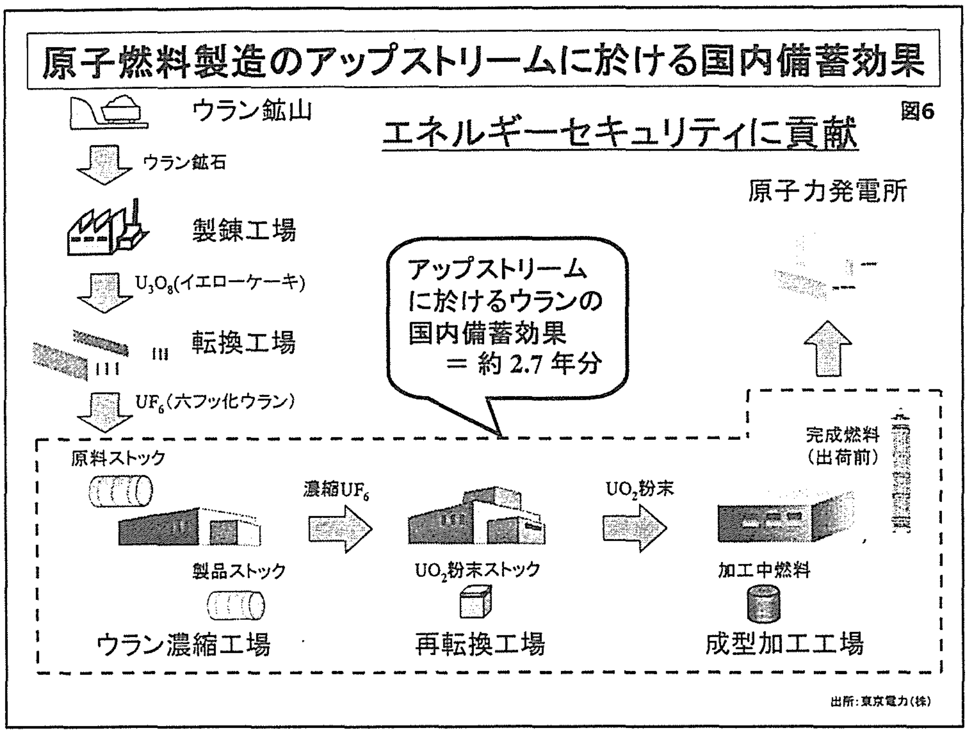


図4
発電原価の変動の少ない原子力
原子力には電気料金を低く安定化させる効果がある
原子力発電単価
火力発電単価
発電原価（円／kWh）
20
18
16
14
12
10
8
6
4
2
0
1965
1970
1975
1980
1985
1990
1995
2000
出所： 総合エネルギー調査会原子力部会資料(平成11年12月16日第70回)


原子燃料製造のアップストリームに於ける国内付加価値
図5
ウラン鉱山
ウラン鉱石
製錬工場
U_3O_8(イエローケーキ)
転換工場
UF_6
国内産業の育成に貢献
原子力発電所
燃料費（アップストリーム）に占める国内付加価値の割合 ＝ 76 %
完成燃料体
UF_6
UO_2粉末
ウラン濃縮工場
再転換工場
成型加工工場
出所：東京電力(株)


原子燃料製造のアップストリームに於ける国内備蓄効果
図6
ウラン鉱山
ウラン鉱石
製錬工場
U3O8(イエローケーキ)
転換工場
UF6(六フッ化ウラン)
エネルギーセキュリティに貢献
原子力発電所
アップストリーム
に於けるウランの
国内備蓄効果
＝約2.7年分
原料ストック
濃縮UF6
UO2粉末
完成燃料
(出荷前)
製品ストック
UO2粉末ストック
加工中燃料
ウラン濃縮工場
再転換工場
成型加工工場
出所：東京電力(株)

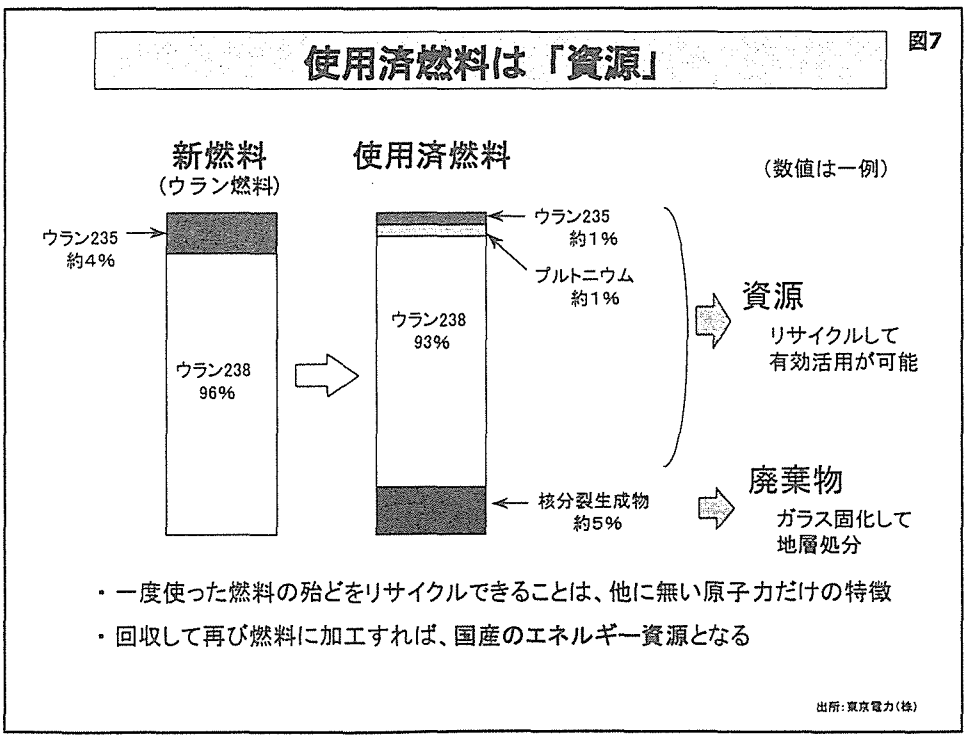
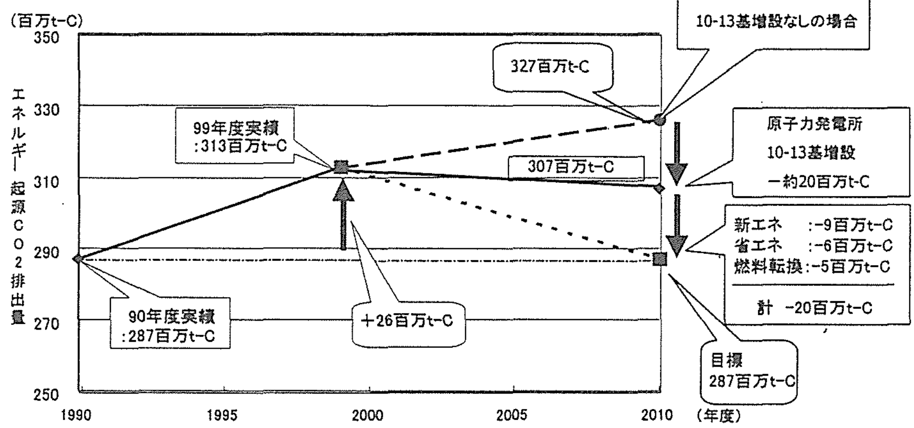

使用済燃料は「資源」
図7
新燃料
(ウラン燃料)
使用済燃料
(数値は一例)
ウラン235
約4%
ウラン238
96%
ウラン235
約1%
プルトニウム
約1%
ウラン238
93%
核分裂生成物
約5%
資源
リサイクルして
有効活用が可能
廃棄物
ガラス固化して
地層処分
・一度使った燃料の殆どをリサイクルできることは、他に無い原子力だけの特徴
・回収して再び燃料に加工すれば、国産のエネルギー資源となる
出所：東京電力(株)

図8

エネルギー起源のCO_2排出量の推移と見通し

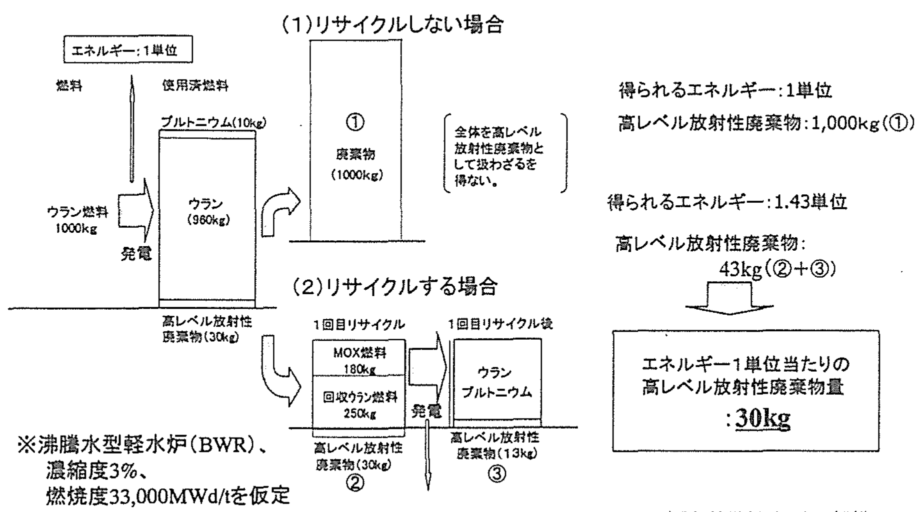
我が国は2010年までにエネルギー起源のCO_2の排出量を1990年と同水準とする目標に対して、半分を原子力発電所の増設によって、残りの半分を新エネルギーや省エネルギー、燃料転換によって達成することを目指している。



出所:総合資源エネルギー調査会報告書「今後のエネルギー政策について」よりAPEF作成

図9

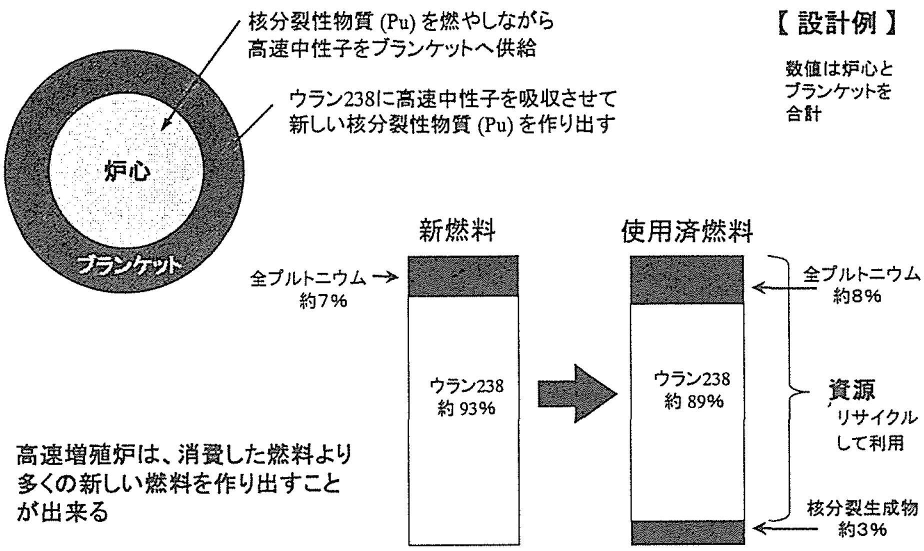
使用済燃料のリサイクルによって高レベル放射性廃棄物量を大幅に低減



出所:核燃料サイクル機構

図10

高速増殖炉の仕組み



高速増殖炉は、消費した燃料より多くの新しい燃料を作り出すことが出来る

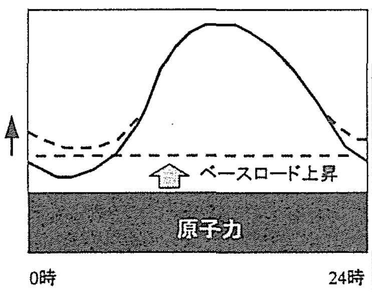
出所：東京電力（株）

図11

水素社会に於ける貢献の可能性

夜間電力の用途を増やし、原子力によるエネルギー供給を増加

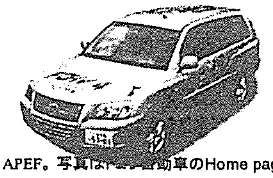
- 夜間通電の電気温水器による給湯の考え方
- 低廉な夜間電力を利用した電気分解により水素を製造（高効率の電気分解技術が国のプロジェクトで開発中）
- 軽水炉から送電網を通し、需要地に分散する水素供給ステーションへ電力供給
- 他のエネルギー源の利用を節約し、原子力の割合を増加



原子力の熱を直接利用して水素を製造

- 暖房や温室、栽培漁業への温水供給の考え方
- 高温ガス炉は、900℃程度の高温を提供可能
- 水の熱分解、高温電気分解、或いは天然ガス改質などにより水素を製造
- これにより、原子力エネルギを電気を経ることなく直接に化学エネルギへ変換

⇨ **水素燃料電池自動車の導入で、輸送セクターでも原子力利用**



出所：APEF。写真は[illegible]自動車のHome pageより

図12

A電力会社の発電電力量（実績）

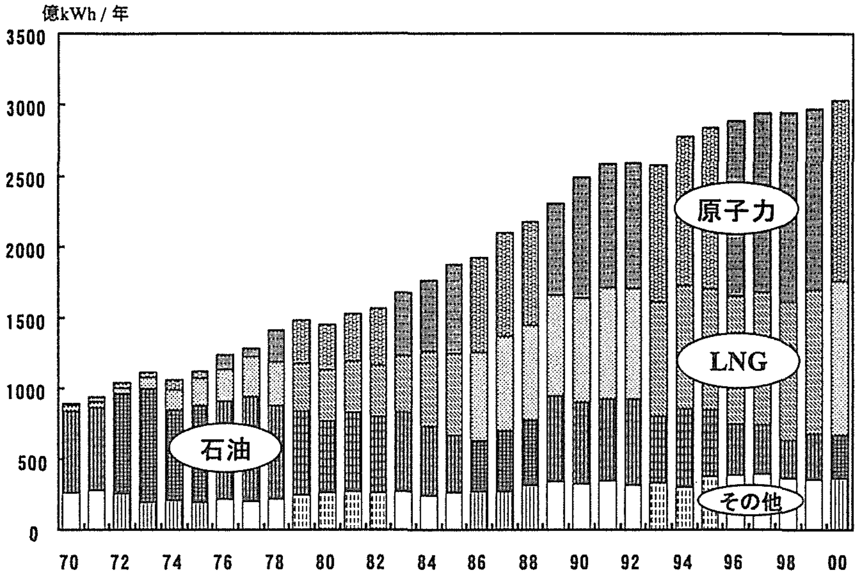


図13

2011年度までの原子力発電開発計画

運開	会社	地点	出力(万kW)	進捗状況	通番
2005年1月	中部	浜岡5	138	建設中	*53基*
2005年7月	東北	東通1	110	建設中	*54基*
2006年3月	北陸	志賀2	135．8	建設中	*55基*
2008年10月	東京	福島1-7	138	02年度着工予定	*56基*
2008年12月	北海道	泊3	91．2	着工準備中	*57基*
2009年7月	電発	大間	138．3	着工準備中	*58基*
2009年10月	東京	福島1-8	138	02年度着工予定	*59基*
2010年3月	中国	島根3	137．3	着工準備中	*60基*
2010年度	東京	東通1	138．5	02年度着工予定	*61基*
2010年度	原電	敦賀3	153．8	02年度着工予定	*62基*
2010年度以降	東京	東通2	138．5	02年度着工予定	*63基*
2010年度以降	原電	敦賀4	153．8	02年度着工予定	*64基*
	合計		1，611．2（12基）		

出所：中央電力協議会（2002年3月）よりAPEF作成

講演“ 21世紀の原子力の課題と展望”

参考図・表

1. 原子燃料サイクルの構図
2. 原子力発電に関する世論調査：日米比較
3. 主要国の原子力発電所の計画外停止頻度の推移
4. 発電原価の変動の少ない原子力
5. 原子燃料製造のアップストリームに於ける国内付加価値
6. 原子燃料製造のアップストリームに於ける国内備蓄効果
7. 使用済燃料は「資源」
8. エネルギー起源のCO2排出量の推移と見通し
9. 使用済燃料のリサイクルによって高レベルの放射性廃棄物量を大幅に低減
10. 高速増殖炉の仕組み
11. 水素社会に於ける貢献の可能性
12. A電力会社の発電電力量
13. 2011年度までの我が国の原子力発電開発計画

以上

第３５回原産年次大会準備委員長
アジア・太平洋エネルギーフォーラム 代表幹事 末次 克彦

SESSION 1

セッション 1

35th JAIF: Nuclear Power in the Changing Socio-Political Environment

Session 1:
Energy Policy of the 21st Century and Nuclear Power

Nuclear Energy and Sustainable Development

Jacques BOUCHARD, Director of Nuclear Energy Division, CEA

22 April 2002

Sustainable Development

Globalization and sustainable development are among the topics of the current societal debate. This is the perspective in which I would like to discuss nuclear energy.

Sustainable development is defined as a development form which meets the needs of the present-day generation without jeopardizing the chances for future generations to meet their own. This concept relies on three major conditions, namely economic growth, environmental conservation and social well-being. Far from being just a fad or a new business communication device, sustainable development seems to be reshaping behavioural patterns.

It is essential for energy debates to take place in this context, first because energy is central to the world potential for development, and second because the choices being made today are commitments for the future.

The importance of oil and gas

A prominent French oil executive recently wrote that he regards oil and gas as energy sources with a future, and potential contributors to sustainable development, provided that two conditions, both realistic, are met. The first would be an expansion of known reserves, which seems likely in view of stepped-up prospection and more efficient operating techniques, leading to new discoveries and improved production. The second is CO_2 sequestering through chemical or biochemical processes or by injection into ground formations or deep water, which should be feasible at a reasonable cost by 2015.

While oil and gas are covering the greater part of our energy needs, I regard it as detrimental to burn such non-renewable energy sources which could be saved for worthier applications.

When it comes to meeting the world's growing energy needs, we are confronted with a challenge: to explain convincingly that nuclear energy offers major advantages which definitely contribute to sustainable development.

The sound economics of nuclear energy

The first advantage of nuclear energy is **cost effectiveness.** I need not elaborate further on this point. As demonstrated by studies and confirmed by experience, **nuclear electricity generation is cost effective** in France, in the U.S., in Japan and in other countries, on deregulated markets open to competition. Profits are likely to reach huge proportions when plant life is extended beyond full depreciation. Thanks to nuclear power, France has **one of the cheapest electrical kWh in Europe** and French consumers' electricity bills remained unaffected by the latest surge in oil prices. Such **price stability**, resulting from uranium market stability and the low incidence of fuel cost on reactor operation, is crucial to a sustainable policy. The geographical distribution of uranium resources is also conducive to the **security of supplies**, also essential to a long-term policy. On this particular point, it should be noted that the European Commission's Green Book on European energy supply security predicts that Europe's dependency is due to rise from 50% to 70% by 2020. In France and in the U.S., recent studies have shown nuclear power to remain competitive, even as compared to gas, its sole competitor under favourable base material cost conditions.

Nuclear energy and the environment

Environmental conservation is the second prerequisite to sustainable development. Already well-known, the city of Kyoto has now become famous in France. The debate on renewable energies and the greenhouse effect has led French media to give the issue extensive coverage. Gradually, the press has been finding it impossible to avoid mentioning nuclear energy as a non-emitter of CO_2. Political leaders realize that reducing **CO_2 emissions** would be difficult, even impossible, without recourse to nuclear energy. In her very clear statements on this point, Ms. Loyola de Palacio, the European Commission Vice-President, has regularly confirmed that position. In France, besides the 15% share of hydro-power, it soon became apparent that 94 MW of installed wind power could never grow to replace the 63 000 MW from nuclear plants, whatever the effort and price incentives. The same orders of magnitude are observed at global level, where, besides hydro-power, the 24 500 MW of installed wind power is to be compared with 357 000 MW from nuclear plants. It is thus clear that nuclear energy is **the only form of base energy – other than hydro-power – which produces no greenhouse gases.**

In the medium term, the emission permits likely to be instituted will enhance nuclear power's advantages, even while nuclear technologies have been excluded, so far, from the "clean" development schemes in the Kyoto protocol.

Any discussion of sustainable development must raise the issue of **long-term resources**. Here also, we all know the advantages of nuclear energy. Uranium resources are widely distributed all over the world, which guarantees geopolitical stability, thereby supporting sustainable development. To secure resources in the very long term, fuel reprocessing, with plutonium recycling and the commissioning of fast reactors will be two key approaches, on which I will elaborate later.

The nuclear industry is frequently cited as exemplary for its systematic, thorough approach of safety issues and environmental impact. I would like to mention COGEMA's MELOX plant, commissioned in 1995, which reached its rated production capacity in 1997. Since then, the plant has been granted ISO 9002 certification in 1997, ISO 14001 in 1999 and the French Quality Award in 2001! Such achievements confirm **the excellent performance of nuclear facilities in the areas of environment, safety and quality.**

Nuclear energy and social equity

Energy is an essential driver of societal progress, as evidenced by the huge consumption disparity between the richer and poorer countries. While OCDE countries should strive to cut down on consumption, the fact is that it will rise sharply in developing countries. If nuclear energy, cheap as it is and well-suited to large cities, can fill their needs, it will contribute significantly to social equity and development.

Beyond this aspect, the nuclear industry's social performance is worthy of consideration. In France, as everywhere else in the world, nuclear energy relies on high-level technologies. This provides enterprises with a permanent incentive to **train their personnel**. For decades, **safety** has been given top priority, not just at facility operation level, but in all everyday moves in the workplace. Because we became aware, at an early stage, of the essential nature of human factors, the entire nuclear industry is attentive to the **well-being** of its employees, and shows high regards for their **statutory rights**. **Salary policies** are consistent with the employees' high qualification levels. This is proof that, in this respect also, the nuclear industry is a leader in social equity.

Necessary and possible progress, for a sustainable development

What are the solutions, improvements and responses needed to further promote the role of nuclear energy in sustainable development?

First, the **waste issue** remains outstanding and should not be brushed aside. Plutonium being recycled and burned in reactors, solutions must be found for the treatment of minor actinides. The CEA is addressing the issue, some of the work being carried out in Japan through a cooperative effort with JAERI. In 2001, we obtained promising results in the areas of minor actinide high-yield separation and transmutation.

Following transmutation, it will be necessary, sooner or later, to place ultimate waste, mainly fission products, in interim storage facilities or in repositories. Finland, Sweden, Germany, Belgium, the U.S. and Japan are already proposing solutions which are, naturally, specific to each country. It is essential that these solutions be understood by civil society, and that proof be given that the best possible efforts were made to manage the waste in the best possible way, to minimize the long-term residual risk, and to keep waste in containment for the required period of time. It should also be stated that the cost of plant dismantling and radwaste management has been included in the power generating cost, and only accounts for a few percent of that cost.

Second, we must also work at **further improving the competitiveness** of existing plants and future power generation facilities. This is an essential point. **Some progress remains to be made** in this area. R & D work on fuel and high burn-ups, plant life extension, not yet effective in France: these are ways to improve cost effectiveness. And, as we live in a world where short-term profitability is particularly attractive, the **initial investment cost must be reduced** so as to encourage the building of new reactors. In this respect, the modular, simpler 4th generation reactors should permit significant progress.

Third, **to ensure that resources remain available in the very long term**, we must turn to two key approaches, namely reprocessing with plutonium recycling, and the commissioning of fast reactors.

Let us first consider the **reprocessing-recycling policy**. In the case of industrial and domestic waste, this is the policy advocated by the political class as a whole, in the interest of the environment. When applied to the nuclear industry, the closed cycle approach – implemented in France and in Japan – permits conserving uranium resources while making use of plutonium's energy content. Further, keeping plutonium within the cycle prevents the building up of inventories. The French experience of using plutonium in the form of MOX fuel for PWRs has demonstrated the feasibility of recycling from both the safety and economic standpoints. I sincerely hope that Japan will very soon be in a position to implement its policy for the use of MOX fuel in reactors. This is the approach the U.S. has chosen for the recycling of weapons-grade plutonium, instead of treating it as waste, which would pose storage problems.
Beyond recycling, **the burning of plutonium in fast reactors is the right approach to very long term sustainable development**. It is my opinion that this option will stand out very clearly in conclusion of the work undertaken as part of the GENERATION IV International Forum to evaluate the concepts proposed for the future. The R & D work conducted in France supports this view. We have gained **extensive experience with sodium-cooled fast reactors**. We are continuing work in this area within an international context, in a cooperative effort with Japan concerning the JOYO and MONJU reactors.
We have also found it essential, in view of advances made in such fields as gas turbines, to go ahead with research on **complementary approaches, among which gas-cooled reactor systems**. While allowing the use of fast spectra, this approach completes the range of available options, by taking advantage of coolant gas properties to operate at high temperatures, leading to improved efficiency and new applications. Sooner or later, fast reactors will be the key to the sustainable development of nuclear energy. When that time comes, having worked out a number of solutions and being in a position to propose them will be a distinct advantage.

<u>Where do we go from here ?</u>
First of all, and I hope I have left no doubt on this point, it is our role to **speak out loudly and clearly in support of the major assets of nuclear energy as a sustainable development agent**.

We should also **think about the improvements** which would help nuclear energy respond even better to society's expectations. As discussed in the GENERATION IV International Forum, we will have to propose **new power generation systems** with constantly improved cost effectiveness and safety, a prime design consideration being environmental protection through resource conservation and a reduction in ultimate waste output. Another task will be, as is currently the case in many countries, **to come up with radwaste management solutions** and propose them to political leaders so that decisions can – at long last – be made.

To quote Antoine de Saint Exupéry, the French aviator and writer, "We do no inherit the Earth from our parents; we only borrow it from our children." By taking nuclear energy through a continuing process of improvement, economic optimization, natural resources conservation and environmental protection, we will work at its sustainable development.

Nuclear Power in Europe:
Will Reality Overcome Ideology?

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35th JAIF Annual Conference,
Saitama City, Japan

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Session 1: "Energy Policy of the 21st Century and Nuclear Power"

Good afternoon, ladies and gentlemen.

It is both a privilege and a pleasure to be able to speak to you today, and I welcome this opportunity to give you a European perspective on the future of nuclear energy.

My role as Secretary General of FORATOM, the Brussels-based trade association for Europe's nuclear industry, and of ENS, the learned society, is normally that of 'nuclear ambassador', but on this occasion I also have the task of 'European envoy' to perform. The messages I bring with me concern a topic of great importance for our region of the world – the prospects for a nuclear power revival in Europe.

In this presentation, I would like to give an overview of where nuclear stands at present and what the future might hold. This will be approached from different directions – political, commercial, economic and environmental. Key national and EU-wide developments will be covered. A summary will be given of the pressures and conditions that could lead to a renaissance. On the negative side, I will speak about the main obstacle standing in the way of this – that is, the public perception of the waste issue. However, there are also some definite reasons for optimism, which I will conclude on.

The use of nuclear power is a political issue and will remain so for a long time to come. Because of this, the rules of the free market economy cannot be applied in their purest form. A power company's plans to build a new reactor unit will undoubtedly come up against loud and persistent opposition from those activist groups that are traditionally opposed to nuclear. These groups will, as ever, work closely alongside their allies in certain political parties. In contrast, the public at large might not take such a negative line and might in fact adopt a more pragmatic approach. But when the crunch comes, and politicians are faced with having to take definite decisions, they may well take the easy option and decide that no action is the best course of action, in the interests of political expediency.

As for the business context, the outlook is rather clearer – at least on paper. Under certain conditions, nuclear remains a highly attractive proposition for a power company seeking to provide baseload electricity on a long-term basis at predictable cost. As well as enhancing energy independence, nuclear represents a 'politically correct' option, thanks to its 'clean air' credentials.

And what of the economic case for nuclear? That too has been underlined by various factors:

- the Californian power crisis,
- the resulting new direction in US energy policy, and
- ongoing plans to build a new reactor in Finland, the country's fifth.

On the political front, we see several instances that highlight the environmental and economic case for nuclear.

At last year's COP 6 climate change conference in Bonn, nuclear was discriminated against due to ideological pressures. But that does not alter the fact that the use of nuclear is already providing major benefits in terms of reduced greenhouse gas emissions. It is already helping certain countries to meet their CO_2 reduction targets and will continue to do so for at least the next two-to-three decades and probably beyond. At a later stage, parties to the agreement might be forced to revise their positions on the issue of nuclear's role in the Kyoto Protocol's flexible mechanisms.

The Bonn conference may have discriminated against nuclear, but the event itself gave the nuclear industry another excellent opportunity to highlight nuclear's present and future role in meeting our future electricity needs while reducing greenhouse gas emissions. To that extent, the effort made by the industry during two years of hard campaigning was a worthwhile exercise. For the future, the environmental arguments for nuclear remain strong.

In addition, the energy review in the UK has revived the nuclear debate there. The two main nuclear companies, BNFL and British Energy, have both called for a resumption of nuclear new-build, partly because the UK's dependency on imported gas is predicted to rise substantially and partly because of the retirement of existing reactors. Under the circumstances, British Energy's call to "replace nuclear with nuclear" makes perfect sense.

In Spain too, the power sector trade association, UNESA, now says the time is right to reopen discussion of the nuclear energy option. This is a position that the EU Energy Commissioner, Loyola de Palacio, would clearly support. In her speeches, she has repeatedly drawn attention to the environmental and economic advantages of nuclear energy.

All these developments have been positive for nuclear. At least now nuclear is being talked about in a more open and dispassionate way. Whether the media coverage is biased or balanced, the debate *in itself* still raises the public's awareness of the issues involved. For the nuclear industry, that cannot be a bad thing. The big danger for the industry is that nuclear will start to fade from public view and from the public consciousness.

In the European media, the word 'phase-out' is often associated with nuclear power. But the fact of the matter is that no European country, currently using nuclear, is in any great rush to stop doing so. That even includes those countries with governments that want to bring the use of nuclear to an end.

The Green Party in Germany, when it became the junior partner in the country's coalition government, sought a quick exit from the use of nuclear. But it was quickly realised that such a move was simply not possible for legal, environmental and economic reasons. So, a longer-term process was demanded by the government and agreed upon with the major power companies, after a year of detailed negotiations.

The planned withdrawal from nuclear in Germany is not the overnight affair that Green Party leaders had hoped for. More importantly, it will be a gradual process that might be halted at any time by a new government. Even if there is no change in the present agreement between the government and the major power companies, Germany's nuclear plants will be in business for at least another two decades.

Meanwhile, the Swedish government, having closed one reactor, is having great difficulties meeting the conditions, set by parliament, for the closure of a second. For the second closure to take place, electricity consumption will have to be reduced and alternative, non-polluting generating capacity will have to be put in place. So far, none of that has happened. Meanwhile, the loss of one reactor has been compensated for by importing electricity from Denmark that has been produced to a large extent by burning coal. In my view, this underlines the way in which hypocrisy has, to a large extent, entered the field of energy policy.

In Sweden, government policy now seems to be switching towards a gradual and slow withdrawal from nuclear, involving an agreement with utilities similar to the one in Germany. Meanwhile, the plan to close the second reactor is expected to be reviewed next year.

Plans for a phase-out in Sweden are nothing new. Originally, the target was to end the use of nuclear by the year 2010, but that deadline has since been overtaken by more recent political decisions and has now been abandoned. Opinion polls in Sweden consistently show that only about 20% of the population favour a phase-out of nuclear. The vast majority of Swedes believe that nuclear should continue to be used so long as the plants are safe and economically viable.

This Swedish situation highlights the benefits that nuclear offers – greater security of energy supply, less dependence on energy imports and less air pollution. It should also serve as a warning sign to other governments that may be contemplating a reduction in the contribution made by nuclear to the national energy mix.

Belgium, which relies on nuclear for nearly 60% of its electricity, is the latest European country to try to enforce a phase-out of nuclear power – by limiting to 40 years the lifetime of the existing seven reactor units. But even so, a draft law on this will contain an escape clause, which will enable the government to lift the time restriction if it becomes clear that there is no alternative to keeping the nuclear plants running.

The phase-out policy of the current Belgian government dates back to 1998, when a 'rainbow' coalition made up of parties of various political 'colours' came to power. A phase-out of nuclear within about 25 years was then the stated long-term objective. But now, due to pressure from Belgian Green parties, there is a determined attempt to convert that policy into a legal requirement. The energy minister, who is pushing for this new legislation, is a member of the Green movement and a former director of Greenpeace. As well as being anti-nuclear, he personally favours increased use of gas-fired power plants and more wind turbines.

There is a common thread running through these phase-out moves. In each case, the principal coalition parties have had to secure the support of Green party leaders in order to build and maintain an operational government machine. This support has been won by allowing the Greens to pursue their anti-nuclear agenda by incorporating it into government policy, even though the Greens may have only limited support among the majority of voters.

So much for the role of nuclear at the national level, but what of the pan-European dimension?

By looking at developments in Germany, Sweden and Belgium, we already see in Europe that extreme ideological positions do not fit in with the practicalities of electricity production and of energy policy in general. If Europe is to meet its future electricity needs in a manner that is economically and environmentally acceptable, it cannot afford to exclude certain options, like nuclear, on purely ideological grounds.

The European Union is facing the threat of growing dependence on external sources for its energy supply. There is a need to strengthen energy independence and to rely to a greater extent on energy sources that offer reliable supplies at prices that are both reasonable and stable. Nuclear satisfies these demands.

The EU is currently importing 50% of its energy from outside the Community, and this level of dependency is expected to rise to 70% in the next 20-30 years. The Community should be seeking to *strengthen* energy independence in the member states, and increased use of nuclear is one way to achieve this objective. This would mean increasing the nuclear share in total EU electricity production above its present level of 35%.

Meanwhile, the EU has given a firm commitment to meet its obligations under the Kyoto Protocol. But it is generally accepted that it cannot do so without the nuclear component in the Community's energy mix.

At the EU level, the most important focus of political debate has been the European Commission's Green Paper on the security of energy supply in Europe. As with the COP climate change process, this policy discussion document has been another important opportunity for the nuclear industry to present the case for nuclear and to argue that nuclear should play a significant role in a balanced and sustainable energy mix.

A public consultation process on the Green Paper ended in mid-February, and the follow-up is expected to involve policy statements and directives from the Commission on overall EU energy policy. In response to the Green Paper, FORATOM has been vigorous in spelling out the importance of nuclear in terms of security of energy supply and CO_2 avoidance. The Green Paper recognises that these factors cannot be ignored in the nuclear debate, but the discussion document – in part – conveys the impression that nuclear is disliked and unwanted, and that moves by certain governments towards phasing out nuclear are part of a general trend.

Regarding fuel supply, we accept that most of the uranium used in European reactor fuel is imported, but we have also stressed, in our response to the Green Paper, that supplies are abundant and from politically stable parts of the world, such as Australia and Canada. In addition, spent fuel reprocessing turns an imported raw material into a domestic energy resource.

What we are hoping for, as a result of the Green Paper, is:

- a realistic appraisal by the Commission of the future role of nuclear,
- official acceptance that nuclear does have an important role to play in Europe's energy future, and
- recognition that Europe could derive even greater benefits from giving nuclear an increased role in the future.

However, we do not argue that nuclear is the only rational option to be pursued. What we do maintain is that Europe's energy situation is so weak and precarious that no single option should be ruled out, especially if certain choices are excluded on purely ideological grounds. In that sense, Europe as a whole is quite similar to France and Japan and other individual nations that are not well endowed with plentiful domestic energy resources.

As I mentioned earlier, it might be possible for politicians to 'buy peace' on the political front by dodging the issue until after the next election. But such an approach will do nothing to maintain the fairly comfortable living standards that most people in Western Europe enjoy today.

In 30 years, due the retirement of existing nuclear plants, nuclear's contribution will be a small fraction of what it is now, if no new nuclear power plants are built. So, we need to ask what the alternatives will be. By then, in 2030, we may still have to wait another 20 years for fusion to become a reality. Gas might become quite a scarce and expensive commodity at that stage. Renewables might help to fill part of the gap. But the massive deployment of wind farms might turn areas of natural beauty into industrialised eyesores, destroying tourism in many European coastal areas.

Policy-makers at national and European Community level have the power at their disposal to make sure that an energy nightmare does not become a reality. In the long-term, we will have to reduce our consumption of fossil fuels in any event. Tighter supplies of gas and higher gas prices, for instance, will start pushing up electricity prices and will start to have a negative impact on our economies.

Nuclear, meanwhile, represents a solution that we have here and now. It is something that is ready and waiting for further deployment, without having to gamble on measures to achieve energy saving and on energy sources that depend on the strength of the wind and the sun.

What we may see in Europe over the next 20 years is limited new-build in specific countries or regions where there is a clear need for new baseload capacity.

I believe that we are currently experiencing the emergence of a growing sense of realism, a feeling that we have to get back to basics and think about how we can best meet our future electricity needs. National or regional government control over electricity production could not be sustained forever, but it did deliver stability and predictability. These are two things that may be lacking in the future, and nuclear power could be part of the solution.

To see a current attempt to bring about a return to stability and predictability, we need to look at what is happening in Finland. In November 2000, the Finnish power company TVO applied for a government decision in favour of constructing another nuclear unit, as an add-on to one of the country's two existing nuclear stations. Since then, the Finnish government has given its backing to the scheme, and the plan will be the subject of a vote in parliament in May.

TVO has spelled out the logic behind its choice of nuclear, and the reasons given point to a typical scenario that could be replicated in other parts of Europe in the years ahead. It is in just such a scenario that nuclear becomes an obvious choice for new investment.

The conditions facing TVO are as follows:

- increasing demand
- a need for new baseload capacity
- environmental requirements
- the risk of even greater dependency on imported gas and electricity.

These are typical factors pointing to nuclear as a new investment choice. In addition, independent researchers in Finland found that a new nuclear unit would be the least-cost option available.

But what are the conditions necessary to make construction of new nuclear plant a real possibility?

A change to longer-term thinking would be one of them. This relates to the desire for stability that companies and governments may have to develop in the future.

Being unable or unwilling to import electricity is another condition that would support investment in new nuclear capacity. Imports and exports are an essential part of any free market, but a certain level of self-sufficiency is also needed at both company and national level. It is worth remembering that energy independence is the central theme in the Commission's Green Paper.

Political commitment is yet another prerequisite for new nuclear power plants to be built. This involves having a government committed to:

* energy independence,
* a versatile energy mix, and
* lower greenhouse gas emissions.

Allied to this political commitment, must be willingness on the part of certain governments in the EU to create a commercial environment conducive to new investment in nuclear power. The private sector is willing to invest in major projects; there is clear evidence of this. But the private sector also needs an assurance that a long-term investment will be matched by long-term government support. Government-designed mechanisms that have already been put in place to encourage investment in renewables can also do the same for nuclear. A sound case can be made for this government support. Nuclear would be helping governments to meet their Kyoto commitments, and would be making an additional contribution to national economic and environmental well-being.

Streamlined planning and plant licensing procedures will also have to be in place for power companies to start taking the road towards new nuclear investment. Companies will need to be sure of a final political decision within a reasonable timeframe.

Public support for a new reactor unit may not be a major problem if existing nuclear plant sites are used and are simply extended. In other areas, public acceptance would need to be fostered by effective public communication programmes conducted by companies and governments alike. Local communities would need to be made fully aware of:

- the economic and social benefits that would flow from the new investment,
- the true environmental impact of the new reactor unit, and
- existing and planned radioactive waste management systems.

As far as public acceptance is concerned, opinion polls in recent years have consistently shown that members of the public generally adopt a common sense approach to the use of nuclear power. The survey results do not show any evidence of massive popular opposition to nuclear, despite what the anti-nuclear groups may say. Even in countries like Sweden and Germany, the polls clearly indicate that people see no real reason to phase out nuclear.

However, the radioactive waste issue is something that must be clarified in the minds of the general public. If this is not done, people will start believing the classic argument of the anti-nuclear groups – that 'no-one knows what to do with the waste'.

The fact – as you all know – is that the nuclear industry <u>does</u> know how to manage its nuclear waste in a safe manner. The safe management of all forms of radioactive waste is a reality and has been for a long time.

The only part of the picture that is still missing involves the realisation of final storage facilities for spent nuclear fuel and for the small amount of high-level waste that remains after spent fuel reprocessing. This material is safely stored on an interim basis, but at some stage, it will have to be isolated from the biosphere permanently.

We already have the engineering techniques and the financial mechanisms to build the necessary underground repositories. But these projects must have political and public backing in order to materialise. The political process has advanced very well in Finland were national and local authorities have already agreed to accept a selected site for a final repository for spent nuclear fuel. This has given the go-ahead for site-specific research work. In Sweden, the political development of the waste issue is also well advanced and major political decisions are expected soon.

The European Commission can play an important role on this issue – in highlighting the need for national governments to press ahead with research into repository projects and public consultation procedures.

The Commission's own research shows that most EU citizens believe this is an issue that should be resolved now, and that it should not be left for future generations to deal with. We have all benefited in one way or another from nuclear technology. Therefore, we are all responsible for the waste produced, and this responsibility must be translated into policy decisions and concrete actions.

It may appear that the pathway towards nuclear new-build may be difficult and complex. But basically, if the economic need becomes strong enough, the next two decades may well see the construction of new nuclear plants in certain parts of Europe. This is assuming, of course, that nuclear is not outlawed by individual governments for purely political and ideological reasons.

This brings me to the question posed in the title of my presentation: Will reality overcome ideology? There is a persuasive argument that nuclear new-build will occur for one simple reason – economic necessity. This provides a strong basis for maintaining the nuclear energy option and the related technological know-how and infrastructure. However, because of the volatility of the political scene, nothing can be guaranteed. One can only hope that, in the long-term, a truly rational approach to energy issues will receive the appropriate public support, with voters and policy-makers acting on the basis of facts, rather than fear.

In conclusion, I am in the fortunate position of being able to end on an optimistic note. There are three main reasons for this.

Firstly, a vote last November in the European Parliament on a parliamentary report responding to the Commission's Green Paper. A paragraph in the resolution called on all EU institutions to promote a shift towards zero-carbon emission fuels for power, notably electricity generation from nuclear energy. It was recommended that this should be done by removing legislative and fiscal obstacles.

Secondly, the EU's Energy Commissioner, Loyola de Palacio, clearly appreciates the need to maintain nuclear in Europe's energy mix. She rejects accusations that she is trying to promote nuclear, arguing that its use is an issue that must be discussed in a calm and rational manner. Her position on nuclear was brought into sharp focus in a recent interview she gave to a major national French newspaper. Pointing to the positive aspects of nuclear in terms of greenhouse gas avoidance and security of supply, she said: "What alternative can you give me to nuclear. There isn't one." She went on to say quite plainly: "We cannot give it up."

The third cause for optimism is contained in the conclusions from a conference on energy and transport, held in Barcelona by the Commission's Directorate-General for Energy and Transport. One of the Commission's top officials described nuclear as "unavoidable" in the short and medium term for security of supply and climate change reasons. "Nuclear energy is coming out of its bunker."

I would agree with him entirely on this point. Nuclear is being brought out of its bunker because climate change concerns and worries about security of supply are forcing policy-makers to take the nuclear energy option much more seriously. 'Coming out of the bunker' will mean new challenges as well as new opportunities for the nuclear industry, but they are challenges that the industry will be only too delighted to take on.

Thank you very much for your attention.

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Nuclear Power in Europe: Will Reality Overcome Ideology?

Dr. Peter Haug, Secretary General,
European Atomic Forum (FORATOM)
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Overview - Political

Nuclear remains a political issue
Not a purely commercial matter

Still bound to provoke opposition, but
Not necessarily from general public

Political inertia: an inherent risk

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Overview - Business

Nuclear a highly attractive proposition:

- reliable source of baseload power
- predictable costs
- enhances energy independence
- politically correct, thanks to nuclear's 'clean air' credentials

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Climate change issue

Rejection at COP 6 in Bonn, but nuclear

- already helps reduce GHG emissions
- already helps nations to meet their Kyoto targets, and
- will continue to do so

Nuclear's role could be reassessed at a later stage

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Economic aspects

The case for nuclear underlined by:

- Californian power crisis
- revision of US energy policy
- plans for Finland's 5th reactor unit
- revived nuclear debate in the UK

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Green Paper on energy security

- Another opportunity to present the case for nuclear
- document recognises nuclear's advantages, but also
- paints a gloomy picture of nuclear's future prospects

However, no countries are rushing towards a nuclear phase-out

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Swedish phase-out

Highlights benefits of nuclear:

- greater security of energy supply
- less dependence on energy imports
- less air pollution

A warning signal to other countries considering a reduced role for nuclear

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Green Paper: What next?

Commission should:

- assess nuclear's role realistically
- recognise nuclear's important benefits
- avoid energy 'discrimination'

Europe cannot afford to play political games with its energy policy

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Nuclear's present status

- 35% of the EU electricity mix
- a solution we have here and now
- ready and waiting for further deployment

Future growth possible - where there is a clear need for new baseload capacity

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Reasons for a nuclear renaissance

– Growing realism about how we should meet future energy needs

– Desire to 'get back to basics'

– Need for greater stability and predictability

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A nuclear new-build scenario

- Predicted increases in demand
- Need to replace ageing capacity
- Pressure to meet environmental targets
- High gas prices
- Need to lower import dependency

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Creating the right conditions

Longer-term thinking

Resistance to import dependency

Political commitment to:

- greater energy independence
- versatile energy mix
- lower GHG emissions

Streamlined planning & licensing procedures

Public awareness, acceptance and support

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Main obstacle: Radwaste issue

- Greater public awareness is essential
- Safe management of all forms of radwaste is a reality
- Solutions are already in place or awaiting implementation
- Political and public support for repositories can be won through consultation and consensus

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The way ahead...

- May be difficult and complex
- Nuclear new-build will happen
  - if the economic need is great enough
  - if nuclear is not rejected for purely ideological reasons

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Reasons for optimism

- European Parliament resolution underlining the important role of nuclear
  'shift towards zero-carbon emission fuels for power, notably electricity generation from nuclear energy'
- Realistic stance taken by EU Energy Commissioner
- New perception that nuclear 'is coming out of the bunker'

Status and Perspectives of Nuclear Power in Russia

Prof. Leonid Bolshov, Director, IBRAE RAS

Dr. Alexandr Vatulin, Director, VNIINM

35th Annual JAIF Conference, April 22-24, 2002

1

Nuclear Safety Institute Russian Academy of Sciences

IBRAE RAS

- Severe accidents analysis (MELCOR)
- Safety assessments (ISAs of Kola, Novovoronezh, Kursk NPPs;
  PSA methodology; regulatory requirements (Pu disposition)
- Radiological effects of Chernobyl accident

2

IBRAE RAS

- Emergency response
- Risk management of radwastes and nuclear spent fuels
- Ecology
- Terrorism (radiological and nuclear)
- Innovative technologies (The Initiative of Russian President)

3

All-Russian R&D Institute of Inorganic Materials (VNIINM)

- VNIINM is lead R&D Institute in the Russian nuclear industry on nuclear material science and technology
- Fuel elements designed by VNIINM are used in all VVER, RBMK, BN (LMFBR) and research type reactors in the CIS and Eastern Europe
- The only CIS spent fuel reprocessing plant (Mayak) uses technologies developed by VNIINM

4

VNIINM

- R&D studies and fabrication technologies of nuclear fuels, fuel elements and reactor structural materials
- Nuclear spent fuel and radwaste reprocessing technologies

5

2000 year

«Nuclear Power Development Strategy in Russia in the first half of XXI century»

The Initiative of President of Russia at the UN Millennium Summit

«Energy strategy of Russia for the period up to 2020»

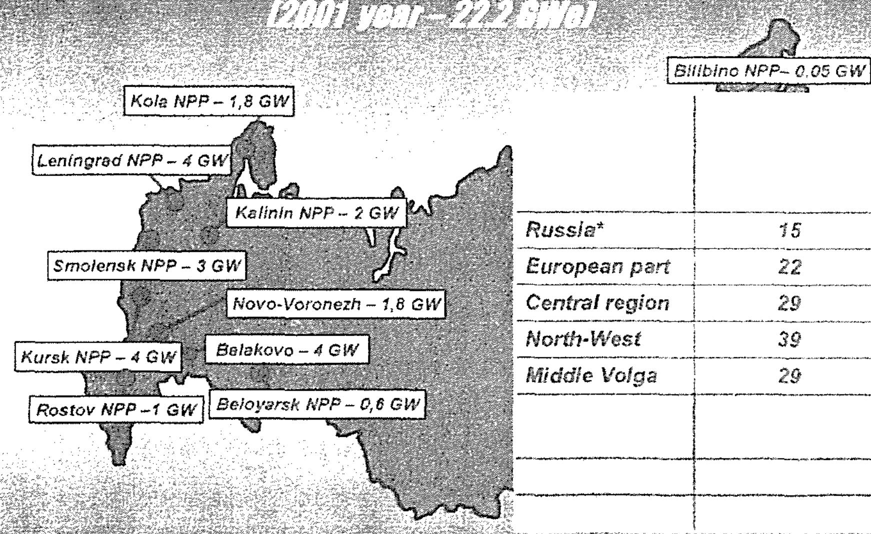
6

THE NEW POWER POLICY

- Independence from exhaustible natural resources
- Gradual increase of the role of renewable energy sources in the fuel and power balance of the country
- Ecological acceptability of power industries
- Saving of organic raw resources for other applications
- Systematic reduction of the share of raw resources in the national export
- Self-financed replacement of aged plants
- Export financing of gas substitution
- State regulation of power market reforms
- Bringing Russian legislature in compliance with her strategi interests

7

Location of Operating Nuclear Power Plants in Russia (2001 year – 22.2 GWe)



Russia*	15
European part	22
Central region	29
North-West	39
Middle Volga	29

Total NPP capacity – 11.5% of the electricity generating capacities in Russia

8

Electricity Generation at NPPs in Russia

In 2000 **129** TWh was generated – Up by **7.5%** vs. 1999

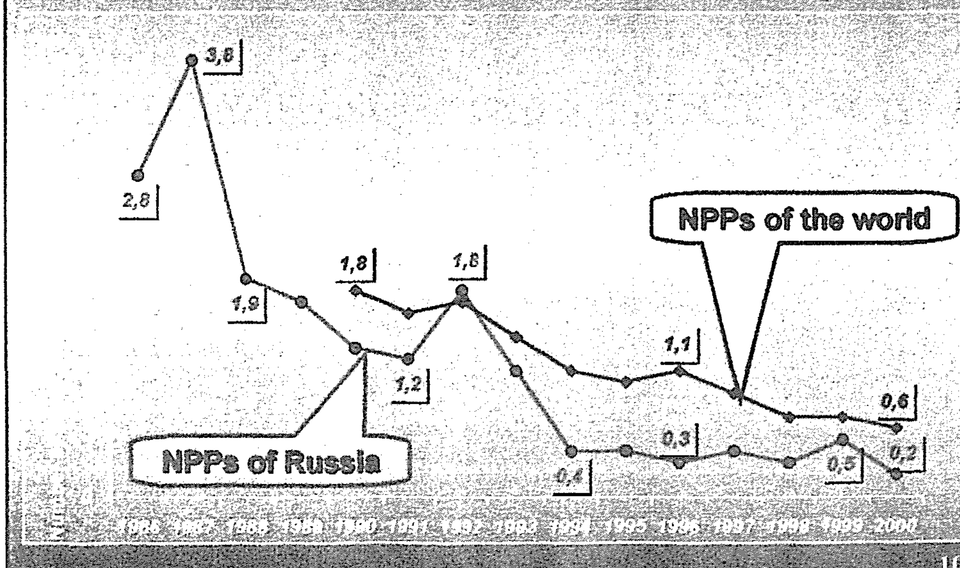
In 2001 **137** TWh was produced – Up by **6%** vs. 2000

NPP share in the electricity generation:
in 1999 – **14.2%**; in 2000 – **15%**; in 2001 – **15.5%**

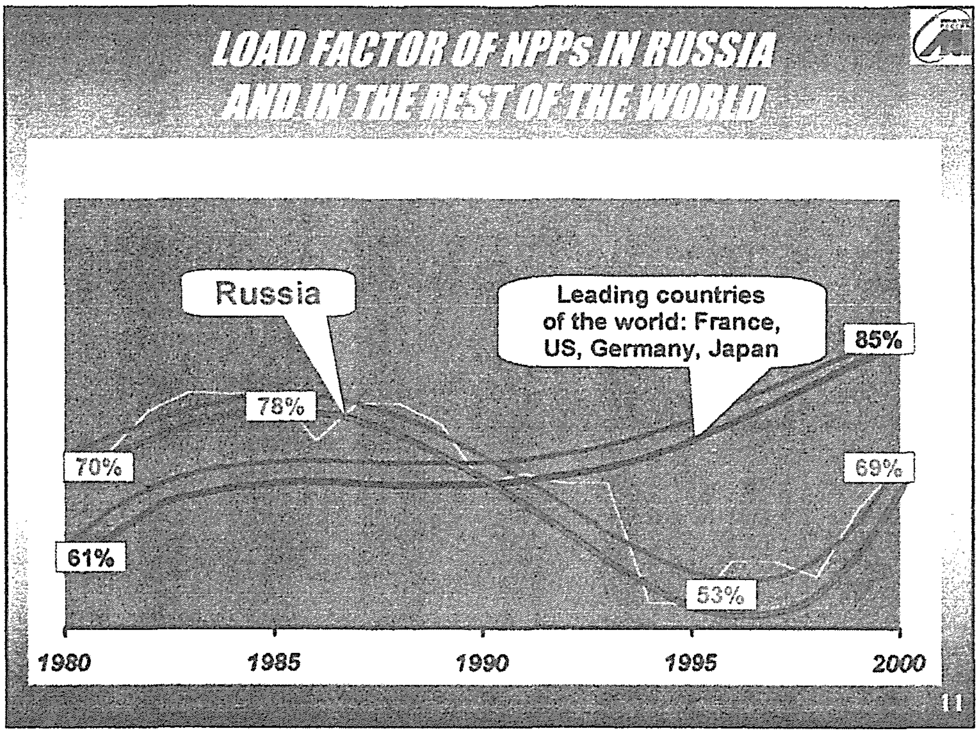
In 1999–2000 **~50%** of the electricity demand growth in Russia was met by NPPs

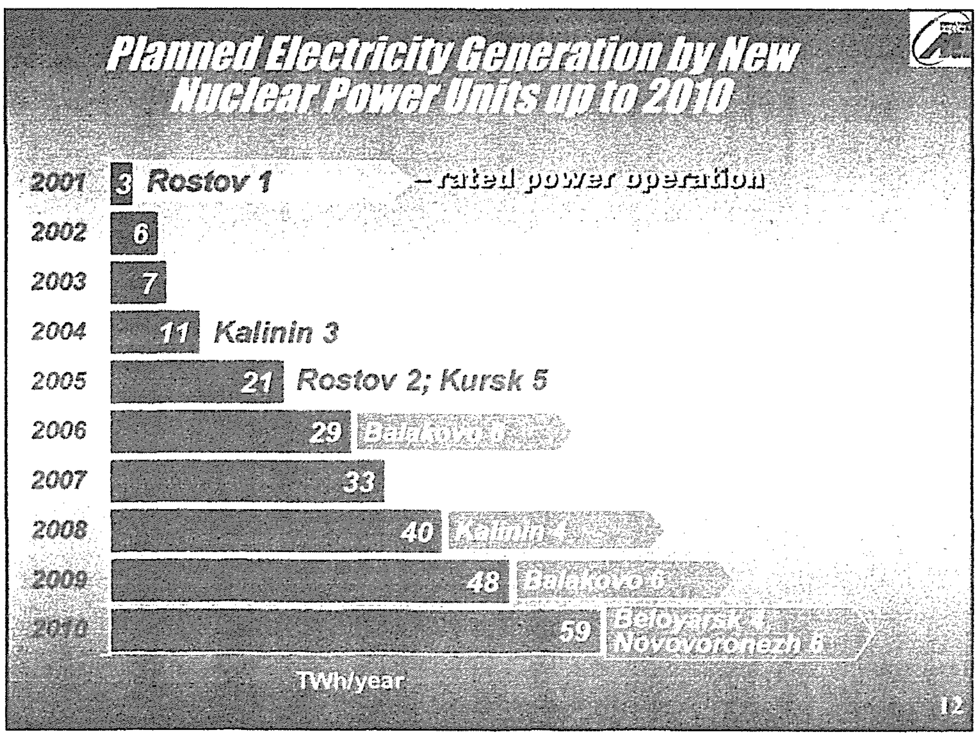
9

Safety Indicators: Automatic Reactor Trips
[source: WANO]



10


LOAD FACTOR OF NPPs IN RUSSIA AND IN THE REST OF THE WORLD
Russia
Leading countries of the world: France, US, Germany, Japan
85%
78%
70%
69%
61%
53%
1980
1985
1990
1995
2000
11

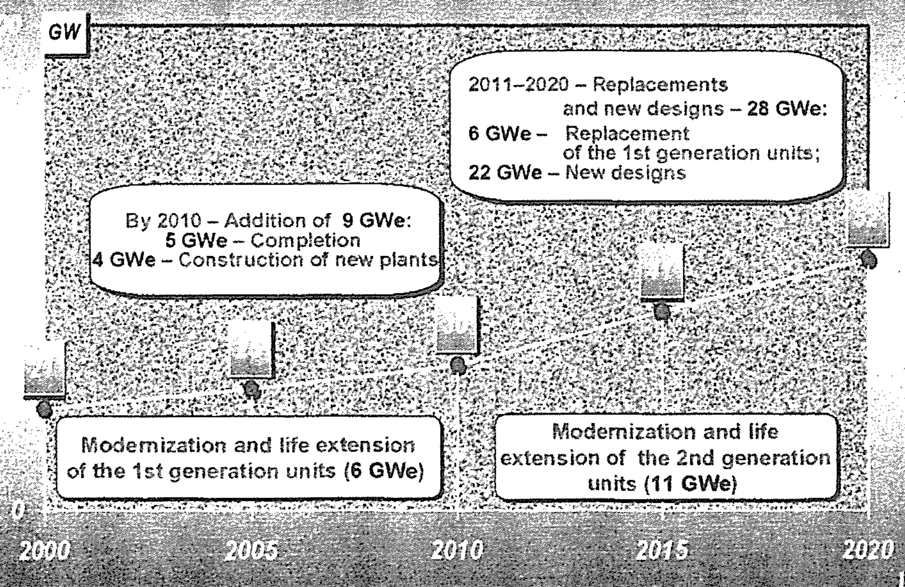

Planned Electricity Generation by New Nuclear Power Units up to 2010
2001 3 Rostov 1 – rated power operation
2002 6
2003 7
2004 11 Kalinin 3
2005 21 Rostov 2; Kursk 5
2006 29
2007 33
2008 40 Kalinin 4
2009 48 Balakovo 6
2010 59 Beloyarsk 4, Novovoronezh 6
TWh/year
12

Targets of the Nuclear Power Development Strategy in Russia

Development indicators	In 2010	In 2020
NPP installed capacity growth, %	140	240
NPP electric output growth, %	160	260
Gas (Bln. m^3/year) replaced by added nuclear capacities	25	63
NPP share in electricity production, %	20	28
Same in the European part of Russia, %	27	37

13

Russian Nuclear Power Development Programme



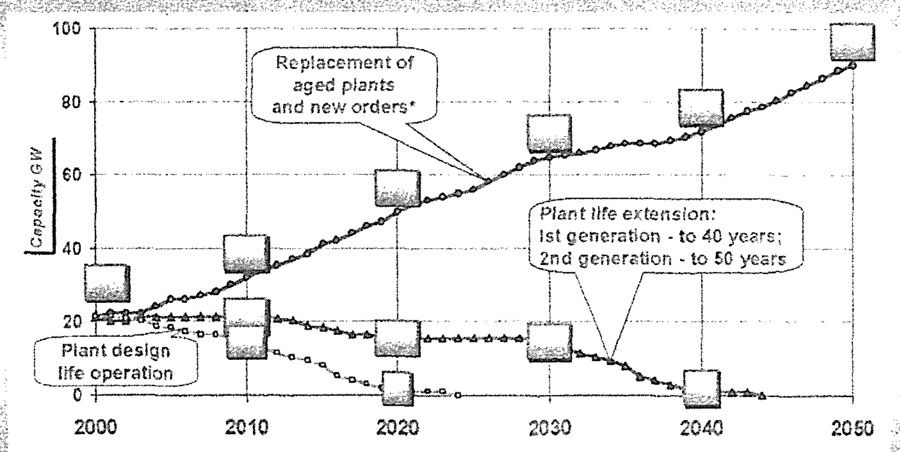
14

NUCLEAR POWER PLANT LIFE EXTENTION TARGETS

- Design life - 30 years
- Life extension to 40 years for the 1st- generation power units
- Life extension to 50 years for the 2nd- generation power units

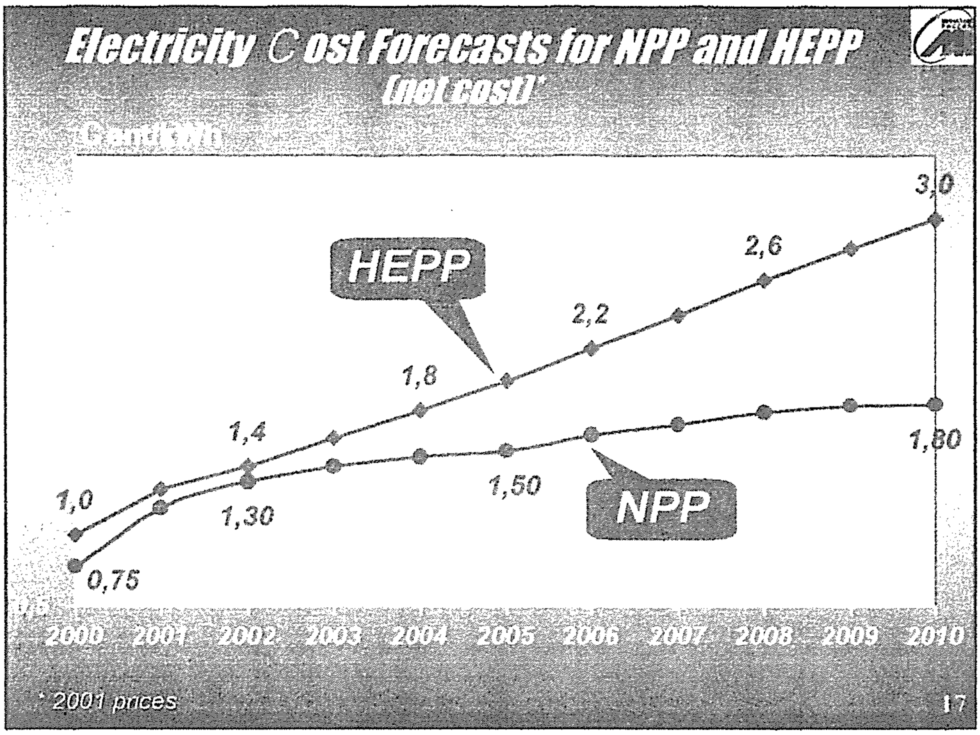
15

NPP capacity dynamics up to 2050

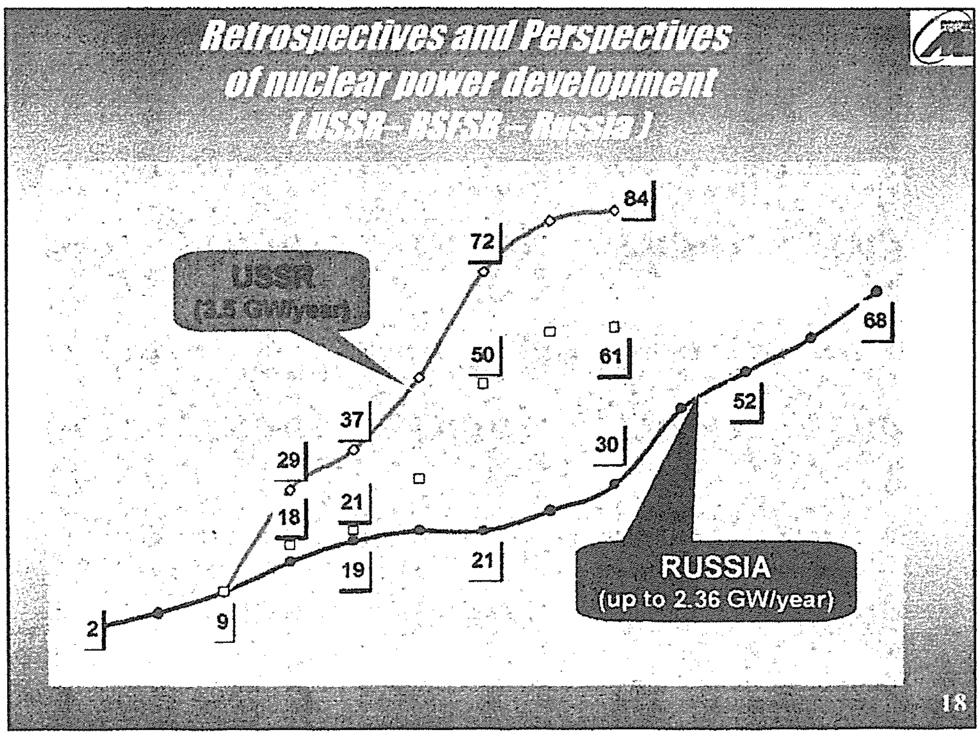


* The upper curve begins from the moment of 1 cent/kWh tariff full payment

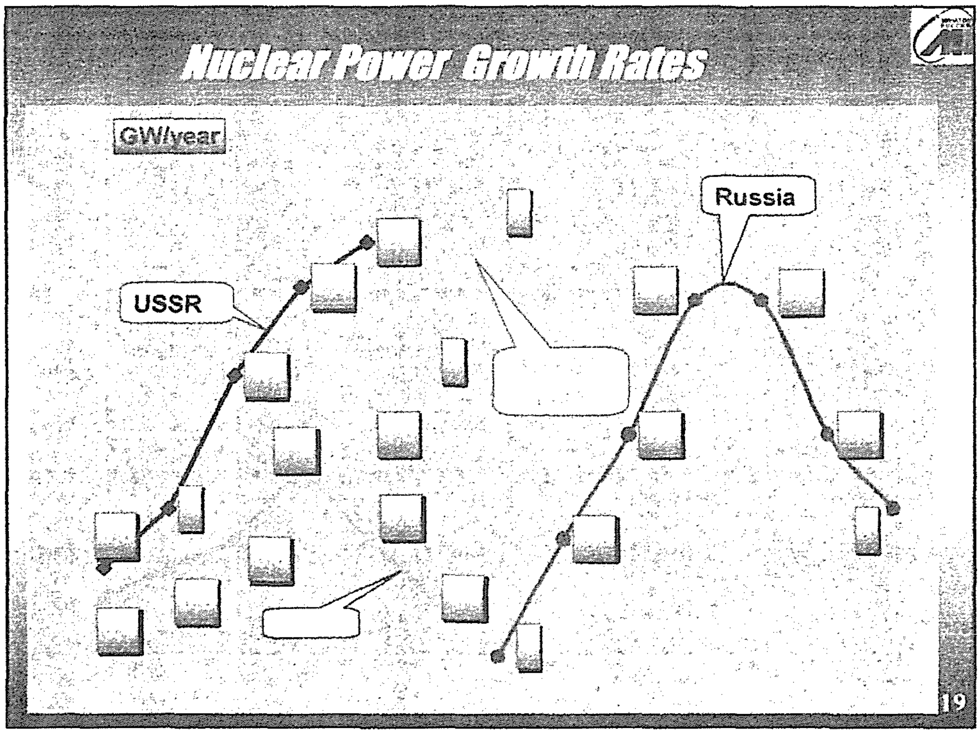
16

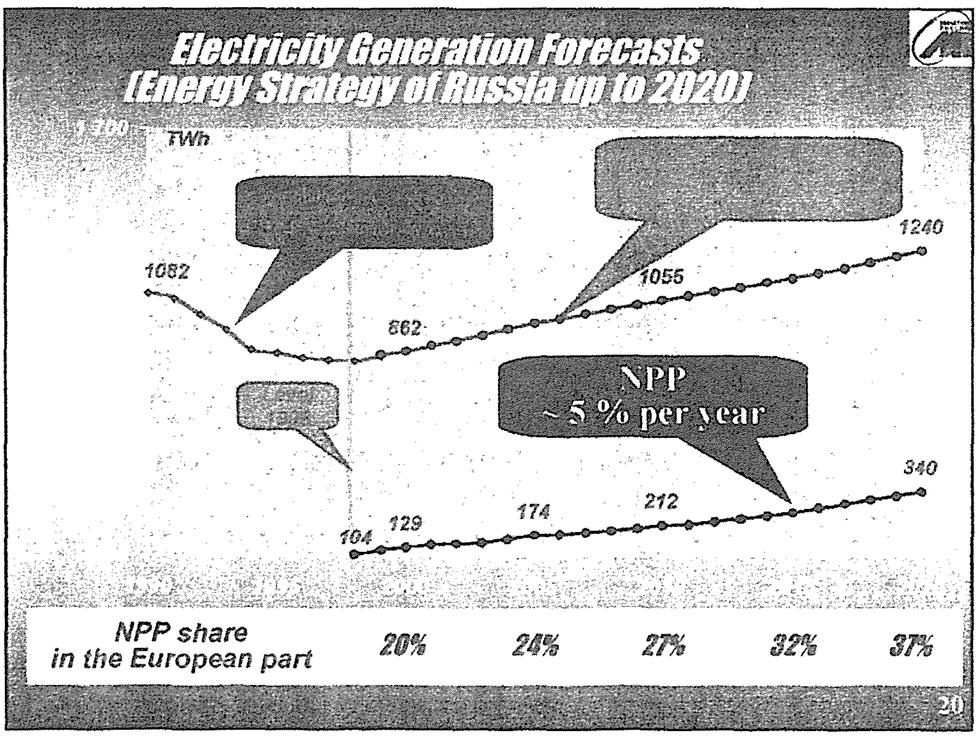


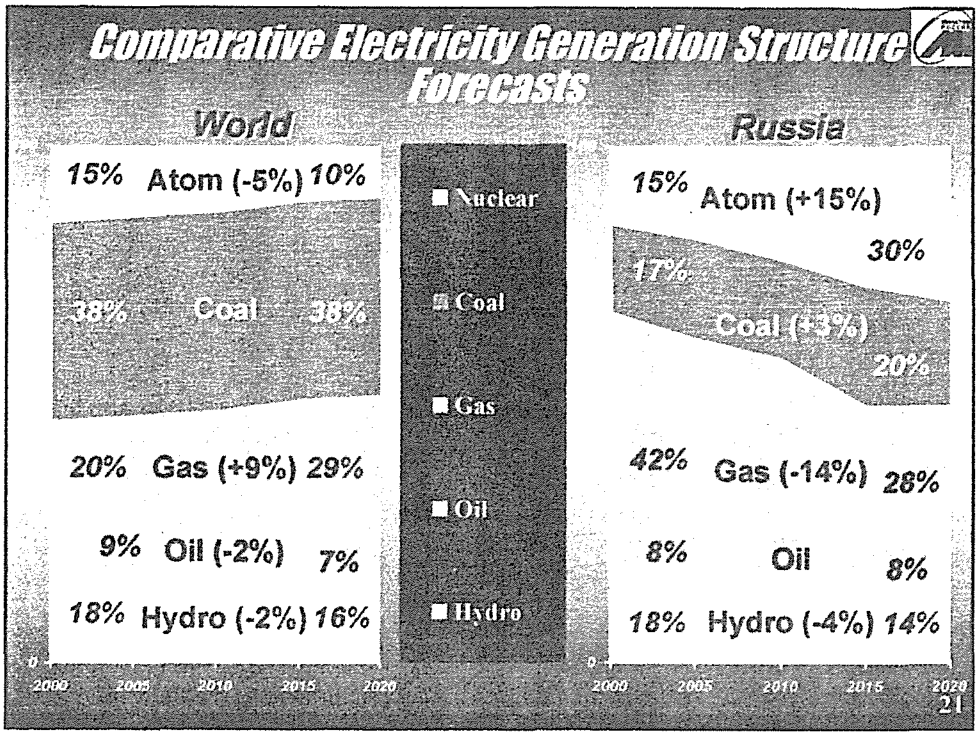
Electricity Cost Forecasts for NPP and HEPP
(net cost)*
HEPP
NPP
1,0
1,4
1,8
2,2
2,6
3,0
0,75
1,30
1,50
1,80
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
* 2001 prices
17



Retrospectives and Perspectives
of nuclear power development
(USSR – RSFSR – Russia)
USSR
RUSSIA
(up to 2.36 GW/year)
2
9
18
29
37
72
84
50
61
21
19
21
30
52
68
18


Nuclear Power Growth Rates
GW/year
USSR
Russia
19


Electricity Generation Forecasts
(Energy Strategy of Russia up to 2020)
TWh
1082
862
1055
1240
NPP
~ 5 % per year
104
129
174
212
340
NPP share
in the European part
20%
24%
27%
32%
37%
20



Electricity Production Forecast (up to 2020)

- World – Gas share growth (from 20% to 30%) with a coal share stable (about 40%)

Russia – Nuclear share growth (from 15% to 30%) with a gas share decrease (from 40% to 30%) and a coal share stable (20%)

22

ISSUES OF ELECTRICITY GENERATING INDUSTRIES

SYSTEM CRISIS:

- Wear-and-tear of main production assets
- Lack of investment funds
- Inefficient use of fuel resources
- Structural imbalance of fuel and energy resources
- Growth of electricity demand and the need to build new power plants

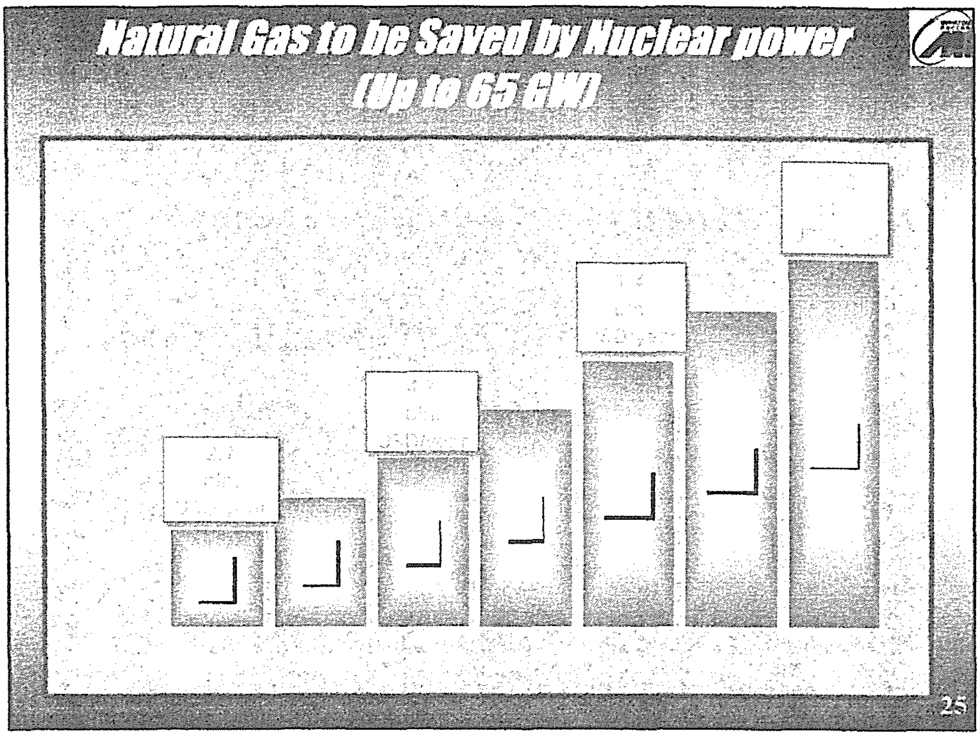
To a great extent the issues could be solved by a priority development of nuclear power industries

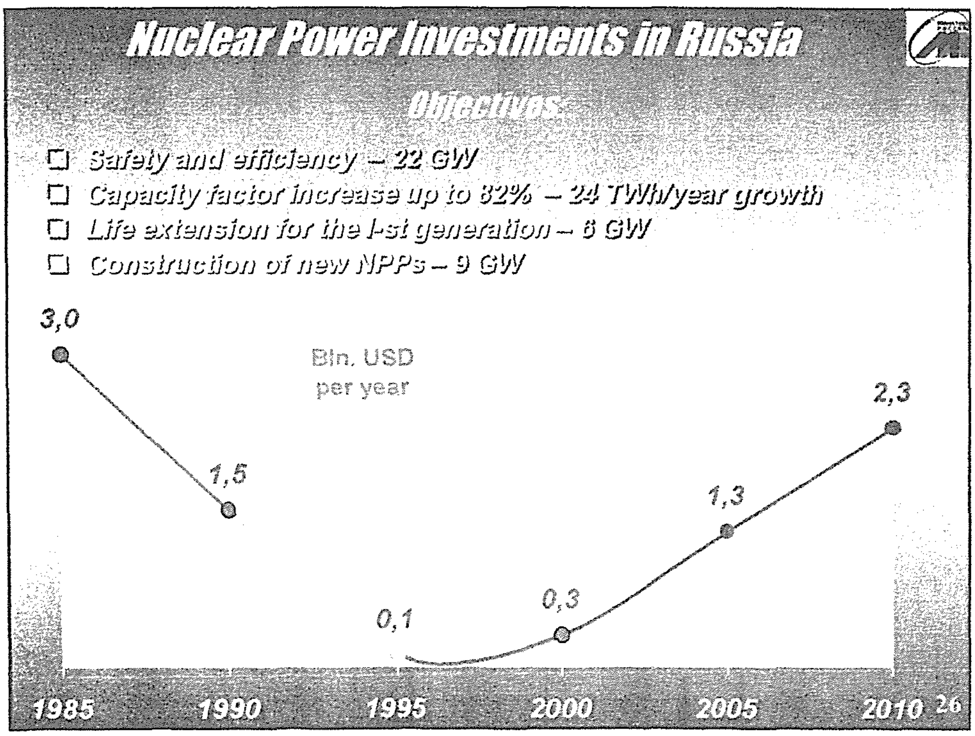
23

Sources of Financing

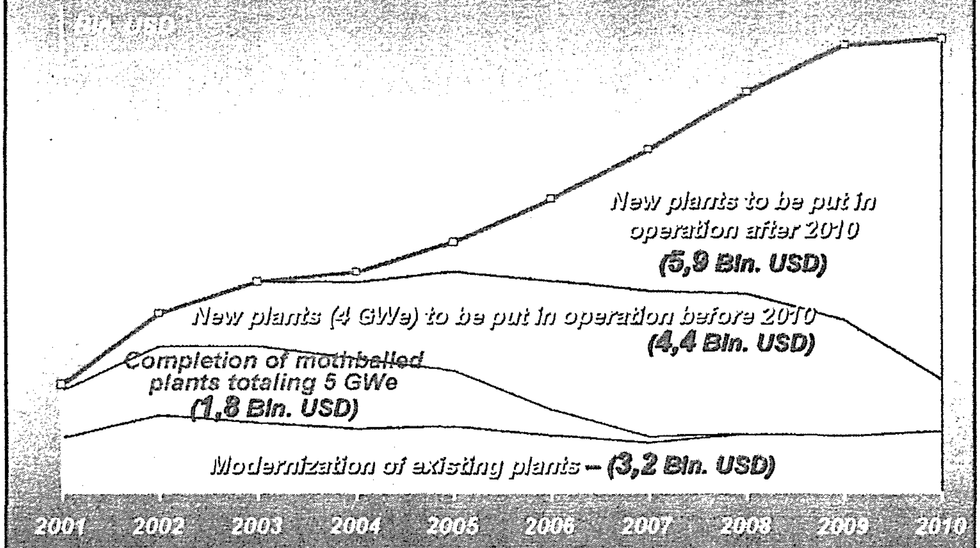
- Revenues from selling electricity
- Extra-budgetary investment funds
- Revenues from spent nuclear fuel management services
- Loans (guaranteed by the State or commercial)

24


Natural Gas to be Saved by Nuclear power
(Up to 65 GW)
25


Nuclear Power Investments in Russia
Objectives:
Safety and efficiency – 22 GW
Capacity factor increase up to 82% – 24 TWh/year growth
Life extension for the I-st generation – 6 GW
Construction of new NPPs – 9 GW
Bln. USD
per year
3,0
1,5
0,1
0,3
1,3
2,3
1985
1990
1995
2000
2005
2010
26

Nuclear Power Investment Structure



27

Investment Effectiveness

Achievement of higher efficiency of NPPs in operation *(equivalent to adding 3.5 GWe by 2006)*	+ 24	< 90
Modernization and life extension *(6 GWe by 2005)*	35	70
Completion of mothballed power units *(5 GWe by 2007)*	+ 37	400
Construction of new plants *(4 GWe by 2011)*	+ 22	850

28

The Initiative of President of Russia (Voiced at the Millennium Summit)

Aimed at pooling motivated world resources to provide the mankind with abundant energy in the long term in a sustainable, economic (competitive), safe, ecologically clean and proliferation resistant way.

Two stages of nuclear power development:

- Stage 1 (on-going) – evolution improvements on the basis of proven nuclear reactor and fuel cycle technologies
- Stage 2 (up-coming) – R&D and introduction of innovative nuclear technologies meeting the requirements above and most of the world electricity demand growth in the 2nd half of XXI.

29

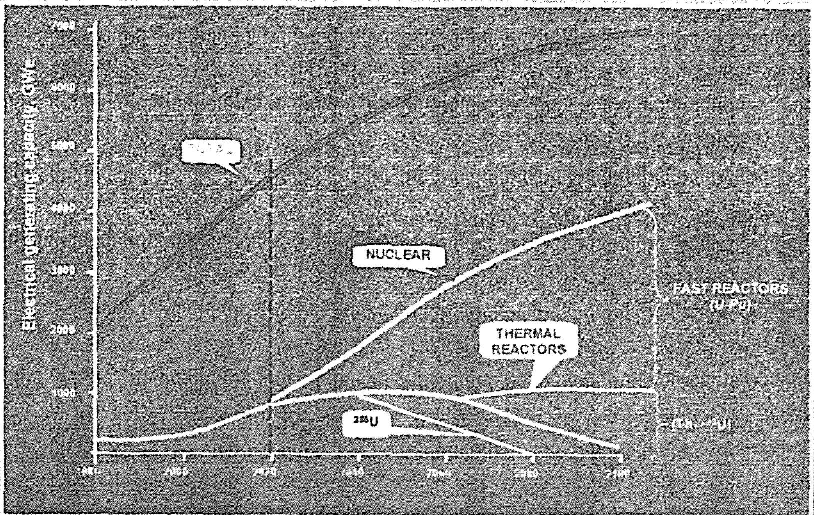
The Initiative of President of Russia Stage 1

- Reduction of nuclear electricity costs
- Plant life extension
- Operational safety upgrades
- Spent fuel and radwaste management
- Non-proliferation

nuclear-powered transport systems

30

Tentative Scenario of Nuclear Capacity Growth with Fast Reactors



37

WHAT ARE WE DISPUTING ABOUT?

	WORLD			RUSSIA		
	Reserves S, GW·year	Utilization rate I, GW	Exhaustion time T, year	Reserves S, GW·year	Utilization rate I, GW	Exhaustion time T, year
Oil				10000	400	20-30
Gas				46000	550	80-90
Coal				110000	170	600-700
Nuclear fuel for thermal reactors				9000	45	200
Σ				175000	1200 (1400)$_{50}$	150 (120)
Nuclear fuel for fast reactors				1500000	1200 (1400)$_{50}$	1300 700

38

Nuclear Power from the View Point of an Environmentalist

by Bruno Comby, President of EFN [1]

> "I personally believe that mankind needs nuclear energy. It must be developed, but with absolute guarantees of safety."
>
> *ANDREI SAKHAROV* [2]

Today, many environmental organizations oppose nuclear energy. They propose many reasons to explain why, according to them, nuclear energy would be dangerously unsafe, unclean, anti-democratic, and should be considered as an energy with no future.

However, as an environmentalist dedicated since 20 years to promoting a better life-style and protection of the environment, and with some knowledge in the field of energy, I propose a new view point, based on solid scientific and environmental facts, rather than on irrational dogmas or political agendas, which shows that, for environmental reasons, well built and well-operated nuclear energy is in fact very ecological and can be considered as a central pillar for the satisfaction in a clean manner of the planet's energy needs, that is for creating or maintaining peace and an acceptable life-style for all inhabitants of the planet Earth, and especially to face the thirst for energy of industrial modern countries while saving as much as possible theuse of fossile energies for other uses than just burning it and for the development of the poorer countries in Asia, South and Central America, and Africa, until they, themselves will access a level of industrial and financial wealth sufficient to access the use of clean nuclear energy.

While many environmental groups continue to criticize nuclear energy, and sometimes influence the political decisions of some countries, this new environmental view point leads to the conclusion that nuclear contrary is in fact the safest and cleanest energy available, and will be absolutely necessary to satisfy the planet's energy needs in the 21st century.

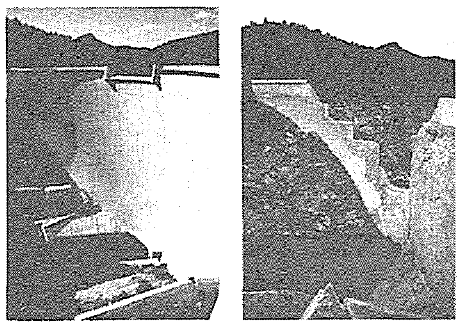
The world's population is growing and the planet's energy needs are too

Today 25% of the world's population in the richest countries, consumes 75% of the energy. We can only hope that the on-going development of developing countries will continue. The world population is increasing constantly and can be expected to perhaps double by 2050. These two effects (development of developing countries, and increase in world population) are going to dramatically increase the global consumption of energy, the use of fossile fuels, and the production of carbon dioxyde rejected in the atmosphere. The world is thirsty for more energy and this is inevitable, even if developed countries were capable of reducing their energy consumption significantly.

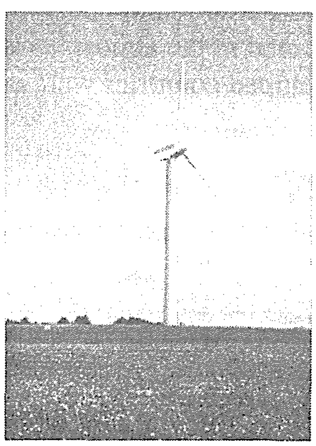
The different types of energy available

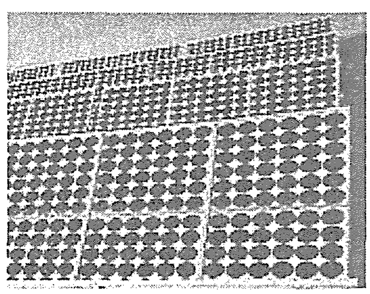
Fossile energies (oil, ags, and coal) are the most consumed energy today. However they massively contribute to the greenhouse effect, especially coal, the only one of the three which has reserves extending out to face our needs throughout the coming century. Because they are mssively polluting the atmosphere, and/or will become scarce in a few decades, fossile energies will not, alone, be capable of facing the growing needs of humanity. The top priority should be to reduce our dependance on these energies.

Hydro-electricity is a renewable energy, but there are only a limited number of sites, the potential is therefore very limited in the future (the most interesting sites are already equipped in most countries). Hydro-electricity can help, and should be encouraged, to produce a certain amount (unfortunately limited) of energy in the future, but will not solve the problem alone. Due to the increase in global consumption, and even if we take in account the development of all new possible sites, the share of hydraulic energy is expected to decrease in the 21st century. Hydraulic dams also have a strong impact on the environment (flooding entire valleys) and are not without risks of major accidents. Although nuclear energy and hydraulic dams have produced similar amounts of electricity in the 20th century, dam bursts in the past have killed much more than nuclear energy. For example a single dam burst in Malpasset, France (December 2nd, 1959), created a giant 40 meter high wave that killed 429 persons in a few minutes (10 times more than the Tchernobyl accident did in 16 years) entirely destroying the village of Malpasset, and flooding the city of Frejus 30 km downstream.



Other renewable energies (solar, wind, etc.) can contribute to some (rather small) extent, and they should be encouraged, but they are too "soft" and "diluted" and "not constant" over time, to contribute significantly. They produce watts or kilowatts, while the population is consuming gigawatts or Terawatts. When a global life cycle analysis of different types of energy production systems is made, solar and wind are largely disqualified due to the amount of energy and construction materials that would be needed to develop large surfaces of such installations (not to speak of the effect on the landscape). For domestic water heating, however, sun heaters by direct circulation of water in pipes exposed to the sun are quite OK. For tropical and some of the poorest countries such as Madagascar, some simple solar heaters could also help to slow down deforestation and the burning of wood just for cooking. Renewable energies can be well adapted for low temperature thermic energy needs (typically cooking or domestic hot water), but they are not very interesting (and would not be ecological) for the fabrication of electricity to be distributed on the grid.





Renewable energies other than hydraulic produce only small amounts of non-constant energy. The only alternative to produce significant amounts of clean energy is nuclear energy.

Radioactivity in nature

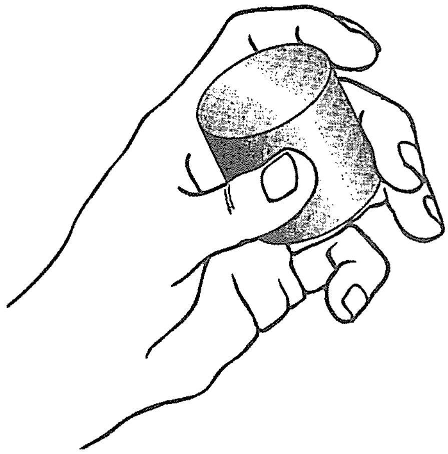
Radioactivity exists everywhere in nature. We are exposed to intense and continuous natural radiation coming from the sun, cosmic radiation (from stars other than the sun), telluric radiation (from the ground), and even to the internal radiation of our own body (about 10 000 Becquerels for an average individual). The amount of natural radioactivity can vary very much from one region to another. The average background radiation on Earth is by the order of 0.2 microSv/h, or about 2 mSv/year. But in some areas such as Guarapari in Brazil, the radiation can be locally as high as 40 microSv/h (400 times more than the average background radiation). In Ramsar, Northern Iran, some people are exposed to natural radioactivity at the level of 260 mSv/year (compared to an average background radiation of 2 mSv elsewhere). No adverse effect whatsoever of such high natural background level of radioactivity has ever been demonstrated (if not some positive effects). Even plutonium exists in nature, where it appears by the effect of cosmic radiation on the U 238 contained in the Earth's crust. If the natural levels of radiation (even the highest ones) do not seem harmful in any way, however, we must be careful to protect the population and nuclear workers from the risk of exposure to very high levels of radioactivity.

The high density of nuclear power

One gram of uranium or plutonium or thorium yields as much energy as one ton of oil. Nuclear energy is therefore much more concentrated and powerful, by a factor of one million, than chemical energy. This is often seen as a danger, but this "**factor one million**" also implies considerable ecological benefits : to produce the same amount of energy, one million times less raw material (fuel) is required, and the volume of the waste produced is by order of one million times smaller, therefore much easier to handle, reprocess and deal with.

Nuclear waste

Nuclear waste is produced in very small amounts (compared to fossile energies), and they are, by definition, self-degradable over time, which is not the case of toxic stable chemical substances. Because of the small volumes of these wastes, they can be easily confined and stored, rather than being rejected into the biosphere or oceans. These waste can and should be reprocessed, and the ultimate waste (only about 3% of the used fuel for PWR's) can than be safely stored underground in a well chosen safe place. The natural reactors at OKLO (Gabon) which have been functioning two billion years ago, show us that, even when the waste is not confined, the heavy metals and waste elements of the nuclear reaction hardly migrate at all in the soil, even when no special protection or confinement system has been installed. Ethically, we must dispose these small volumes of initially highly radioactive waste in a safe way, and morally it is our duty that this be done by the same generation who built and operated the NPP's and benefited from it's electricity. For ecological reasons, used nuclear fuel should not be considered as waste, and should be reprocessed, as is the case in France, Great Britain, Russia, and Japan.



This cylinder represents the volume of high-level vitrified long-lived radioactive waste resulting from the nuclear fuel that would produce enough electricity to meet the needs of a typical family in all-electric housing with modern conveniences (heating, cooking and other household appliances) for about 30 years. These wastes are not discharged into the environment, but are carefully confined. They are harmless to man and to the environment if they are buried deep under-ground. Nuclear waste represent only a very small volume and their radioactivity decreases very rapidly in the first years.

The example of France

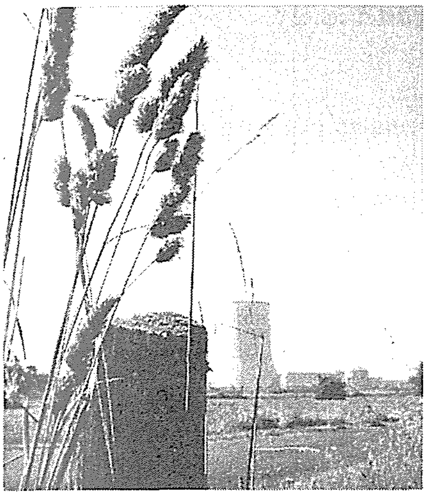
I am very proud as an environmnentalist to be a citizen of the country with the highest share of nuclear electricity (80% of the French electricty production is nuclear), because, in great part thanks to our NPP's, we are one of the cleanest of all developed countries. A French citizen rejects into the atmosphere about half the amount of carbon dioxyde as a German or Danish citizen (their windmills don't produce enough energy to significantly reduce their emissions), and three times less as American citizens. Every year, France's 58 nuclear reactors avoid rejecting more than 200 million tons of CO2 into the planet's atmosphere. France shows to the world to what great extent developing nuclear energy can contribute to protecting the environment.

Informing the public

There are still many myths about nuclear energy. It is essential for the future, and for a cleaner planet, to better inform the public, and much remains to be done in this area. Environmental organizations can and should play a major role in this regard, because they are the most appropriate organizations when it comes to speaking about the environment. However this information should be done in a complete and honest manner, not by manipulating the public opinion with scary highly unrealistic scenarios as some anti-nuclear organizations often do. Now the time has come, and it is a vital issue for humankind, to, as Prof Akimoto nicely writes " dispel the many myths surrounding atomic energy that have been created by international intrigue and power struggles, individual ambition and sensationalism, and release ... (citizens) ... from the misunderstandings and confusion created by scientists and statesmen with narrow views."

Conclusion

Well built and well-operated nuclear reactors are a very safe and very clean source of energy for the future. We absolutely need to be very cautious about building safe nuclear reactors, and avoiding exposure to very high radioactivity or to prevent any military use of nuclear energy, but, this being said and done, we need not be afraid of relatively small (that is comparable to natural quantities) of radioactivity which have always been bathing the whole of the universe since it exists. As explains James Lovelock, author of the Gaia Theory, one of the main founders of environmentalism " Life began nearly four billion years ago under conditions of radioactivity far more intense than those that trouble the minds of certain present-day environmentalists. Moreover, there was neither oxygen nor ozone in the air so that the fierce unfiltered ultra-violet radiation of the sun irradiated the surface of the Earth. We need to keep in mind the thought that these fierce energies flooded the very womb of life. I hope that it is not too late for the world to emulate France and make nuclear power our principal source of energy. There is at present no other safe, practical and economic substitute for the dangerous practice of burning carbon fuels." (4)



The Civaux nuclear power plant in France.

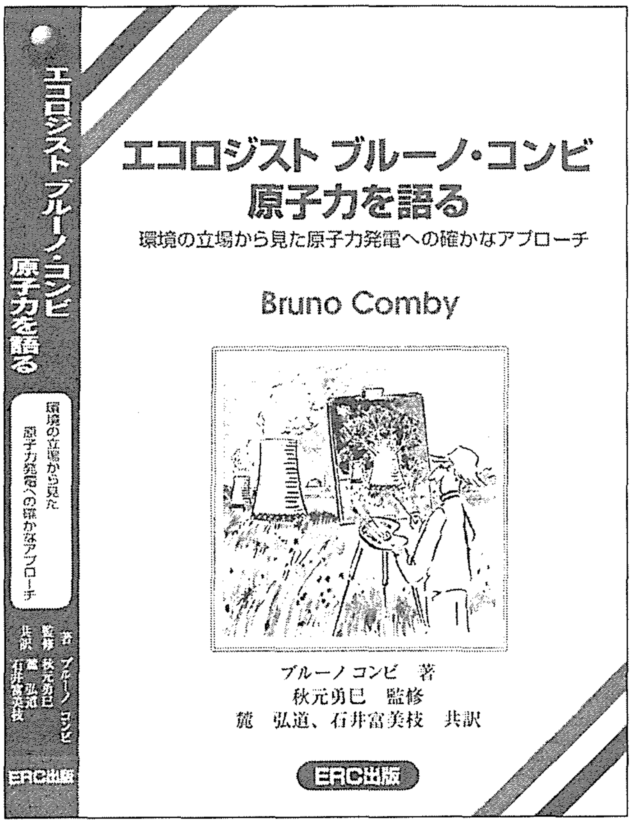
NOTES :

(1) EFN : Association of Environmentalists For Nuclear Energy - www.ecolo.org - EFN is a non-governmental, non-political international organization gathering more than 5000 members and supporters in more than 40 countries.

(2) Andrei Sakharov, in his foreword to "The Truth about Chernobyl," by Grigori Medvedev, translated from the Russian by Evelyn Rossiter, I. B. Tauris & Co Ltd, London - New York (May 1989).

(3) Pr. Yumi Akimoto, in his introduction to the Japanese edition of the book "Environmentalists For Nuclear Energy", by Bruno Comby, recently published in Japan by ERC SHUPPAN Publishing Co., April 2002.

(4) Pr. James Lovelock, in the book "Environmentalists For Nuclear Energy", TNR Editions, Paris, 2001 (recently published in Japan by ERC SHUPPAN Publishing Co., April 2002).


エコロジスト ブルーノ・コンビ
原子力を語る
環境の立場から見た原子力発電への確かなアプローチ
Bruno Comby
ブルーノ コンビ 著
秋元勇巳 監修
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JAPAN ATOMIC INDUSTRIAL FORUM ANNUAL CONFERENCE
SAITAMA CITY, JAPAN
APRIL 22, 2002

"U.S. Energy Policy and the Nuclear Renaissance"

Good morning ladies and gentlemen. I am delighted to be back in your beautiful country. We have just completed our annual Cherry Blossom Festival in Washington, D.C., commemorating the generous gift of the Japanese government that has so beautified our Nation's Capitol. I am pleased to see that it is an equally lovely season of the year here.

Two years ago, I was honored to be able to address my Japanese nuclear industry colleagues at your annual conference. Many of you may have been in attendance. I told that audience that the U.S. nuclear industry had achieved unprecedented levels of safety, reliability and operating efficiency during the 1990s. I offered some statistics to support my statements, and I predicted even brighter days ahead.

I am pleased to say that the U.S. nuclear industry has more than justified my optimism. Every performance and safety category I cited two years ago is even more improved...the support for nuclear power in U.S. energy policy is even stronger...and the issues that our critics would like to use to limit the role of nuclear power in America's energy future – such as the Yucca Mountain used fuel repository -- are closer to resolution.

We are in every sense experiencing a nuclear renaissance in the United States. Nuclear energy is continuing to prove its tremendous value both to our environment and to our economy. Support for nuclear energy among U.S. government officials and the general public remains high, despite the security concerns raised after the September 11 attacks. We have been very successful in our efforts to assure the public that our nuclear facilities are safe, robust and well protected. I will discuss security further in a few minutes.

The U.S. nuclear industry's outstanding record of safety, reliability and production has created this nuclear renaissance we are now experiencing. In fact, it is the unparalleled performance of the industry in these fundamental areas over the last decade that forms the basis for the future of the U.S. industry.

[OUTPUT SLIDE]

When I was here two years ago, I said that nuclear output was up about 8 percent in 1999, to a record total of 728 billion kilowatt-hours. Production rose further in 2000, and we just got the results of the U.S. industry for 2001, and found that production had risen still further, to yet another record – 767 billion kilowatt-hours. We like to say that nuclear productivity has risen 33 percent since 1990 – and added the equivalent energy to the grid of 24 new nuclear plants.

(CAPACITY FACTOR SLIDE)

Two years ago, I also told you that the average capacity factor of all U.S. reactors reached a record level of nearly 87 percent in 1999. Final numbers for last year show an average of about 91 percent – another new record. The last decade has seen significant achievements in performance that have given our industry considerable reason for pride.

(COMPARATIVE SAFETY SLIDE)

This outstanding performance is largely a result of the industry's focus on safety at all of our facilities. Time and time again we have seen that the safest plants are the most efficient. Safety is ingrained in the behavior of every employee at every nuclear facility in the country.

This slide shows comparative data for industrial safety, and you can see that it is safer to work in a nuclear plant than in an office. Not because a nuclear plant is inherently safer than an office. It isn't. But because of the attitudes and continued focus on safety of the people who work at nuclear plants.

(PRODUCTION COST SLIDE)

Increased productivity and a focus on safety have dramatically lowered nuclear production costs in the U.S. In 1999—the latest year for which we have complete comparative data—nuclear energy's production costs were 1.83 cents per kilowatt-hour, well below the costs of competing fuels. Production costs include operations, maintenance and fuel. In 2000, we continued to lower the bar, at 1.74 cents per kilowatt-hour, and we expect to beat that again when the latest complete year's data come in.

I might add that these are industry averages, and our top quartile plants are much lower, averaging production costs of about one-cent per kilowatt-hour.

There is an obvious question, with average capability factor so high, and costs dropping so low – is this level of performance sustainable? The answer to that question, also, is yes! Not only is the level of performance sustainable, but there's a realistic prospect for further improvement.

(SHIELD SLIDE)

Another obvious questions presents itself in the wake of the tragic events of September 11. Despite the excellent performance, and the economic and environmental advantages, is nuclear energy in the U.S. in danger of being curtailed or shut down as a perceived target of terrorism?

No, we are not. Since that date, NEI has coordinated industry efforts to enhance security and safety, to allay public fears and to prevent ill-considered actions by our government.

U.S. nuclear plants have been at the highest level of alert since September 11. As you know, our plants are robust physically and are well protected by highly trained and well-armed security forces of over 5,000 officers.

We have been working closely with government at all levels -- including the new Office of Homeland Security – to coordinate the development of a seamless responsibility for security among local and state law enforcement, the private sector, and the military, if necessary. Resolution of the security issue has taken a lot of time, and there remains work to be done, but our latest surveys show continued strong support for nuclear energy among the American people, and their confidence that U.S. nuclear facilities are both safe and secure.

[PAUSE]

It is extremely helpful in a time of uncertainty to have such a supportive Administration in Washington. The Bush Administration announced its national energy policy last year, and envisions an expanded role for nuclear energy in the future U.S. energy mix. After decades of either being ignored or mentioned negatively in U.S. government policy statements, it was gratifying to hear President Bush declare that nuclear energy must be a major part of our national energy policy and that we need to build more safe nuclear power plants.

(YUCCA MOUNTAIN SLIDE)

It is satisfying to hear that there is a role for nuclear energy in the national energy policy. But in the past, energy policy in Washington has sometimes not gotten past the talking stage. The Bush Administration, however, is vigorously turning its policies into action.

Perhaps the most positive action is the decision by President Bush that the Yucca Mountain site in Nevada is well suited to be the national repository for used nuclear fuel. The state of Nevada opposes the choice of Yucca Mountain, despite the 20 years and $7 billion that has been spent establishing a firm base of scientific support for its suitability. Nevada has disapproved of the selection, as is its right under the law, but we are confident that the U.S. Congress will override Nevada's action by voting in favor of the Yucca Mountain repository. The Department of Energy will then be able to proceed with licensing and, eventually, construction.

That will resolve the main obstacle to widespread deployment of new nuclear facilities in the United States.

The Administration also has begun implementation of the Nuclear Power 2010 Initiative, which it calls "a roadmap" for the deployment of new nuclear plants in the U.S. by 2010.

"Under this new initiative," said Secretary of Energy Spencer Abraham in making the announcement, "the government and the private sector will work together to explore sites that could host new nuclear plants...to demonstrate the efficiency and timeliness of key Nuclear Regulatory Commission processes designed to make licensing of new plants more efficient, effective and predictable...and to conduct research needed to make the safest and most advanced nuclear plant technologies available in the United States."

The first of these steps is already under way. Two U.S. nuclear operators, Dominion Resources and Entergy Corporation, have revealed that they have begun studying existing sites at the North Anna station and the Grand Gulf station, respectively. Another major nuclear plant operator, Exelon, is expected to make its plans public shortly.

They will test the new Nuclear Regulatory Commission early site permitting processes, which make it possible for a company to set aside, or "bank" sites in advance of making a decision to build a new plant. The early site permitting process is only one example of regulatory improvement by the NRC, which is aiding the industry in both its current operations and future planning.

(NRC REACTOR OVERSIGHT SLIDE)

Another example is the NRC's revised reactor oversight process, which is more objective, focused on safety and transparent to the public than the old process. The new process tracks 18 safety-related performance indicators, and the level of oversight is directly related to a plant's performance. Performance is color-coded into four bands – green, white, yellow and red. Green indicates a high level of safety, white slightly lower, yellow acceptable, and red indicates a problem. This chart summarizes recent safety performance, and you can see that the industry is doing very well.

(LICENSE EXTENSION SLIDE)

The NRC and the industry have improved the process for renewing the operating licenses of existing nuclear plants. The new process has reduced both the time and expense of license renewal. But the really significant factor in the decision to renew a plant's license is the value of the nuclear asset.

When I was here two years ago, I was proud of the fact that the first two 20-year license extensions had been approved, and that 30 percent of the U.S. nuclear fleet were expected to seek extensions. Since then, six more license extensions have been approved, and 40 more plants have either applied or announced their intentions to apply. We now expect virtually all U.S. nuclear plants to seek license extension.

(LIFE CYCLE SLIDE)

I am sure that some of you recognize this slide, which shows the life cycle CO2 generation from various fuels. It originated with your Central Research Institute of Electric

Power Industry. I enjoy sharing this information with American audiences, because it illustrates quite well one of the most important reasons for the renaissance of nuclear energy in the U.S. -- its environmental superiority.

The U.S. government declined to sign the Kyoto Accords, as you know, but the Bush Administration is committed to finding its own way to attain rigorous environmental goals. In outlining his goals for clean air and greenhouse gas reduction earlier this year, the President acknowledged the role nuclear energy must play.

Environmental considerations also played a role in the renewed interest in nuclear energy by the government of Great Britain. And here in Japan, the government has said it will rely on nuclear energy in achieving the goals of the Kyoto Accords.

(CARBON REDUCTION SLIDE)

I do not believe that any meaningful environmental goals for the future can be achieved anywhere in the world without reliance on nuclear energy. In the U.S., for instance, nuclear energy now accounts for 43 percent of the total in the current Voluntary Carbon Reduction program, far more than any other source. That alone would make a clear case for retaining the existing nuclear fleet, even if demand for electricity in the United States remained unchanged. But electricity demand will not stay unchanged.

(DEMAND GROWTH SLIDE)

The U.S. Energy Information Agency projects that the United States will need an additional 393,000 megawatts of electricity to meet a modest growth rate in electricity demand of 1.8 percent annually over the next 20 years. That would add 50 percent to our national grid. And that level of increase assumes a growth rate that is actually slower than the 2.2 percent growth in electricity demand that the U.S. has experienced over the past decade. If the growth rate is 2.5 percent, we will need to increase our grid by over 70 percent.

Where will this electricity come from? Certainly, some future demand will be met by renewable sources, such as solar and wind, and probably distributed generation. But the logistics of these still-fledgling industries tells us that massive deployment will not be possible. Some will of necessity be generated using natural gas and coal – particularly clean coal technologies.

(MAINTAINING AMERICA'S CLEAN AIR SLIDE)

But a certain amount of it must come from nuclear energy. About 60,000 megawatts of new nuclear capacity and, supplemented by an increase in electricity from renewables, will be needed just to maintain the current level of 30 percent of U.S. power from emission-free sources. The need for that large a contribution from nuclear energy helped us to shape our vision for the nuclear future in the U.S.

(VISION 2020 CAPACITY SLIDE)

Last year, we unveiled *Vision 2020*, a plan to provide America with the needed 50,000 megawatts of new nuclear capacity, **(VISION 2020 EXPANSION SLIDE)** and another10,000 megawatts of expansion of existing capacity. An additional 60,000 megawatts of capacity might seem like an ambitious goal -- the equivalent of three new 1,000-megawatt plants per year between now and 2020 -- but it is in reality not excessive, when we consider America's energy needs.

In the year since we announced *Vision 2020*, we have begun laying the groundwork to make it a reality. The early site permitting initiative I mentioned earlier is part of a system of new legislative and regulatory processes for building and licensing new nuclear plants that includes the Department of Energy's plans. The NRC also has pre-certified three advanced plant designs, and more such approvals are expected.

In addition, NEI is coordinating an industry-wide program to attract the capable young people we will need to run the nuclear plants of the future, and we are working with industry to make sure that the necessary infrastructure – the materials, equipment and construction capabilities -- are in place when needed.

This is truly an exciting time for the U.S. nuclear industry. Nuclear energy has compiled a record of safety and performance that has proven its value to the U.S. economy, and to environmental quality. Nuclear energy is no longer a choice for the future, it is an imperative. No other fuel for electricity generation available in the United States can match nuclear energy's combination of low production costs, forward price stability, environmental and energy security advantages.

Let me acknowledge that the U.S. is not alone in experiencing a nuclear renaissance. We are heartened by the positive developments in Japan, the United Kingdom, Finland and elsewhere in the world. Our industry is truly poised for a new era worldwide.

(WORLDWIDE RENAISSANCE SLIDE)

I spoke recently to the World Association of Nuclear Operators biennial meeting, and brought them the same optimistic message. In my final words to them, however, I added a caution. I will leave you with the same message.

"Without our collective, underlying commitment to safety," I said, "the promise of nuclear energy for future generations around the world will evaporate before our eyes." That is something none of us in the nuclear industry must ever forget.

I thank the members of JAIF for your contributions to the world's nuclear industry, and look forward sharing with you the challenges, and the successes, of the future.

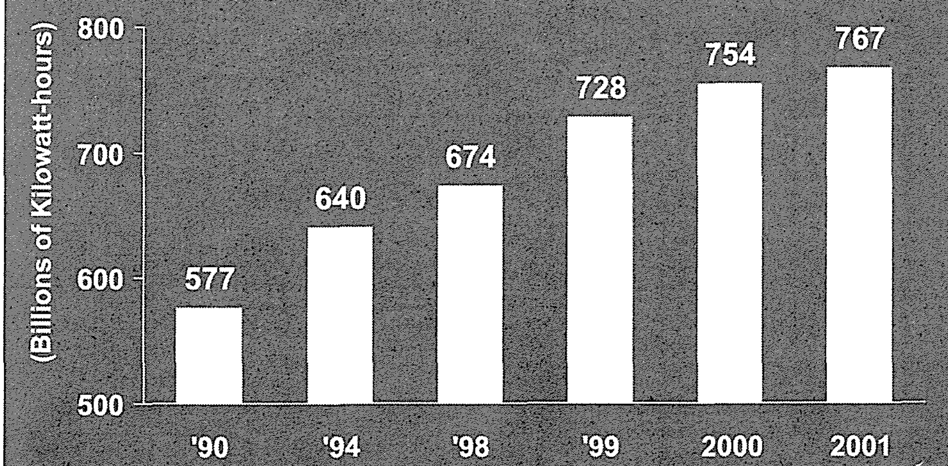
Thank you.

U.S. Energy Policy and the Nuclear Renaissance

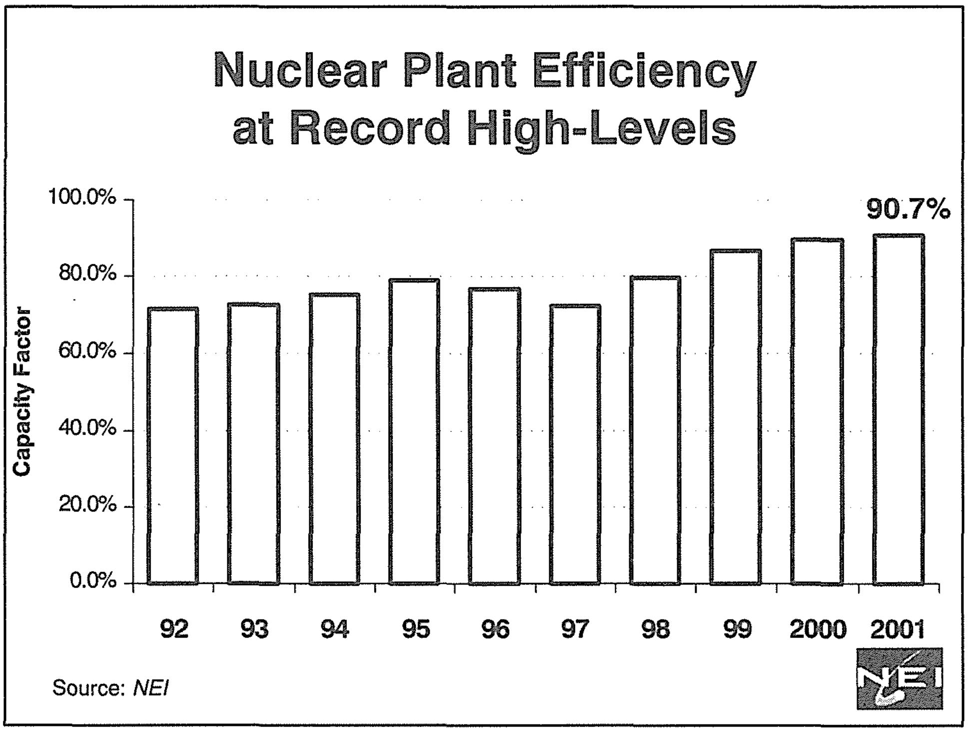
Presentation of Joe F. Colvin
President and Chief Executive Officer
Nuclear Energy Institute
To the Japan Atomic Industrial Forum
Saitama City, Japan
April 22, 2002

NEI
NUCLEAR ENERGY INSTITUTE

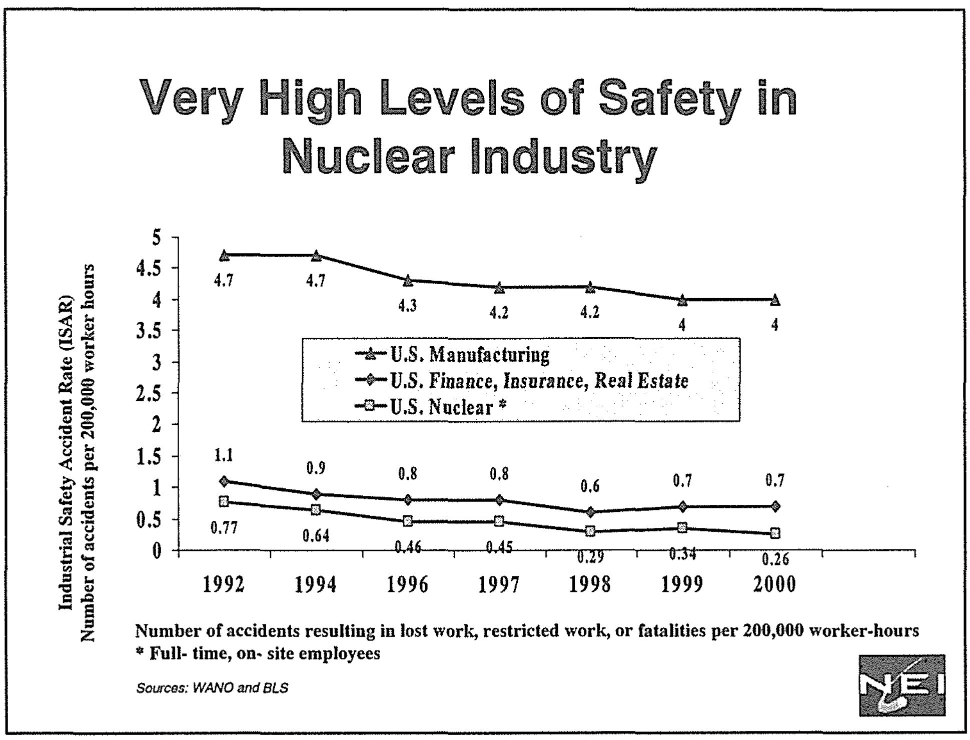
Record Nuclear Electricity Production Is Sustainable



NEI

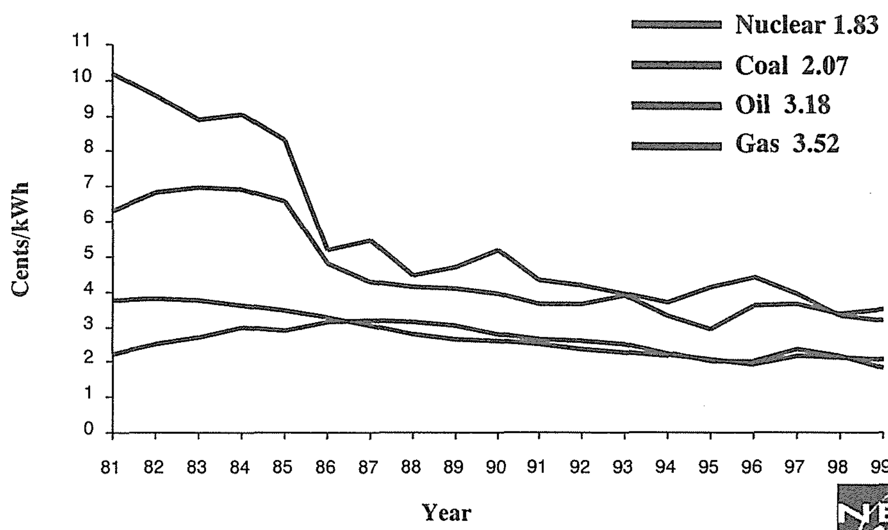


Nuclear Plant Efficiency
at Record High-Levels
Capacity Factor
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
90.7%
92
93
94
95
96
97
98
99
2000
2001
Source: NEI



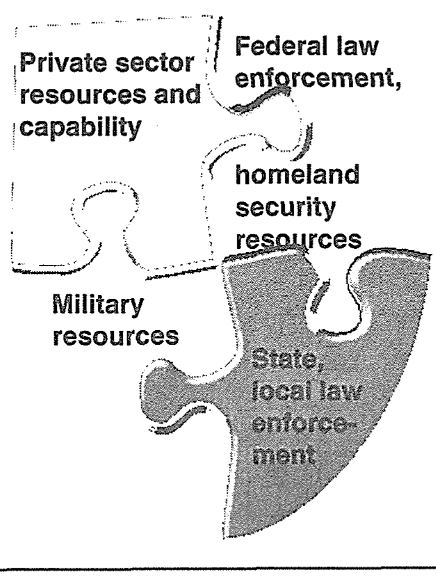
Very High Levels of Safety in
Nuclear Industry
Industrial Safety Accident Rate (ISAR)
Number of accidents per 200,000 worker hours
U.S. Manufacturing
U.S. Finance, Insurance, Real Estate
U.S. Nuclear *
4.7
4.7
4.3
4.2
4.2
4
4
1.1
0.9
0.8
0.8
0.6
0.7
0.7
0.77
0.64
0.46
0.45
0.29
0.34
0.26
1992
1994
1996
1997
1998
1999
2000
Number of accidents resulting in lost work, restricted work, or fatalities per 200,000 worker-hours
* Full- time, on- site employees
Sources: WANO and BLS

Electricity Production Costs



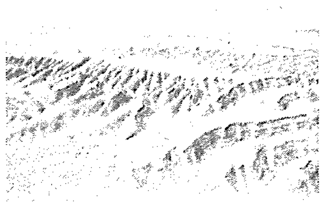
Source: UDI for actual data

The Appropriate Strategic Response: Seamless Defensive Shield



Yucca Mountain: Critical Decisions in 2002

- President recommended Yucca Mountain site based on rigorous scientific assessment
- Nevada Objection



Next Steps:

✓ Simple majority vote in House and Senate overrules Nevada objection

✓ DOE License Application to Nuclear Regulatory Commission

U.S. Nuclear Plant Performance: Sustained High Levels of Safety

Reactor Oversight Process: Key Results		
1st Quarter 2001	2nd Quarter 2001	3rd Quarter 2001
92 units all "green"	93 units all "green"	95 units all "green"
9 units with one "white"	10 units one "white"	8 units one "white"
1 unit with two "whites"		
1 unit with three "whites"		

Source: U.S. Nuclear Regulatory Commission

License Renewal: Unlocking Additional Value

Approved ◆
Calvert Cliffs 1,2
Oconee 1,2,3
Arkansas Nuclear One Unit 1
Hatch 1,2

Already filed
Turkey Point 3,4
North Anna 1,2
Surry 1,2
Peach Bottom 2,3
Catawba 1,2
McGuire 1,2
St. Lucie 1,2
Fort Calhoun

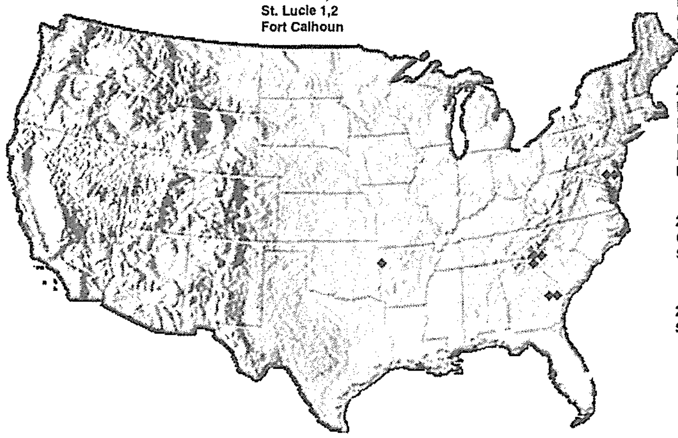
Announced 2002
Robinson 2
Point Beach 1,2
Ginna
V.C. Summer

2003
Dresden 2,3
Quad Cities 1,2
Farley 1,2
Arkansas Nuclear One Unit 2
Nine Mile Point 1,2
Cook 1,2
Browns Ferry 2,3

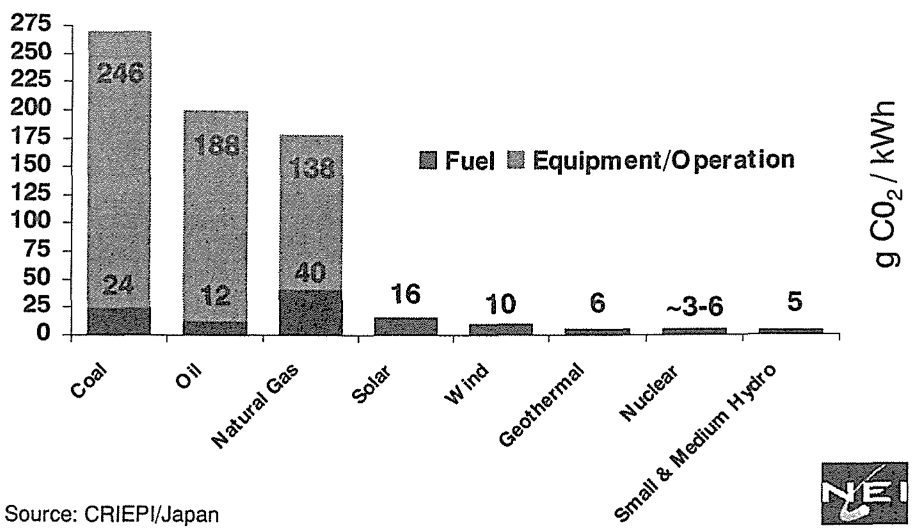
2004
Brunswick 1,2
Beaver Valley 1,2
Davis-Besse
Pilgrim
Millstone 2, 3

2005
Cooper
Susquehanna 1,2

2007
Sequoyah 1,2

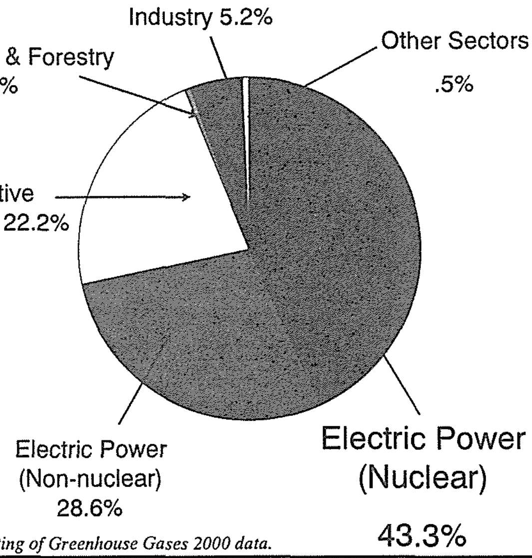


Life Cycle CO_2 Emissions from Sources of Electricity Generation



Source: CRIEPI/Japan

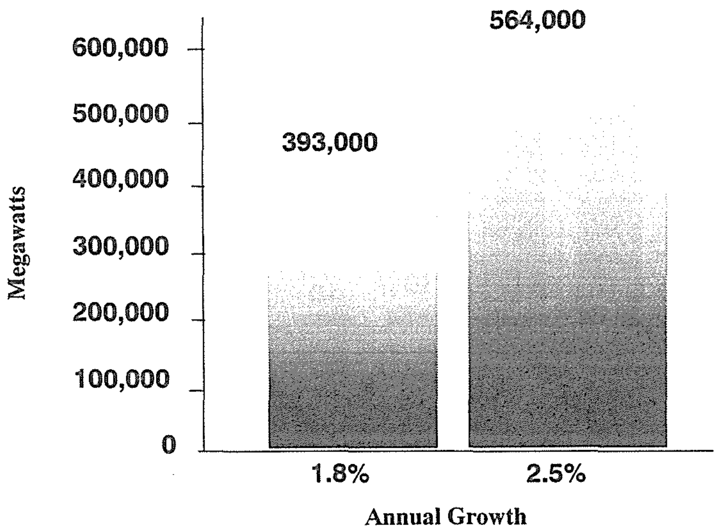
Carbon Reductions: Nuclear Power Dominates U.S. Voluntary Program

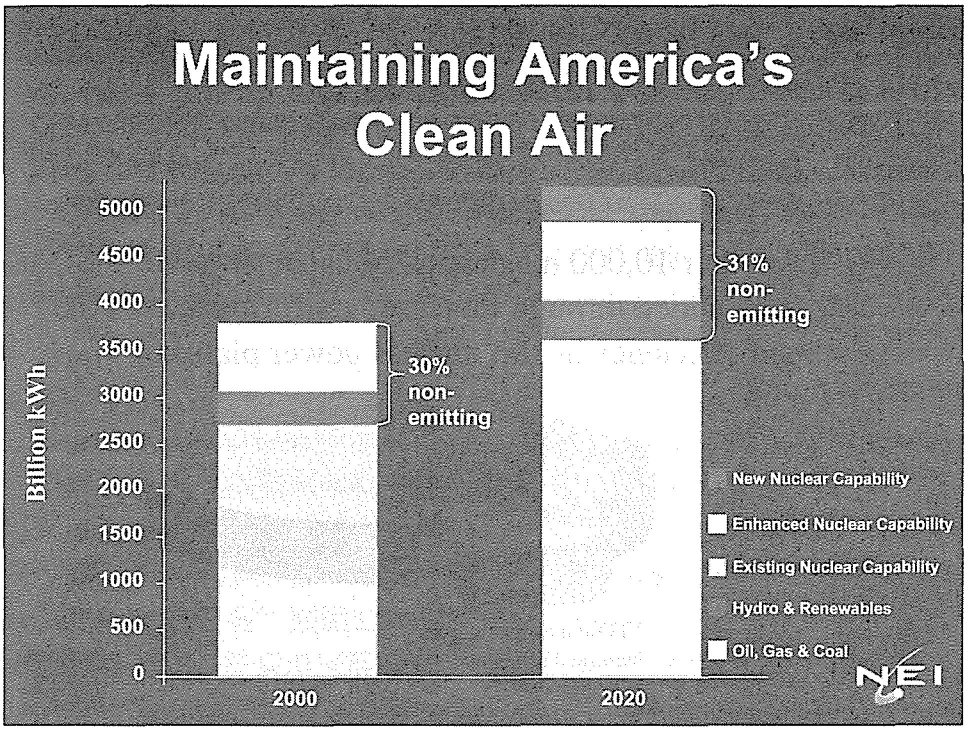


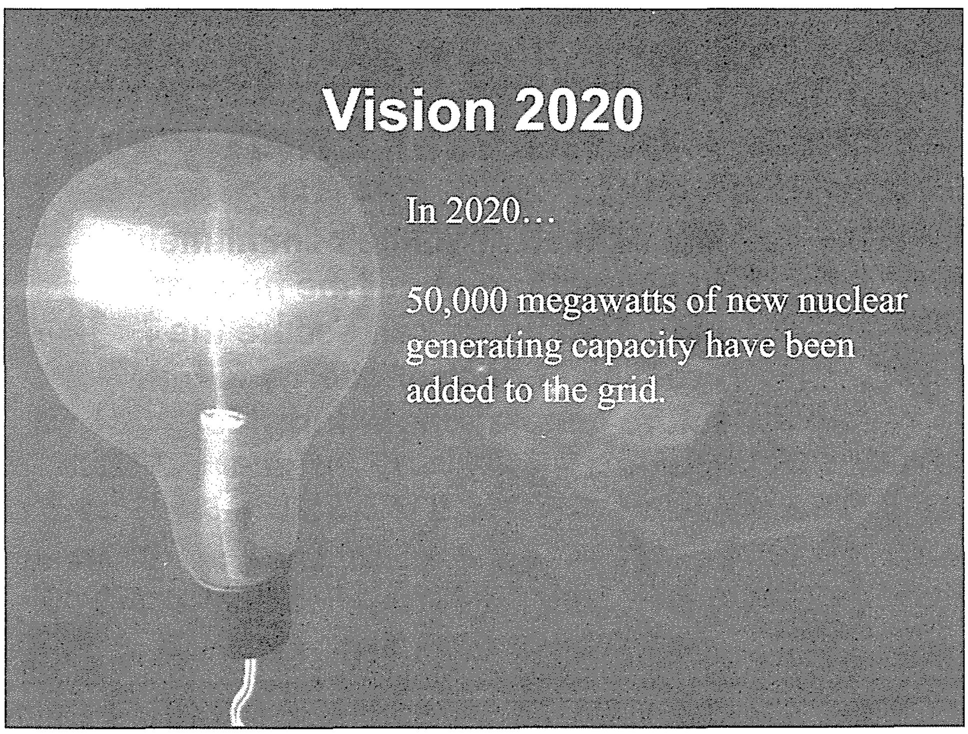
- **Carbon emissions avoided by nuclear plants as a result of improved performance: Largest single component of Carbon reductions achieved by the U.S. voluntary program**

Source: Prepared by NEI with EIA Voluntary Reporting of Greenhouse Gases 2000 data.

Significant Increase in Electricity Demand



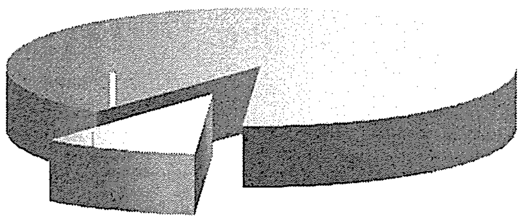

Maintaining America's Clean Air
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Billion kWh
30% non-emitting
31% non-emitting
New Nuclear Capability
Enhanced Nuclear Capability
Existing Nuclear Capability
Hydro & Renewables
Oil, Gas & Coal
2000
2020
NEI


Vision 2020
In 2020…
50,000 megawatts of new nuclear generating capacity have been added to the grid.

Vision 2020

In 2020…

Another 10,000 megawatts of capacity have been added through increased performance and efficiency at 103 nuclear power plants.



Worldwide Renaissance of Nuclear Energy

Maintain an absolute commitment to safety throughout the nuclear industry and we can secure the promise of nuclear energy for future generations worldwide.

（第三十五回原産大会講演）

二十一世紀のエネルギーと原子力

電気事業連合会会長
東京電力株式会社社長
南　直哉

○ご紹介いただいた南でございます。

「二十一世紀のエネルギーと原子力」という大きなテーマをいただいていますが、私からは、地球との共存と言う視点を中心に、改めて原子力の役割、そして今、我々原子力関係者がなすべきことについて、思うところをお話しさせていただきたいと思います。

（環境の世紀）

○新しい世紀がスタートしてから一年余りが経ちましたが、世界では、市場主義とグローバリゼーションが大きな流れとなり、こうした中で、ヨーロッパでは、国家を超えた統合も実現されつつあります。けれども、一方では、地域や民族、宗教による対立が絶えず、世界中の人々が、平和と繁栄を享受できる時代がこの世紀に実現できるのか、道筋はなお見えていません。

○こうした繁栄と発展を求める人間の営みは、同時に、地球の資源や環境との関わりと言う点で、より根元的な課題を提起しています。この課題にどのように取り組み、答を見出していくのか、二十一世紀は環境の世紀とも言われますが、こうした意味で、我々の子孫や文明の将来を方向付ける重要な世紀になるのではないかと考えております。

○四十六億年におよぶ地球の歴史の中で、生物が殆ど絶滅した時期が五回あったとされますが、今日、急速な種の消滅によって、これらに次ぐ大量絶滅の時代を迎えているとも言われています。これは、とどまるところを知らない人間の活動が、生態系に及ぼした影響によるものですが、そうした自然に対する負荷の中でも、最も深刻なのは、CO_2の蓄積を主因とする地球温暖化の問題です。

○過去、ほぼ一定していた大気中のCO_2の濃度は、十八世紀末の産業革命以降、CO_2排出量の増大により急速に高まり、第二次大戦後は、さらに急峻なカーブを辿って上昇しています。仮に、横軸のタイムスケールを数万年の人類の歴史とおくなら、詳しい数字はともかくとして、グラフは、長い横這い状態から最後にきて直角に立ち上がった形となるでしょう。

○ＩＰＣＣは、CO_2の増大により、二十一世紀末には地球の気温が一・四度から最大では六度近くまであがる可能性を警告しています。青森県に有名な三内丸山遺跡がありますが、この時代には、現在より気温が二度程度高かったそうです。冬の青森は、今より住み易かったかもしれませんが、その頃の関東平野はと言うと、三分の一が海だったわけです。

○温暖化の影響については必ずしも解明しきれていないので、過剰な危機感ということになるかもしれませんが、極めて短期間に大きな変化が生じているのは事実です。人類の歴史に思いをいたせば、この急峻な立ち上がりをいつまでも

続けられないことは、直感的に理解できるのではないでしょうか。

（エネルギー問題が鍵）

○ご承知の通り、産業革命以降の飛躍的な生産力の増大は、石炭に始まる化石燃料の大量使用によって実現されたものです。近代工業文明は人々に多大な便益をもたらしましたが、同時に、エネルギー消費とCO２排出量の急速な増大を招来しました。

○エネルギー消費と一言で言っても、国や地域によって大きな格差があり、開発途上国の一人当たりのエネルギー消費量は、先進国の概ね十分の一にすぎません。電力について申すなら、世界の人口の三分の一は、未だ電気の恩恵に浴していないのが現実です。

○中国の例をとらせていただくことをご容赦願いたいと思いますが、今急速に発展しつつある中国の一人あたりエネルギー消費量は、大雑把に言って日本の五分の一から六分の一、他方人口は十倍です。仮に中国の一人あたり消費量が、現在の日本の半分程度・・日本は米国の半分ですが・・となるだけで、計算上、世界最大のエネルギー消費国である米国がもう一つ生まれることになります。大きなインパクトは避けられません。

○世界の人口は、現在の六十億人から、途上国を中心に増大し、二十一世紀半ばには九十億人を超えると予測されています。このような途上国の人口の増大と、当然の願いである経済発展への渇望は、エネルギー需要を必然的に増大させます。逆に、十分なエネルギーが得られなければ、貧困と絶望が一層蔓延し、世界は不安定さを増すことになるでしょう。

○化石燃料資源には、地球のキャパシティという点で、CO２問題以前にそれ自身の資源賦存量の制約があります。石油四十年、天然ガス六十年といった確認埋蔵量と可採年数の議論は、技術的、経済的条件に依存する面があるので、相当の幅を持って考えることが必要です。けれども、増大するエネルギー消費を化石燃料に頼っていれば、太古の時代に取り込んで、地中深く蓄えてきた太陽の恵みを、地球の歴史から見れば一瞬の間に使い尽くすことに変わりはありません。

○とりわけ先進国において、大量生産と消費、そして大量廃棄による使い捨ての経済社会から、省エネルギーを志向した社会、循環型の社会への転換を目指していかなければなりません。このことは、今日の文明のありかたそのものを変えていくことにもつながるわけで、言葉で言うのは簡単ですが、実現はそう容易なことではないと思います。

○一方、エネルギー供給面においては、今日までの発展を支えてきた化石燃料、すなわち炭素サイクルから生み出されるエネルギーへの依存を減らしていくことが必要です。炭素サイクルは、引き続き世界のエネルギー供給の中心であり続けるでしょうが、より複合的なエネルギー供給システムを取り込んでいくことが不可欠です。この意味で、エネルギーの供給と消費の両面において、新しいパラダイムへの転換が求められていると思います。

（原子力の意味あい）

○私どもエネルギー供給者としては、こうした地球の制約要件を満たしつつ、世界の発展に必要なエネルギーを供給できるのは、見通しうる将来において原子力しかないと考えているわけです。ここにおられる皆さんには自明のことでしょうが、原子力は、原子核の反応という宇宙を司る原理に根ざしたエネルギーであり、炭素サイクルから解放され、かつ化石燃料に比べ遥かに大きなエネルギーを生み出します。発電段階でＣＯ２を発生することはありませんし、ライフサイクルでの発生量を比較すれば、太陽光や風力等の自然エネルギーよりも優れていると評価されています。

○世界では、現在四三八基三億五〇〇〇万ＫＷ（三五〇ＧＷ）の原子力発電設備が運転中で、二兆四〇〇〇億ＫＷＨ（二四〇〇ＴＷＨ）の電力を供給しています。この分、石油火力による発電が不要になったと考えると、世界最大の産油国サウジアラビアの生産量を上回る約九四〇万バーレル／デイの石油消費と、これに伴うＣＯ２の発生を削減したことになります。

○さらに、化石燃料と大きく違うのは、一旦使用した燃料をリサイクルできることです。将来的にＦＢＲと組み合わせて原子燃料のサイクルを完成できれば、超長期の持続可能性を手に出来るポテンシャルを有しており、この点からも、新しいパラダイムにふさわしいエネルギーと言えます。

○多くの皆さんの期待を集める自然エネルギーは、おおいに可能性を追求すべきものであり、またオフグリッド地域などでは重要な役割を果たせると思います。けれども、今日の我々の文明を前提とする限り、世界的には補完的役割にとどまらざるを得ないでしょう。

○水素エネルギーを利用したサイクルも、実用化にはまだ課題がありますが、有望と考えられます。この場合、水素を生み出すためのエネルギーが必要であり、すでに研究が行われていますが、原子力と組み合わせることができれば、より効果的なシステムになると考えられます。こうした形で水素利用が実現できれば、自動車を始め、発電以外の分野で原子力を利用する途が開けるかもしれません。エネルギー供給やＣＯ２抑制に果たす原子力の役割は、一層拡大することになるでしょう。

○勿論、技術の可能性について、時間軸をあいまいにした議論は避けなければなりませんが、原子力が持続可能な発展を担う欠かせないオプションであることは間違いありません。現在の軽水炉を中心とする成熟段階にある技術体系によって数十年をつなぎながら、新しい可能性を追求していくことができるわけです。

（原子力の再興に向けて）

○本日午前中からの皆さんのプレゼンテーションに接し、発電所の新規建設が絶えて久しかった米国や、エネルギー自給国である英国において原子力復活に向けた新しい息吹があること、また各国の原子力への着実な取り組みを確認し、

心強く感じました。

○わが国においても、原子力の着実な開発を進めており、先般公表した二〇〇二年度の計画では、日本全体の発電電力量に占める原子力の割合を、現在の三十四％から、十年後には四十一％へ増大することとしております。わが国はまた、サイクル路線を基本としており、現在、二〇〇五年の運転開始を目指して、青森県で再処理施設の建設を進めているところです。

○しかしながら、原子力に対する批判には大変強いものがあります。かつては夢を持って語られた原子力開発は、チェルノブイル事故を始めとする安全性への不安の高まりの中で、欧米を中心に停滞ないしは後退が続きました。一連のＣＯＰの議論でも、その役割は十分に評価されていません。安全性と並び、放射性廃棄物の発生とその処理・処分のあり方も、原子力に対する不安と批判の大きな要因となっています。

○原子力に携わるものとして、こうした原子力固有のリスクや課題の解決に全力で取り組んでいくことは当然です。特に、高レベルの廃棄物処分に道筋をつけることは、原子力がシステムとして完結される上で極めて重要な課題だと思います。その上で、こうしたリスクや課題も併せながら、地球の資源、環境問題とその中で原子力の果たしうる役割について、広く社会に議論を巻き起こしていくことが必要ではないでしょうか。

○太古の五回の大絶滅期は、宇宙の営みの中で自然がもたらしたものでした。これと同列に論じられるかは別として、今迎えつつある危機は人間の営みがもたらしたものであり、人間の手によって克服可能なはずです。しかし、手をこまねいていたら間に合わないかも知れません。

○いかにして人類文明に投げかけられたこの重大な試練を乗り越え、持続可能な発展を実現して世界中の人々に繁栄と進歩をもたらしていくのか、原子力をノーと言うなら、他にいかなる手段があり得るのか、国民世論、国際世論を巻き込んで真正面から議論をし、徹底的かつ虚心に考え、回答を求めていく時だと思います。それが私を含め、ここにお集まりの皆さん、原子力に携わり、原子力を信じる皆さん方の責務ではないでしょうか。

○すぐにも原子力が、かつての夢と勢いを取り戻すことにはならないでしょうが、米国や英国の状況に見られる新しい息吹が、少なくとも原子力の正当な評価に人々の目を向け、大きな変化の流れの始まりになればと期待しています。この流れを加速し、より幅広く、より確かなものとなるよう皆で力を合わせていこうではありませんか。

ご静聴有り難うございました。

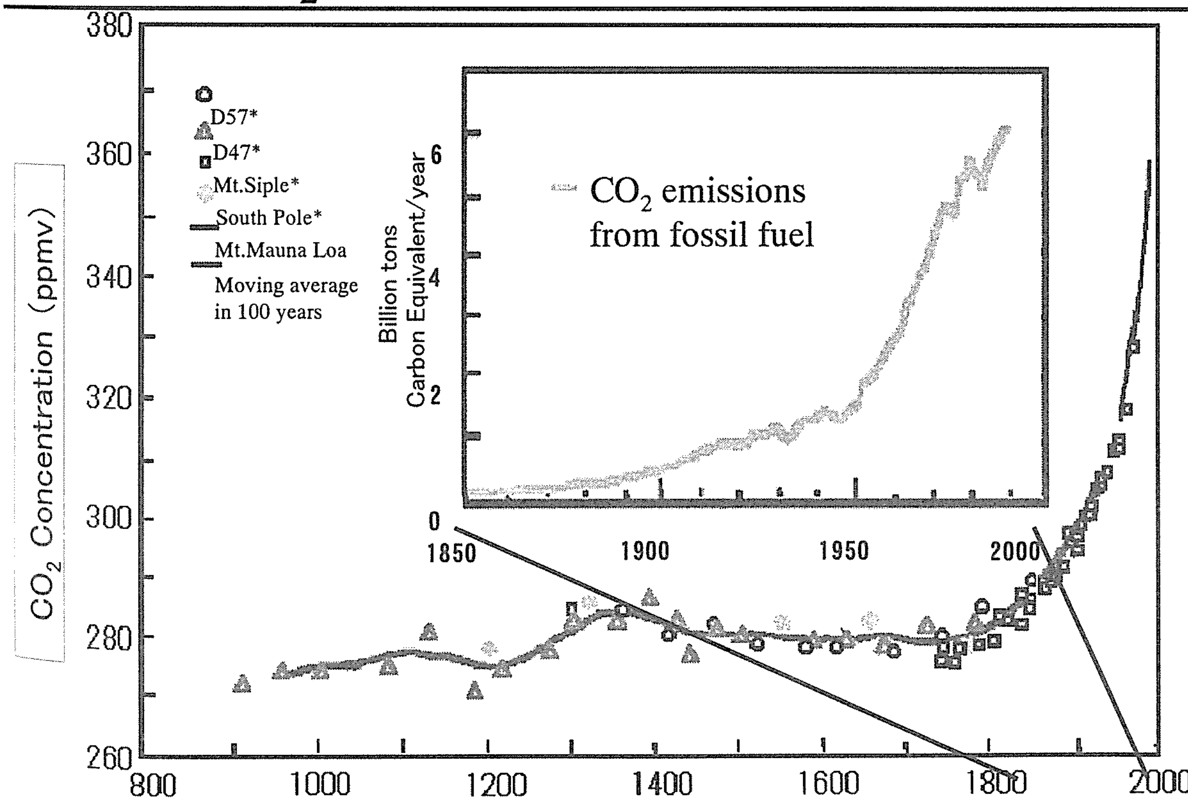
以上

Energy and Nuclear Power in 21st Century

April 22, 2002

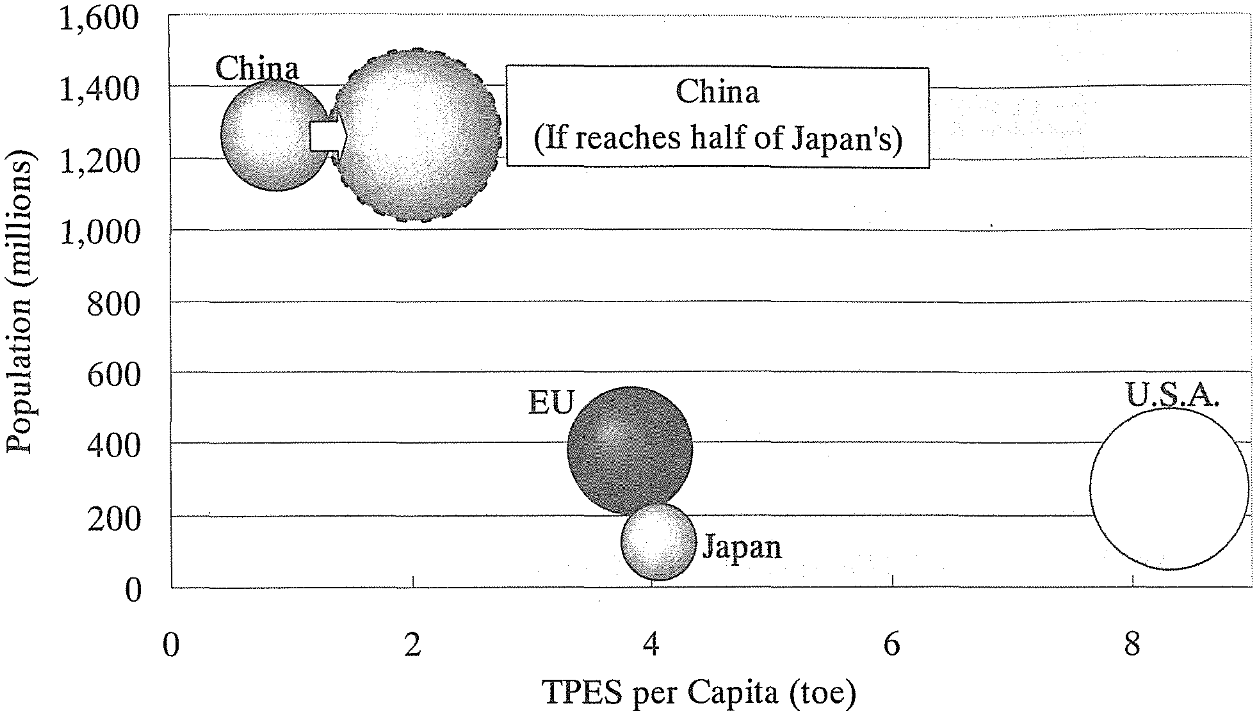
Nobuya MINAMI

CO_2 Emissions and Concentration



*: Data from Antarctic ice cores   Source: Environmental White Paper (Japanese Government, 1997)

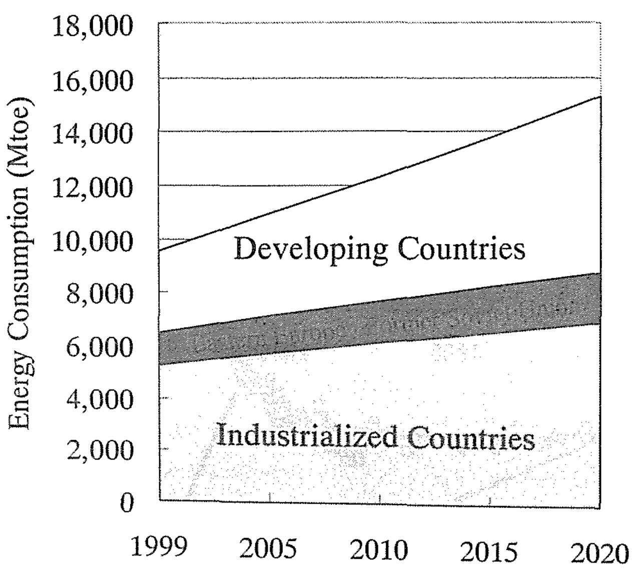
Energy Consumption per Capita



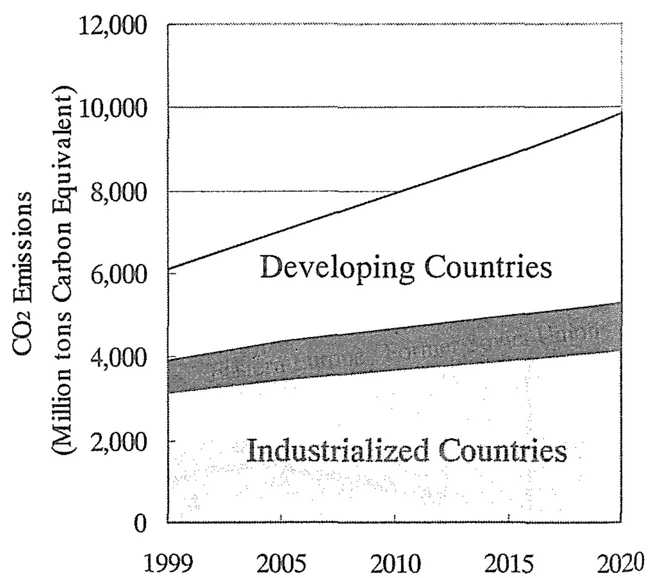
Source: Energy Balances of OECD Countries (IEA, 2001)
Energy Balances of NON-OECD Countries (IEA, 2001) 3

World Energy Consumption and CO_2 Emissions

World Energy Consumption

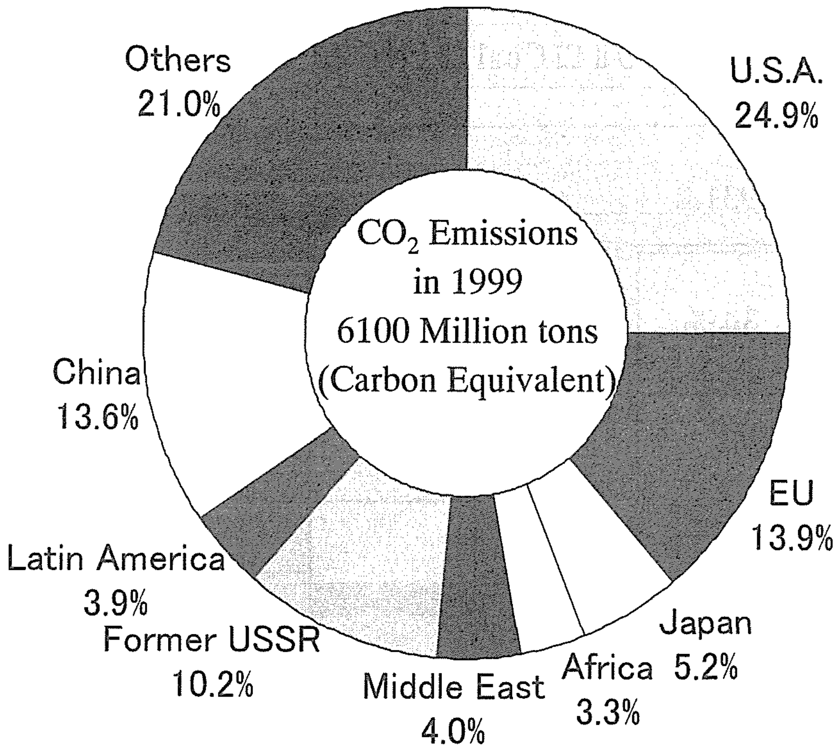


World CO_2 Emissions



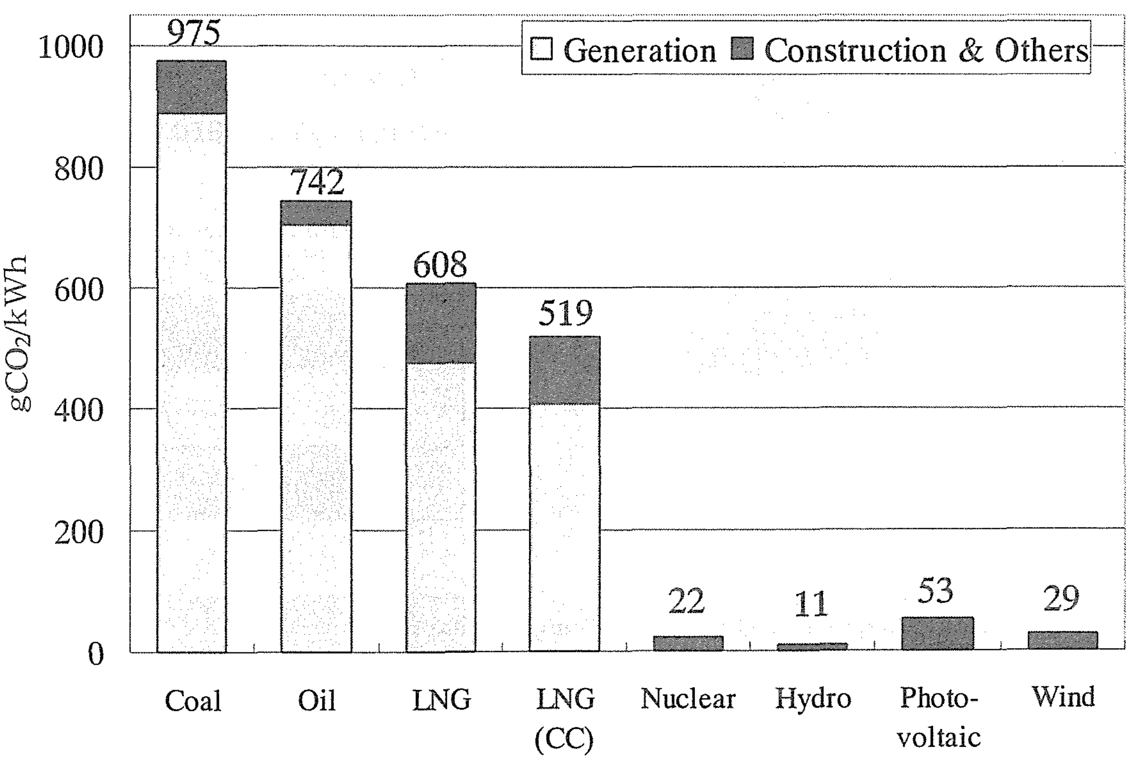
Source: International Energy Outlook (DOE, 2002) 4

CO_2 Emissions from Fossil Fuel



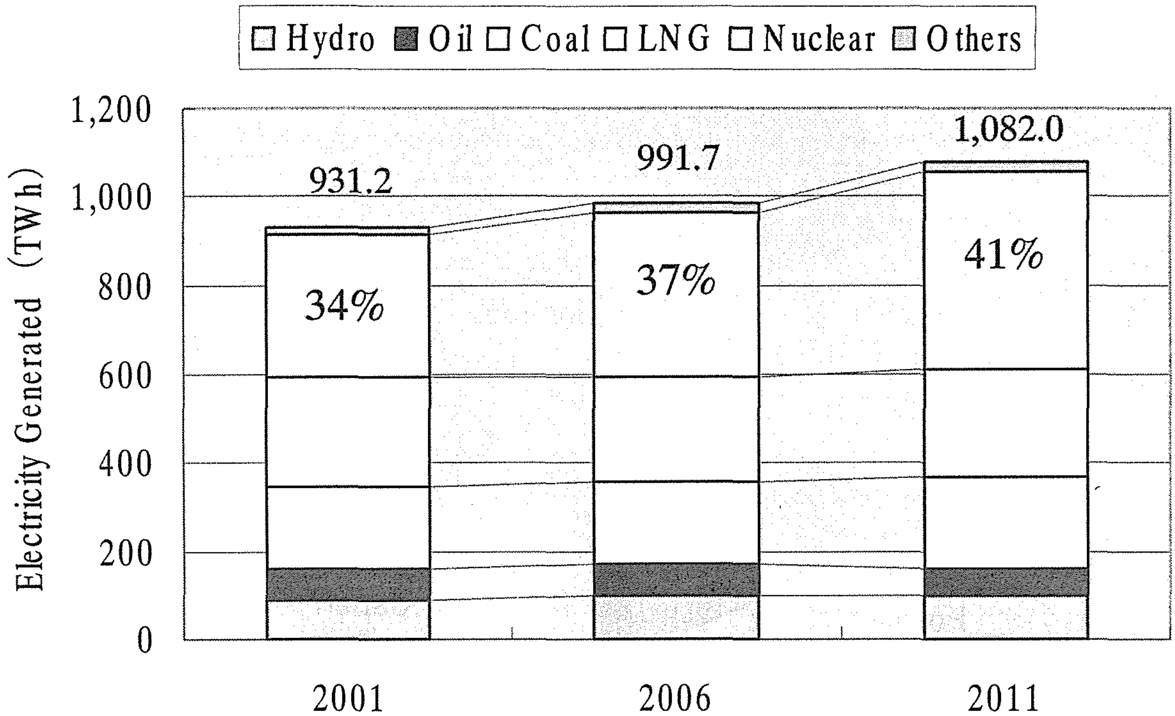
Source: CO_2 Emissions from Fuel Combustion (IEA)

Life Cycle CO_2 Emissions by Type of Power Generation



Source: Central Research Institute of Electric Power Industry

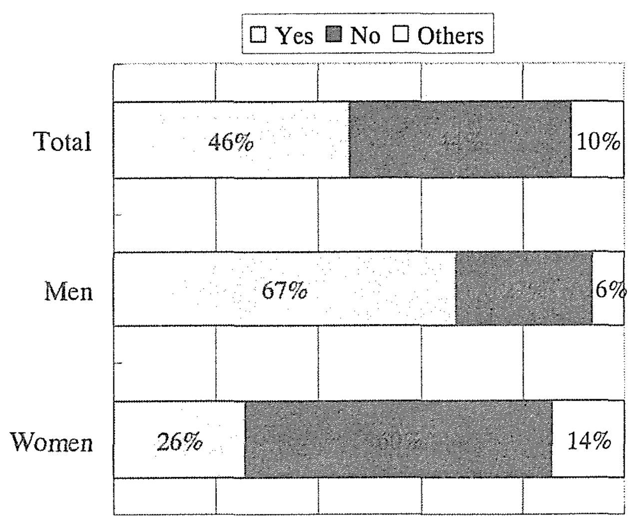
Projected Electricity Supply in Japan



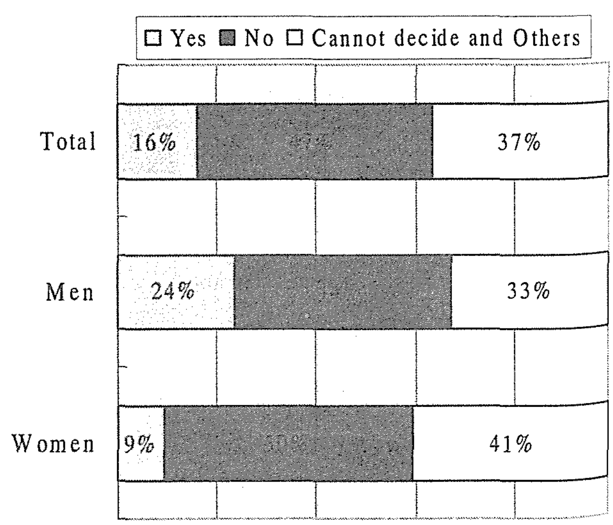
Source: Abstract of Electricity Supply Plan (Japanese Government, 2002)

Opinion Poll on Nuclear Power

Do you know "Nuclear power plants produce ***NO CO_2 emission*** in operation" ?



Do you think "Nuclear power plants are ***safe***" ?



Figures include "somewhat" yes/no

Source: Japan Productivity Center for Socio-Economic Development 2001

TEPCO

Thank you

35th JAIF Annual Conference

Nuclear Power in the Changing Socio-Political Environment

Session 1 :
Energy Policy of the 21th Century and Nuclear Power April 22, 2002

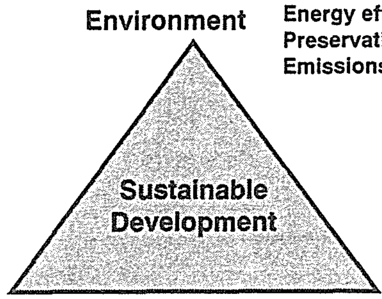
Nuclear Energy and Sustainable Development

Jacques Bouchard,
Director of Nuclear Energy Division, CEA
jacques.bouchard@cea.fr

The sustainable development : economic, social & environmental performances

Environment

**Energy efficiency,
Preservation of the resources,
Emissions, effluents & waste, ...**



Social equity

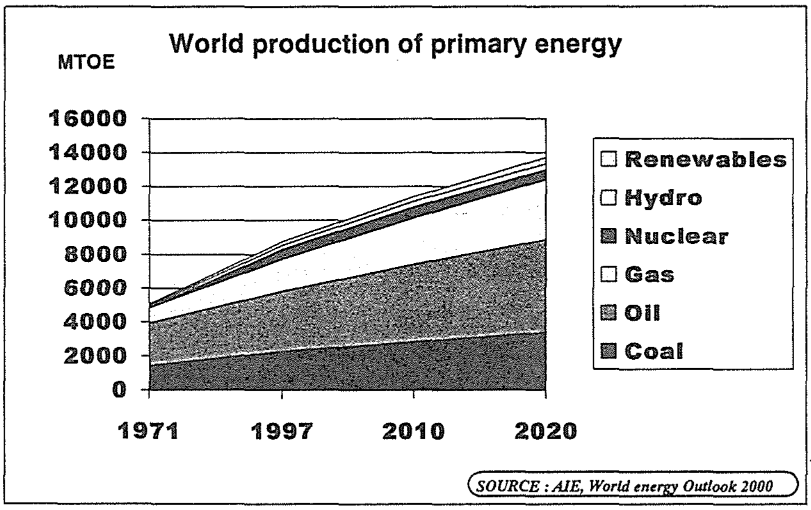
**Quality of management,
Training/Education, Health & safety,
freedom of association, Human Rights, ...**

Economic performance

**Profits, Investments,
labor productivity, ...**

In the USA, 1$ out of 9 is invested in sustainable development

Is current energy consumption sustainable ?



3

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The nuclear electricity is competitive

	Production costs in the US (cents/kWh)	
	1998	1999
NUCLEAR	2.13	1.83
COAL	2.07	2.07
OIL	3.24	3.18
GAS	3.30	3.52

Source : Utility Data Institute 2001

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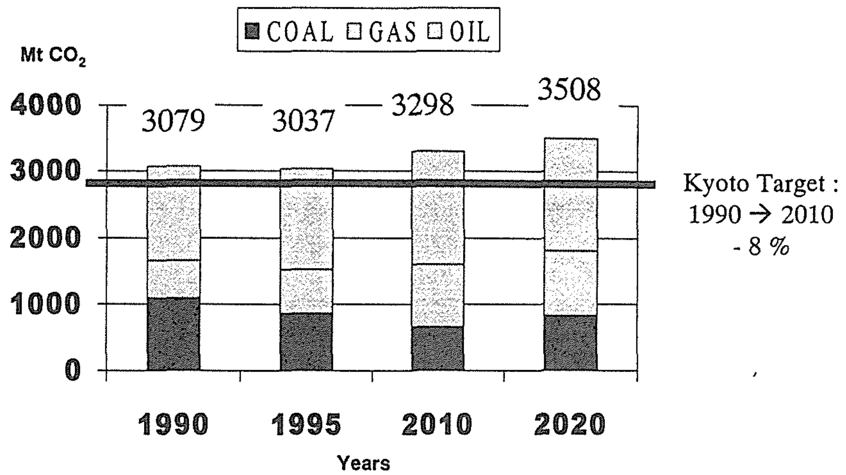
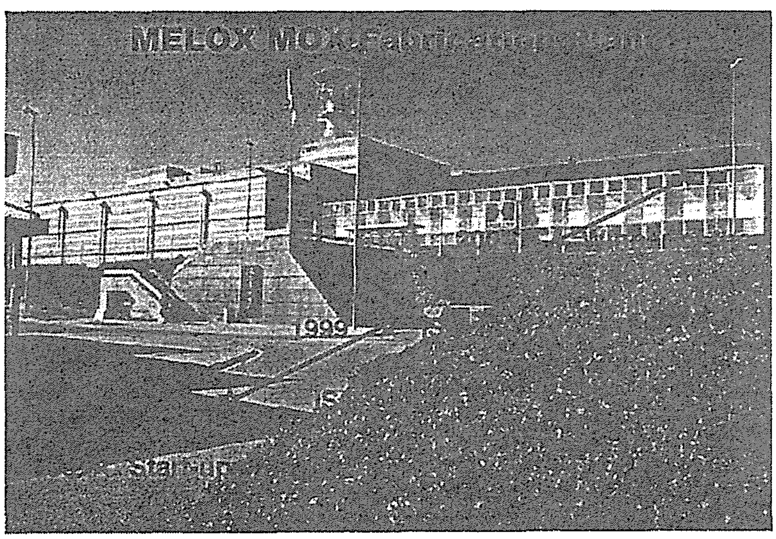
European CO_2 emissions by type of energy (source : UE)



5

Nuclear industry : A Total Quality Approach



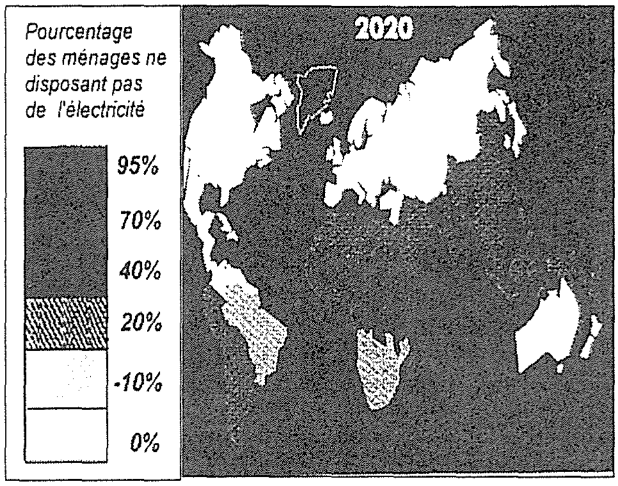
6

Energy : a factor of social development

Energy is a factor of development
(An afghan uses 300 times less energy than an US citizen)

20 % of the population consume some 60% of the energy

2 billion people still have no electricity



7

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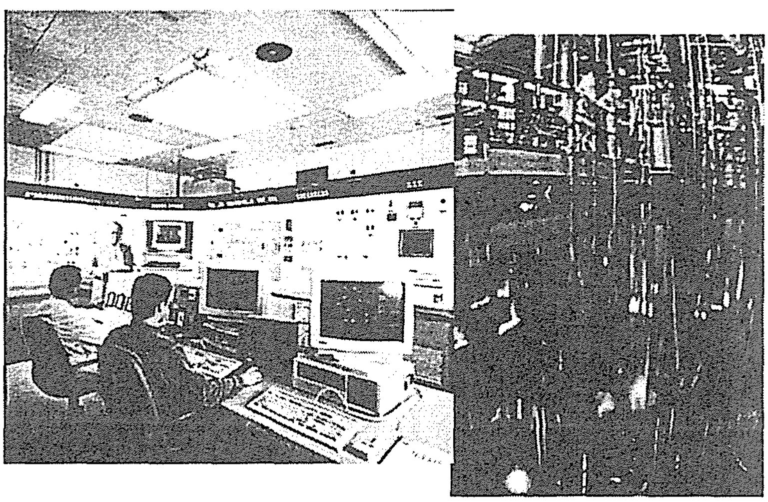
Nuclear Industry : a permanent concern for the personnel



8

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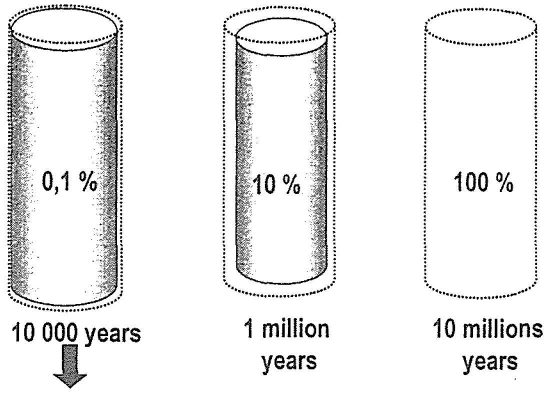
Long term durability of vitrified waste

Alteration by water



After 10 000 years
the radiotoxicity of vitrified HLLLW
have drastically decreased

9

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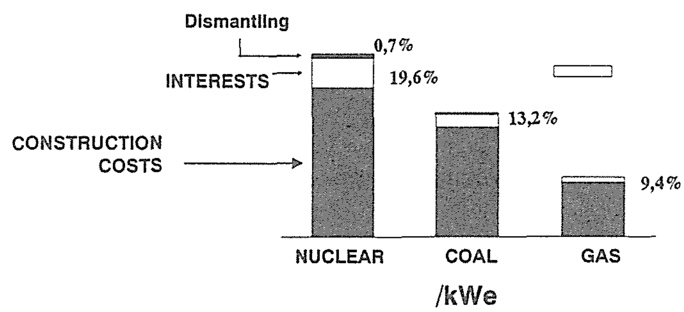
A challenge : how to reduce the construction cost of nuclear power plants

Investment costs for electrical Power Plants



SOURCE : DIGEC 1997

10

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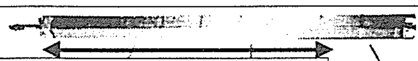
Reprocessing & Recycling, a cornerstone for future energy needs

➢ Extract the maximum energy from the fuel



Valuable materials (96%)

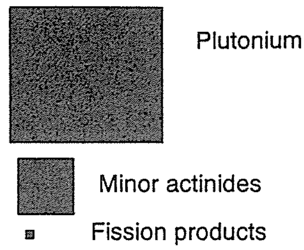
- **Uranium** (94 to 96 %)
- **Plutonium** (1 %)

→ **Reprocessing & Recycling**

Wastes (4%)

- **FissionProducts** (3 to 5 %)
- **Minor Actinides** (0,1 %)

➢ **Drastically minimize radiotoxicity of the waste**



Radiotoxicity after 1 000 years

➢ **Pu stockpile stabilisation : the Pu produced could be consumed in LWR**

11

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The Gas Cooled Reactors, a new option for the future energy systems

- **A coolant suitable for different neutronic spectra**
  - ✓ Waste minimisation
  - ✓ Optimised resource utilisation
- **A coolant compatible with high temperatures**
  - ✓ Direct cycle, high energy output
  - ✓ Direct use of heat (H_2 production, ...)
- **A coolant which allows easy inspections and handling**
- **Crucial developments since the 70-80's**
  - ✓ Turbine with a direct cycle
  - ✓ Materials compatible with high temperatures

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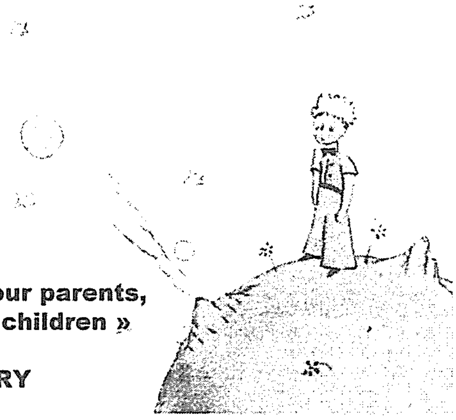
Nuclear Energy & Sustainable Development

Nuclear Energy has major avantages as regard Sustainable Development

We must neverseless still improve it :

- ✓ Future energy systems
- ✓ Waste management



**« We are not inheriting earth from our parents,
we are just borrowing it from our children »**

Antoine de SAINT- EXUPERY

13

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Nuclear Energy Division

セッション 2

大都市圏と原子力施設立地地域の課題

生活環境評論家　松田　美夜子

発表内容

現在、私は大学で「廃棄物概論」や「産業活動と環境負荷」などを教えており、あわせて２０年以上、ごみとリサイクルの活動に関わってきた。

しかし、正直なところ、原子力発電については、５年前に国の原子力バックエンド専門委員になるまではあまり関心がなかった。原子力発電の事故では、マスコミは不安を煽り、激しい反対運動にもたじろぎを覚えており、積極的に知ろうとはしなかったのである。

おそらく今でも、私の周辺の学者達も、また私の友人たちも、原子力発電の話をすると一歩下がってしまう人が多い。ほとんどの人が、以前の私と同じ気持ちなのだろう。

しかし、原子力廃棄物の管理を検討する委員になり、責任を感じて、外国ではどのような取り組みをしているかを、自費で学びに行き、外国の取り組みに圧倒されてくると、この問題に私たちが無関心でいると、日本のエネルギー政策も躓いてしまうという危機感を持つようになっている。

この問題は、知らない、知りたくないではすまされず、みんなで知恵を出し合って、考えていかねばならないことが分かってきた。また、私たちが生活系ごみの分野で培ってきた知識や、体験が役に立つのなら、原子力関係者の人々と力をあわせていきたいと思うようになってきた。

振り返ってみると、２０年前、生活系ごみが日本中にあふれ、ごみ処理が深刻な状況になった時、自治体の清掃担当者は、現在の原子力廃棄物担当者と同じように、独りで問題を抱え込んで、出口の見つからない状態になっていた。

しかし、情報が正しく伝えられ始めると、ごみはみんなで出すのだから、みんなで考えれば知恵が出てくると考える市民がどんどん出てきて、この１０年間に、生活系ごみのリサイクルシステムは、世界でもトップを行くものになっている。

私はこの体験を通して、原子力発電も、その後に出てくる廃棄物も、正しく情報が伝わると、きちんと考えてくれる市民は大勢出てくると実感している。原子力廃棄物は、生活系ごみの応用編だと仲間には伝えている。決して難しいことではないので、共に考えようと呼びかけている。

今、全国の市町村には、環境学習リーダー、ごみとリサイクルのアドバイザーなど、環境やごみに関わる市民活動をしている人たちが大勢いる。その人たちが、ごみとリサイクルの応用編として、原子力廃棄物についても学び始めてくれたら、どんなに心強いだろう。私はそんな仲間の輪を広げていきたい。

これまで「電力消費地」の人たちは「電力生産地」の人々の痛みを知らないとマスコミに言われてきたが、私たちはこのようなくくり方をされると、かえって萎縮してしまい、何も出来なくなる。電力消費地、つまり都会の人々にも、また電力生産地、つまり発電施設のある地区の人々にも、いろんな考えの人がいるはずだ。にもかかわらず、マスコミにはんで押したような言い方をされると、かえって市民の反発を受けるだけである。発電施設のある地区の人たちにも、マスコミのつけた誤ったイメージに反発を覚えている人もいるはずである。

これからは、ごみとリサイクルで培った知識や体験を生かして、原子力発電やその廃棄物について、電力消費地とか電力生産地というようなくくりをはずして、共に顔の見える環境の中で語り合っていきたいと思う。

そのためには、電力を生産していく過程でも、廃棄物の埋設地を選定していく過程でも、原子力関係者は、先進国がすでに実行しているように、市民に全ての情報を開示し、共に語り合いながら、気長により良い結論に導くように努めていくべきであろう。そのことが、日本のエネルギー政策を国民と共有していく基軸につながる。

大都市消費地と地方の電力供給地との共生

福島大学経済学部教授　下平尾　勲

電源立地は、一方では電力の安定供給を図るという国家的要請にこたえるとともに、他方では電源立地を起爆剤として地域振興を推進するという二つの課題を同時に解決しなければならない。

しかし過去３０年間に原子力発電所の立地に関して大きな変化が生じており、その新たな課題の解決が重要である。

〔発電所立地の性格の変化〕

（１）原子力発電所の立地は最新の技術をもつ産業の立地として地域で歓迎されたが、今日ではそうではなくなった。発電が続いているかぎり、地域にとっては不安を伴う負の遺産という意識が生じた。リスク管理と責任の所在が問われている。

（２）電源三法交付金等の施策は、どちらかというと立地を促進するという性格を持っているが、今日原子力発電所施設５４基のうち２０基は２０年以上経過しているので、発電期間中のみならず、廃炉に向けて具体的な指針が地元で期待されるようになった。立地、運転、廃炉という三つの側面に即した方針と制度の拡充が課題となっている。

〔共生内容の変化〕

（３）電力は集中的、一括的、大規模の投資を必要とするが、一度び運転がはじまると、生産と消費とが同時に行なわれるために、地域経済への波及効果は保守点検を除いて著しく小さい。４０～５０年間電力の供給を継続するとすれば、電力供給を受けて経済発展する地域（消費地）と電力を一方的に供給する地域（生産地）との長期的、総合的な共生は不可欠である。

　発生電力の多くは地元で消費されず、主として大都市に移出され、大都市の産業の発展や住民の生活向上に貢献しているという役割を考えるならば、電力供給地の産業活動や生活向上に電力が低料金で有効利用されるか、消費地の開発利益の一部が発電地域に再配分すべきであるという住民感情が強い。

〔広域的、長期的地域振興〕

（４）発電所の立地によって雇用が拡大し、所得が増え、若年層の定着が期待されたが、立地後２０年経過すると、一挙に地域の人口流出、高齢化がすすんでいる。若者が地元に定着する産業が不足していることのほか、大学等の進学率の向上のためである。立地地域では進学率が著しく高くなる傾向がある。地域産業振興のほかに高等教育機関の配置

や医療・福祉政策が重要性をましている。

〔地方分権と電源立地〕

（５）地方分権が進むと、地方における原子力発電所の立地は困難となると予想される。その地域に必要な電力は自給すべきだという考えが台頭してくるからである。電力の安定供給のためには、国家政策として特別の立法措置が必要となろう。立法の制定にあたっては電源地域の広域的な振興策の充実が重要であろう。

〔電力自由化と電源立地〕

（６）電力の自由化については、電源地域の住民にとっては、不安要因が大きい。電気は水、ガス、電話等とともに人々の生活にとって不可欠の基本的なインフラであるから、経済効率性になじまない側面が多い。とくにわが国においては立地対策に多くの経費がかかり、遠方から送電するから、電力料金が高いのはやむをえないことであろう。電力料金を下げるとすれば、装置の見直し、点検や補修の短縮、人員削減が不可欠であり、経費を圧縮することにより原子力発電所の立地に関する不安、不信が高まっている。

地方で生産された電力を大都市で買っていただくという関係ではなく、大都市で必要な電力を地方で生産していただくという関係に立っているから、安定した電力供給を前提として自由化をすすめるべきである。

長期にわたって電力の安定供給を推進するためには、以上のような点を十分配慮のうえ、消費地と供給地とが共存できる道をさぐることが必要であると思われる。そのためには情報の交換、交流、相互信頼、相互扶助の精神の函養が不可欠と考えられる。

電力消費地として考えること

さいたま市 助役　　岩木　浩

○ はじめに

３５回目を迎えられる原産年次大会が，さいたま市で開かれ，発言の機会を頂きましたことを大変光栄に思っております。

さいたま市は昨年（平成１３年）の5月１日に，浦和市・大宮市・与野市の3つの市が合併し，人口１０３万人を擁する大都市として誕生いたしました。

来年，平成１５年には，全国で１３番目の政令指定都市への移行を目指し，市民が安心して暮らし，働き，憩うことができると同時に，地方分権の進展など様々な課題に対応できる自立都市の実現に向けて取り組みを進めております。

○ 環境共生都市　さいたまを目指して

本市は，東京都心から３０km 圏内に位置しながらも豊かな緑地環境を有しており，その一方で，本日の会場に近い大宮駅は新幹線５路線を含む鉄道の結節拠点であり，東日本の玄関口としての位置にもあります。

こうしたことから，合併時に策定をした新市建設計画において，さいたま市の将来像を「２１世紀をリードするみどりの広域交流・生活文化都市」とし，都市の基本目標として「広域交流都市の形成」と「持続的活力都市の形成」を，市民生活の基本目標として「生活文化都市の形成」と「環境共生都市の形成」を掲げました。

この内，最後の「環境共生都市の形成」は，本日のテーマとも密接な関係がありますので，主な内容を紹介しておきます。

①見沼田圃（面積約 1257.5ha の大規模緑地空間）や荒川河川敷などの自然環境を保全し，活用・創造する先進的な取り組みを進めること。

②従来の市街地やさらには周辺部での新たな開発においても，環境との共生に配慮したまちづくりを進めること。

③市民や企業の協力のもと，徹底したごみの発生・排出の抑制に努めるとともに，資源ごみのリサイクル，再資源化などの循環型社会システムを構築すること。

④大気汚染の低減，温室効果ガス削減のために，低公害車の普及を促進す

るなど，地球規模の環境問題への市のレベルからの取り組みを進めること。

⑤環境共生に対する市民や企業の意識を育み，多くの人が良好な自然環境の維持や創造を行えるようなまちづくりを進めること。

⑥資源のリサイクルやエネルギーの有効活用に積極的な取り組みを進めること。

このような施策実現のための第一歩として，さいたま市誕生と同時に，市の環境保全と創造に対する基本的方向と枠組みを示した「さいたま市環境基本条例」を制定し，平成１５年には，環境基本条例の基本理念の実現を図るための総合的な計画として，「環境基本計画」を策定する予定です。

○ アンケート調査に見る環境問題への関心

「環境基本計画」の策定にあたり，その基礎調査の一環として，市民・小学生・事業者の環境問題に対する意識調査を昨年実施いたしました。

調査対象は，２０歳以上の市民５千人と事業者５百件を無作為抽出で，小学生は市内８６校の各小学校５年生１クラス計３千人です。

もちろん，この調査結果がさいたま市民の意識傾向を代表している訳ではありませんが，参考にはなると思いますのでご紹介しておきます。

回答では，市民の環境問題に対する関心は全般的に高く，とりわけ「水質汚濁」「大気汚染」「廃棄物・リサイクル」の問題に対する関心が上位を占め，いずれも８８％を超えています。一方，小学生の場合は市民に比べると全般的に低いものの，「動植物や自然環境の減少」「廃棄物の不法投棄」に対する関心が８２％を超えていました。

「資源やエネルギーの過剰消費」については，市民が８２％，小学生が６９％ほど関心を寄せています。

事業者からは，事業活動に伴う環境問題への影響として，業種による相違はありますが，「廃棄物の処理問題」と「自動車騒音・排ガス等の交通公害」が１位に，次いで「地球温暖化問題」があげられています。

それでは，具体的な環境に配慮した行動はどうでしょうか。

市民の場合は，分別やポイ捨てをしないなどの「廃棄物」関係の取り組みが圧倒的に多くあげられていますが，これに次いで，電気をこまめに消したり冷暖房温度を控えめにするなどの「省エネルギー」に対する取り組みも９０％ほどとなっています。

小学生の場合は，ポイ捨てをしない，文房具を大切に使うなどが多くあげられており，「省エネルギー」に対する取り組みは市民よりも低いものの８６％ほどであり，それなりに気をつけている様子が伺えます。

事業者においては，ほとんどの業種で「資源物の分別回収」「不必要な照明や冷暖房運転などへの省エネルギーの努力」「環境配慮型製品の購入・利用（グリーン購入）」に対する取り組みが上位を占め，中でも，製造業，運輸・通信業，小売業においては「省エネルギー」が１位となりました。

○ 省エネルギーへの取り組み

環境問題に対しては，さいたま市が誕生する前の旧３市でも取り組んできたところですが，その中心は生活・近隣公害であり，近年，特にここ１０年ほどは廃棄物処理・リサイクルへの取り組みが大きな比重を占めて参りました。

正直申し上げて，電力などのエネルギー問題に対する市としての取り組みは，端緒についたばかりと言っても良いかと思います。

もちろんこれまで，エネルギー問題に対する取り組みが皆無だった訳ではなく，公共施設への太陽光発電の導入例や省エネの率先実行も行ってきましたが，あくまでも試行の範囲は出なかったと申せます。

唯一，本格的と言えるのは廃棄物発電で，現在市内３ヶ所のごみ焼却施設の全てが発電を行い，施設内の電力を賄うと共に，２施設では余剰電力の売電も行っております。

今年の３月に，職員による１年ほどの検討の結果，「さいたま市地球温暖化対策実行計画」がまとまりました。

これは，１事業者でもある市が，その事務及び事業を行なうに当り，温室効果ガスの排出抑制に努めるため，消費電力量の節減，用紙使用量の削減，燃料使用量の削減，ごみ排出量の削減等の具体的取り組み項目をまとめたものです。

市役所はオフィスビルでもあることから，温室効果ガスの排出に関しては，電気使用量によるものが約７９％と最も多くなっているだけに，照明やＯＡ機器の節電には特に重きを置いております。

たとえば，本庁舎では現在，昼休み１時間の消灯を行なっていますが，試算では，本庁舎を含む全施設の照明器具類は２０万５千本以上あり，これを１日９時間使用するものとして，全照明器具の８割を１日１時間消灯すると，照明器具全体使用量に対し約２％の削減が可能と考えられます。

この他，パソコンやプリンタなどのＯＡ機器類も同様であり，全体での使用台数が多いだけに，不要時に電源を切るだけで大きな節電効果が生れます。

この計画は，１事業者でもある市役所の率先実行ですが，その成果をも踏まえて，市民や市内事業者に広げていきたいと考えております。

○ 理解を深めるために

本日の会場になっておりますソニックシティビルの３１階には，東京電力の「エネルギー物知り館 テプコソニック」があり，来館者が年々増えて，昨年度は８３０万人を超えたそうです。

エネルギー問題，特に原子力発電に関しては，なかなか正確なところが理解できていないのが実状ではないでしょうか。原子力というと，日本人には広島・長崎の記憶もあることから，賛成か反対かの二元論で終始しがちの印象もあります。

先にあげた市民等の意識調査においては，環境問題に関する情報はマスメディアからのものが最も多いという結果でしたが，より深い理解を得るためには，このような学習施設の利用がもっと必要であり，市としても環境学習にもっと力を注いで参りたいと考えております。

また今回，参考資料でいただいた中に，原子力発電所立地地域の方々の声がのっておりましたが，大変興味深く拝見いたしました。特に，私ども電力消費地との交流を有益だと考えている方が９８％にもなることは，今後，いろいろと検討させていただく必要がありますし，本日のように，立地地域の市長さんからお話を伺えることは大変ありがたいことと捉えております。

最後に，電力消費地としてまず考え行なっていかなければならないことは，やはり省エネルギーの実践に尽きるものと思いますので，今後一層努力して参ります。

LUNCHEON

午餐会

県知事挨拶

福井県知事　栗田　幸雄

本日は、社団法人日本原子力産業会議が主催されます「第３５回原産年次大会午餐会」において、次回開催県の知事として発言の機会を与えていただき誠にありがとうございます。

また、西澤会長をはじめ皆様には、本県県政の推進につきまして、日ごろより多大なご理解とご支援をいただいておりますことに感謝申し上げます。

さて、次回「第３６回原産年次大会」は、来年４月１４日から１７日までの４日間、福井県の敦賀市および福井市を中心に開催させていただくことになりました。西澤会長をはじめご出席の皆様のご配慮に心からお礼申し上げます。

福井県は、研究開発段階の原子炉である高速増殖炉もんじゅを含めて１５基の原子力発電所が立地しており、本県での年次大会を通して、我が国の原子力政策およびエネルギー政策に大きく貢献している本県を内外にアピールできますことを大変ありがたく思っております。

本県は、現在、原子力を巡り多くの課題に直面しております。

まず、日本原子力発電株式会社敦賀発電所３、４号機の増設計画につきましては、環境影響評価の手続きが終了し、先般、第一次公開ヒアリングが開催されました。

今後は、国の電源開発基本計画に組み入れることについて、総合資源エネルギー調査会から知事意見が求められることになりますので、安全性の確保や地域振興等について十分検討し、総合的に判断していきたいと思っております。

次に、平成７年１２月にナトリウム漏えい事故を起こした「もんじゅ」の問題につきましては、改造工事について国の安全審査が進められておりますが、「もんじゅ」全体の安全性を確認するため、県独自の専門委員会において安全性に対する県民の疑問や不安などをもとに、慎重に審議を進めております。

ＭＯＸ燃料のデータ不正問題により中断している高浜発電所のプルサーマル計画につきましては、保管されているＭＯＸ燃料を英国に返還することで日英両国政府の合意がされ、先月、「日米原子力協定」に基づく米国の同意が得られたことから、英国への返還が速やかに実現されるよう、国や事業者に対し強く要請しております。

プルサーマル計画の実施につきましては、国や事業者の輸入ＭＯＸ燃料に関する品質保証体制が確立され、それに対する国民・県民の信頼確保が必要であると考えております。

次に、新型転換炉ふげん発電所については、平成１５年３月の運転停止が決まっており、停止後、具体的な廃止措置の準備に入ることになります。

さらに、立地地域の高速交通体系の整備の一つとして期待され

ております近畿自動車道敦賀線につきましては、計画どおりに早期に整備されるよう、国に対し強く要望しております。

これらの課題の解決につきましては、県議会をはじめ関係市町村においてさまざまな取組みが行われておりますが、本日、ご出席の皆様方におかれましても本県の実情をご理解いただき、ご支援を賜りますよう、よろしくお願い申し上げます。

また、来年春の近畿自動車道敦賀線の舞鶴東から小浜西間の供用開始やＪＲ小浜線の電化開業などを機に、地域の資源である「食」、「祭」、「海」、「エネルギー」をテーマとした多彩なイベントとして『若狭路博２００３』を計画しております。

１５基の原子力発電所や火力発電所が立地する若狭地方の特徴を踏まえ、若狭路博のテーマの一つに「エネルギー」を取り上げており、その関連イベントの一つとして「第３６回原産年次大会」を位置付けております。

来年春の原産年次大会の開催によりまして、原子力をはじめとするエネルギーについて、県民、地域住民、さらには消費地の方々の理解が深まることを念願しており、次回開催県として大会の成功に向け万全の準備を整え、皆様をお迎えしたいと考えております。

日本の中央に位置し、「越前」と「若狭」の二大文化圏をもつ福井県には、恐竜化石をはじめ、奈良・平安時代開基の寺院である明通寺、一乗谷朝倉氏遺跡、永平寺などの貴重な歴史的文化的

遺産が数多く残されており、また、四季折々に姿を変える海や山、川など人々の心を感動させる豊かな自然に恵まれております。

そして、季節感いっぱいの味覚、人情あふれるやさしさに満ちた県民性により、皆様に「やすらぎと感動」を感じていただけることと思います。

県民を挙げて皆様のご来県を心よりお待ちいたしております。

終わりに、「第３５回原産年次大会」のご成功と西澤会長をはじめご出席の皆様の今後ますますのご活躍を祈念申し上げまして、ごあいさつといたします。

セッション　3

プルトニウムのリサイクル利用をなぜ進めるのか

筑波大学 機能工学系教授　内山洋司

1．原子力は最も頼れる化石燃料の代替エネルギー源

京都議定書で公約した削減目標を達成するための地球温暖化対策推進大綱が今年の３月１８日に発表された。政府は、わが国が掲げる２０１０年の削減目標を達成していくには、省エネルギーや新エネルギーの政府目標を達成できたとしても、１０から１３基の原子力発電の建設が不可欠になるとみなしている。温暖化対策は一過性のものではなく、２０１０年以降は、さらに大きな削減目標を掲げていく必要がある。経済的に見てさらに大幅な省エネルギーと大規模な新エネルギー導入を達成していく目途は立っておらず、長期的な視点から量的かつ経済的な面で原子力が最も有望な選択肢である。

日本を取り巻くアジアの国々はその多くが開発途上にあって、現在、経済発展の最中にある。経済発展はエネルギー需要を増大しており、特に人口が多いアジア地域におけるエネルギー需要の伸び率は著しい。世界はエネルギー供給の大半を化石燃料に頼っているが、アジア地域における石油、天然ガスの資源量は欧米など他の地域に比べて極めて少ない。日本およびアジアの多くの国々は、欧米に比べてエネルギー供給の構造が脆弱な状態にある。将来のエネルギー需要増を満たしていくエネルギー源として石炭は有望であるが、その大量消費は酸性雨だけでなく地球温暖化を深刻にしていく。水力や太陽光などの再生可能エネルギーの開発も大切ではあるが、供給面と経済面で大きな問題を抱えており、将来の需要を満たしていく見通しはない。エネルギー供給に脆弱な構造をもつ日本を始めとするアジアの国々にとって原子力は最も頼れる化石燃料代替エネルギーである。

原子力開発は、地球温暖化対策とエネルギーセキュリテイ確保の面で重要であるが、問題は導入スケジュールである。わが国の場合、電力需要の伸びの低迷と電力自由化の流れを考えると、原子力発電の開発規模は当面それほど大きなものにはならない。しかし、政府が掲げる地球温暖化対策を考慮すると、市場で導入できる規模を上回る設備を政策的に開発していかざるを得ない。原子力発電所が建設され運転できるようになるまでには、許認可手続き、公開ヒヤリング、建設工事などで１５年以上もの長い期間が必要になる。他の対策技術のように必要になったらすぐに導入できるようなものではなく、中長期の視点でもって開発計画を検討していかなければならない。中長期の経済社会の見通しには不確実性があるが、将来の必要性が大きい原子力に対しては、できるだけ早やくから、建設計画を立案し実行していくべきである。

2．不可欠となるプルトニウム利用

原子力は温暖化対策だけでなく供給安定性と経済性を兼ね備えたエネルギー源であ

る。しかし、天然ウランに含まれるウラン235の量は僅かで、その資源の可採年数は約６０年といわれている。現在の軽水炉用燃料を使っていればいずれは化石燃料と同じように燃料の供給に制約が生じることになる。特にアジア地域において、将来、原子力発電の開発が進むとウラン燃料の需給逼迫が発生する恐れもある。原子力を推進していくためには、原子力発電所から出る使用済燃料を再処理し、有用資源を回収する核燃料サイクルを確立することが不可欠となる。

一度使った燃料をリサイクルできるという点は、他の資源にはない原子力の特徴といえる。使用済燃料中に含まれているウランとプルトニウムは、リサイクルしなければ単なる廃棄物に過ぎない。しかし、再処理によって回収して再び燃料として使うようにできれば、国産のエネルギー資源として利用していくことが可能になる。再処理技術は欧州において既に商用化されており、プルトニウム利用が経済的に成り立つ見通しは得られている。

エネルギー供給構造の脆弱さでは他のアジア諸国も日本と同じような立場にある。日本およびアジア地域において、商用再処理の基盤技術が確立されなかった理由には、技術的、経済的な面で欧米に遅れていたことの他に、核拡散という政治的な問題があった。残念なことにアジア地域には、将来の核拡散を防ぐためのシステム造りが整備されていない。わが国はアジアの先進国として、将来のアジア地域におけるエネルギーセキュリティと原子力の平和利用に貢献していく責務がある。それには技術開発とシステム造りの面から積極的な役割を果たしていく必要がある。

３．技術的信頼性の確保が重要：商用規模での運転が不可欠

プラント事故の原因には、人為的な操作ミス、設計ミス、材料劣化などがある。六ヶ所村に建設中の再処理プラントは、すでにフランスで運転されている実用プラントであり、設計および運転方法は確立されたものである。設計や運転のミスによって発生するトラブルは、フランスにおけるこれまでの経験を生かすことで回避できる。問題は材料劣化に伴うトラブルである。

材料の劣化を示す経年変化は温度や化学的な環境条件および運転方法に大きく影響を受ける。同じ設計で造られたプラントであっても、信頼性は長期間になると同じとは限らない。現に実用化されている同一設計の軽水炉であっても材料劣化によるトラブルは、プラントごとで異なり問題になっている。研究開発と科学技術の進歩で材料の劣化現象は解明されつつあるが、長期間にわたり運転し続けるプラントにおいて、それがいつ配管や機器の破損に繋がっていくかを正確に予測することはできない。特に商用規模の大型技術になると、熱変化を受けている配管や装置が数多くあるため、すべての材料劣化を正確に予測することは極めて難しい。実用プラントでできるだけ多くの経験を積むことがプラントの信頼性確保になる。

大型プラントは30から60年といった長期にわたり運転しなければならないため、その間の信頼性向上は、プラントの経済性のみならず、周辺住民の不安解消のためにも大切なことである。また、小さなトラブルを未然に防ぐことが重大事故の発生防止に繋がることになる。再処理プラントでは機器が高温と腐蝕の環境下に晒さらされている。その環境条件はプラントの運転状況で変化しており、そういった環境下での材

料劣化を科学的に正確に把握することは難しい。信頼性は経験によって勝ち得るしか、他に方法はない。できるだけ早期に実用プラントを運転し、経験を積んでいくことが大切になる。

4．リサイクル社会を目指す：“トイレなきマンション”からの脱却

使用済燃料の再処理には、経済的な資源賦存量を拡大するだけでなく、リサイクルによる環境負荷の改善という大きな役割がある。使用済燃料の9割以上は燃料として再利用できるウランとプルトニウムである。もし再処理しなければ、使用済燃料全体を高レベル放射性廃棄物として処分することになる。再処理によって使用済燃料から回収されるウランとプルトニウムは、元の燃料の最大2～4割に相当する新燃料となる。ウラン235の使用量が減った分は、ウラン鉱山における環境面と安全面でのリスクも軽減される。

２１世紀は循環型社会の構築を目指した産業の発展が望まれている。社会の資源消費をできるだけ少なくしていくことが必要だが、発生する廃棄物もできるだけリサイクルで有用な資源として利用していくことが大切になる。現在、一般廃棄物や産業廃棄物のリサイクル活動が進み、静脈産業が育ちつつある。使用済燃料も再処理によってリサイクルが可能になり、新産業の創出にもなる。表１は、使用済燃料の核物質を再処理で分別し、それぞれの物質を利用してどのような産業が創出できるかを示したものである。

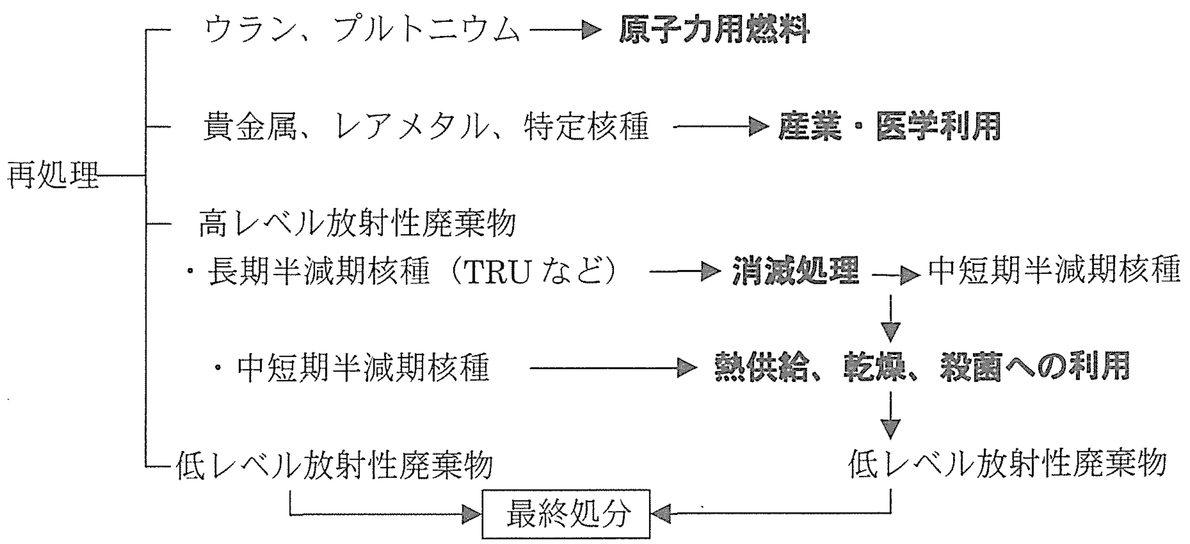

表１　再処理による新産業の創出

再処理によって得られる有用な物質であるウラン、プルトニウム、貴金属、レアメタルなどは産業用材料としての利用が期待できる。高レベル放射性廃棄物の中で、長期半減期のものは消滅処理によって中短期半減期の核種を変換する。変換された中短期半減期の核種は、使用済燃料から直接、取り出される中短期半減期核種と一緒に低レベル放射性核種になるまで熱供給、乾燥、殺菌など産業で利用していく。これからは、原子力の開発が“トイレなきマンション”と言われないように、負の部分を産業として発展させていくことが大切となる。

MOX Program: Its Needs and Issues
MOXプログラムの必要性と課題

The 35th JAIF Annual Meeting
第35回原産会議年次大会
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Need for MOX Program(1)
MOX プログラムの必要性

- Safer Plutonium Management
  (プルトニウム在庫管理の重要性)
  - Civilian Pu stockpile is still growing
    - 民生用Pu在庫量は世界規模で増大
  - Japan has committed to "no plutonium surplus" policy
    - 日本は「余剰Puを持たない」政策を堅持
  - MOX program is essential to implement its policy goal
    - MOXプログラムの円滑な実施が不可欠

Civil Plutonium Inventory 1999
民生用Pu在庫量(1999)

Civil Unirradiated Plutonium 1999

(tons, reported to IAEA, December 2000)

	Britain	France	Belgium	Germany	Japan	Switz.	Russia	U.S.	China
At reprocessing plants	69.5	55	0	n.a.	0.5	n.a	30.9	n.a.	n.a.
At MOX plants	2.2	8.2	1.4	5.48	1.2	0.6	0.2	n.a.	n.a.
elsewhere	0.8	18	2.5	1.71	3.5	n.a	0.9	n.a.	n.a.
Total	72.5	81.2	3.9	7.19	5.2	0.6	32	0	0
foreign ownership	11.8	37.7	n.a.	n.a.	0	<0.05	n.a.	n.a.	n.a.
in other countries	0.9	<0.05	0.9 n.a.		27.6		n.a.	n.a.	n.a.

source: Institute for Science and International Security, 2001

Civil MOX Programs
民生用MOXプログラム

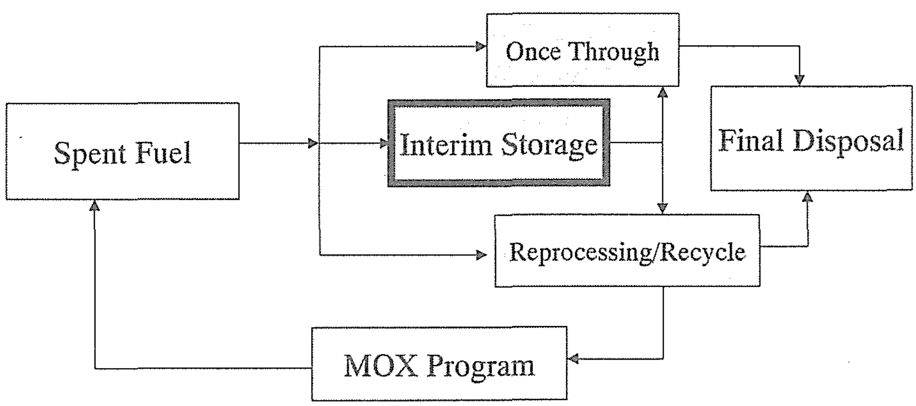
Civil MOX Progam

	MOX Plant (ton/y)		Licensed Reactors	
	Now	Planned	Now	Planned
Belgium	35	75	2	2
France	155	250	20	28
Germany	——	——	11	11
Japan	(16)	100	3	16-18
Britain	128	128	--	--
Total	348	553	36	57~59
(Pu tons)	(~20)	(~30)	(~10)	(~18)

Need for MOX Program (2)
MOXプログラムの必要性

- Better Spent Fuel Management
  使用済み燃料管理の重要性
  - Lack of spent fuel storage capacity is a source of concern
    - 使用済み燃料の貯蔵容量不足が懸念の的
  - MOX program is an important option for better SF management (as a part of nuclear fuel cycle)
    - MOXプログラムは使用済み燃料管理対策としても重要な選択肢の一つ(燃料サイクルの一環

MOX Program and Spent Fuel Management
MOXプログラムと使用済み燃料管理



Major Issues(1)
主要課題

- Lack of incentives to use MOX fuel
  MOX利用のインセンティブ減少
  - Soft uranium market (for a forseeable future)
    - ウラン需給緩和が当分続く
  - Liberalization of electricity market
    - 電力自由化でコストダウン圧力
  - Expensive reprocessing program
    - 再処理プログラムのコスト増

Major Issues(2)
主要課題

- Unclear division of responsibility between the government and private industry
  政府(国策)と民間(電気事業)の責任不明確
  - MOX program considered as "National Project"
    - MOXプログラム(燃料サイクル確立)は国策
  - But its implementation is private industry's responsibility
    - しかし実施･投資責任は電気事業にある
  - Unclear who is finally responsible for (its risk)
    - リスクを最終的に誰が負うのか？

Major Issues(3)
主要課題

- Lack of mutual trust with local community
  地元との信頼関係欠如
  - Local referendum caused by lack of trust (rather than anti-MOX, anti-nuclear)
    - 住民投票は反MOX, 反原発ではなく、信頼の欠如
  - Public trust is eroding for the government (and public projects) as a whole
    - 原子力のみならず、政府、公共事業への不信増大

Future Options (1)
今後の進め方

- Share responsibility by the Government for security reasons
  安全保障上、政府の責任も明確化
  - Ownership can be transferred (partially)
    - 所有権一部政府へ移管、管理･削減義務を負う
  - Financial assistance, giving contracts to private utility are among the options
    - 民間へMOX事業委託、または財政援助などの案

Future Options (2)
今後の進め方

- Creating programs to restore public trust
  信頼回復プログラムの実施
  - Need for sincere dialogue for confidence building
    - 地元自治体、電気事業、政府間の真摯な対話
  - Possible appointment of the third party as a reliable "mediator"
    - 賛成、反対の立場をとらない中立的な第三者(仲介)の設置

Future Options (3)
今後の進め方

- Promotion of interim storage of spent fuel
  使用済み燃料の中間貯蔵促進
  - Secure storage capacity of spent fuel
    - 中間貯蔵容量の確保が最大の課題
  - Reduce unnecessary commitment to reprocessing (better Pu supply/demand management)
    - 不必要な再処理の減少が在庫量管理最善の策

Future Options (4)
今後の進め方

- Increasing options for Pu management and disposition
  Pu在庫量管理・減少の選択肢増大
  - Sooner, less transportation, fewer sites are three key principles (for better physical protection)
    - 早期、輸送減少、燃焼地域制限が重要
  - Domestic Pu stockpile should be reduced first
    - 国内Pu在庫量削減を優先（もんじゅの活用？）
  - Possible int'l program for Pu in Europe (int'l custody?)
    - 欧州のPuについては、政府間協力プログラムを（国際管理？）
  - Limited number of sites is better
    - 全電力ではなく、最小限のサイトで実施
  - Immobilization can be also considered：ガラス固化も検討

プルトニウム問題について

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大過剰時代を迎えたプルトニウム

現在、日本を含めて世界はプルトニウム大過剰時代を迎えようとしている。

わが国では使用済み燃料中に蓄積されたプルトニウムはまもなく 100 トンを超え、そのうち海外委託再処理分 30 トンは 2005 年までに返還される予定である。世界的に見れば、軍事利用目的で生産されたプルトニウムは 270 トン、商用プルトニウムのうち未分離のものが 800 トン、分離されたものが 200 トン合計 1000 トンに上っている（1995 年の数字、Makhijani、IEER report）。さらに問題なのは現在の蓄積量の大きさだけではなく、その増加速度である。わが国の原子力発電の設備容量は時間とともに直線的に増加しているが、このことはプルトニウムの蓄積量が 2 次曲線を描いて上昇することを意味しており、実績もそれに従っている（世界の増加傾向も同様である）。もしこの傾向が続くならば、21 世紀半ばには、日本で 1000 トン、世界全体で 1 万トンにも上り、原子力発電体系はプルトニウムの「重み」によって崩壊しかねない。

硬直化したわが国のプルトニウム政策

このような中でわが国の核燃料政策、とくにプルトニウム政策は事態の変化に対応できず、新潟県刈羽村の住民投票の結果にも見られるように一般市民の理解も得られないままにデッドロックに乗り上げている。政府はプルトニウム問題の全面的検討を怠り、プルサーマル推進にのみ固執しているが、こうした態度はむしろ問題解決を遅らせるものである。

従来の原子力長期計画などによると、わが国の核燃料・プルトニウ政策の基本は次のようなものであると理解できる。

①「準国産エネルギー源」としてのプルトニウム利用推奨。

②使用済み燃料の全量再処理（つまりプルトニウムの全量回収）。

③「諸外国に核武装を疑われないために、余剰プルトニウムを持たない」（プルトニウムの全量利用）方針の堅持。

一見もっともらしく見える政策であるが、政策立案の時点から技術的現実を無視したものであり、またその後の事態の推移の中で矛盾をますます拡大させていった。「準国産エネルギー」といっても米国起源の核物質から抽出されるプルトニウムについては米国の強力なコントロールが適用されることは、カーター

の動燃東海再処理工場ストップ事件で明らかであり,決して自主的エネルギー源と言えるものではない。全量利用については、原子力委員会は高速増殖炉（FBR）、新型転換炉（ATR）、軽水炉を 3 本の柱としてあげていたが,そのうち FBR,と ATR（電力業界からの申し入れで開発中止）がだめになり、残るは軽水炉での利用（プルサーマル）だけという惨憺たるありさまとなった。さらに「余剰プルトニウムを持たない」といいながら、プルトニウムをどんどん生産する FBR 利用を推進するのは矛盾した態度である。また「余剰プルトニウム」とは厳密に何を指すかも明確でない。

諸外国から核武装を疑われるかどうかは、「余分の核物質を持っているか否か」ではなく、国の方針として、日ごろから核兵器廃絶に向けて真剣に努力しているか否かにかかっており、技術の問題ではなく、政治・外交の問題である。

問題理解のかぎ、プルトニウムの同位体組成

現在、大量に存在するプルトニウムは①解体核兵器から取り出されたプルトニウム,②使用済み燃料から分離されたプルトニウム、③使用済み燃料中にある未分離のプルトニウムに大別できる。さらにプルサーマルが実施されれば④MOX 燃料を再処理して取り出したプルトニウムが生じる。これらは一括してプルトニウムと呼ばれるが、その中に含まれる同位体の組成が異なり、したがって核的性質や、放射能としての性質も異なる。

①は核兵器級と呼ばれ、約 93％のプルトニウム - 239、および若干（7％以下）のプルトニウム - 240 を含んでいる。高速増殖炉から取り出されるプルトニウムもこの核兵器級である。

②、③は原子炉級と呼ばれ、プルトニウム - 239 が 55～60％で、この他-240（17％以上）、-241 さらには - 238 などの同位体を多く含んでいる。このようなプルトニウムを高次化プルトニウムと呼び、-241 などの同位体は、作られてから時間が経過すると、中性子やガンマ線など防御しにくい放射線を出す核種へと変化する。このためプルトニウムを扱う研究者はダーティ・プルトニウムと呼んで嫌っている。また偶数の原子量の同位体（全体の約 30％）は核分裂性でなく燃料としての価値も下がる。

④の使用済み MOX 燃料を再処理して取り出したプルトニウムではさらに高次化が進むため、経済的、技術的にみて燃料としての価値があるかどうかさえ疑わしい。

プルトニウムの政策的位置付けの明確化が必要

前述のように、国が推進しようとしているプルトニウム政策が国民から受け入れられていない最大の理由は、プルトニウムが「生産すればするほど利益を生

む資源」なのか、「生産するほどその処理・処分にコストがかかる廃棄物」なのか,プルトニウムの政策的位置付けが不明確のまま、あるいは故意に不明確にしたまま、強引にプルサーマルだけを唯一の選択肢として押し付けようとしている点にある。たしかに物理的には、プルトニウムは両方の側面を備えている。しかしながら、MOX 燃料の製造コストがウラン燃料の数倍はかかるという、現在の技術状況、経済状況を考えれば、プルトニウムを「処分にコストのかかる廃棄物」として明確に規定し、たとえば燃やすことによって発生する電気から生じる利益はそのコストから差し引く、という考えで対処すべきである。

可能な選択肢は

対応する政策としては、消極的なものから順に、①使用済み燃料のまま、(地中などに)処分する、②使用済み燃料のまま一時的に保管し、将来の技術開発に待つ、③プルサーマルを推進する、④積極的に「プルトニウム・バーナー」を開発し処分を進める、などが考えられる。

①は米国などが採用しようとしている方法であるが、プルトニウムを地中処分してしまうことについての安全性を保障する科学的根拠はない。②は短期的には採用せざるを得ないことは明らかであるが、その先の処分についても考えておかなければ無責任のそしりを免れないだろう。

現在国は、③のみを推進しようとしており、他の選択肢については全く考慮しようとしていない。そこで③についてその問題点を述べておこう。先にも述べたようにわが国のプルトニウム蓄積量は約 100 トン、毎年 20 トン程度増加している。1/3 炉心で 20 基に導入した場合年間のプルトニウムの年間消費量は１５トン程度,となり、導入の仕方によっては増加を食い止め、あるいは蓄積を減らすことができる。ただし、使用済みのＭＯＸ燃料中には１％程度のプルトニウムが残るが、このプルトニウムは先に述べた、きわめて扱いにくい高次化プルトニウムであり、MOX 燃料の再処理技術さえ確立していない。その他長寿命の高レベル廃棄物である超ウラン元素（ＴＲＵ）が増大するなどの技術的困難が予想され、推奨できる方法ではない。

さらに多くの原発に MOX 燃料が導入されれば,それはプルトニウムを多量に取り扱う施設として、核物質防護上の第一群に位置付けられ,一般市民の接近が遮断される。つまり公開の原則が大幅に侵害されるが、これは安全確保の上から言っても大きな問題である。

プルトニウム・バーナーの研究を

そこで④のプルトニウムを積極的に「燃やす」方法について考える。その際重要なことはこれを燃やす炉つまり「プルトニウム・バーナー」と、プルトニウ

ムを含む燃料の形態である。まず「バーナー」であるが、もっともよく知られているのは高速増殖炉である。高速炉については①技術的困難を抱えていること、②プルトニウムを「増殖」する炉であること③生成するプルトニウムが高次の同位体を含まないプルトニウムである。これらの点を考慮すると、プルトニウムを大量に使用する高速増殖炉の技術体系が、技術的完成を経て社会に受け入れられるようになるにはまだ時間がかかりそうである。

日本でも優秀なプルトニウム・バーナーが開発されていた。新型転換炉（ATR）「ふげん」である。最近、政府は「プルサーマル連絡協議会」を」立ち上げ、その議論の中で「MOX燃料を使用している『ふげん』の実績などその安全性を十分にアッピールしていきたい」としている（原産新聞）。同協議会が今となって大いに評価しているこの炉は、電気事業連合会から「開発費用がかかりすぎるから中止を」という申し入れを受けた原子力委員会が、検討らしい検討もせず中止を決めてしまった。先見性のない決定であったといえる。

「プルトニウム・バーナー」として、Geel 等はキャンドウ炉や高温ガス炉を推奨している(V.J.Geel,Hj.Matzke and J.Magill, Nucl.Energy, 1997, Vol.34, No.4,p.305)。

燃料についていえば,ウランとプルトニウムを混合した通常のMOX燃料では、ウラン 238 が中性子を捕獲してプルトニウムとなるため、消費しながら生産するという効率の悪いことを行っている。そこでプルトニウムをウラン以外の物質(イナート・マトリックスという)に混ぜて燃料を作れば、このような問題は避けることができる。マトリックスとして、ジルコニアやスピネルなどが試みられているが、Geel らは酸化トリウムを推奨している。

このようなプルトニウム・バーナーが作られれるならば、バーナーの消化量に応じて再処理の処理速度を調節すれば、過剰な分離プルトニウムの蓄積は避けられる。

いずれにせよ発生したプルトニウムは燃やすという選択肢を取らざるを得ないだろう。その場合、プルサーマルという形で現在の軽水炉発電体系に全面的に投入するのではなく、プルトニウム・バーナーという形で一本にまとめることが、技術、安全性、経済性などの面から優れているといえる。

結論として、プルトニウム問題を解決するためには,プルサーマルに固執する態度を改め,「ふげん」の復活も含めて、プルトニウム・バーナーや燃料の技術開発に力を注ぐべきである。

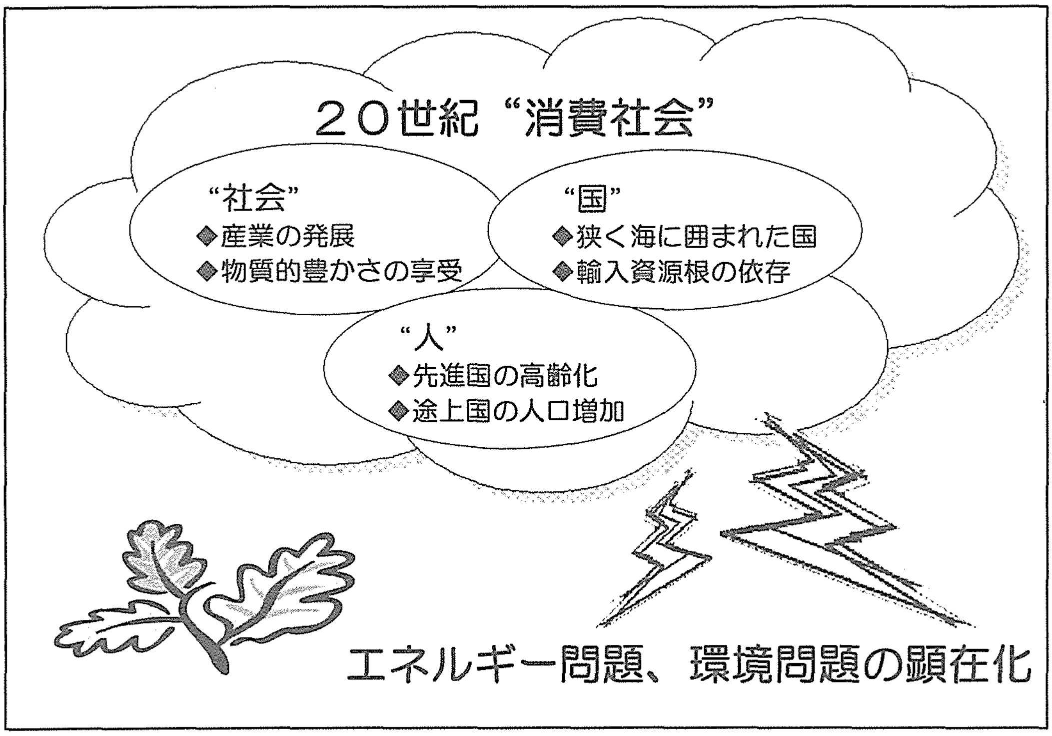
このような技術開発も含め,プルトニウム問題解決のための正面からの取り組みが待たれているといえよう。

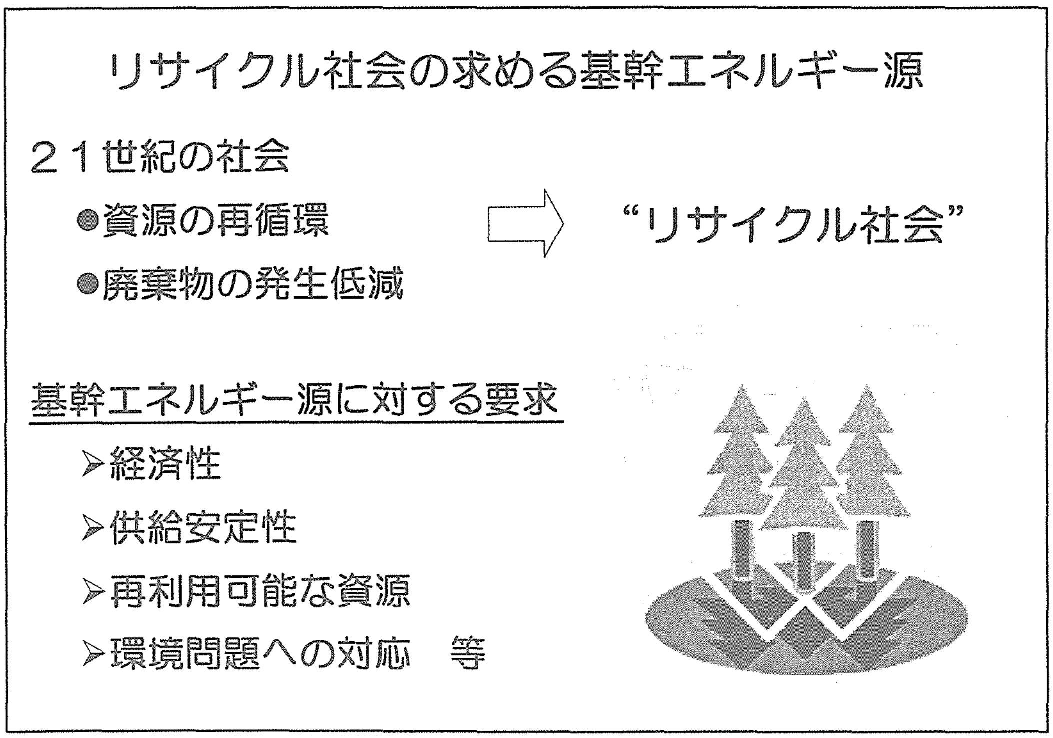
Ｐｕ利用の確立に向けて

核燃料サイクル開発機構
ＦＢＲサイクル開発推進部
野田　宏

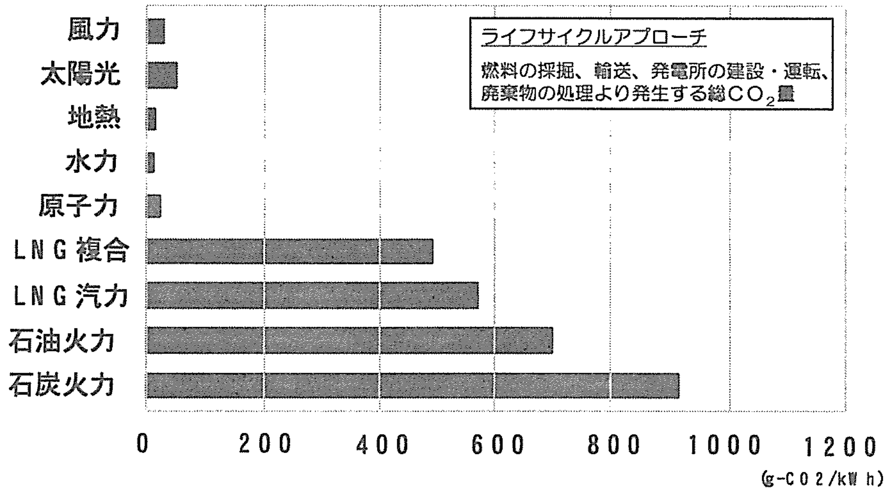
内　容

- ２１世紀の社会と基幹電源
- 地球温暖化防止と原子力発電
- Ｐｕの利用と燃料サイクルの開発状況
- ＦＢＲ実用化戦略調査研究の概要
- 第４世代原子炉プロジェクトの燃料サイクル
- まとめ


２０世紀“消費社会”
“社会”
◆産業の発展
◆物質的豊かさの享受
“国”
◆狭く海に囲まれた国
◆輸入資源根の依存
“人”
◆先進国の高齢化
◆途上国の人口増加
エネルギー問題、環境問題の顕在化


リサイクル社会の求める基幹エネルギー源
２１世紀の社会
●資源の再循環
●廃棄物の発生低減
“リサイクル社会”
基幹エネルギー源に対する要求
➢経済性
➢供給安定性
➢再利用可能な資源
➢環境問題への対応　等

ライフサイクルCO_2排出量



出典：電力中央研究所報告書より作成

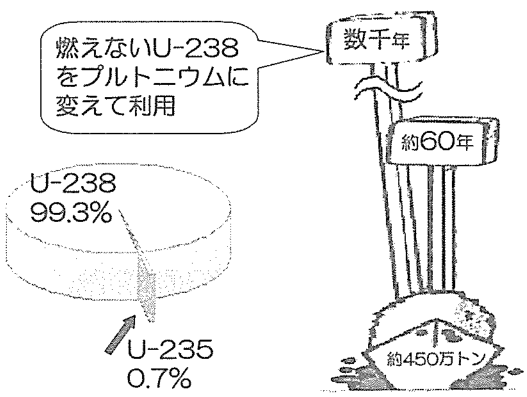
原子力はプルトニウム利用が究極

ウラン資源も有限

⇩

プルトニウム利用により超長期資源

（可採年数は数千年）



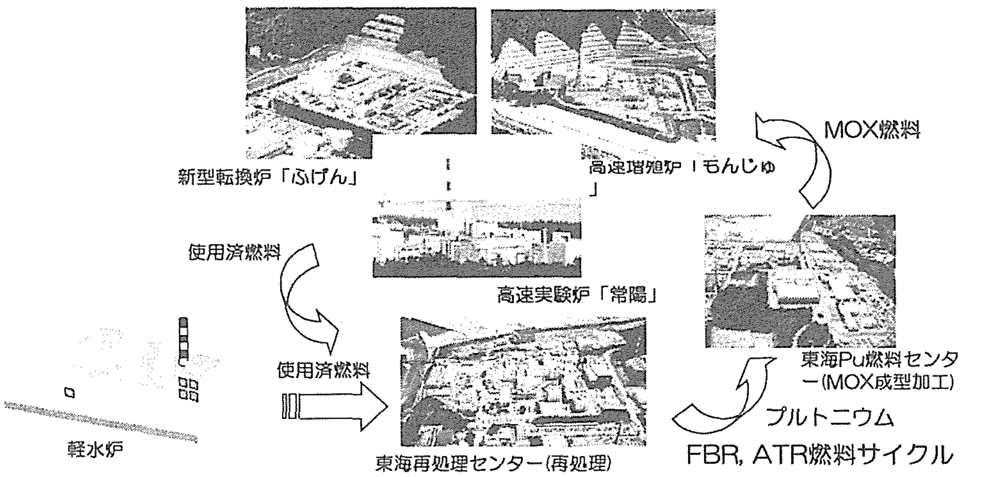
天然ウラン利用効率

原子炉	ウラン利用効率
軽水炉（ワンススルー）	０．５%
軽水炉（プルサーマル）	０．７５%
高速増殖炉	６０%程度

出典：「プルトニウム」鈴木篤之編著

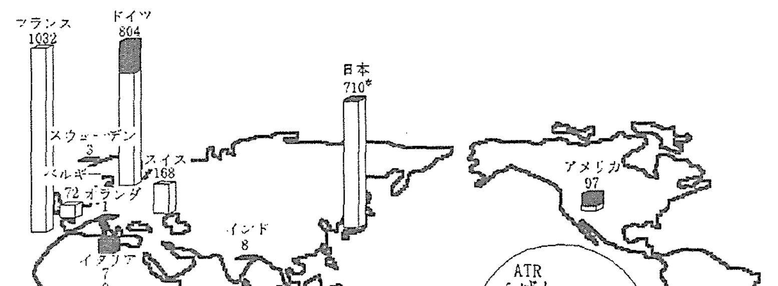
核燃料サイクルの技術開発

- Ｐｕを準国産エネルギーとして活用
- リサイクル社会への貢献



「ふげん」でのMOX燃料利用実績

- 世界的にも有数のMOX燃料使用実績：726体装荷
- 「ふげん」の柔軟なMOX燃料利用特性：34～72%の MOX装荷率を経験

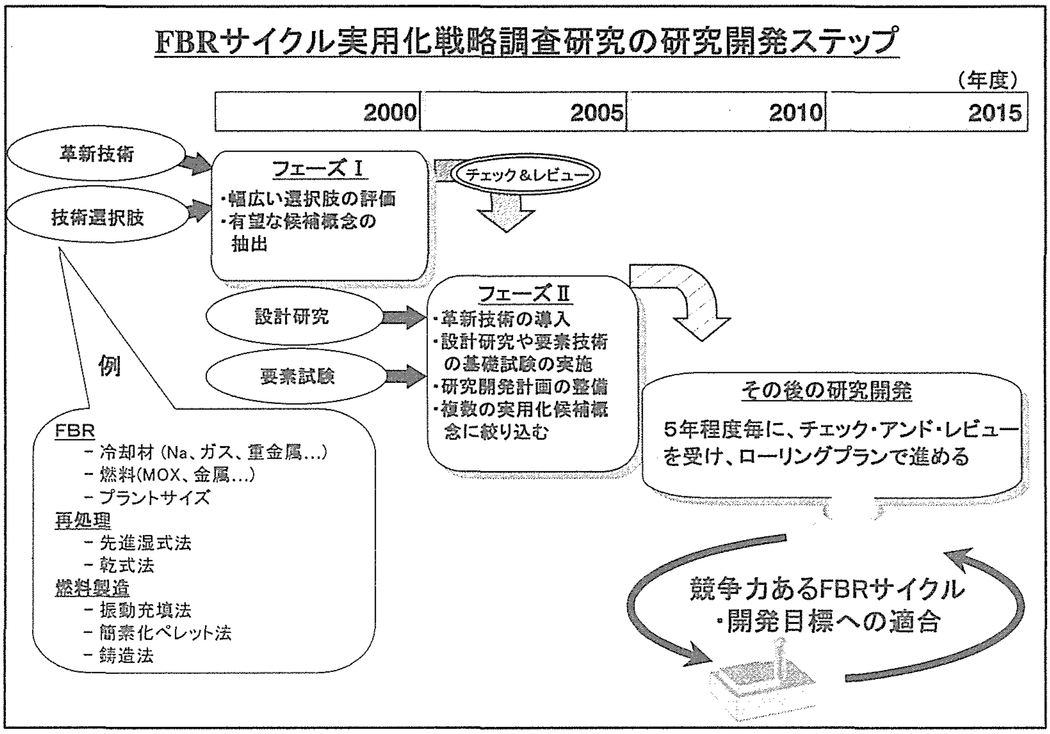


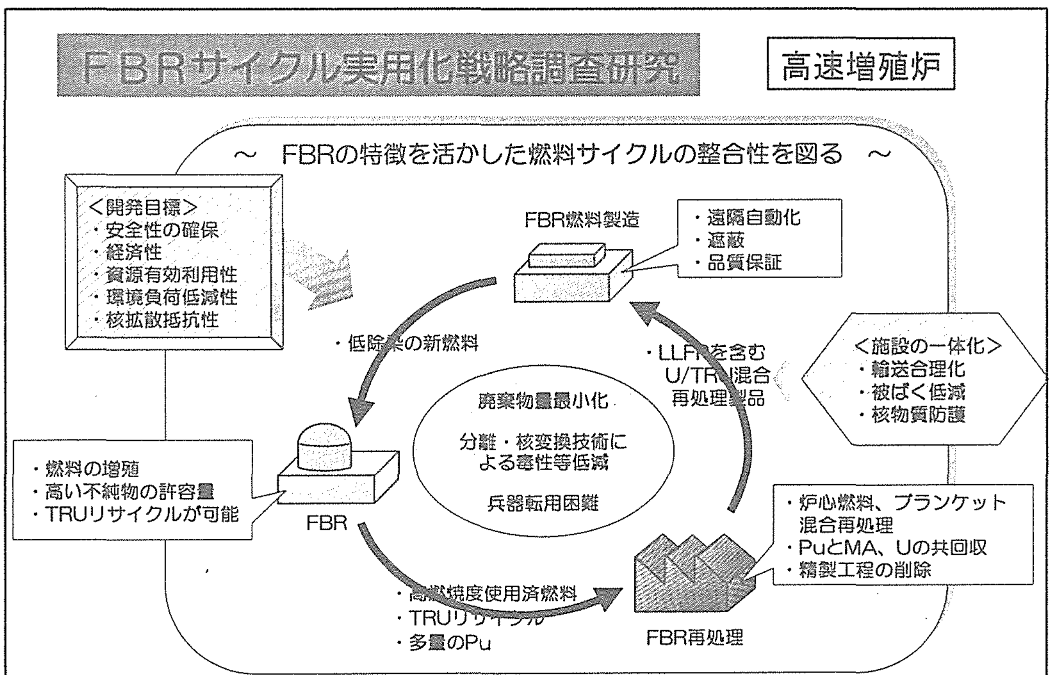
国名	BWR	PWR
フランス	—	1,032
ドイツ	178	626
スイス	—	168
ベルギー	—	72
インド	8	—
イタリア	70	8
オランダ	12	—
スウェーデン	3	—
アメリカ	73	24
日本	2	4
ATRふげん	704*	
合計体数	[illegible]	

*：照射用燃料11体含む

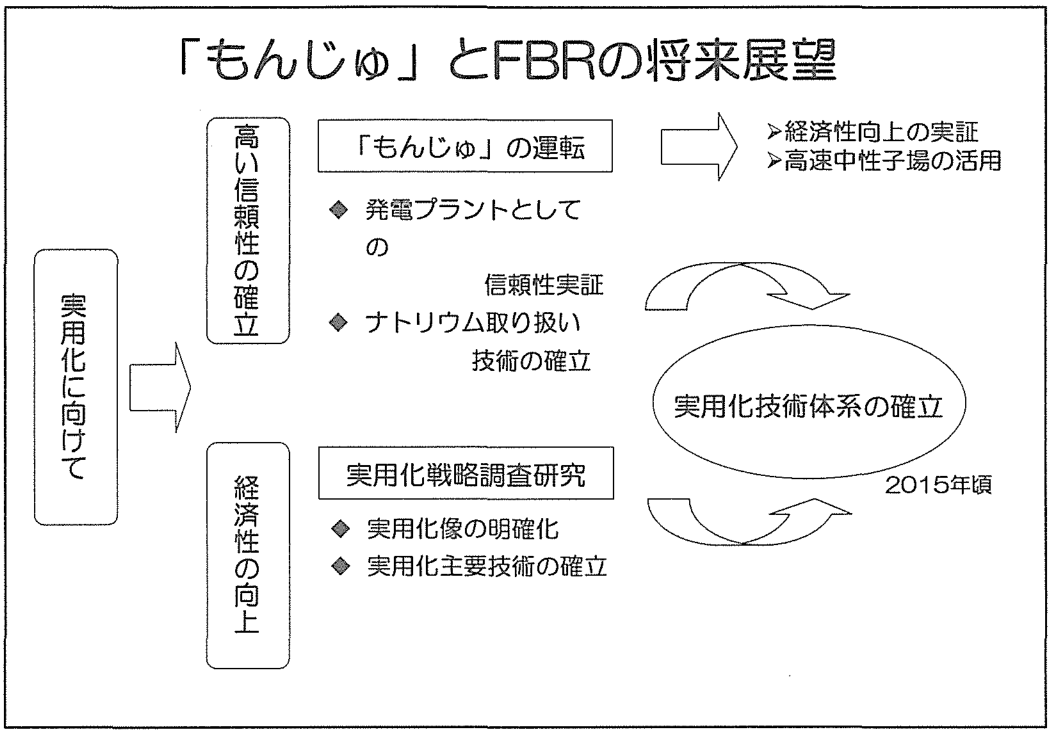
(平成11年5月現在)

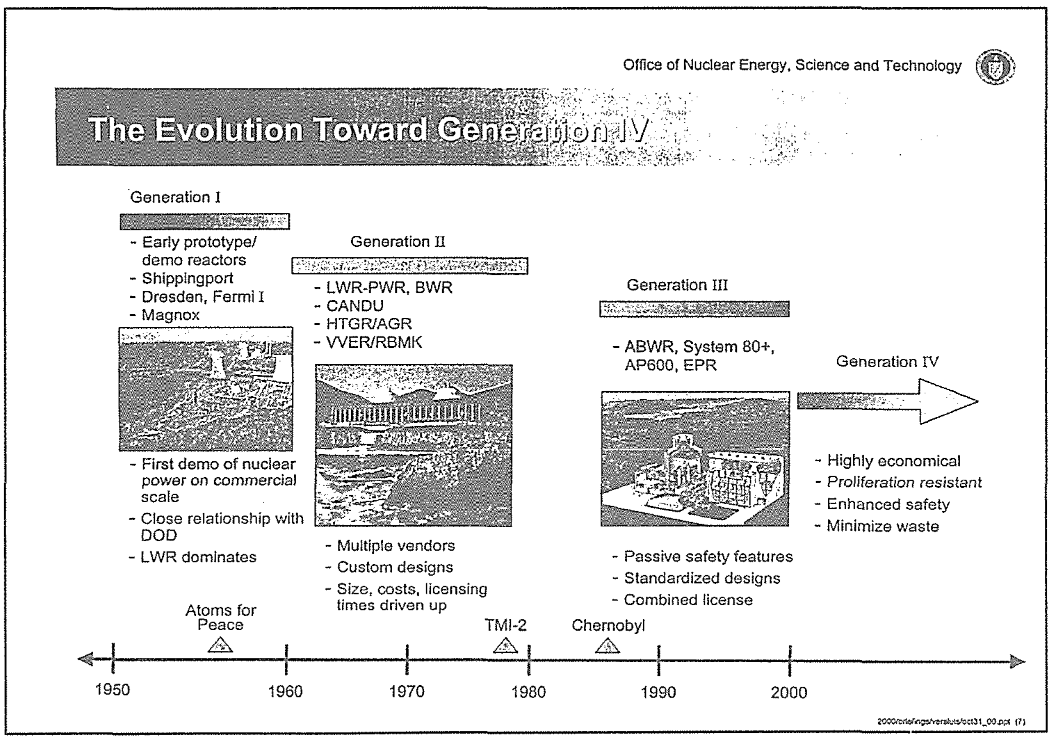
出典：「原子力年鑑 1999～2000」(日本原子力産業会議)
(ふげん装荷実績を除く)





FBRサイクルの整合性に関する基本的な考え方

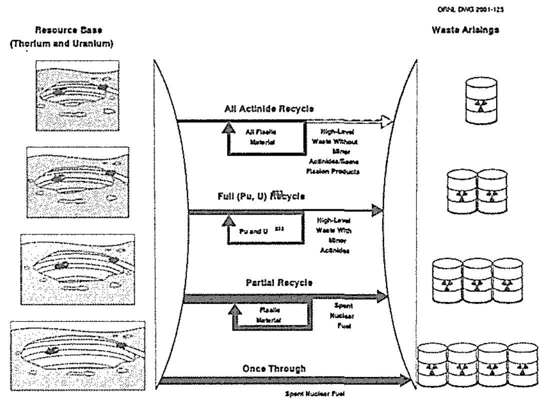

「もんじゅ」とFBRの将来展望
実用化に向けて
高い信頼性の確立
「もんじゅ」の運転
◆ 発電プラントとしての
信頼性実証
◆ ナトリウム取り扱い
技術の確立
>経済性向上の実証
>高速中性子場の活用
実用化技術体系の確立
2015年頃
経済性の向上
実用化戦略調査研究
◆ 実用化像の明確化
◆ 実用化主要技術の確立


Office of Nuclear Energy, Science and Technology
The Evolution Toward Generation IV
Generation I
- Early prototype/ demo reactors
- Shippingport
- Dresden, Fermi I
- Magnox
- First demo of nuclear power on commercial scale
- Close relationship with DOD
- LWR dominates
Generation II
- LWR-PWR, BWR
- CANDU
- HTGR/AGR
- VVER/RBMK
- Multiple vendors
- Custom designs
- Size, costs, licensing times driven up
Generation III
- ABWR, System 80+, AP600, EPR
- Passive safety features
- Standardized designs
- Combined license
Generation IV
- Highly economical
- Proliferation resistant
- Enhanced safety
- Minimize waste
Atoms for Peace
TMI-2
Chernobyl
1950
1960
1970
1980
1990
2000

Fuel Cycle CrossCut Group

Roadmap GENERATION IV nuclear energy systems

Four Fuel Cycles



Generation IV Goal	
Sustainability	Fuel Utilization
	Waste Minimization and Management
	Non-proliferation
Safety and Reliability	Excellence in Safety and Reliability
	A Very Low Likelihood and Degree of Reactor Core Damage
	Elimination of the Need for Offsite Emergency Response
Economics	A Life-Cycle Cost Advantage over Other Energy Sources
	A Level of Financial Risk Comparable to Other Energy Projects

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

UT-BATTELLE

まとめ

◆ 21世紀：リサイクル社会

- 経済活動の持続可能性：資源安定供給確保と環境保全

◆ Pu利用の確立と発展

- 長年の技術実績に基づくプルサーマルの実施
- U資源の有効利用と廃棄物量の低減、毒性の低減に優れた FBRサイクルへと発展

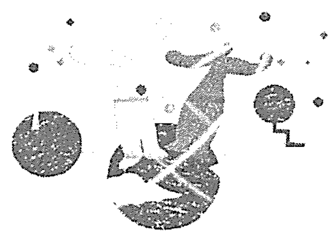
◆ 21世紀の基幹電源

- 軽水炉等の熱中性子炉と高速中性子炉との混合共生 エネルギーパークの形成

◆ 新たな開発活動：2030年頃の商業化を目標

- 日本：FBRサイクル実用化戦略調査研究
- 国際協力：GenerationⅣ、INPRO

Toward the establishment of Plutonium Use



Hiroshi NODA
FBR Cycle System Development Office
Japan Nuclear Cycle Development Institute

Contents

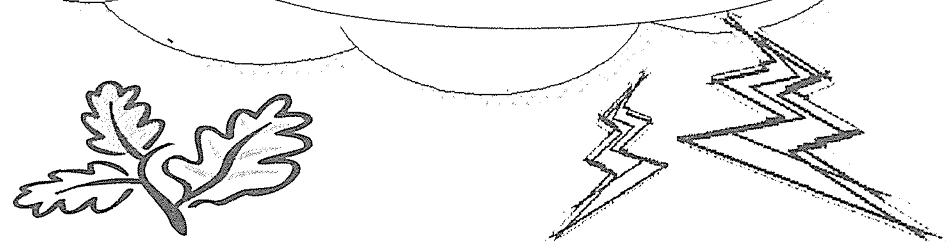
- ◆ 21^{st} century society and primary energy resources
- ◆ Prevention of global warming and nuclear power generation
- ◆ State of Pu utilization and fuel cycle development
- ◆ Outline of feasibility study of FBR commercialization strategy
- ◆ Fuel cycle in the Generation IV reactor project
- ◆ Conclusions

20th Century "Consumption Society"

"Society"
- ◆Development of industry
- ◆Enjoyment of material abundance

"Nation"
- ◆Seagirt country
- ◆Dependence on imported resources

"Human beings"
- ◆Aging society in advanced countries
- ◆Population growth in developing country



Actualization of issues relating to energy and the environment

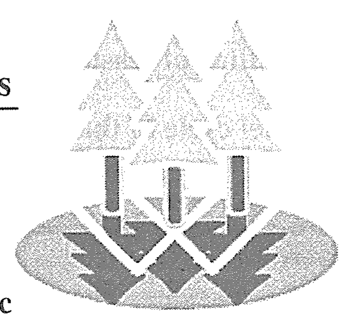
Primary energy resources demanded by recycling society

Society of 21th century

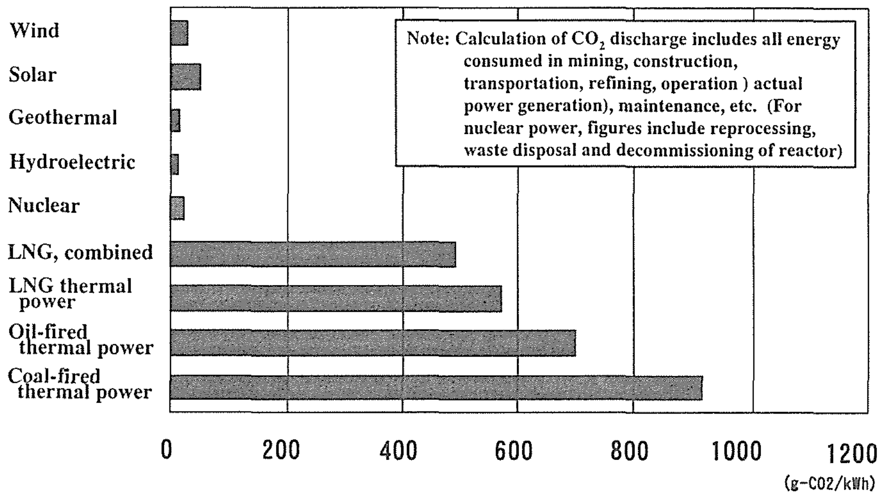
- ●Resource recycling ⇨ "Recycling society"
- ●Reduction of waste discharge

Demand for primary energy resources

- ➢Economic competitiveness
- ➢Stable supply
- ➢Availability of recyclable resources
- ➢Dealing with environmental issues, etc



The amount of CO_2 discharge through life cycle



Source: Central Research Institute of Electric Power Industry Report etc.

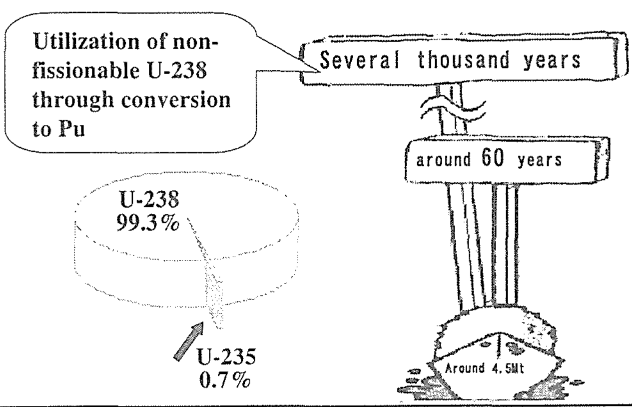
Plutonium utilization is the ultimate prospect for nuclear power

Uranium resources are limited

⇩

Uranium is an ultra-long-term resource in combination with plutonium

"Uranium sufficient for several thousand years exists on Earth"



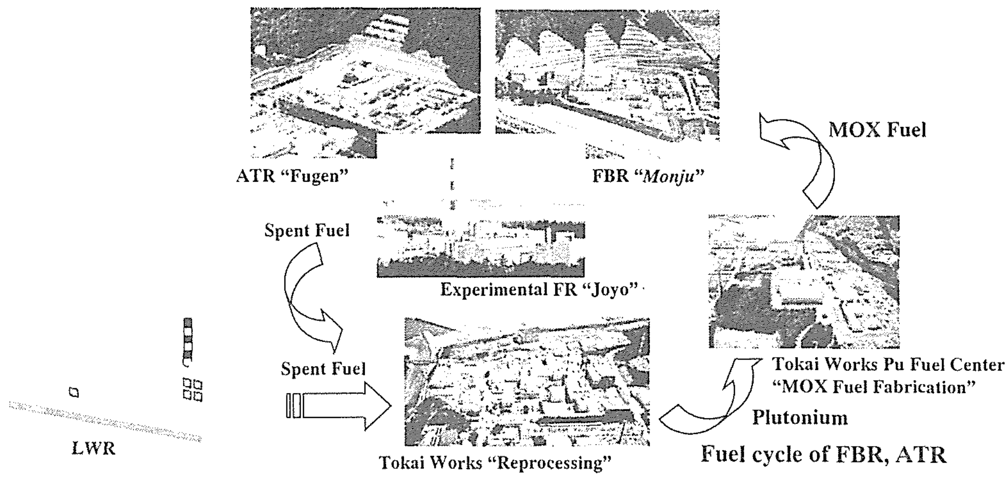
Utilization rate of natural uranium

reactor	utilization rate
LWR (once through)	0. 5%
LWR (Pu-thermal)	0. 75%
FR	around 60%

Reference from "Plutonium" edited by Atsuyuki Suzuki

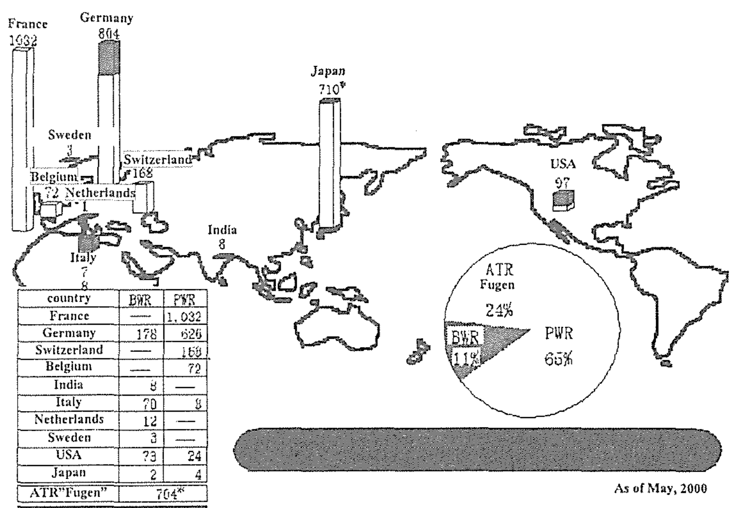
Technical development of fuel cycle

- **Making best use of plutonium as semi-domestic energy**
- **Contribution to recycling society**



Record of MOX Fuel used in "Fugen"

- Globally leading record : 726 MOX Fuel Assemblies loaded
- Flexible characteristic to use MOX Fuel : 34% - 72% loading ratio experienced

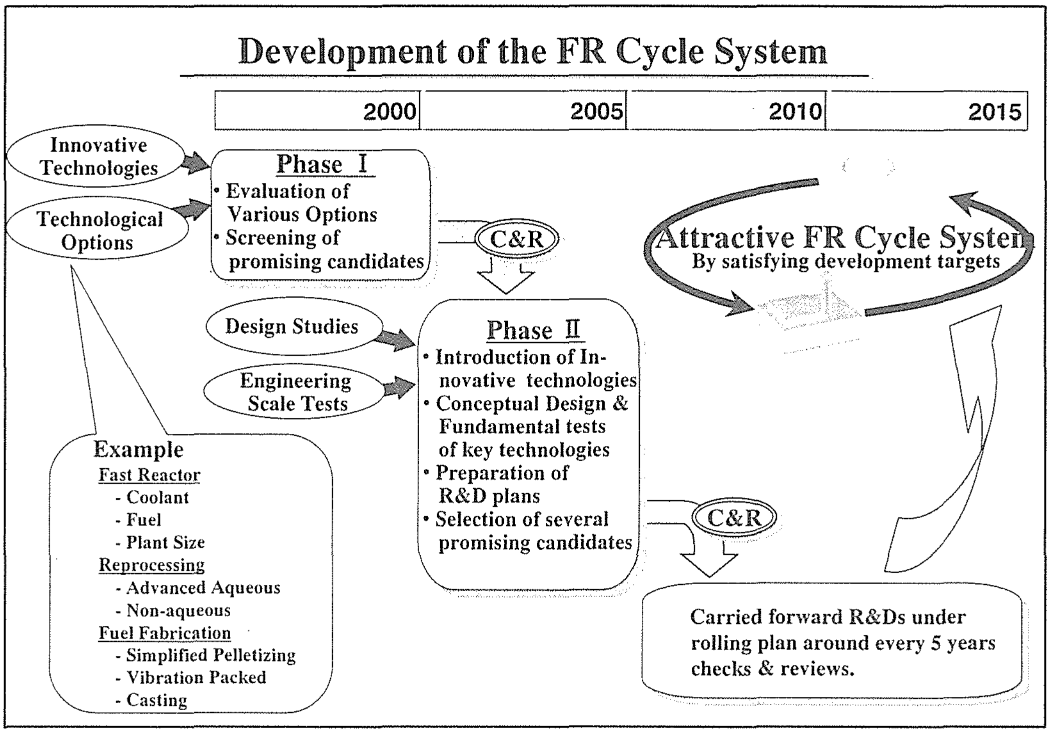


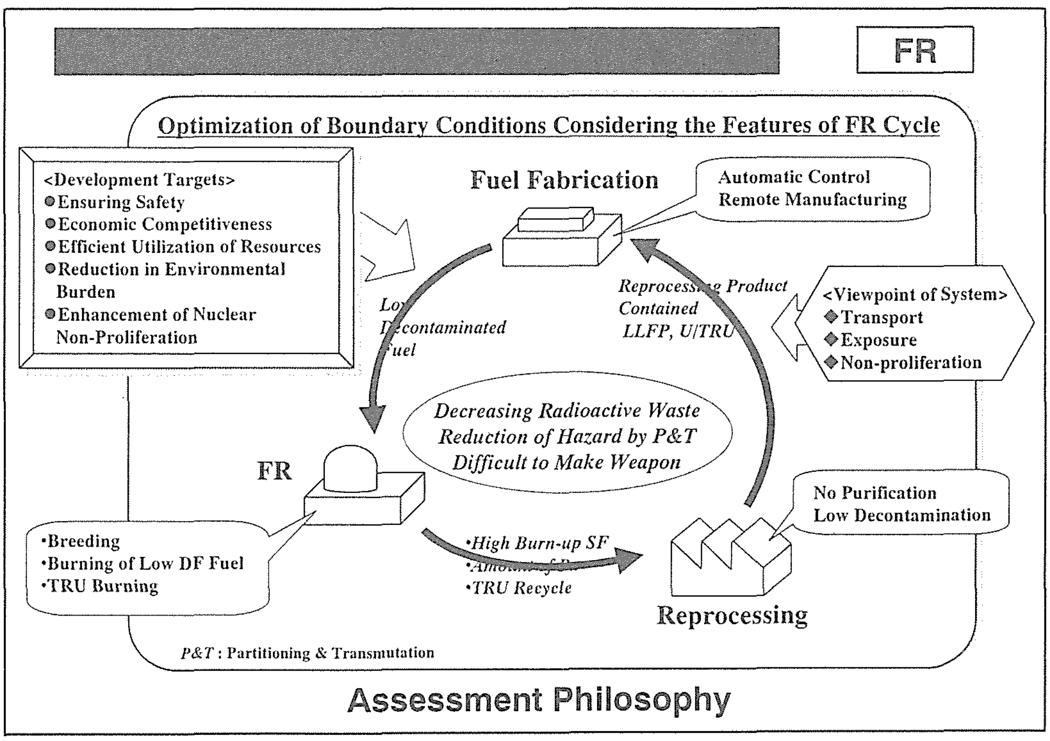
country	BWR	PWR
France	—	1,032
Germany	178	626
Switzerland	—	168
Belgium	—	72
India	8	—
Italy	70	8
Netherlands	12	—
Sweden	3	—
USA	73	24
Japan	2	4
ATR"Fugen"	704*	
[illegible]		

* : Including 11 Irradiation Fuels

As of May, 2000

Referrence from Nuclear Yearbook by JAIF


Development of the FR Cycle System
2000
2005
2010
2015
Innovative Technologies
Technological Options
Phase Ⅰ
• Evaluation of Various Options
• Screening of promising candidates
C&R
Attractive FR Cycle System
By satisfying development targets
Design Studies
Engineering Scale Tests
Phase Ⅱ
• Introduction of Innovative technologies
• Conceptual Design & Fundamental tests of key technologies
• Preparation of R&D plans
• Selection of several promising candidates
C&R
Example
Fast Reactor
- Coolant
- Fuel
- Plant Size
Reprocessing
- Advanced Aqueous
- Non-aqueous
Fuel Fabrication
- Simplified Pelletizing
- Vibration Packed
- Casting
Carried forward R&Ds under rolling plan around every 5 years checks & reviews.


FR
Optimization of Boundary Conditions Considering the Features of FR Cycle
<Development Targets>
Ensuring Safety
Economic Competitiveness
Efficient Utilization of Resources
Reduction in Environmental Burden
Enhancement of Nuclear Non-Proliferation
Fuel Fabrication
Automatic Control
Remote Manufacturing
Reprocess… Product Contained LLFP, U/TRU
<Viewpoint of System>
Transport
Exposure
Non-proliferation
Lo… …contaminated …uel
Decreasing Radioactive Waste
Reduction of Hazard by P&T
Difficult to Make Weapon
FR
No Purification
Low Decontamination
•Breeding
•Burning of Low DF Fuel
•TRU Burning
•High Burn-up SF
•TRU Recycle
Reprocessing
P&T : Partitioning & Transmutation
Assessment Philosophy

Future prospects for *Monju* and FBR

Toward commercialization →

Establishment of high reliability

Operation of *Monju*

- ◆ Verification of reliability as power generation plant
- ◆ Establishment of sodium handling technology

→

- ➢ Verification of improvement of economic competitiveness
- ➢ Making best use of high-energy neutron field

Improvement of economic competitiveness

Feasibility Study on Commercialized FR Cycle Systems

- ◆ Clarification of commercialization prospects
- ◆ Establishment of essential technologies for commercialization of FR

Establishment of technical systems for commercialization of FR

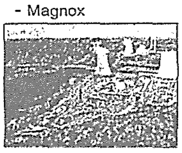
around 2015

Office of Nuclear Energy, Science and Technology

The Evolution Toward Generation IV

Generation I

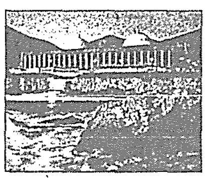
- Early prototype/ demo reactors
- Shippingport
- Dresden, Fermi I
- Magnox



- First demo of nuclear power on commercial scale
- Close relationship with DOD
- LWR dominates

Generation II

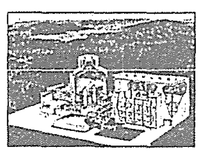
- LWR-PWR, BWR
- CANDU
- HTGR/AGR
- VVER/RBMK



- Multiple vendors
- Custom designs
- *Size, costs, licensing times driven up*

Generation III

- ABWR, System 80+, AP600, EPR



- Passive safety features
- Standardized designs
- Combined license

Generation IV

- Highly economical
- *Proliferation resistant*
- Enhanced safety
- Minimize waste

Timeline: 1950 — Atoms for Peace — 1960 — 1970 — TMI-2 — 1980 — Chernobyl — 1990 — 2000

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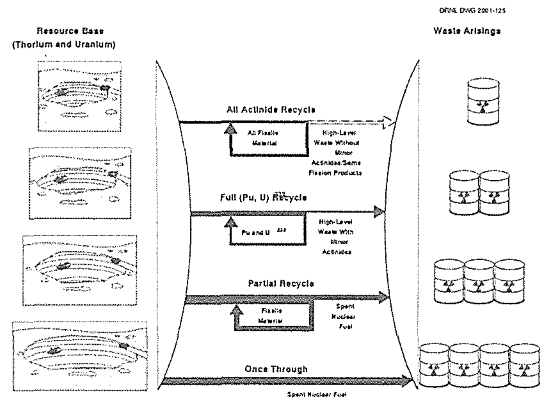
Fuel Cycle CrossCut Group

Four Fuel Cycles



Generation IV Goal

Sustainability	Fuel Utilization
	Waste Minimization and Management
	Non-proliferation
Safety and Reliability	Excellence in Safety and Reliability
	A Very Low Likelihood and Degree of Reactor Core Damage
	Elimination of the Need for Offsite Emergency Response
Economics	A Life-Cycle Cost Advantage over Other Energy Sources
	A Level of Financial Risk Comparable to Other Energy Projects

Conclusions

- ◆ **21st century: Recycling society**
  - Sustainability of economic activities: securing a stable supply of resources and environmental protection
- ◆ **Establishment of Pu utilization and development of full-scale utilization**
  - Introduction of Pu-thermal LWR based on long-term technical results
  - Progress to FBR cycle suitable for effective utilization of U resources and reduction of radioactive waste and toxicity
- ◆ **Primary energy resources of 21st century**
  - Establishment of LWR/FBR symbiotic energy park
- ◆ **New development activities: targeting commercialization in 2030**
  - Japan: feasibility study of FBR commercialization strategy
  - International cooperation: Generation IV, INPRO

35th JAIF: Nuclear Power in the Changing Socio-Political Environment

Session 3:
Why Plutonium recycling ?

Strategy and Perspective on Plutonium Utilisation, including the concepts of Advanced MOX fuel and future Nuclear Energy Systems

Jacques BOUCHARD, Director of Nuclear Energy Division, CEA
23 April 2002

Mr. Chairman, Ladies and Gentlemen:

From the beginning, reprocessing of spent fuels, followed by recycling of valuable materials, uranium and plutonium, is intended to increase the use of natural resources. It is part of a scheme which includes breeders in order to extract most of the energy contained in natural uranium. That remains a clear objective for the future. With existing light water reactors, we burn only 1% of the natural uranium and we let aside 99%, either in provisional storages or in waste disposal. If we don't improve the situation, with increasing energy needs, we shall exhaust in a few decades the uranium resources which can be recovered at a reasonably low price.

Thus, reprocessing is a cornerstone for satisfying future energy needs.

It means, nuclear spent fuel is not a waste, as it still contains a huge amount of energy valuable products. But, the way we treat it at the output of the reactor is also of major importance for the waste management policy. With present technologies, the fuel unloaded from reactors still contains 95% of uranium and 1% of plutonium. It contains also 4% of actual wastes, fission products and minor actinides.

Plutonium is not only a highly energetic element but also the main contributor to the long-life radio toxicity of spent fuel. If you reprocess the spent fuel and recycle the plutonium, you can decrease the radio toxicity of waste.

While recycling, you can stabilize the plutonium stockpile. If we don't recycle, either we accumulate spent fuels, with a continuously growing content of plutonium, or we keep more and more plutonium on shelves. Buried spent fuels would constitute forever a mine of plutonium; plutonium on shelves should be in the shorter term a risk of proliferation or accident.

The first recycling enables us to reduce, by approximately 20%, the quantity of plutonium produced each year, and constitutes a first step towards plutonium inventory stabilisation.

As you know, it is what we are doing presently in France, on a large scale. More than fifteen thousands tons of fuel were reprocessed in the **La Hague plant** during the last fifteen years. Once extracted from spent fuels, the plutonium is sent to the **MELOX** fabrication plant which, at the present time, produces a little more than one hundred tons of MOX fuels per year. It is an important point in our policy, the plutonium extracted from spent fuels should be re-used as soon as possible in MOX fuels.

Then, the MOX subassemblies are loaded in reactors. Since 1987, more than eighteen hundred MOX fuel assemblies have been loaded into 20 French (over 58), 2 Belgium and 3 German reactors. Except the necessary hold-up for recycle management, the goal is clearly not to have any plutonium on shelves.

But, mono-recycling will not be sufficient if we need to stabilise or to decrease the global amount of plutonium. We should consider the possibility of reprocessing MOX spent fuels and multi-recycling the plutonium.

We are now working, at CEA, on new generations of MOX S/A, so called CORAIL or APA subassemblies, which could be used for multi recycling allowing to strictly stabilize the plutonium inventory or even to reduce it. These developments will make easier the multi recycling of plutonium in LWRs.

The new CORAIL assemblies, derived from current plutonium fuel technologies, with islands of standard UO2 rods surrounded by MOX rods. With this design, the recycling of plutonium will be made in a more homogeneous way, allowing the possibility to burn plutonium with rather poor isotopic distribution. The CORAIL S/A could be, after design studies and qualification in reactor, rather quickly industrialised and initially implemented in the existing reactors during the next decade.

A second solution requiring further research and development into the fuel could conceivably be implemented after 2020. It consists in Advanced Plutonium Assemblies, called APA, an heterogeneous bundle including UO2 rods and annular rods made of plutonium oxide within an inert matrix. In addition to controlling the plutonium inventory, it would lead to reduce its overall quantity in the fuel cycle and, potentially, allow us to limit the inventory of the minor actinide.

If LWRs were to be the end of the nuclear story, we should consider the possibility of burning all the plutonium in these reactors or in specific burners, which could be conventional fast reactors or accelerator driven systems. But, we are convinced that the growing of energy needs and the limited amount of other energy resources will more probably lead to an increased use of nuclear energy.

To ensure sustainability, future systems will have to produce a minimum amount of waste, use fuel energy most efficiently and be as proliferation-resistant as feasible.

Fast neutron reactors will be unavoidably part of the future nuclear energy systems, integrating into their design the objective of transmutation and the minimising of wastes. They will enable a considerably better use of the natural fuel, and give humankind a sustainable energy source for several thousand years.

Therefore, sooner or later, fast reactors will be the right tool for using plutonium. They are fit to accept any isotopic composition and they are also suitable for burning minor actinides.

So, why not to wait and keep all the plutonium resources generated in LWRs for future use in fast reactors? It could be the wise policy if one is quite clear about the schedule for fast reactor implementation. But even in countries which are quite positive regarding the future of fast reactors, it remains a large uncertainty on the right time for their implementation, not speaking of doubts about the best choices for their technological development.

The most optimistic people in France speak of 2040 for starting the implementation of fast reactors. May be they are wrong and it will be a little bit sooner... or later... Even if they are right, at this time we shall have accumulated in France near 600 tons of plutonium if we don't recycle it in LWRs and near 500 tons if we make only a first recycling.

Keeping in mind that we shall need approximately 10 tons of plutonium per GWe to launch a fast reactor fleet, one can see that the reasonable reserve for this objective would be somewhere between 200 and 400 tons. If we keep more plutonium we shall have to find a way of burning it later.

There are other reasons to avoid to keep the plutonium in spent fuels, assuming it will be used later in fast reactors:

- It will require these fuels to be stored in safe conditions with a complete guarantee of retrieving them after several decades for reprocessing; from this point of view, a first recycle is already beneficial as it allows a reduction by a factor six to seven of the volume of spent fuels to be stored.
- The radioactive decay of plutonium 241 will lead to both a loss of valuable resource and a quite strong increase of the quantity of minor actinides in the wastes.
- If the implementation of fast reactors needs to be done in a short range of time, it will be necessary to built and operate a very large capacity of *reprocessing plants to recover the plutonium.*

A mature technology, industrially speaking, even if the experience is considerably more limited than for light water reactors, is that of the sodium cooled fast neutron reactors. Unfortunately, the early shutdown of Super Phenix put at least for some times an end to the development of this technology in Europe.

The PHENIX reactor, is currently the subject of inspection, renovation and maintenance operations, in order to be back on power end of this year, pending upon an agreement of the Safety Authority. Then, its operation for six irradiation cycles, will be focused on experimental studies, fuels in particular, contributing to the technological demonstration of transmutation with fast neutron reactors. Its end of life is now programmed for 2007.

The intrinsic advantages of fast neutron reactors remain their capability to make use of most of the potential energy from the uranium and to produce less long-life radwaste for a given amount of energy produced. These attractive features are still a major incentive to the designers to investigate other coolants than sodium, particularly gas. The CEA is conducting research in this option, in the frame of a larger program for the development of gas cooled reactors.

Whatever the technology selected for fast reactors, sodium cooled, gas cooled or any other solution, the availability of an important reserve of plutonium for starting these reactors will allow us to design them with a low conversion ratio, near one, thus avoiding or limiting to a strict minimum the necessity of breeding zone. It will enhance the security of the concept, in particular for proliferation resistance and simplify the requirements for the related fuel cycle.

In conclusion, the legitimacy of using nuclear power as part of sustainable development in order to meet future energy needs, rests on our ability to demonstrate that we are capable of safely managing nuclear materials and especially spent fuel and waste.
Multiple recycling of plutonium allows us to diminish by several units the long-term radiotoxicity of long-lived elements; savings could even be greater, by several magnitudes, if we include the additional recycling of minor actinide series.
The reprocessing of spent fuels and their potential developments form the keystone of a strategy that has set its sights, at the very least, on achieving a control over the plutonium inventory in the fuel cycle, motivated by the drive to provide our environment with the maximum possible protection and to save on our use of energy materials. Even now, we can foresee solutions involving the recycling of plutonium in water reactors other than Mox, alongside a modest financial impact. By using these solutions, we could gradually increase the amount of plutonium burned until we stabilise its inventory at the end of a twenty to thirty year period.
This strategy will also allow us to be ready for starting a large use of fast reactors as soon as needed.

Thank you for your attention.

35th JAIF Annual Conference

Nuclear Power in the Changing Socio-Political Environment

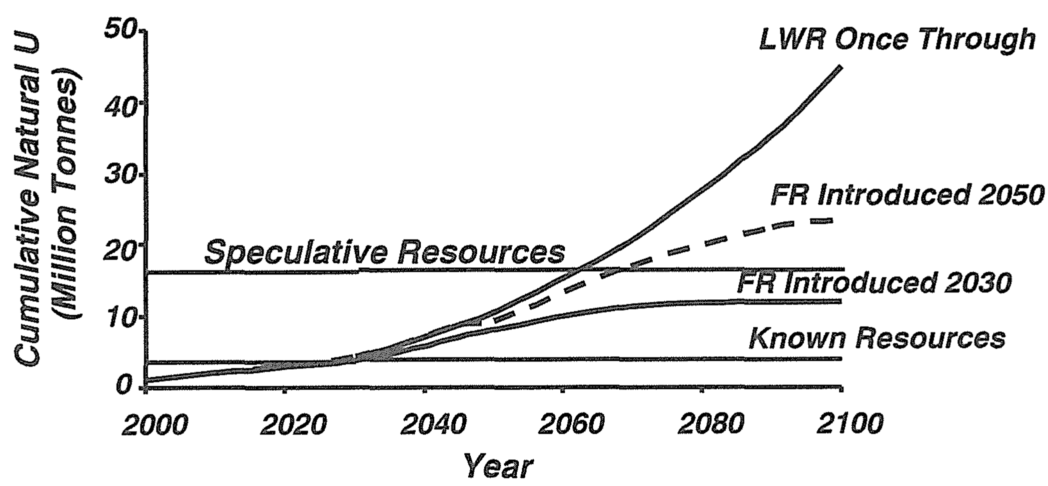
Session 3 :
Why Plutonium Recycling ?
April 23, 2002

Strategy and Perspective on Plutonium Utilisation, including the concepts of Advanced MOX fuel and future Nuclear Energy Systems

Jacques Bouchard,
Director of Nuclear Energy Division, CEA
jacques.bouchard@cea.fr

Why Plutonium recycling ?

Natural resources saving



Resources may be extended for 1000 years

Why Plutonium recycling ?

Efficient use of natural resources

➢ Extract the maximum energy from the fuel

Valuable materials (96%)

- Uranium (94 to 96 %)
- Plutonium (1 %)

→ Reprocessing & Recycling

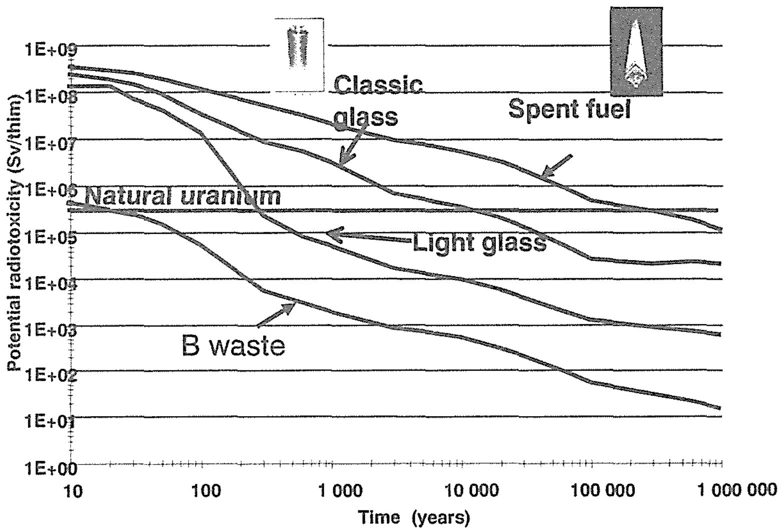
Wastes (4%)

- FissionProducts (3 to 5 %)
- Minor Actinides (0,1 %)

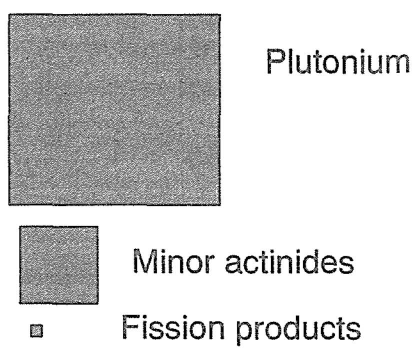
Why Plutonium Recycling ?

Minimization of radiotoxicity of waste

Potential radiotoxicity versus time



Drastically minimize radiotoxicity of the waste

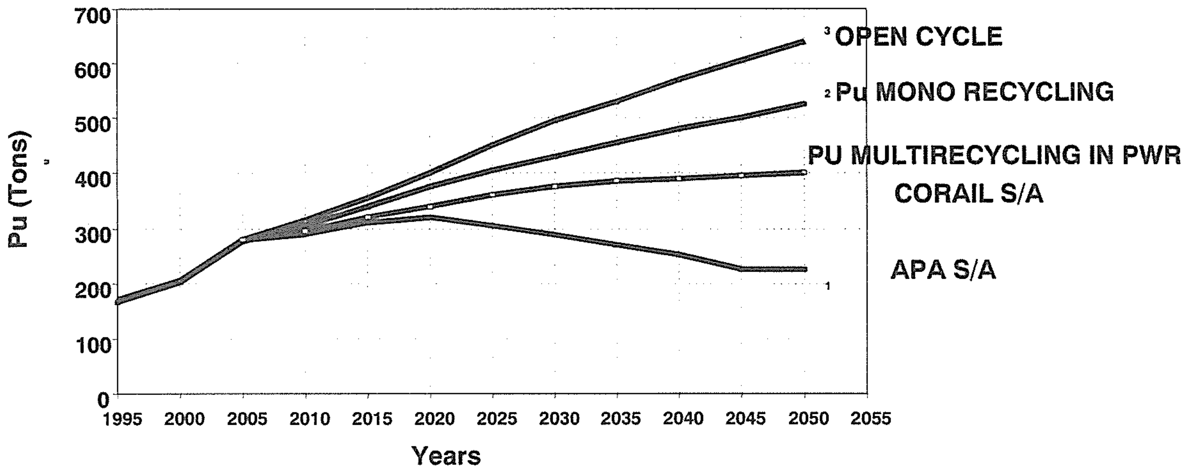


Radiotoxicity after 1 000 years

Why Plutonium recycling ?

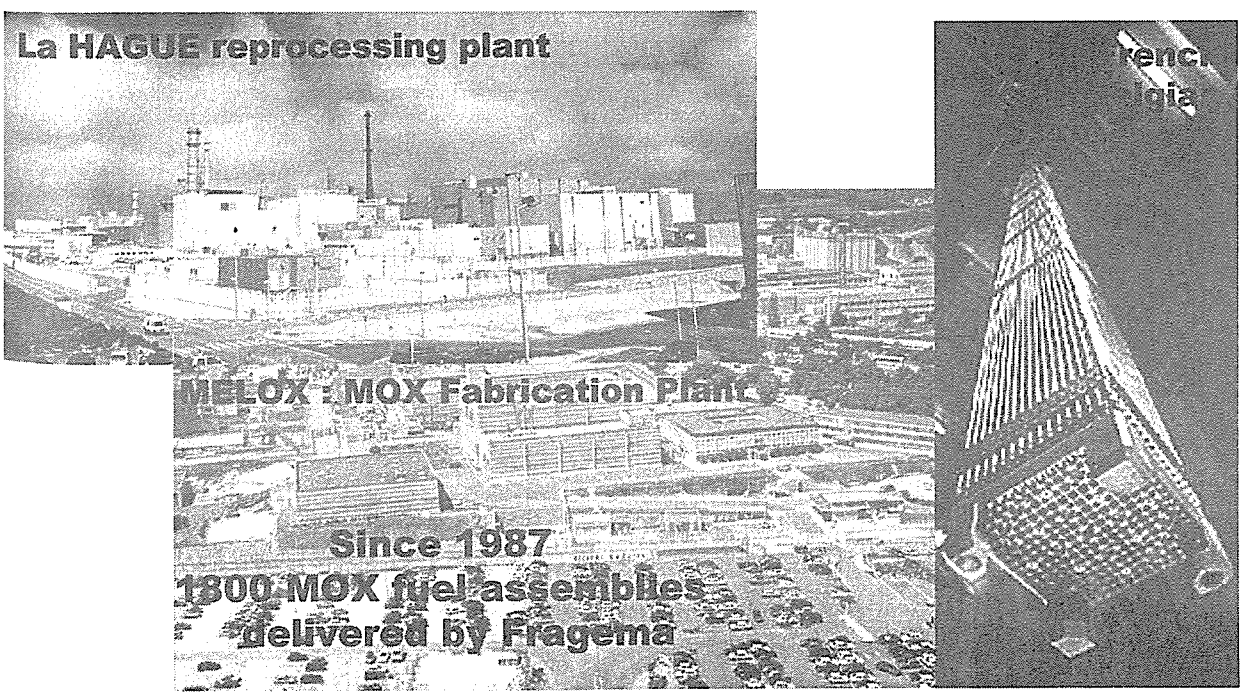
Stabilisation of Pu stockpiles

Plutonium management in PWR (400 TWh/year)



Short term : Pu recycling in LWR

A today's reality in France



Medium term : Pu multirecycling in LWR

CONTEXT

➢ Major role of LWR in the 21st century

➢ A transition step awaiting future nuclear energy systems

OBJECTIVES

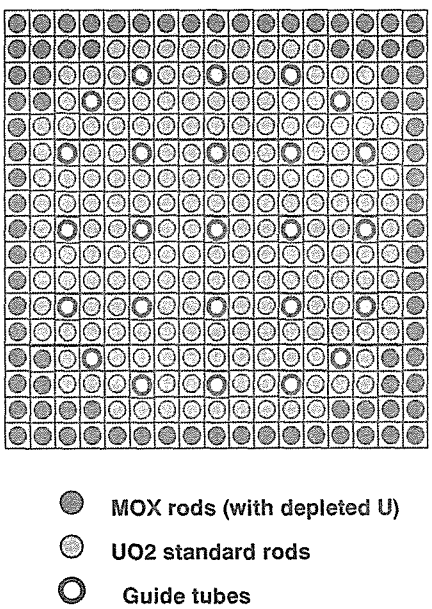
✓ Design New S/A with high Pu burning capabilities

✓Confirm thier ability for multirecycling in LWR cores

✓ Evaluate their potential for waste minimisation

New subassemblies for Pu recycling in LWR

CORAIL Assembly



- 160 UOX rods surrounded by 84 MOX rods
- Heterogeneous S/A, homogeneous core
- Standard rods and standard S/A

Main R&D Steps (2001-2015) :

✓ Feasibility studies (2001-2006)

✓Qualification (2004-2010)

- Fabrication of demonstration S/A
- Irradiation
- Qualification of calculation tools
- First Post Irradiation Examinations

✓ Industrial Perspectives (2010-2015)

New subassemblies for Pu recycling in LWR

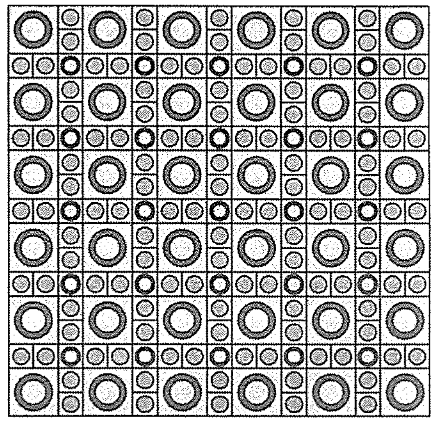
Advantages

- ✓ High Pu consumption, high Burn up
- ✓ Flexibility towards Pu isotopy
- ✓ Small fabrication capacities
- ✓ High impact on Pu inventory

Large R&D needed (2001-2025) :

- ✓ Preliminary studies (2001-2003)
- ✓ Development of the fuel (2003-2010)
- ✓ Qualification (2004-2017)
- ✓ Industrialization (2020-2025)

APA (Advanced Pu Assembly)



- Pu rods
- UO2 standard rods
- Guide tubes

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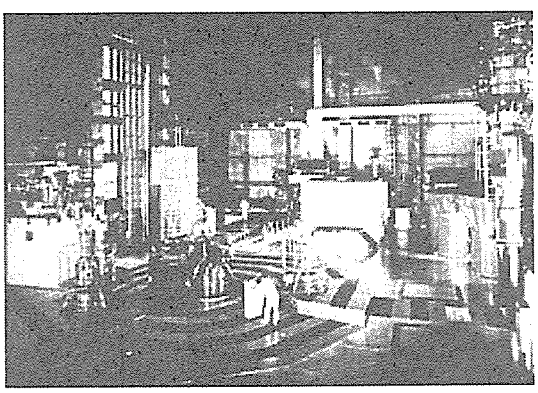
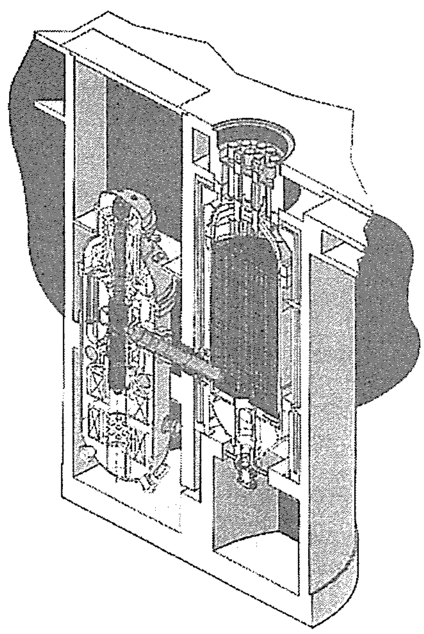
Fast reactors for long term Pu recycling



Metal cooled fast reactors



Gas cooled fast reactors

10

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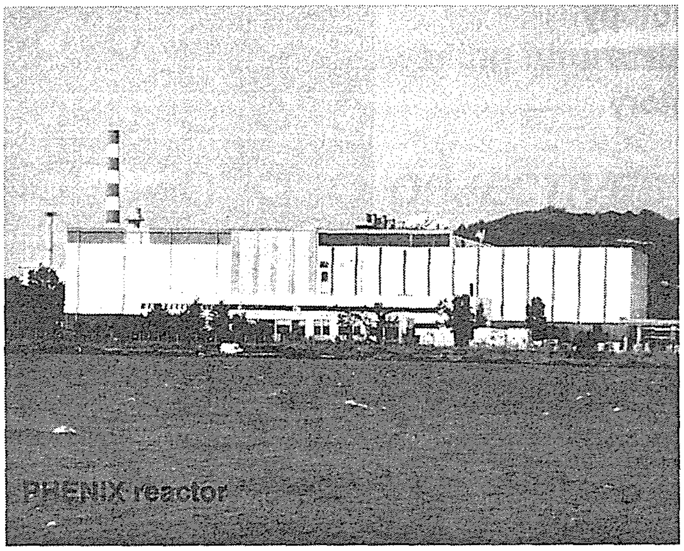
Liquid metal fast reactors

Advantages :

- ✓ A mature technology for sodium
- ✓ An efficient use of the energetic potential of the fuel
- ✓ A cooling enabling a good output



French R&D in this field :

- ✓ Keep an expertise on liquid metals coolants
- ✓ Share experience feed-back on PHENIX, MONJU, BN600 reactors

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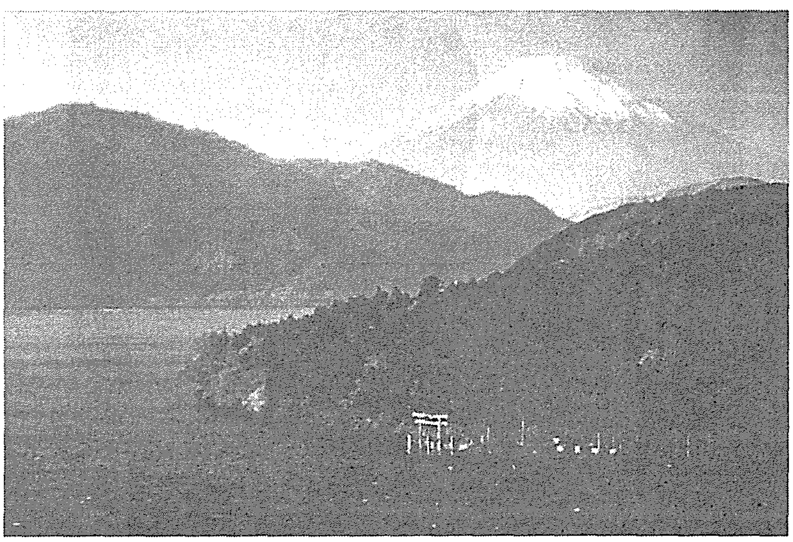

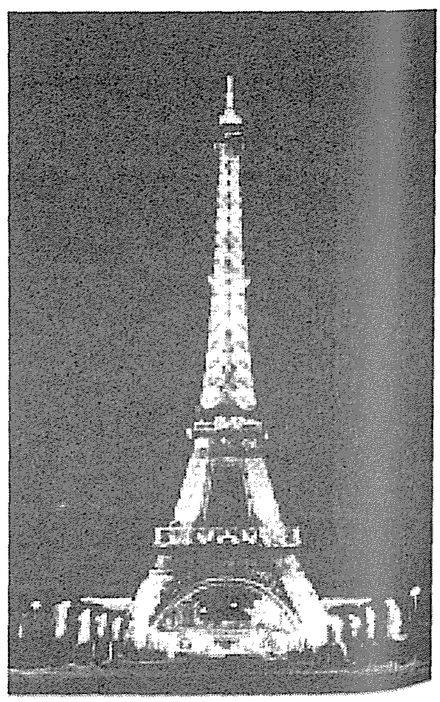

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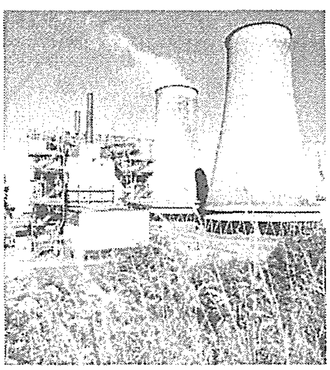
Japan Atomic Industrial Forum | Saitama, Japan

Liberalization of the UK Electricity Market: Current Status and Future Plans

Steve Brosnan
Executive Director
Energy Sales and Trading
Magnox Electric plc
A BNFL Group Company

UK Magnox Stations (operational)



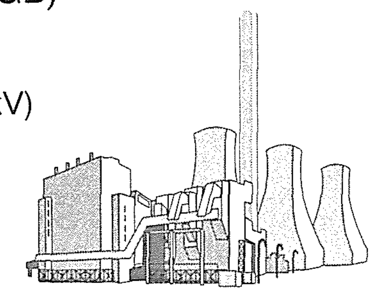
Calder Hall

Total ~ 2700 MW

Market share ~5%

The Electricity Market in England and Wales until 1989

- 1 National Company (CEGB)
  - Generation
  - Transmission (above 132kV)

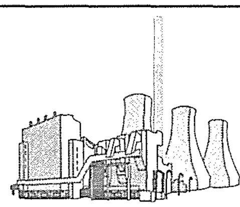


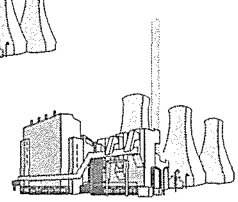
- 12 Regional Companies
  - Distribution (below 132kV)
  - Supply (sales to customers)

Magnox Electric plc

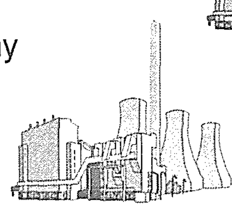
The Electricity Market in England and Wales after Privatisation (1990)

- Generation
  - 1 Nuclear company
  - 2 Non-nuclear companies





- Transmission
  - 1 Transmission company



- Distribution/Supply
  - 12 Regional companies

All except nuclear generator were sold (Privatised)

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The England and Wales Electricity Market in 2002

- One Transmission company
- Distribution separated from Supply
- Many new market entrants including US and European companies
- More vertical integration between Generation and Supply
- Every customer can choose their Supply company
- Gas-fired power stations now account for 40% of market (from zero in 1990)

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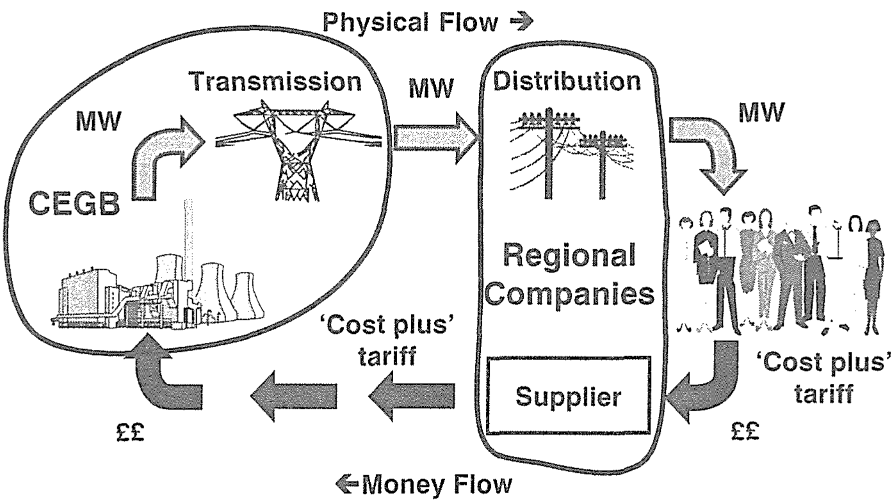
Before Privatisation



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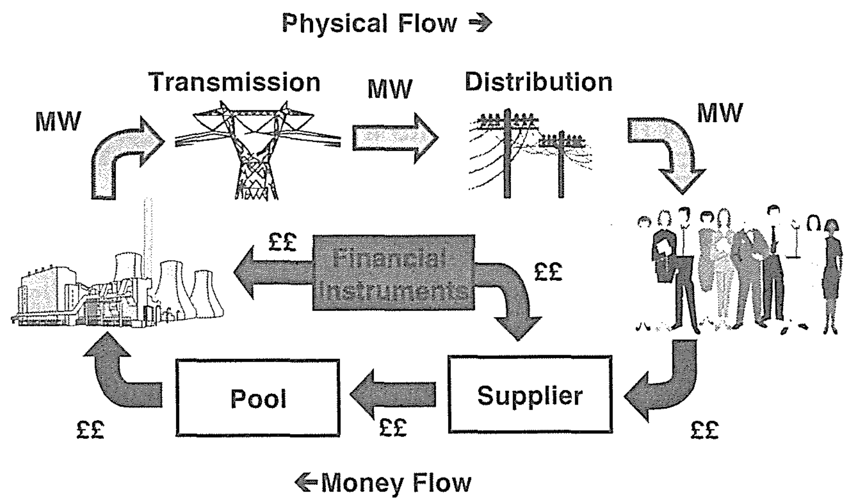
The Electricity Pool (1990-2001)



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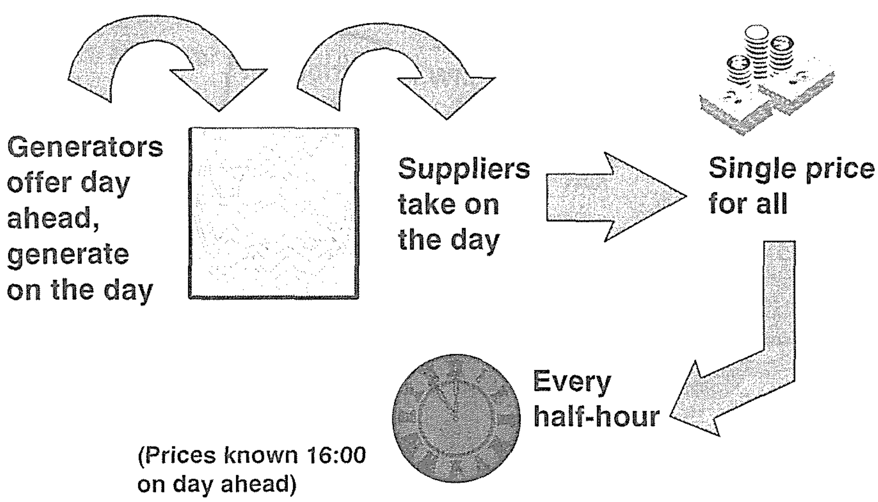
Trading Through The Pool



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What was wrong with the Pool?

dti
Department of Trade and Industry

- Prices were too high
- Lack of competition in generation
- Abuse of market power by major generators
- Price setting was complex and not transparent
- Lack of liquidity in forward contract markets
- Did not encourage demand-side participation
- Favoured gas and nuclear plant at expense of flexible coal plant
- Pool organisation was inflexible

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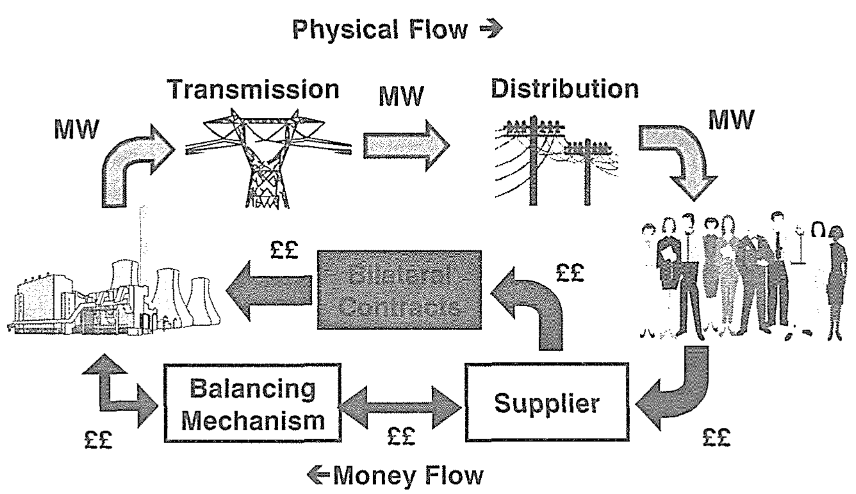
The New Electricity Trading Arrangements or "NETA" (from 27 March 2001)



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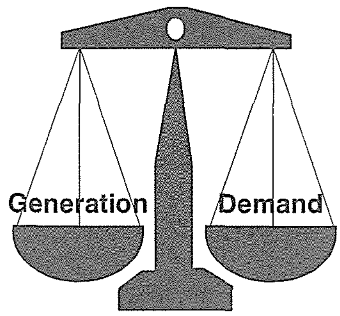
The Balancing Mechanism

- Generators make offers/bids to increase or decrease generation
- Demand can make bids/offers to increase or decrease demand
- System operator chooses bids/offers appropriately
- The chosen bids/offers set the cash-out prices for those 'out-of-balance'



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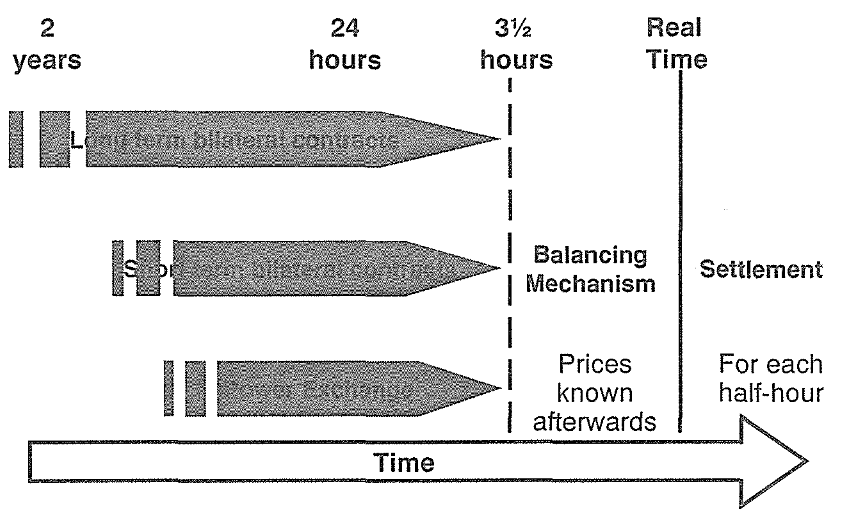
The New Electricity Trading Arrangements



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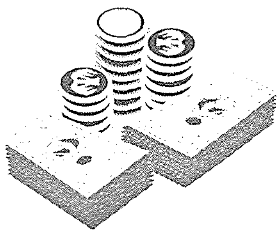
Settlement – with *two* Imbalance Prices

- Company total generation or demand should match contract position
- If we generate less than our contract volume, we pay a high price ("System Buy Price")
- If we generate more than our contract volume, we receive a low (or even negative) price ("System Sell Price")



➔ Commercial incentive for contracts to match generation (in every half hour period)

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Magnox Electric under...

the Pool ...

- We offered zero prices
- We were despatched to our declared availability
- We were paid Pool Purchase Price for whatever we generated
- We bought and sold financial instruments to stabilise the price we received.

➔No commercial incentive to be predictable

... and NETA

- We forecast output as well as we can
- We sell contracts to match our forecast
- We run our plant to our own plan.
- We buy or sell contracts to match any changes in output as closely as possible

➔ Commercial incentive to be predictable and to trade well

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Prices in March 2002 - £/MWh

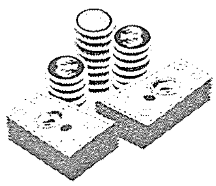
System Sell Price

- Average £11
- Minimum - £15

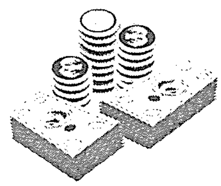
System Buy Price

- Average £23
- Peak £380

Power Exchange Price



- **Average £14**
- **Peak £34**
- **Minimum £8**



Forward Prices

Baseload 2002/03 £ 15.40

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Recent Developments

- Government report issued on long-term policy
- Price controls for domestic customers removed
- New subsidy for renewable power stations
  - (target 10% by 2010 - up from 3% today)
- Stations taken out of service because of low prices
- Innogy/PowerGen both taken over
- NETA balancing mechanism to be reduced to 1 hour duration

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Future Issues

- Conflicting Government Priorities?
  - Environment (higher prices or pollution taxes?)
  - Social issues (low prices for domestic customers)
  - Industry competitiveness (low prices)
  - Competitive energy markets (less regulation)
  - Security of Supply (more regulation, planning)
- Dominance of gas
- European-wide competition

Magnox Electric plc

Japan Atomic Industrial Forum — Saitama, Japan

Will Nuclear Energy be the Answer in the New Century?

James A. Fici
Senior Vice President
Nuclear Plant Projects
Westinghouse Electric Company
A BNFL Group Company

JAIFNPP.1

An Economic Model of the World in 2042
The 100th Anniversary of Nuclear Fission

- World population will have reached nine billion
- Assume an acceptable standard of living to be half that now enjoyed in the US, or $15,750 GDP per capita in constant dollars
- Assume that conservation and energy efficiency will cut worldwide electricity use per unit of economic output in half to 0.2 kWh

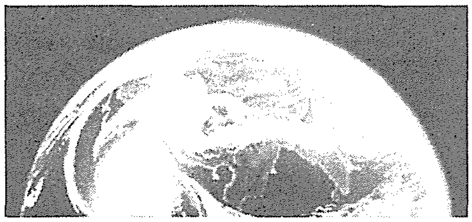
0.2 kWh/GDP X $15,750 GDP/person X 9 billion = 28.4 trillion kWh

- This is more than double current world electricity production of 12.5 trillion kWh

JAIFNPP.2

Nuclear Energy Benefits Address Energy Security, Economics and the Environment

- Safe, reliable and cost competitive electricity generation to achieve diversity and security of energy supplies
- Predictable and stable fuel costs that provide protection against natural gas price volatility
- Clean electricity generation that avoids emissions of SO_2, NO_x and CO_2



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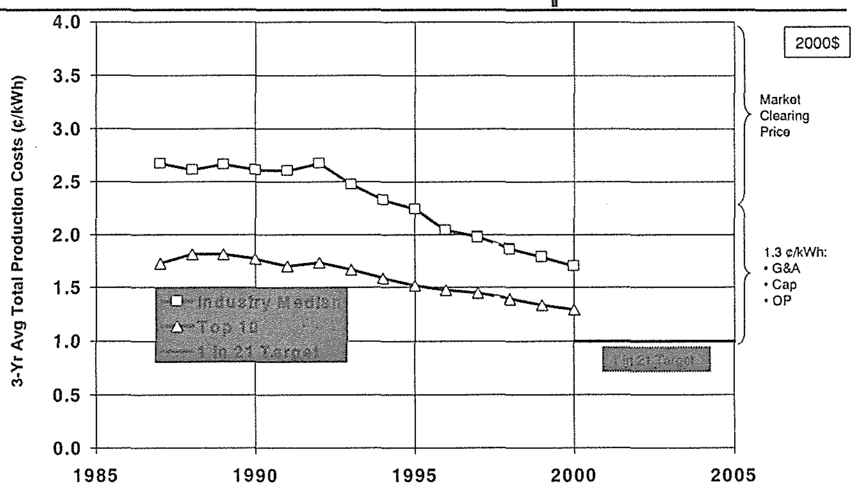
Production Costs* Approaching 1 ¢/kWh Drive US Nuclear Plant Competitiveness



UDI Data; Westinghouse Analysis

*O&M, Fuel

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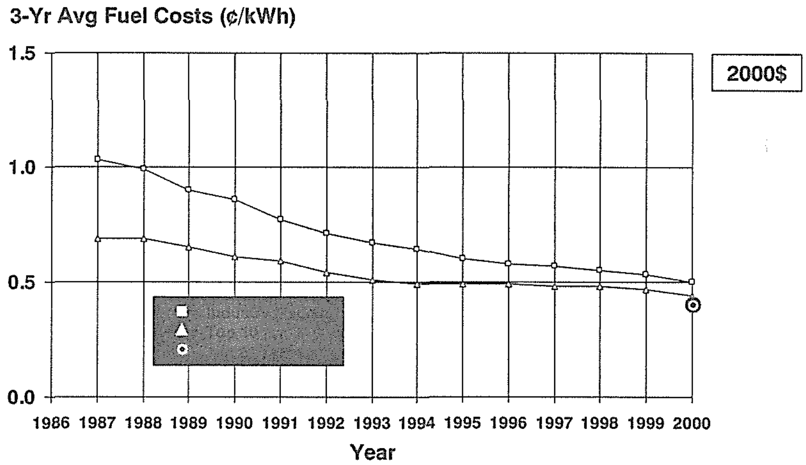
US Nuclear Fuel Cycle Costs Are Very Low and Have Long-Term Predictability



UDI Data; NEI Analysis

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Increasing Generation, Decreasing Costs Create Value for US Nuclear Plant Owners

US Nuclear Industry Case Description	Present Value $B	Production Cost $/MWh	Created Economic Value $B	$/kWe
Nuclear Average	46.7	18.7	Base	Base
@ Top 10 Cost & CF	97.2	12.9	50.5	510
@ Top 10 Cost & CF + 20 y	118.0	12.9	20.9	211
@ Top 10 Cost & CF + 20 y + 105% Cap	127.9	12.6	9.8	99
Total			81.2	820

UDI Data; Westinghouse Analysis

- Improving average plant cost and performance to those of the industry Top 10 will create 50 billion dollars in value over the current life of those plants
- Extending plant life by 20 years adds another 20 billion dollars in value
- Each 5% increase in plant capacity adds 10 billion dollars in value
- Overall $820 of economic value potential for each kWe of capacity

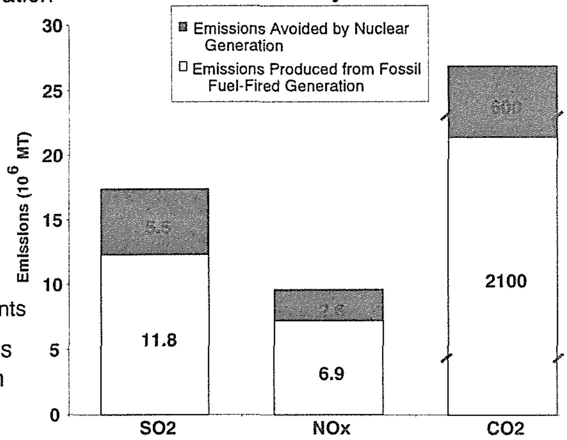
JAIFNPP.6

73106A

Nuclear Power Plants Avoid Emissions of Air Pollutants and Greenhouse Gases

- Each year, US nuclear generation avoids
  - 5.5 million MT of SO_2
  - 2.6 million MT of NO_x
  - 600 million MT of CO_2
- "Environmental service" by nuclear plants currently unvalued
  - presumed a "free good"
  - implicit subsidy to fossil plants
- Each year, avoided emissions reduce compliance obligation and costs to fossil plants by at least 12 billion dollars

2000 US Electricity Emissions



Source: Energy Resources International

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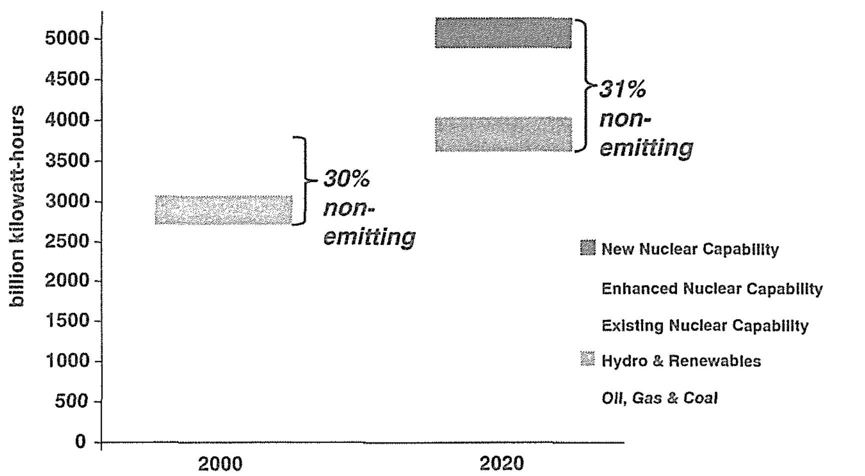
US Nuclear Energy Institute (NEI) *Vision 2020* - 50 New Nuclear Plants



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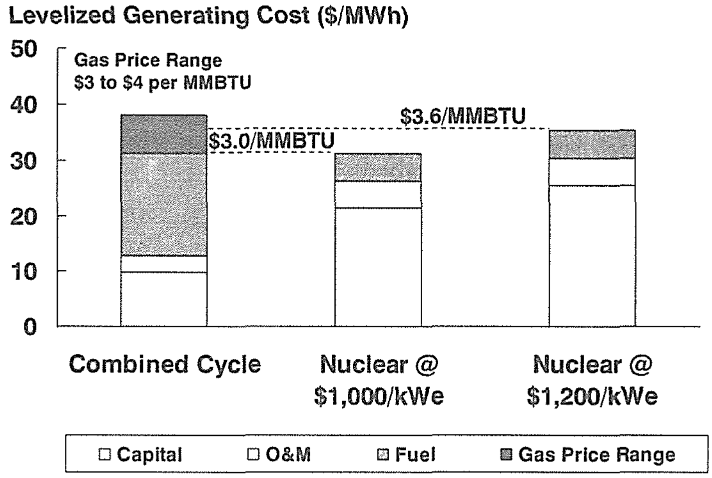
The Competitive Cost Challenge for New Nuclear Capacity in the US



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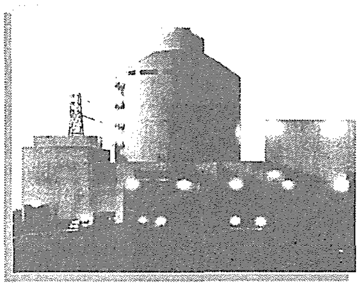
Benefits of New Nuclear Power Plants

- New advanced LWRs with passive safety systems and modular construction (e.g., AP1000) can meet capital cost target
- AP1000 will have forward production costs (O&M, fuel) of ~0.9 ¢/kWh... more competitive than today's reactors



Westinghouse AP1000

JAIFNPP.10

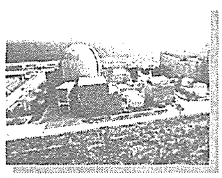
Benefits of New Nuclear Power Plants

- ***Emission credits, properly monetized, would not only make nuclear energy far more competitive, but would encourage deployment of new nuclear plants...further reducing emissions***
- **New nuclear energy plants preserve the environment and enable economic growth *at the same time***

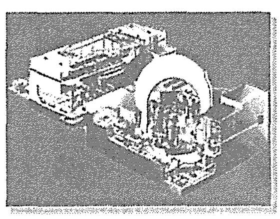
JAIFNPP.11

Westinghouse Is Ready for the Future with a Wide Range of Nuclear Plant Designs

Today

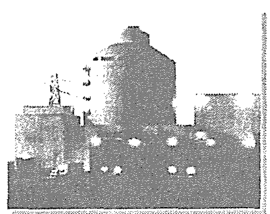


System 80 & System 80+ Designs in Korea



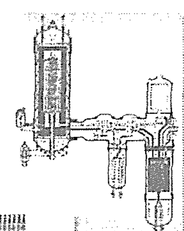
MHI/W APWRs for Japan

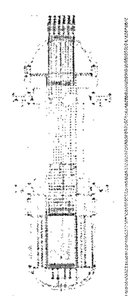
Near-Term



AP1000 Passive Plant Option

Later



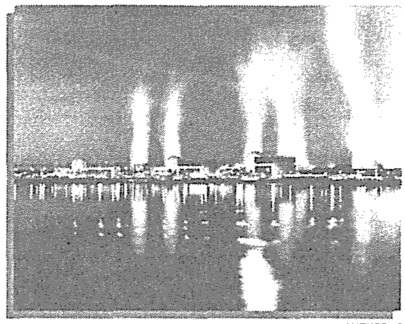


BNFL and Westinghouse Supporting Development of the PBMR and IRIS *Conceptual* Designs

JAIFNPP.12

Will Nuclear Energy be the Answer in the New Century?

- Nuclear energy is an essential part of the energy mix for the new century
- New technology, new laws and new leadership ensure a pivotal role in improving the quality of life around the globe with safe, clean, reliable and affordable electricity
- Nuclear energy is part of the answer to sustainable growth for *everyone* on the planet



JAIFNPP 13

Regulating Nuclear Safety in Today's Socio-Economic Environment

Jeffrey S. Merrifield
Commissioner, United States Nuclear Regulatory Commission

Introduction

Good morning. Thank you very much for the opportunity to be the keynote speaker for this session, which will focus on the contribution of nuclear power in today's socioeconomic environment. Today in the United States, the major factors shaping the socioeconomic environment for nuclear power are a progressively deregulated domestic energy market, President Bush's national energy plan, and Congressional legislation aimed at improving the regulatory environment for nuclear power.

Let me start by saying that the U.S. nuclear industry appears well poised to adapt to this changing environment and, as a result, the outlook for nuclear power is the brightest it has been in several decades. By almost any safety, reliability, or economic performance indicator, the 103 operating nuclear power plants in the U.S. are operating better today than ever before. Our licensees have developed sound maintenance and corrective action programs, improved operator training and performance, made significant process improvements, shortened refueling outages, and as a result, significantly increased both safety and generation of power in the nuclear fleet. This improved performance has not only resulted in an increase of generation from the existing fleet equivalent to placing 23 new 1000 megawatt power plants on line, but it has also set the stage for nuclear power to be a significant factor in our nation's ongoing energy debate.

You will hear from several distinguished industry representatives today. My perspective, of course, will differ from theirs because I am a regulator, not an industry official. My perspective is also different from other government agencies that promote domestic energy policies. In the United States, the Nuclear Regulatory Commission (NRC), of which I am a member, was created as an independent agency to regulate the use of nuclear power. The mission of our agency is to ensure that nuclear materials are used in a manner that protects public health and safety. Nevertheless, because the regulation of nuclear power significantly influences the environment within which the industry must operate, the NRC's activities have a demonstrable effect on the competitiveness of the nuclear power industry.

One conclusion that I believe will be shared by all speakers today is that safe operation is a cornerstone to maintaining the economic value of nuclear power facilities. To believe that safety and economic value are mutually exclusive goals simply ignores the realities that history has unmistakably, and sometimes painfully, taught this industry. Poor safety performance ultimately manifests itself in poor plant reliability and poor economic performance, factors that will undoubtably produce severe economic consequences in a competitive energy marketplace.

Restructuring of the Energy Market

The nuclear power industry in the U.S. is competing in a progressively changing domestic energy market that is being restructured or deregulated to become more competitive. To understand the U.S. energy market, one has to appreciate that although the federal government establishes national energy policies, each individual state retains control over electricity service within its borders. Because of this, and because demand, generating capacity, and transmission systems differ from state to state, there is a wide disparity of electricity rates across the U.S. For example, in 1998, when restructuring was in its early stages, consumers in New York paid more than two and one-half times the rates that consumers in Kentucky paid for their electricity. Thus, as one would expect, the restructuring movement within the U.S. varies from state to state.

The U.S. Department of Energy (DOE) reports that as of March 2002, twenty-four states have either enacted enabling legislation or issued regulatory orders to implement retail access. Although half the states have some form of a restructuring plan, not all of these states have implemented these plans. Seventeen states have active programs, 7 states have delayed, to some extent, implementation of any program, and California has suspended its plan.

California experienced significant problems with its restructuring program. Electricity prices more than tripled when retail competition was introduced in 1998 and there have been repeated supply problems. As you are probably aware, in 2001, power shortages were so severe that utilities were forced to impose rolling blackouts to ensure the integrity of the grid. The major California utilities, Pacific Gas and Electric and Southern California Edison, were driven to dire financial straits. Some observers have concluded that California's difficulties resulted from its unique restructuring plan and the significant deficit in generating capacity within its borders. The experience in California has caused many states to reconsider their restructuring positions, and in some states restructuring efforts have completely stopped.

As a nuclear regulator, we have had to monitor each state's restructuring efforts to anticipate the effects that they may have on nuclear plant operations. Deregulation has sparked numerous nuclear industry initiatives that have required regulatory oversight including corporate mergers and acquisitions requiring license transfers, requests for new and increasing power uprates, and the need for the NRC to ensure that licensing is carried out in an effective and efficient manner. More predictable regulation and the positive economics for nuclear power have, in turn, sparked license renewal applications. I will now discuss each of these areas in more detail.

License Transfers

The economic realities of the deregulated electric industry are leading to mergers and acquisitions of nuclear assets. The most notable merger was between Unicom Corporation and PECO Energy Company to form Exelon, which now has the largest nuclear fleet in the U.S : it owns 10 nuclear stations with a total of 17 reactors. Similarly, deregulation has led electricity companies to sell generating capacity. Since 1998, dozens of nuclear power plants have been acquired or are in the process of being sold. These assets are being acquired by industry leaders like Dominion, which now owns 6 operating reactors, and Entergy, which now has 9 units. Deregulation has also led nuclear licensees to restructure existing companies. For example, the Nuclear Management Company now operates, but does not own, 8 operating units. Another trend has been toward cooperative arrangements between licensees, like the arrangement between the 11 units included within the STARS utility group.

For the NRC, these mergers, acquisitions, and restructuring efforts have led to significant regulatory challenges. License transfers have been required to effectuate the changes in ownership. The NRC reviews license transfers to ensure that the proposed new licensee is financially and technically qualified to own or operate the nuclear facilities. Between January 2000 and March 2002 we completed the review of 41 transfer applications. More than half of those transfers, 23, took place in the Year 2000. Since that time, the number of transfer applications has been steadily declining.

Transfers involving complex corporate structures, with new holding companies and multiple subsidiaries, combined with the larger overall size of the nuclear power companies have presented novel and distinct issues for the NRC to consider. The NRC recognized that the state of the industry would require an efficient and timely review of license transfer applications and an effective public participation and communications process. In response, we dedicated new staff resources to transfers and developed a new streamlined adjudicatory process, to review these applications. These efforts have been effective at reviewing transfers in a timely and efficient manner.

The larger companies created by industry consolidation have the advantage of pooling management expertise and financial assets to achieve higher performance for plants that were not operating at those levels previously. However, a challenge facing these larger companies is the need to ensure that their resources are not too thinly spread. Larger companies face unique challenges to ensure that every plant that they own is adequately managed and financed to ensure safe operation. Also, larger companies must ensure that they do not become insular. I have previously cautioned the industry to continue to recognize the value of looking outside their organizations for solutions, and sharing information outside of their organizations for their own good and the common good of the industry.

Power Uprates

Another initiative that is taking on rapidly growing relevance in the industry's efforts to enhance the economic value of its plants is power uprates. Power uprate applications are continuing to require increased Agency resources. Power uprates are frequently the industry's least costly means by which to increase generation. To date, the NRC has completed reviews of 74 power uprate applications, resulting in a combined increase of over 3470 megawatts electric (Mwe) in the power levels at the affected plants. In 2001 alone, the NRC reviewed 22 power uprate applications.

The increase in the number of uprate applications is creating a significant challenge for the Agency, and this challenge is now being compounded by requests for uprates that are several orders of magnitude greater than requests in past years. Previous power uprates were typically on the order of 2-7 percent. More recently, however, some licensees are capitalizing on a General Electric Topical Report and have submitted applications for Extended Power Uprates of 15 to 20 percent, which usually involve significant modifications to plant equipment. Some industry analysts are predicting that licensees will pursue power uprates totaling 8,000 to 12,000 megawatts electric in the coming years.

To ensure the uprate applications are reviewed in a timely manner that is fully protective of public health and safety, the NRC has continued to improve its process for reviewing applications. Most recently, the staff has made process enhancements to address the criticism that its efforts associated with small uprates, such as those related to improved feedwater flow measurement techniques, were too intensive for the small risk associated with these uprates. The staff has also recently completed its reviews of Extended Power Uprate applications for Duane Arnold, Quad Cities, and Dresden nuclear power facilities. The staff has also just approved the largest uprate, for 20%, for the Clinton nuclear power plant. These represented the largest power uprates to date and were completed within one year of the submissions of the applications.

Reactor Oversight Process

While industry initiatives such as power uprates have enhanced the industry's ability to compete, few would argue that predictable, transparent and risk-informed regulation is equally important to the nuclear industry remaining competitive. The NRC developed the Reactor Oversight Process (ROP) to achieve these regulatory goals. The ROP is also an essential tool for the NRC to remain confident that, in this competitive environment, nuclear plants continue to maintain adequate safety and to communicate that message to our stakeholders. The ROP evaluates plant performance by analyzing information from NRC inspection findings and a set of performance indicators reported by the licensees. Both the inspection findings and the performance indicators are given a color designation based on their safety significance. The goal is to utilize the indicators as a means of anticipating declining trends in safety performance and to provide a clear and understandable tool that the public can use to judge plant safety.

The ROP was developed after receiving significant input from the industry and the public.

We and our stakeholders view the ROP as a significant improvement over our former regulatory methods. However, we have received criticism that our assessments may be taking too long and that the system is still not as consistent across our Regional offices as it should be. We are continuing to examine the process and are working with our stakeholders to gain insights into this program. Although the Commission has many substantial challenges facing it in other program areas, I believe it would be absolutely irresponsible to become so distracted that we lose the potential opportunity to make further safety enhancements to this important program.

License Renewals

One of the most significant developments following deregulation efforts and the NRC's efforts to become a more risk informed and transparent regulator was the desire of many licensees to seek license extensions, or renewals. In the U.S., reactors are typically licensed for 40 years of operation, but licensees may seek renewal to extend that period for an additional 20 years of operation. The desire of industry to seek license renewals is a clear indication that the economic value of nuclear plants has increased. The NRC received its first two license renewal applications in 1998. Since then, we have received 8 more applications and we are expecting 16 more by April 2005. In March 2000, we approved our first license extension application, and have now approved 3 others, for a total of 8 units. Given this level of activity, renewal applications represent a significant ongoing challenge for our agency.

Our success in effectively managing this program is, in part, the result of our expectation that our licensees develop sound programs for managing plant aging and submitting renewal applications of high quality. Our focus is to ensure that safety is never compromised in order to enhance a plant's economic value. We have an obligation to review licence renewal applications; we do not have an obligation to approve them.

Having said that, I believe we also have an obligation to ensure that our review process is conducted in as efficient and timely manner as possible.

We must continue to dedicate the time and resources necessary to keep this important program on track and to apply lessons learned from the initial applications to make further process improvements.

New Plant Licensing

Not only has the energy market progressed toward deregulation, but the political climate for nuclear power has also changed significantly in the last two years. Of particular significance is President Bush's decision to include nuclear power in the nation's energy policy for the future. Similarly, Congress has introduced several energy bills that include broad-based legislation aimed at increasing the competitiveness of nuclear power and the prospects for new nuclear generation. In February 2001, the DOE unveiled the Nuclear Power 2010 initiative, which is aimed at building new nuclear power plants in the U.S. before the end of the decade. This program partners DOE with the private sector to explore potential sites for a new reactor, identify key NRC licensing issues, and conduct research into nuclear technologies.

Industry is responding to this political climate change. As many of you may know, a U.S. publication, Nucleonics Week, reported a few weeks ago that Dominion Energy became the first U.S. company to announce a potential site for a future new power reactor, saying that its plans are to submit an Early Site Permit for its North Anna station in the state of Virginia by September 2003. Exelon Generation and Entergy have also said that they plan to seek Early Site Permits by June 2003 but have not announced the sites they may choose.

We at the NRC are keeping a close eye on these developments. It will be up to the industry to decide whether to seek a new plant license. Our task will be to ensure that we are prepared to review the safety issues raised by new plant licensing requests.

The challenge of new plant licensing is daunting. It has been many years since the NRC has licensed a new plant. Although we have made significant strides in the past year to prepare for a new plant application, we may not be fully prepared. In the future we will have a tremendous need for scientific, technical, legal, and public-policy expertise. We have a highly qualified and dedicated staff, but in the near future, we are facing a wave of retirements of our most seasoned and qualified personnel. This will occur at a time when fewer students are entering the nuclear field to fill this void. Our communication efforts will have to support a public that is unfamiliar with the details of a new age of nuclear power plant design and construction. In the midst of any new licensing request, we will continue to be responsible for the safety of the present fleet of nuclear plants and materials licensees and the regulatory demands that they will place on the Agency, including the possible review of a license application for a high-level waste repository.

To respond to these concerns, we are in the process of reviewing our regulations to ensure that they are appropriate for new plant licensing. We are reviewing our technical expertise to understand our shortfalls and know where to direct our recruitment efforts. We have asked Congress for legislation that will make employment with our Agency a more attractive option, and I, and some of the other Commissioners, have visited Universities to encourage students to pursue studies in the nuclear field.

There is no doubt that a new application would have a profound impact on our Agency, and any failure to be fully prepared would have immeasurable consequences.

Conclusion

In conclusion, it is clear to me that we are at the beginning of yet another chapter in the history of nuclear power. While it is unclear whether this will result in a renaissance or merely the continuance of the status quo, both the NRC and the industry need to ensure that safety of the existing fleet of nuclear units remains our principal focus. Thank you very much for this opportunity.

Which Way Forward

- US Energy Plan - 1200 new power plants over next 20 years
- US installed capacity remained steady at ~ 700 gigawatts - now showing some increase
- Forecast - 50% increase in US demand over next 20 years

1

Which Way Forward

- Demand will start to be met by natural gas or clean coal
- Increased use of natural gas will impact supply - higher cost per kw-hr
- Other fuel sources for new plants are needed to add to mix - including renewals

2

Which Way Forward

- Efficiency improvements, increased capacity, and power uprates being made to nuclear plants - increased generation without environment impacts
- Exelon Nuclear is achieving the following increased generation
  - Power uprates: 439 MW achieved
    385 MW in 2004
  - Efficiency improvements: 99 MW achieved
    65-85 MW in 2004
  - Increased capacity: 4.5 million MW-hrs in 2002 (est.)
    2.1 million MW-hrs in 2004
- More generation will be needed to meet demand

3

One Way to Get There

- Nuclear is one of the generation choices - no greenhouse gases
- Economics favor modular concept
- Pebble Bed Modular Reactor (PBMR) - inherently safe design reduces need for redundant backup safety systems resulting in lower construction and operating costs
  - ~ 120MW/module
  - ~ $1200/KW

4

One Way to Get There

- PBMR advantages
  - Large safety envelope
  - Combines Combined Cycle-Gas Turbine plant staffing and nuclear fuel economies
  - Short time to construct
  - Reasonable incremental capital investment over short time

5

Prospects and Competitiveness of the Korean Nuclear Industry

Prepared for the 35th JAIF Annual conference

APRIL 24, 2002

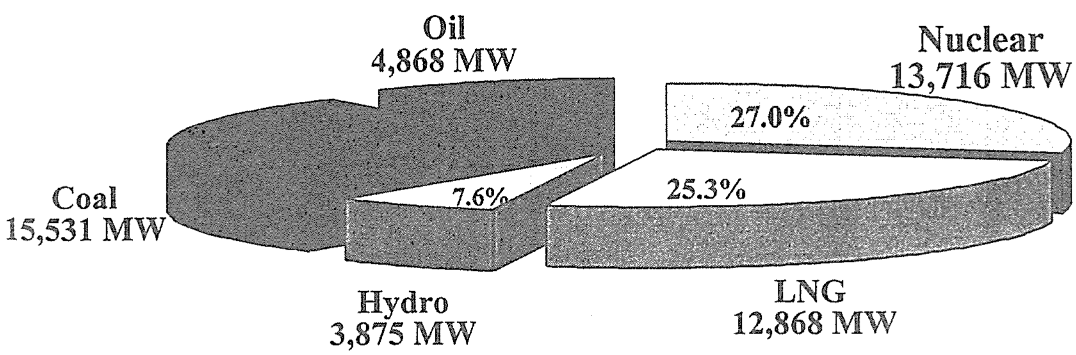
CHOE, Yang-Uoo

President & CEO

Korea Hydro & Nuclear Power Company

Current Status in the Korean Nuclear Industry

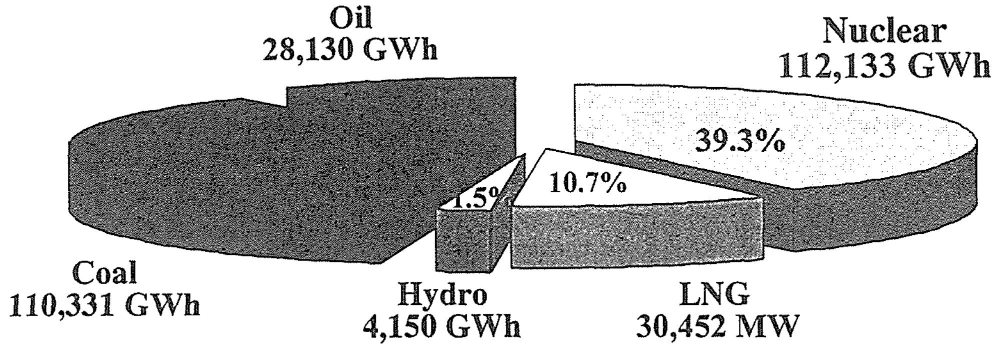
Installed Capacity



- Total installed Capacity : 50,858MW (as of the end of 2001)

Current Status in the Korean Nuclear Industry

Electricity Production



- **Total Electricity Production : 285,196GWh (in 2001)**

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KOREA HYDRO & NUCLEAR POWER CO., LTD

Current Status in the Korean Nuclear Power Business

- The operational performance has shown remarkable improvement so far.
- Achievements in 2001
  - Capacity factor : 93.2%
  - Unplanned outage : 0.5 occurrences pe r reactor

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Future Nuclear Power Development

- Continued safe operation of existing plants and continued construction for new nuclear power plants
  - In anticipation of increased environmental regulations and energy supply uncertainty
- Continuous upgrade of KSNP design and deployment of APR1400 to enhance safety and economic efficiency

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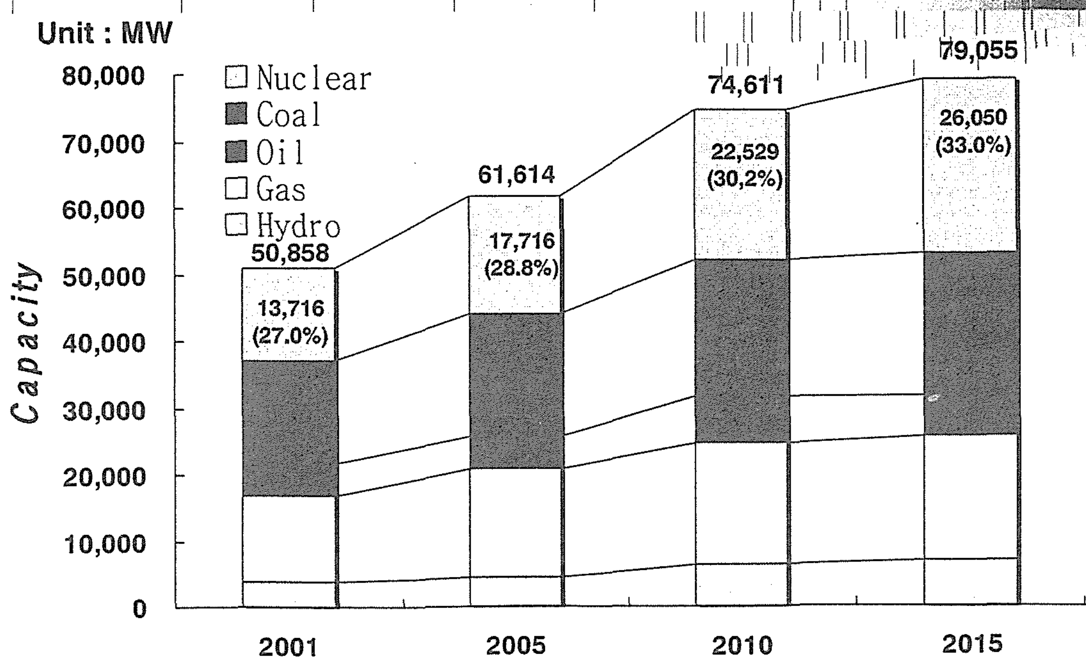
Long-term Power Development Plan



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NPPs under Construction : 4 Units (4,000 MW)

Plant		Reactor Type	Capacity (MW)	Project Management	NSSS Supplier	Plant A/E	Commercial Operation
Yonggwang	#5	PWR	1,000	KHNP	DOOSAN/WH	KOPEC	Apr. 2002
	#6	PWR	1,000	KHNP	DOOSAN/WH	KOPEC	Dec. 2002
Ulchin	#5	PWR	1,000	KHNP	DOOSAN/WH	KOPEC	Jun. 2004
	#6	PWR	1,000	KHNP	DOOSAN/WH	KOPEC	Jun. 2005

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NPPs in Planning : 8 Units (9,600 MW)

- To complete 4 KSNP+ units & 4 APR1400 units by 2015

Plant		Reactor Type	Capacity (MW)	Commercial Operation	Remarks
Shin-Kori	#1	PWR	1,000	Sep. 2008	KSNP+
	#2	PWR	1,000	Sep. 2009	KSNP+
	#3	PWR	1,400	Sep. 2010	APR1400
	#4	PWR	1,400	Sep. 2011	APR1400
Shin-Wolsong	#1	PWR	1,000	Sep. 2009	KSNP+
	#2	PWR	1,000	Sep. 2010	KSNP+
New Project	N#1	PWR	1,400	Jun. 2013	APR1400
	N#2	PWR	1,400	Jun. 2014	APR1400

KSNP+ : Improved KSNP

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APR1400 Project

- APR1400 Project to develop a 1,400MW evolutionary PWR enhanced in terms of safety and economics since 1992
- Based on self-reliant technology from previous nuclear construction projects and feedback from current operating experiences
- The first KNGR unit launched by 2010

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APR1400 Project

- Adoption of a fully digitalized man-machine interface (MMI) system*(fig. 1)*
- Incorporation of direct vessel injection and an in-containment refueling water storage tank*(fig. 2)*
- Ensure a high level of safety
  - Using safety engineering principles*(fig. 3,4)*
- Enhance economic competitiveness
  - Using a high power level and improved construc tion methods

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Competitiveness of Nuclear Power

- Continued development of nuclear power needs enhanced competitiveness through assurance of nuclear safety and economic efficiency.

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Competitiveness of Nuclear Power

- The recent remarkable improvement in plant performance is making nuclear power more and more competitive,
  — proving that economic competitiveness and safe operation are fully compatible.
- Nuclear units have to compete with a broad range of alternatives, on the basis of full generation costs.

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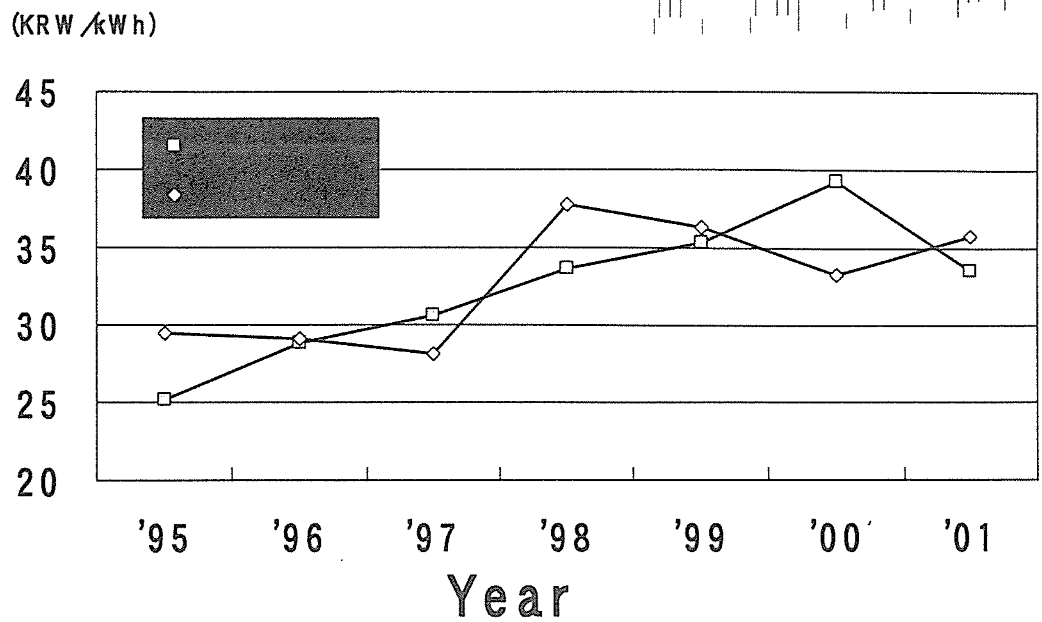
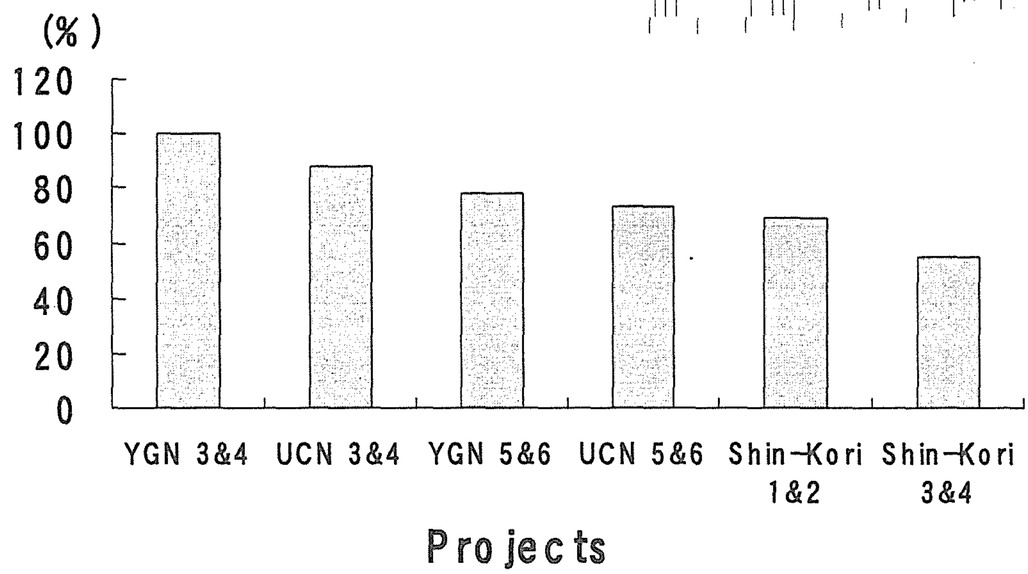
Generating Costs



Competitiveness of Nuclear Power

- Life extension of nuclear power plants is a critical issue worldwide with respect to economic viability.
- The immense capital costs of nuclear power create financial risks, especially in deregulated markets.
- Nuclear power is far inferior to the bituminous coal-fired in terms of construction costs.

Trend of Construction Costs



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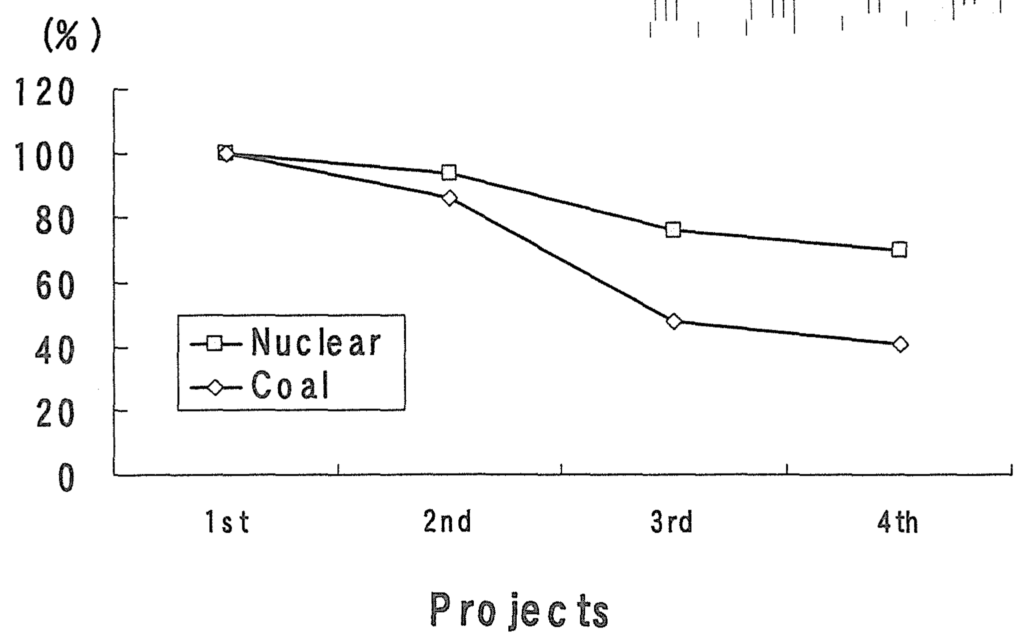
Trend of Contract Prices



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Conclusion

- Concerted efforts to secure nuclear competitiveness through the continued improvement of nuclear safety and economic viability
- Changes in today's management environment offer new challenges and opportunities to the nuclear power industry
- Our competitiveness to open the way for nuclear power to play a critical role as a sustainable energy source in the future.

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Thank you for your attention.

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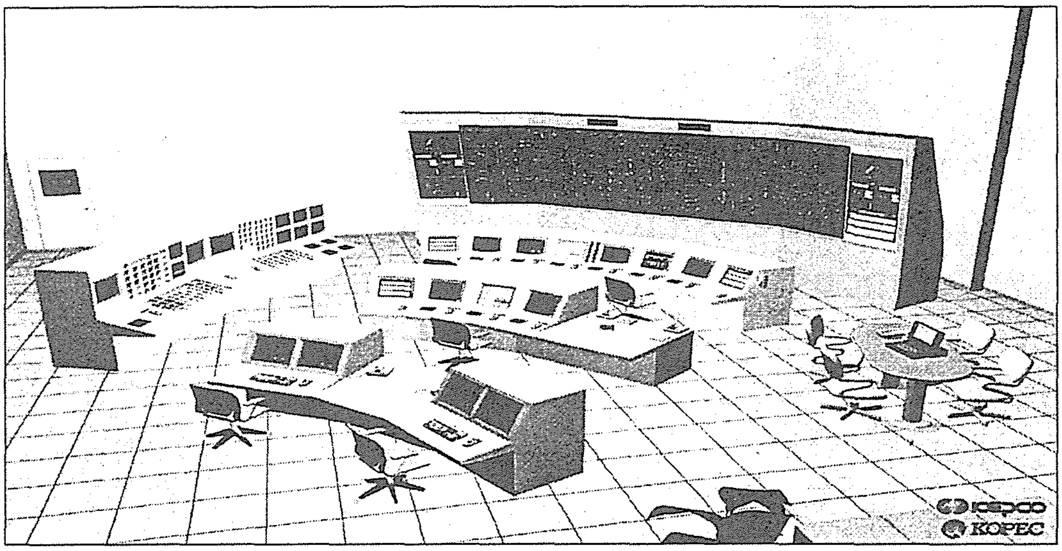
ARR1400 Project

<Fig. 1> APR1400 Control Room



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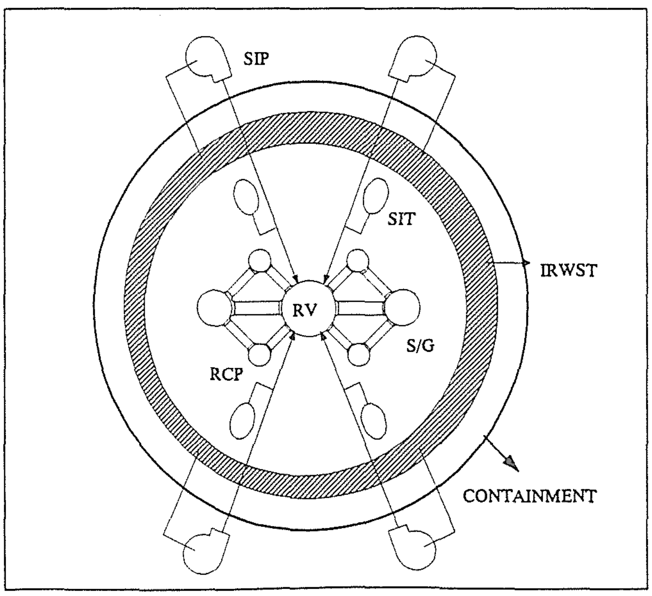
ARR1400 Project

<Fig. 2> 4-Train Direct Vessel Injection



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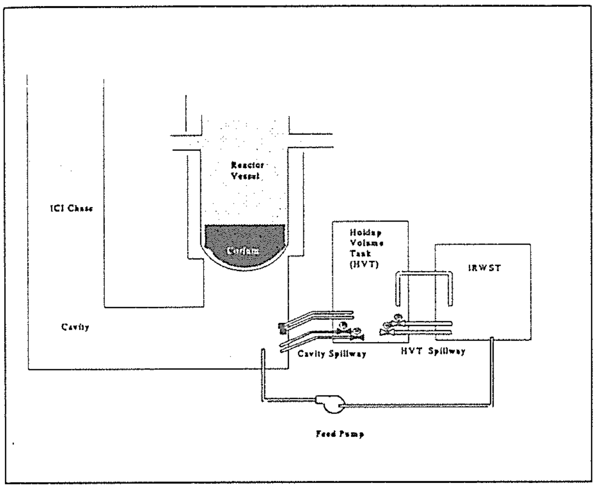
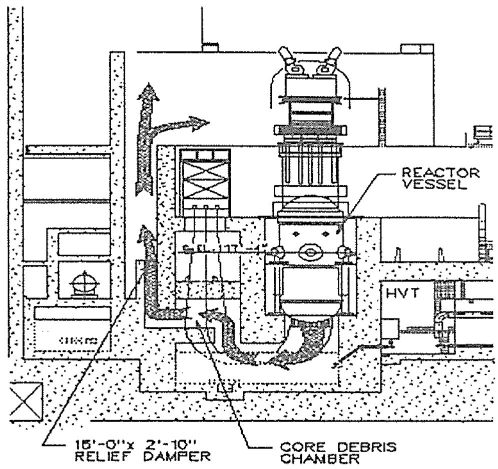
ARR1400 Project

<Fig. 3> In Vessel Retention Concept



<Fig. 4> Cavity Flooding System



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KHNP
KOREA HYDRO & NUCLEAR POWER CO., LTD

市民の意見交換

Pebble Bed Modular Reactor

DR Nicholls
CEO PBMR (Pty) Ltd
Eskom/IDC/BNFL/Exelon Project

1

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Utility Selection Criteria

- Competitive Economics (with CCGT)
- Distributed Generation (independent of fuel source)
- Short Lead Times and Small Unit Size (reduce risk of capacity mismatch)
- Load Following (increased commercial pressure)
- Reduced Environmental Impact (atmospheric emissions)

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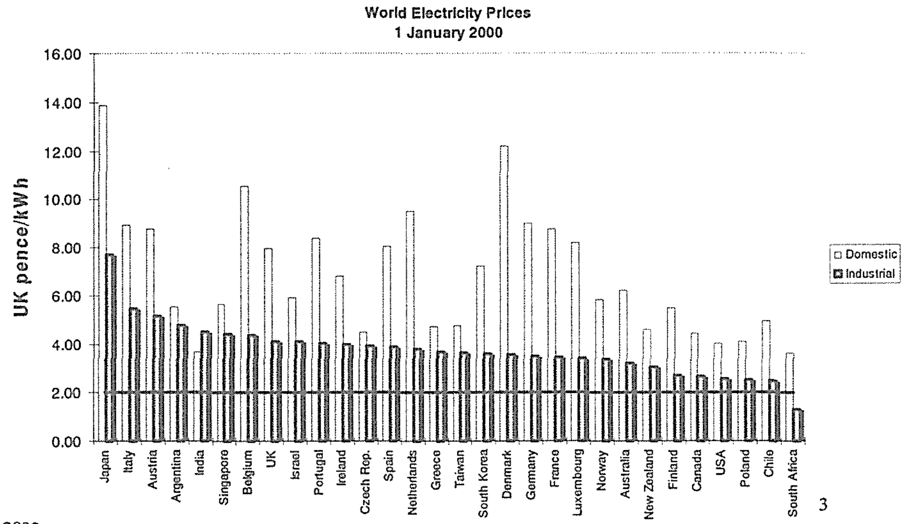
World Electricity Prices



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Industrial rates based on 2.5MW @ 40% load factor

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Current Nuclear Option

• PWR/BWR unit size large	600 MW+
• Construction schedules long	48 months+
• Unit cost high	$1500/kWe+
• Siting Restrictions	~16 km EPZ

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Current Reality

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Long Term Central Planning

is being replaced in most countries by

Short Term Market Forces

Size and timeframes acceptable in the past are no longer viable.

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Project Targets

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The Real Targets

$1000/kWe installed

24 months construction

400m EPZ

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The Real Targets

$1000/kWe installed

Economics

24 months construction

400m EPZ

8

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PBMR

The Real Targets

$1000/kWe installed

Economics

24 months construction

Commercial Risk

400m EPZ

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9

PBMR

The Real Targets

$1000/kWe installed

Economics

24 months construction

Commercial Risk

400m EPZ

Safety/Acceptance

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Design Philosophy

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Key Strategies

- Standardisation
- Small Size
- Simple Systems

- Internationalise

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Key Strategy - Standardisation

- Design
  - Minimise Engineering Cost
  - Minimise Support Efforts
  - Speed Construction
- Licensing
  - Internationally Agreed Norms
- Utility Support
  - Maximise vendor support
  - Minimse utility specific support
  - Industry Common Spares Holding by Vendor

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Key Strategy – Small Size

- Shorten Construction Period
- Minimise Engineering Effort
- Minimise Market Disruption
- Achieve Repetition on 3-4 months
- Maximise Learning Curve
- Achieve Inherent Safety

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Key Strategy – Simple Systems

- Minimise Engineering Effort
- Minimise Operations & Maintenance
- Achieve Inherent Safety
  - No Early Moving Components Required

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Technical Design

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Plant Fundamentals

- High Temperature Helium Cooled Reactor
- Coated Particle Fuel
- Spherical Fuel Elements (as per German reactors)
- Direct Cycle Gas Turbine (multi-shaft)
- No "safety systems"
  - fuel integrity maintained under most severe possible accident (full control rod removal from 100% power followed by pipe rupture and loss of all cooling).

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Plant Target Specification

• Max. sent out power	110-150 MW
• Continuous stable power range	0-100%
• Ramp rate (0-100%)	10%/min
• Load Rejection w/o trip	100%
• Base Construction Cost	$1000/kWe
• Construction Schedule	24 months
• General Overhauls	30 days per 6 years
• O&M and Fuel costs	$4-5/MWh
• Emergency Planning Zone	<400meters
• Plant Operating Life Time	40 years

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Main Power Systems

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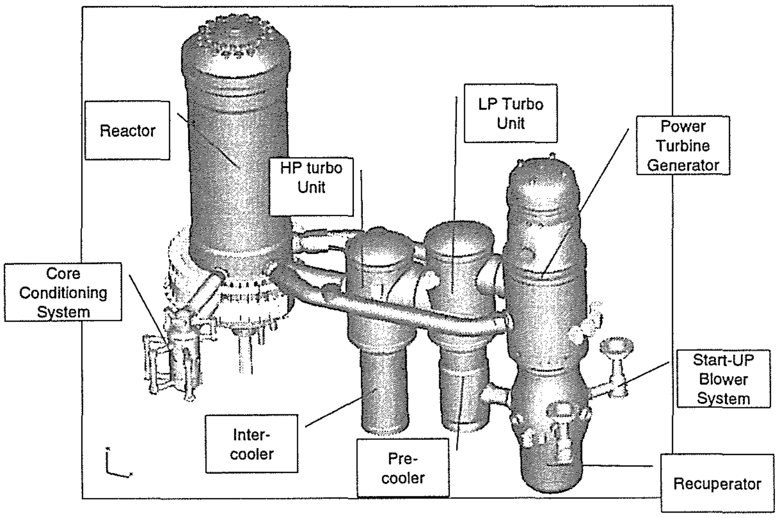

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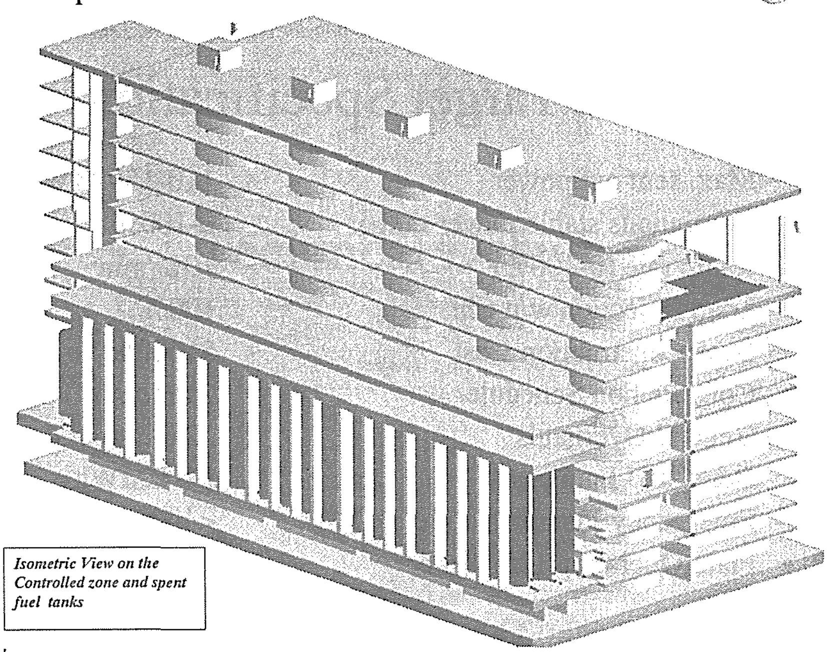
5-Pack Option



Isometric View on the Controlled zone and spent fuel tanks

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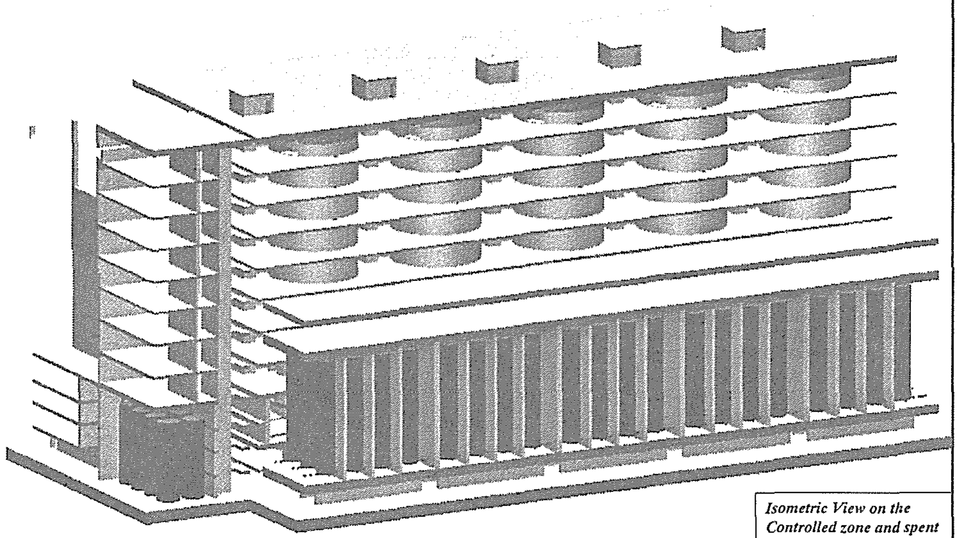
5-Pack Option



Isometric View on the Controlled zone and spent fuel + Helium tanks

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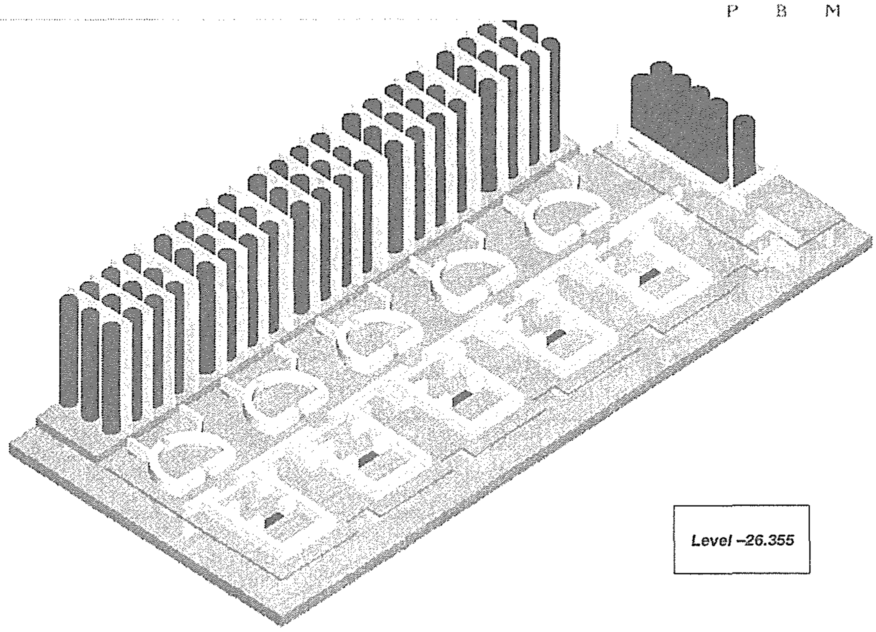
5-Pack Option

P B M R



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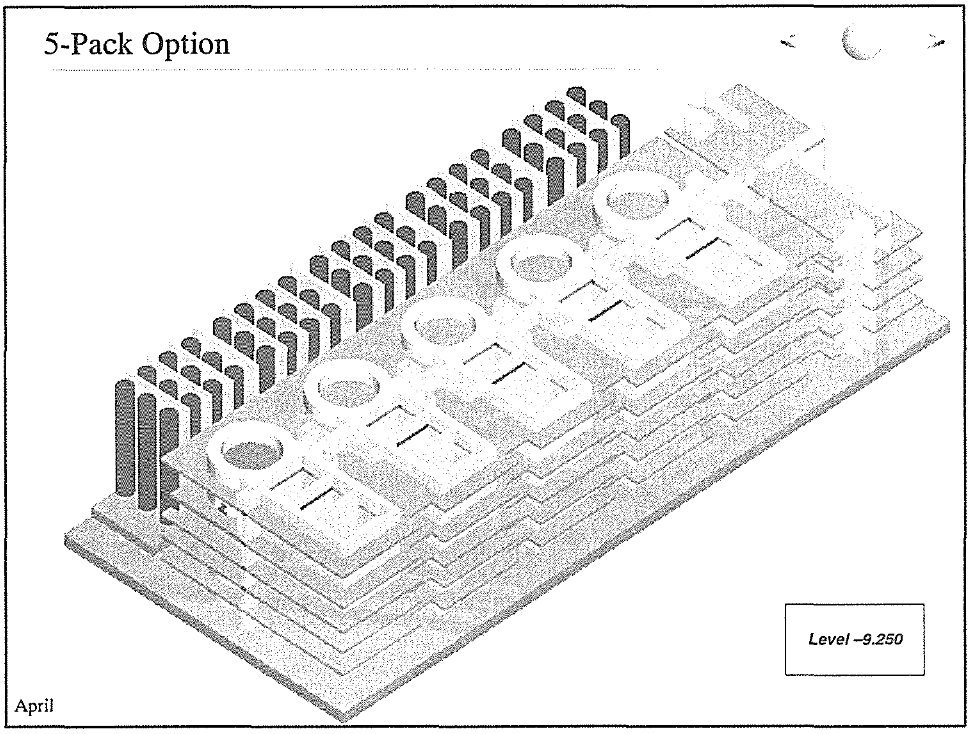
5-Pack Option
Level –9.250
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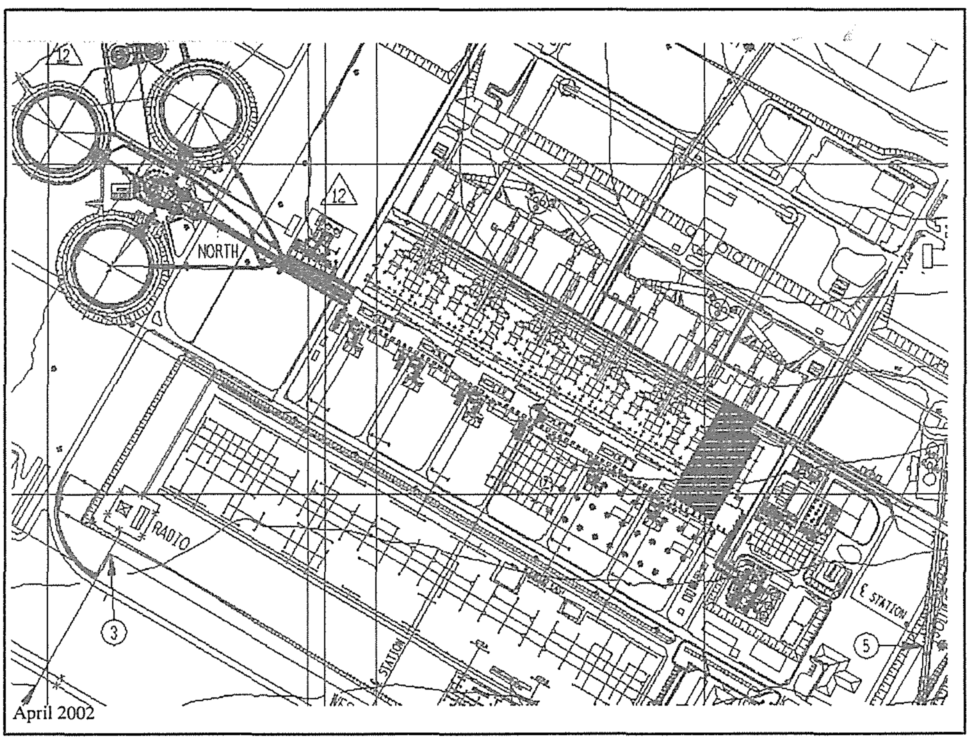
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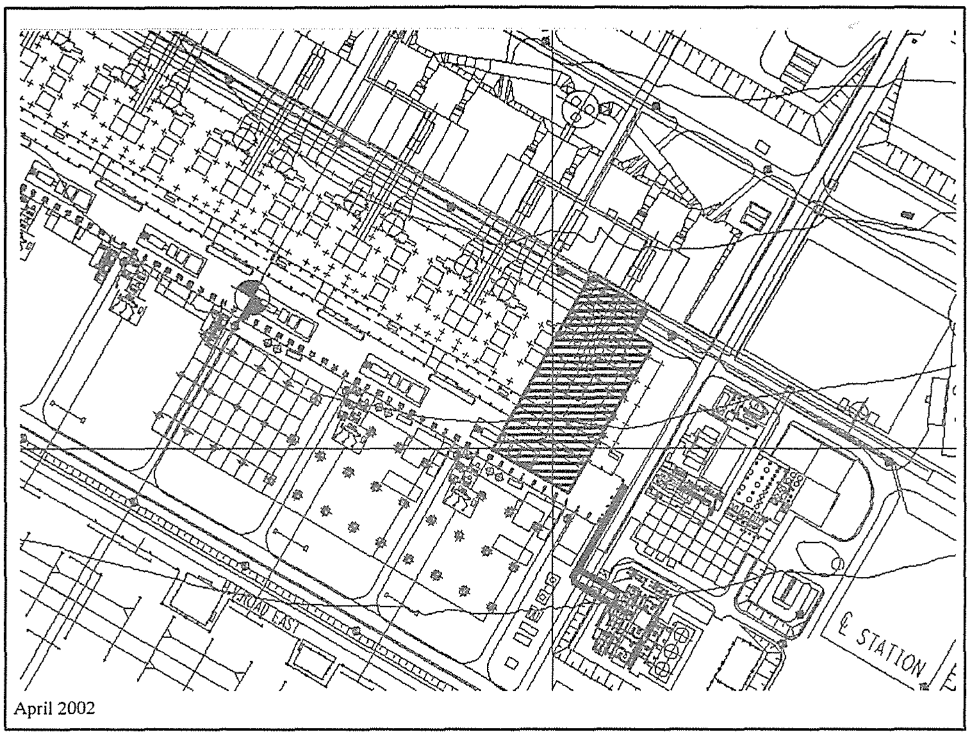

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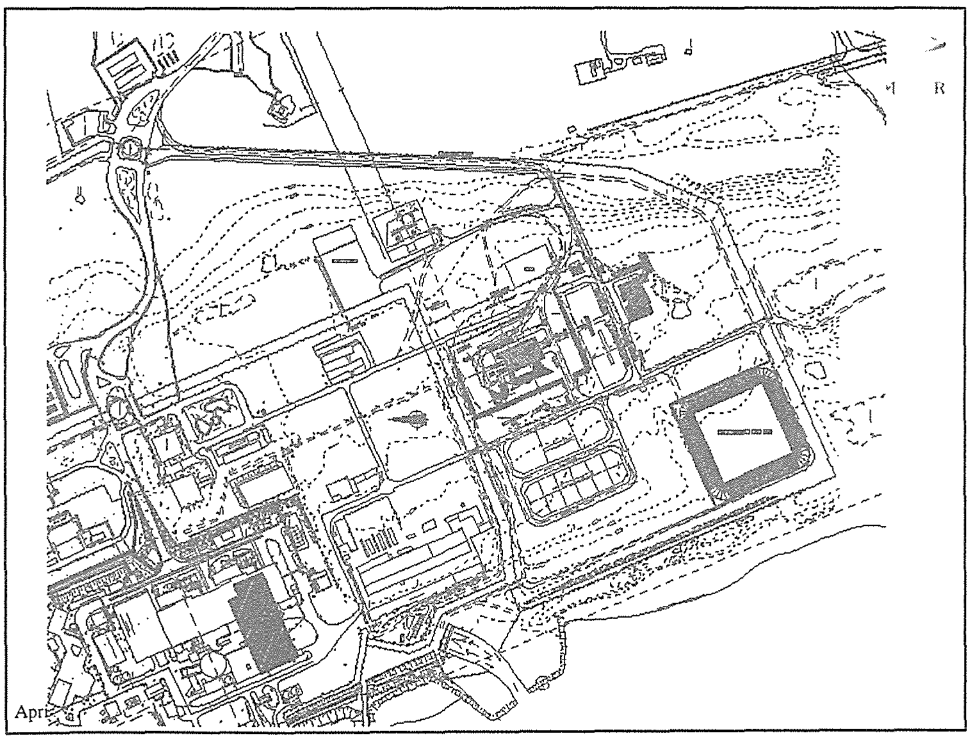
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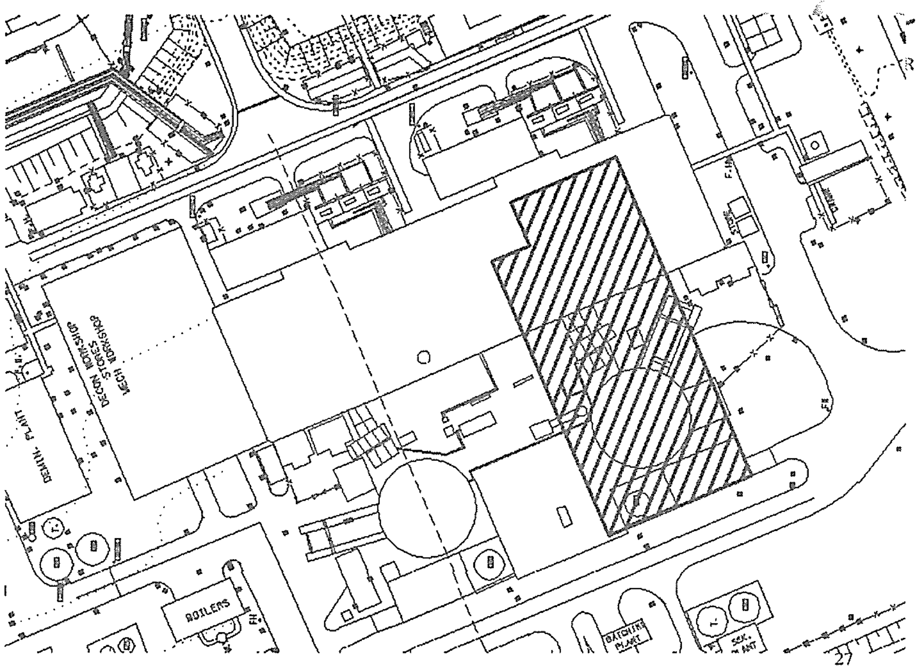

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Nuclear Safety

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Accident Categories

- Reactivity Excursions (Chernobyl)
  - Negative temperature feedback
- External Events (Aircraft Crash etc.)
  - Building Design
- Core Melt ("China Syndrome", TMI)
  - Low Power Level
  - Large Reactor Surface Area
  - Temperature Resistant Fuel

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Key Safety Issues

- The safety of the reactor is not dependant on the presence of the coolant (cooling or criticality).
- In no accident scenario is the early insertion of control rods required (early means in the first few days).
- There is no meaningful limit on transient power levels – only long term power level.

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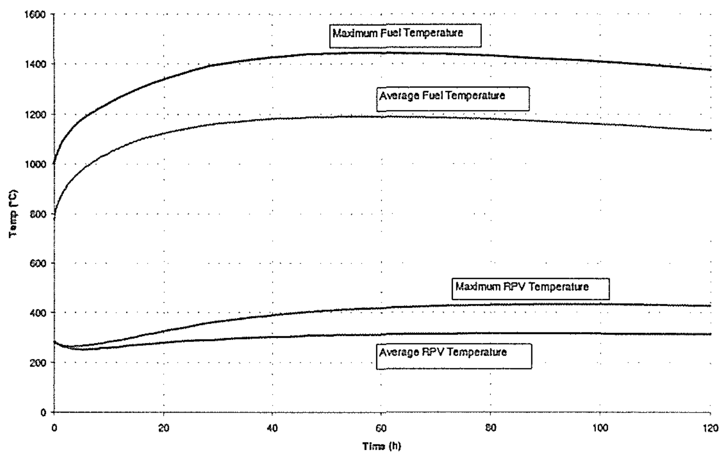
Loss of Coolant Event

265 MW PBMR Ref. Core: Temperature Distribution during a DLOFC



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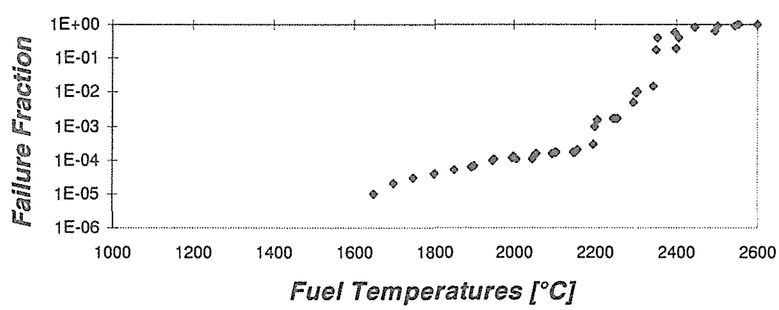
Fuel Performance



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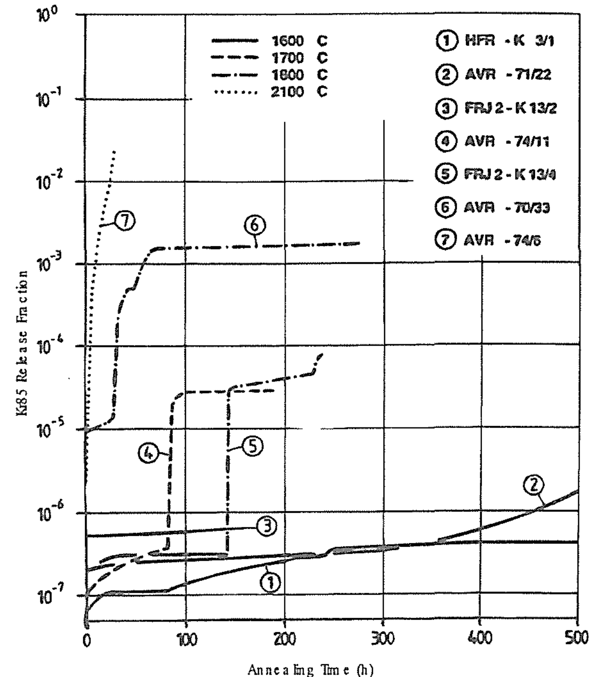

Figure 3: Kr85 Release Fraction as Function of Annealing Time

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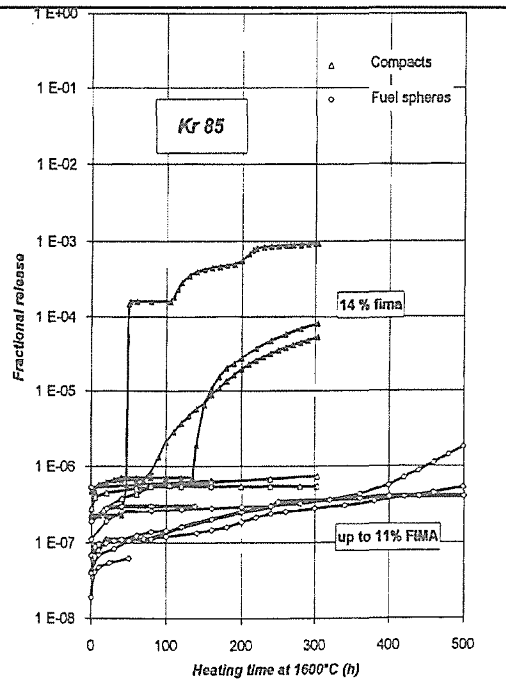

Fig. 4.6: ^{85}Kr release at 1600° C from compacts (10.7 to 13.9 % FIMA) and fuel spheres (3.5 to 9% FIMA)

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Doses @ Site Boundary

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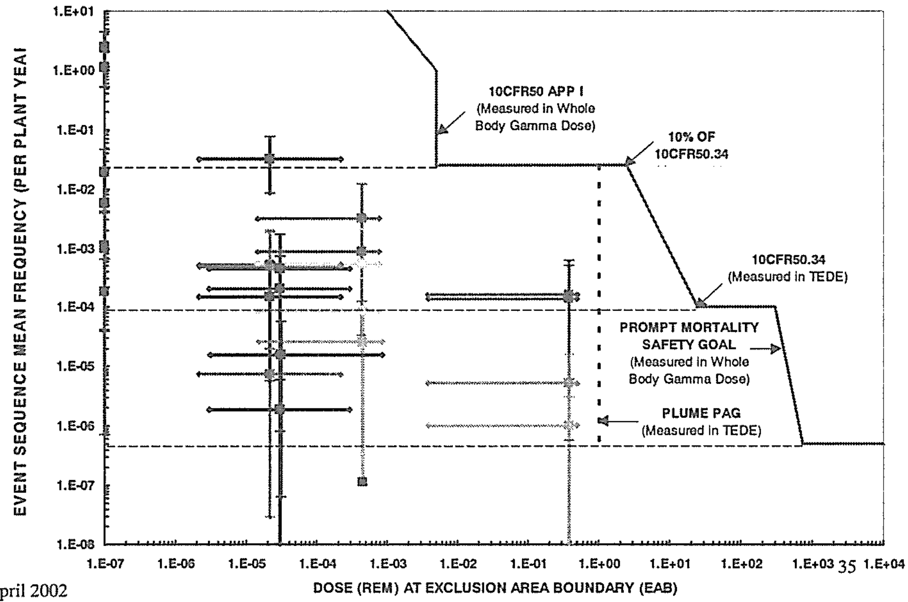

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Economics

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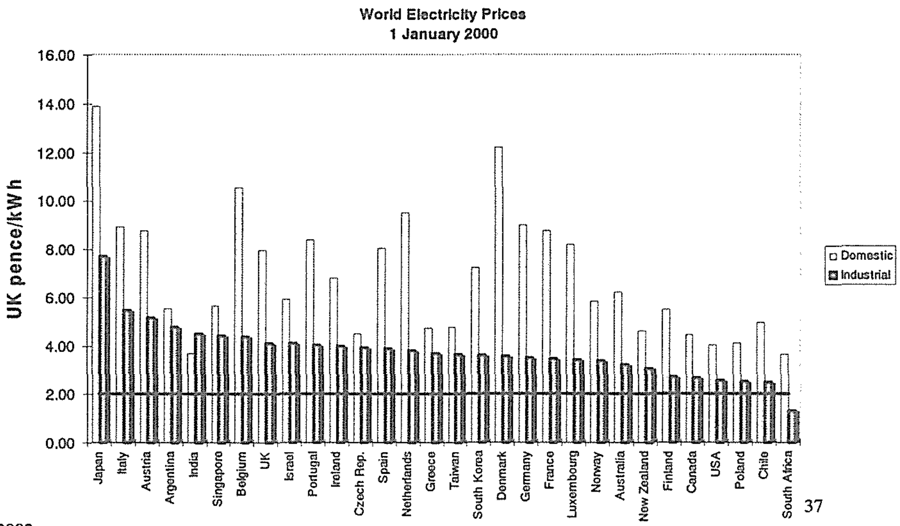
World Electricity Prices



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Industrial rates based on 2.5MW @ 40% load factor

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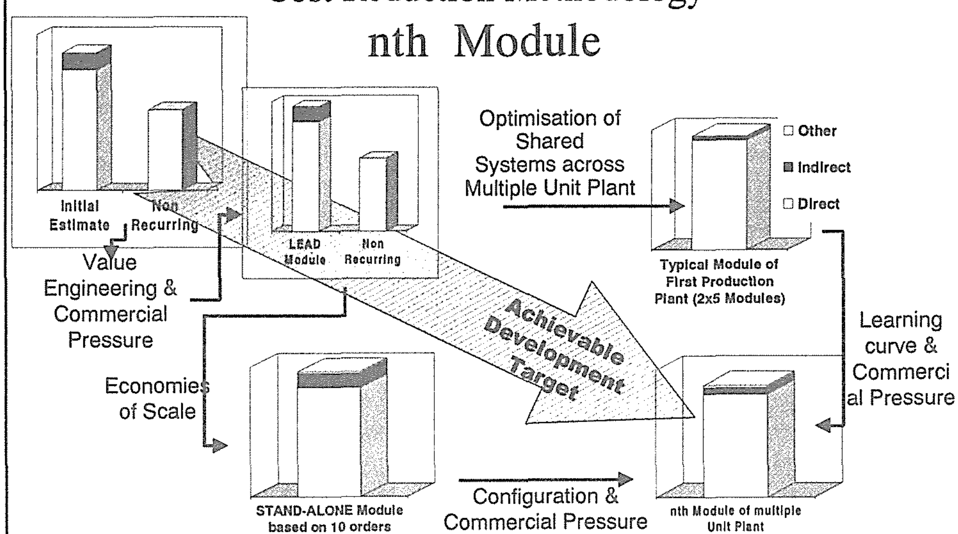
Cost Reduction Methodology
nth Module



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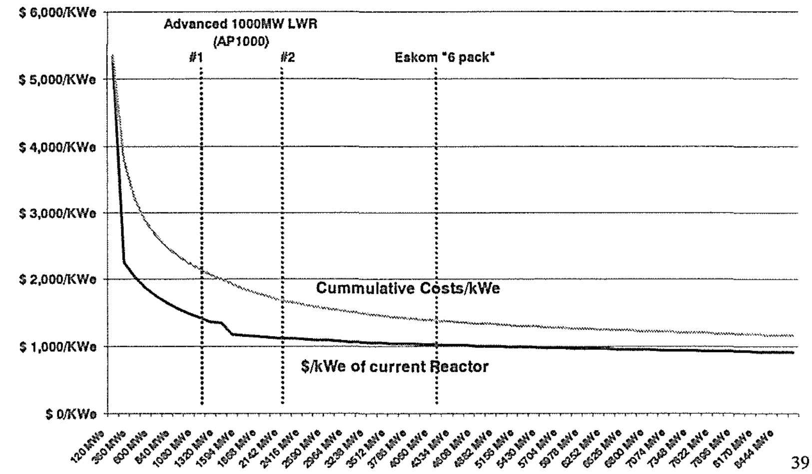
(Less Contingency, Corporate O/H & Owners Costs

Programme Costs/kWe



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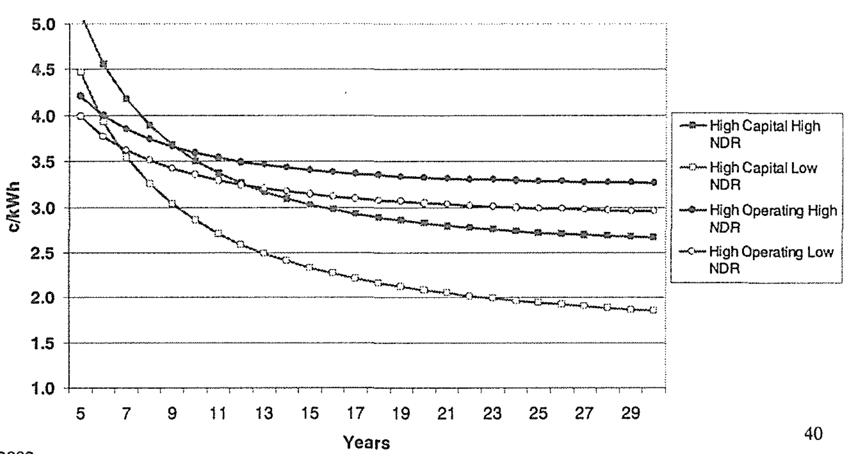
PBMR/CCGT Comparison

Two options analysed, one with High Capital and Low O&M & Fuel, other with Low Capital and High O&M & Fuel.

IRR		Capital/kWe		O&M & Fuel	
High	12%	High	$1,250	High	$ 25/MWh
Low	6%	Low	$500	Low	$ 7/MWh



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International Option Comparisons

(Illustrative Estimations)

	Capital ($/kWe)	Fuel ($/MWh)	Operating ($/MWh)	Construction Period
Coal	$800-$1000	$12-$15	$4-$6	42 months
Gas	$400-$650	$20-$30	$2-$3	18 months
Nuclear *(LWR)*	$1500-$2500	$3-$5	$5-$10	54 months
Nuclear (PBMR)	**$1000-$1200**	**$4**	**$2-$4**	**24 months**

The future?

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Approvals Required

- Shareholders
- Cabinet
- National Nuclear Regulator
- Department of Environment & Tourism (EIA)
- National Electricity Regulator
- Department of Minerals & Energy

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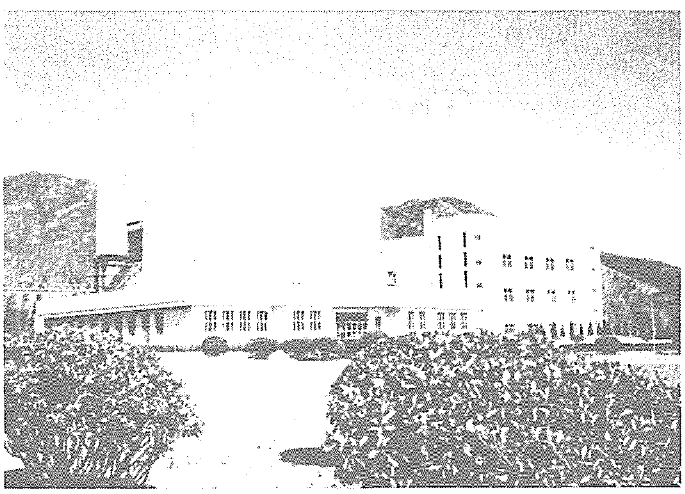
HTR-10 Beijing



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革新型軽水炉の開発

三菱重工業株式会社 特別顧問　饗場 洋一

まえがき

原子力発電は日本の基幹電源として位置づけられ、今では全電力量の１／３強を供給するに至っている。もともと原子力発電はエネルギー資源に乏しい日本にとって、将来のエネルギー安定供給を目指し導入されたものであり、今ではエネルギーのベストミックス形成の一翼を担っている。また世界的にみても電力をはじめとするエネルギー需要は増大の一途をたどることは必至であり、人類の英知が生み出した原子力エネルギーを最大限に活用することが将来の経済発展、地球環境保護の上で欠かせない施策である。

（１）原子力発電の必要性と開発課題

ここで「原子力発電の必要性」についてもう一度整理をしてみたい。

先にも述べたとおり

・日本はエネルギー資源に乏しい上にエネルギー多消費国である
・今後の世界、特にアジアの発展途上国のエネルギー需要は増大する
・日本は地球環境（＝地球温暖化）問題を解決する必要がある

一方で

・石炭・石油など化石燃料の使用には需給面、環境面から限度がある

また

・国土の狭い日本では風力、太陽光発電の利用にも量的な限度がある

この状況では原子力エネルギーの利用は今後とも有望な選択肢である。

しかしながら、原子力エネルギー開発を今後とも進める上で、我々メーカーを含め原子力関係者は以下の課題に取り組んでいく必要がある。

①原子力のより一層の安全性と経済性の向上
②地球環境問題の解決とエネルギーセキュリティの確保

特に昨今、原子力の「安全性と経済性の両立」が強いニーズとしてあがっている。

国レベルで検討されている革新炉検討専門部会においても「高い安全性と信頼性」「他電源に劣らぬ経済性」「エネルギーセキュリティーの確保」「放射性廃棄物量の低減」など様々なニーズに応える新型炉が紹介され、検討されている。

ここでは原子力プラントメーカーである三菱、東芝、日立が開発を進めている「革新型軽水炉」について、開発のねらい、概要とその特徴について紹介する。

他電源に劣らぬ経済性を達成するにはまずスケールメリットを活かし、プラントを大容量化することが考えられる。これまでの軽水炉の技術を継承し、かつ改良を加えた１７０万ｋｗ級のＡＰＷＲ＋、ＡＢＷＲⅡの開発が電力との共同研究の形で進められている。

（２）大容量軽水炉

（２－１）ＡＰＷＲ＋

最初にＡＰＷＲ＋について紹介する

ＡＰＷＲ＋はＡＰＷＲ技術を基礎として２０１０年代後半以降の主力電源向けに国内ＰＷＲ電力／三菱が共同研究で開発を進めているものである。

①ＡＰＷＲ＋の開発の狙い

経済性を高めるため

・ＡＰＷＲ１５０万ＫＷ級を１７５万ＫＷ級に大容量化する

・設備利用率９５％以上を目標とし、２４ヶ月運転も可能とする。

・開発費を最小とするため炉心はＡＰＷＲベースとする

安全性をより一層向上させるため

・受動的安全設備の利用拡大により設備を単純化する

・最終除熱手段や非常用電源を多様化する

・耐震性を高めるため建屋免震装置を採用する

②ＡＰＷＲ＋の原子炉の特徴

・出力の増強は１２ｆｔ・１７×１７燃料を１４ｆｔ・１７×１７燃料に変更することで達成している。

・燃料の長尺化に伴う炉心の長さを下部炉心プレナムの簡素化で吸収し、原子炉容器高さをＡＰＷＲと同寸法にしている。

・これまで下部にあった炉内計装を上部に配置している。

・高性能制御棒を採用することで制御棒本数が１０～１５％減少している。

③ＡＰＷＲ＋のプラントの特徴

・より一層の安全性向上の観点から受動的安全設備の採用拡大し設備を単純化している

・蒸気発生器（ＳＧ）による除熱機能を活用し、高圧注入系を削除している

・最終除熱手段の多様化を図っている

・耐震性向上のため建屋免震装置を採用している。これはプラント標準化にもつながる

（２－２）ＡＢＷＲ－Ⅱ

ＡＢＷＲ－ⅡはＡＢＷＲを基礎として、将来のニーズに適合させるべく、19９１年より次世代型ＢＷＲとして国内ＢＷＲ電力／ＢＷＲメーカ（日立、東芝、ＧＥ社）による共同研究として開発を進めているものである。

①ABWR の開発の狙い

ＡＢＷＲ－Ⅱでは、発電コストを低減するため、

・出力密度の増大による増出力(電気出力 1700MW)

・長期運転サイクル(18ヶ月)と定検期間短縮(20日)による設備利用率(稼働率96%)の向上

・燃料サイクル費の低減による発電単価の抑制(発電単価 25%減)

・制御棒、制御棒駆動機構の削減による建設費の低減(建設単価 20%減)

などを目標としている。

また、燃料サイクルに柔軟に対応するため、

・高燃焼度化
・運転サイクルの長期化
・MOX 燃料の利用
などを考慮した設計を行っている。

② ABWR-Ⅱの特徴

ABWR-Ⅱの主な特徴としては大型K格子炉心、静的崩壊熱除去システム、大容量逃し安全弁（ＳＲＶ）などがある。

大型K格子炉心では、大型燃料集合体の採用により、燃料、減速材の設計自由度が増大し、炉心設計の柔軟性が向上してる。また、広翼十字制御棒の採用により、制御棒価値が増大し、炉停止余裕の安全性が向上している。

また、次世代炉の国際標準を満足する安全設計を先取りして苛酷事故（ＳＡ）を設計上考慮し、静的崩壊熱除去システムを採用している。静的原子炉冷却系は、原子炉隔離時に隔離時冷却系（ARCIC)及び残留熱除去系（ＲＨＲ）が使用できない場合のバックアップとして、原子炉蒸気を直接熱交換器に導いて凝縮させ、原子炉へ貫流して崩壊熱を除去する。また、静的格納容器冷却系は、１次冷却材喪失事故（LOCA）又はSA時に格納容器の蒸気を熱交換器に導いて凝縮させ、サプレッションプールへ排出し、格納容器の圧力上昇を抑制させる。このように、ＳＡ時の格納容器過圧防護設備を強化させている。

「経済性と安全性の両立」に対し、スケールメリットや設備簡素化による経済性の向上と受動的安全設備の導入により安全性をより一層高めた大型炉２件を紹介した。

（３）革新型軽水炉

次に電力需要の伸びに応じ建設投資を柔軟にでき、かつそれぞれのねらいに対応した革新的技術を取り入れた中小型炉の開発も進められている。この中小型炉プラントのうち３点を紹介する。これらは、これまでの軽水炉の技術と経験をベースとし、安全性の向上、建設単価や発電単価の低減、将来のエネルギーセキュリティの確保など様々な要求を取り入れた革新型軽水炉である。革新型軽水炉としてメーカーが開発しているものには下表のようなものがある

表　各社開発の革新型軽水炉

	三　菱	日　立	東　芝
小型一体化炉	①ＩＭＲ	ＳＳＢＷＲ	ＬＳＢＷＲ
超臨界圧水冷却炉		ＳＣＰＲ	②ＳＣＰＲ
低減速炉	ＲＰＷＲ	③ＲＢＷＲ	ＲＢＷＲ

①小型一体炉は機器数の低減、プラント構成の簡素化を図ることで大型炉に匹敵する経済性（建設費低減）を追求した軽水炉

②超臨界圧軽水炉は熱効率を向上し、機器の簡素化を図ることによって発電原価を低減した軽水炉

③低減速スペクトル炉は将来のエネルギーセキュリティ確保と高レベル放射性廃棄物の低減を図ったリサイル型軽水炉

（３－１）小型一体炉（ＩＭＲ）

小型一体炉は系統、機器の簡素化を図るとともに、機器、配管類をパッケージ化して現地工事を簡略化し、建設工期、費用の最小化を図って建設費の低減を図るとともに安全性を高めた革新的軽水炉である。この小型一体炉は（財）エネルギー総合工学研究所（IAE）が実施する公募型プロジェクトで、京都大学、（財）電力中央研究所、日本原子力発電（株）と共同で実施している。

①原子炉の概要と特徴

小型一体炉は出力１５万ＫＷｅから３０ＫＷｅの簡素化された原子炉で、コンパクトで高効率化を図るため

・蒸気発生器、制御棒駆動装置を原子炉内に収納する
・加圧器や一次冷却材管を削除する
・２相自然循環方式を採用する
・炉心出口温度を高温化（３４５℃）

また、より一層安全性を向上させるため

・１次冷却材喪失事故（ＬＯＣＡ）、冷却材流量喪失事故、制御棒飛び出し事故など燃料破損要因を排除する
・気発生器による事故時直接除熱を可能とする

②プラント設備の概要と特徴

小型一体炉のプラント設備は以下の特徴を有し、経済性の向上を図っている。
・受動的安全設備の採用で系統構成を簡素化
・ＮＳＳＳ（原子炉の蒸気供給系）の簡素化による小型格納容器
・標準化、モジュール化による短期建設

また、安全性を向上させる観点から
・事故時においても、外部からの人的支援、電源、冷却水を不要とする自立型直接除熱系を採用

次に超臨界圧水冷却炉について説明する

超臨界圧軽水炉は機器の簡素化を図るとともに発電効率をあげて発電原価を低減することをねらった革新的軽水炉である。

（３－２）超臨界圧軽水炉（ＳＣＰＲ）

SCPRは1990年に東京大学から提案され、研究開発が続けられているが、その主要な特徴は従来軽水炉などと比較して、次の 4 点：発電性能向上、システム簡素化、成熟技術利用、柔軟炉心設計であり、結果として経済性大幅改善が見込めることである。

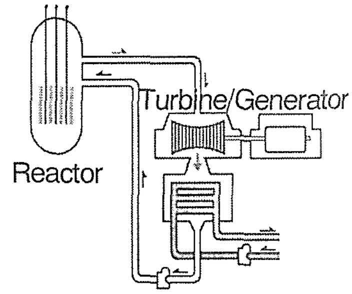


図 1 超臨界圧水冷却炉（SCPR）のプラント構成

発電性能向上、すなわち熱効率の改善は従来軽水炉（熱効率約３５％）と比べて、蒸気タービン入口条件が高温高圧化しているためであり、熱効率は40％を大きく上回り４４％も可能である。システム簡素化は、超臨界圧水のエネルギーあたりの比容積が、軽水炉条件と比べて小さいことと、水と蒸気の区別がないことによりもたらされる。つまり、タービンや熱交換器などの機器の容積が従来軽水炉より小型化し、軽水炉で用いられている再循環系統、気水分離器・蒸気乾燥器、もしくは蒸気発生器

が不要となる（図 1）。付随して、原子炉圧力容器、格納容器、原子炉建屋も小型化する。成熟技術利用は、実績豊富な軽水炉技術のみならず実用化済み火力超臨界圧タービン・ボイラー技術を適用できることを指す。柔軟炉心設計とは、超臨界圧水の高い冷却特性により、炉心の設計自由度が高まり、熱中性子炉としても高速炉としても設計可能であることを指す。

このように魅力ある超臨界圧水冷却炉は国内はもとより、諸外国でも予算化して研究開発が行われている。中でも、我が国では、いわゆる公募型プロジェクトである（財）エネルギー総合工学研究所（IAE）が実施する公募型プロジェクトにおいて、東芝、日立、東大、九大、北大からなるチームでSCPRの技術実用化開発が実施されている。このプロジェクトは、5 年間を予定しているが、その後に、実証 R&D 段階に移行し、10 - 15 年で実証炉建設につなげていくことを考えている。

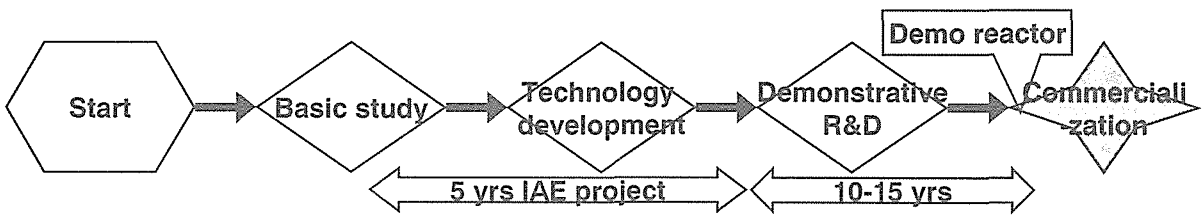


図 2 SCPR 実用化開発

SCPR は我が国から発信され、今や諸外国でも開発が進められている革新炉概念である。その発電性能、簡素なシステム、成熟技術利用、柔軟炉心設計の点から、経済性の大幅改善が見込めるだけでなく、高速炉としての実現性も高い。国内の産官学の連携のみならず、国際協力も視野に入れて早期実用化へ向けての技術開発を進めていきたい。

次にリサイクル型軽水炉である低減速スペクトル炉につき説明する

低減速スペクトル炉は原子力開発の原点であるエネルギーセキュリティの確保と廃棄物量の低減に重点を置いた革新的軽水炉である。

（３－３）低減速軽水炉―ＲＢＷＲ－

原子力発電において、軽水炉が主力である時代が今後も継続すると予測され、

ウランやプルトニウムのより一層の有効利用が望まれている。

RBWR は、現行の軽水炉技術をベースに可能な限り炉心の水割合を小さくして、硬い中性子スペクトルを実現する炉心概念で、軽水炉によりウランからプルトニウムへの転換比の増大を大きくし長期間に渡り安定したエネルギー供給を可能とする。ＲＢＷＲのプラント・システムは基本的にＢＷＲと同一であり原子炉内の炉心部の構造･仕様を独自の設計としている。

ＲＢＷＲは燃料サイクル上の主要な課題である、

・ウラン資源の節約

・Ｐｕ有効利用

・使用済み燃料貯蔵量の低減

・放射性廃棄物の低減

等に応えられることが期待されている。

一般に、高い転換率を達成するには燃料対水の原子数比率を小さくする必要があるが、ＲＢＷＲでは稠密な六角格子を採用すると共に、ＢＷＲの特徴を活用して炉心流量を低減した高ボイド率炉心、フォロアー付き Y 字型制御棒などを採用している。

これにより、冷却材に軽水を用いた炉心で転換比 1.0 を達成する。

燃料集合体は外径 10.1mm、間隔 1.3mm の燃料棒を稠密な六角形に構成している。炉心は、燃料集合体 720 本と燃料集合体の間隙に配置された 223 本の制御棒で構成されている。RBWR は、転換比 1.0 を達成することにより、現行の軽水炉単独では、2080 年までに天然ウラン使用量が 1,500 万トンとなるのに対して、現行の軽水炉と RBWR を併用すると、天然ウラン使用量が 1,500 万トンとなる時期は 2200 年頃となり、以降は天然ウランを必要とせず劣化ウランにより長期間に渡りエネルギーの安定供給が可能となる。

また、ＲＢＷＲでは硬い中性子スペクトルを有するため、マイナーアクチニドの炉内核変換に有利であり、超寿命放射性廃棄物の低減に利用することが可能となる。

これらはすべて国の研究機関や大学、ユーザーである電力と共同で実施されているものである。ここでは革新型軽水炉開発について紹介したが他に高温ガ

ス炉や金属冷却高速炉も選択肢となっていることを付け加えておく。

（4）まとめ

○世界経済の持続的発展にはエネルギーの安定的供給が必要である。

○エネルギーの安定供給と地球環境保護には、原子力エネルギーが現在でも重要な役割を担っており、その重要性は今後ますます増す。

↓

○我々原子力メーカーは今後とも国、研究機関、大学、ユーザーと連携をとりながら、革新型軽水炉の開発を進めるとともに原子力の技術基盤を維持・発展させていく。

↓

○人類の永遠の発展と地球環境保護に貢献するために原子力エネルギーの利用が重要である。

Development of Innovative Light Water Reactors

Yoichi Aeba

Company Advisor, Mitsubishi Heavy Industries, Ltd.

Nuclear generation, a key power source for Japan, now provides one-third of the total national electricity. It was initially introduced to Japan which has few natural energy resources, to provide a more stable energy supply for the future. Now it plays as an important role in the energy "best mix" for Japan. Internationally, increasing demand for electricity is inevitable, and the maximum use of nuclear energy – a product of human discovery and wisdom – is essential in order to sustain the economic growth and preserve the global environment.

(1) The necessity for nuclear power generation

- Japan has few natural energy resources but consumes a large amount of energy.
- Energy demand is sure to increase, especially in the developing countries of Asia.
- The new environmental problem of global warming emerges from the overuse of fossil energy.

↓

We require means to ensure both energy security and global environmental protection.

- Use of fossil fuels, such as coal and petroleum, will be limited when viewed in terms of supply and demand, and environmental protection.
- Wind power generation and solar batteries are not expected to play a major role.

↓

- So nuclear energy is a powerful alternative to fossil energy.

We should tackle the following problem in developing nuclear energy.

- Safety improvement and cost effectiveness of nuclear energy.

  And we also have to provide

- Answers to the question of whether nuclear power can solve environmental problems and achieve energy security.

There has been growing need to achieve economic efficiency whilst maintaining safety in nuclear generation. A government working group is currently studying a variety of innovative reactor designs to meet diversified needs, including high levels of safety and reliability, economic competitiveness to other power sources, energy security, and reduction in the volume of radioactive waste.

Today, I am going to outline the purpose, value, and characteristics of innovative light water reactors being developed by Mitsubishi, Toshiba and Hitachi.

Taking advantage of economies of scale, in order to compete with other power sources, larger plants – higher capacities – have been developed in cooperation with electric power companies. ABWR-II and APWR+ are 1,700-MW-class plants, which reflect improvements on conventional LWR technology.

(2) Large capacity LWR

(2－1) ＡＰＷＲ＋

First, I am going to introduce ＡＰＷＲ＋.

ＡＰＷＲ＋ has been developed, as a key electric power source the late 2010's , based on the APWR technology realized, by Mitsubishi and PWR utilities joint development.

① The purpose of APWR+ development and its value and characteristics

● Economic advantage competing with other power sources

Enlarged capacities ： 1750Mwe

High availability ： more than 95% (24 months cycle operation)

Minimized development use based upon APWR technology

- Safety improvement

  Good use of passive safety systems and equipment and simplification

  Good use of diverse safety equipment

  Good use of seismic isolation system to the reactor building

② Characteristics of APWR+ reactor

- Long size 14ft 17×17 fuel 257assemblies to enlarge capacity.
- Simplified Lower Plenum to reduce the height of the reactor vessel (Same size as 1500Mwe APWR Reactor Vessel)
- Changed location of ICIS from the bottom to the top.
- High performance control rod, condensed B4C+AIC Hybrid Rod, reduces the number of rods to 85%~90%.

② Characteristics of APWR+ Plant

- Passive Safety Systems improves safety and simplifies the system and component.
- SG depressurization system eliminates High Head Injection system.
- Diversified heat removal system for CV integrity and using in vessel retention for CV integrity
- Enhanced seismic reliability by adopting seismic isolation system. This is also effective measures to standardize Plant design.

(2－2) ABWR－Ⅱ

BWR utilities and Hitachi, Toshiba, GE joint development program has been developing the next generation BWR, ABWR－Ⅱ since 1991.

In order to reduce generation cost

- Increased Electric Power, 1700Mwe, by increased core density.
  - Higher availability, 96%, due to 18 months long cycle operation and 20days short periodical inspection.
  - Reduced generation cost due to reduction of fuel cycle cost.(25%reduction of

Generation cost)

- Reduced construction cost to due to reduction of the number of control rods and control rod drive mechanisms. (20% cost reduction)

And in order to have flexibility in fuel cycle strategy, the following measures are considered.

- High burn up Core
- Long operation cycle
- Use of MOX fuel

The characteristics of ABWR-Ⅱ are Large K −Lattice core, Passive RHR system, Large capacity SRV, etc.

A Large K −Lattice core using large fuel assembly increases the flexibility of fuel and moderation design and make core design more flexible.

Utilization of wide cruciform control rod increase shutdown margin due to increase of control rod worth.

ABWR-Ⅱ adopts the passive residual heat removal system to satisfy international standards of safety requirements against severe accidents.

Passive residual heat removal systems are provided to back up the active core cooling system in case of ARCIC and RHR failure. These systems condense nuclear steam at the heat exchanger and return the condensed water to the reactor to remove residual heat.

Passive containment cooling systems condense the steam at the heat exchanger to prevent pressure increase inside containment vessel in case of LOCA or severe accident, and discharge it to suppression pool.

ABWR-Ⅱ enhances the protection system of the containment vessel over-pressurization.

I explained APWR+ and ABWRⅡ, which were two typical large scale PWR and BWR

Realizing the coexistence of cost-saving and high safety by enlarging capacity, using simplified systems and components, and passive safety system components.

(3) Innovative light water reactor

Medium- and small-scale reactors have also been developed. These will enable investments in construction to meet new electricity demands in a more flexible manner. Mitsubishi, Hitachi, Toshiba have been studying various type of innovative reactors to meet the current and future requirements in cooperation with the research institutes, universities sponsored by METI & MEXT.

I will present three types of those small and medium sized reactors here.

These are the innovative light water reactors which satisfy various requirements such as improving safety and improving construction and operating cost and ensuring future energy security, and so on.

	Mitsubishi	Hitachi	Toshiba
Simplified LWR	①IMR	SSBWR	LSBWR
Supercritical LWR		SCPR	②SCPR
Recycle LWR	R－PWR	③R－BWR	RBWR

① IMR is a small capacity reactor which achieves a comparable cost to a large scale reactor by
simplification of the plant system and reduction of the number of components

② SCPR(Super critical power reactor) is a reactor that reduces running cost by improving thermal efficiency and also allows a simplified reactor internal

③ RBWR is a reduced moderation water BWR that uses a tight lattice fuel assembly to maintain energy security and reduce radioactive waste.

(3－1) Integrated Modular Type Reactor (IMR)

IMR is a small, simplified light water reactor, constructed at reduced cost and in a shorter construction period employing simplified systems and equipment, whilst at the same time, enhanced safety.

① The characteristics of IMR　－Reactor－

IMR is a simplified compact reactor that has an output of 150Mwe～300Mwe, and in order to improve thermal efficiency and reduce construction cost

- Install SG and CRDM in reactor vessel
- Without pressurizer, main coolant pipe
- Adopts two phase natural circulation
- Raises core outlet temperature to 345℃

IMR also improves the safety by taking the following measures.

- Excludes the core damage capability for LOCA, loss of flow, rod ejection accident.
- Enables direct heat removal by SG in the accident conditions.

② The characteristics of IMR －Plant－

ＩＭＲ plant has the following characteristics to improve economies and safety.

- Simplified plant system
- Small compact containment vessel due to simplified NSSS without loop.
- Standardization, modularization make construction period shorten
- Standalone residual heat removal system unnecessary for power, cooling water, operational support from outside.
- Standalone residual heat removal system unnecessary for power, cooling water, operational support from outside.

Another is the supercritical-water cooled power reactor. This is also a reactor with reduced costs through simplified equipment, and with improved generation efficiency.

(3－2) **Supercritical-water cooled power reactor** (SCPR)

SCPR was proposed by Tokyo University in 1990 and developed thereafter. It has the following 4 characteristics compared with the conventional LWR.

① Enlarged electrical output by improving the thermal efficiency.

② Simplified Nuclear steam generation system and component

③ Adopts mature technology

④ Core design flexibility

These lead to a remarkable improvement of economics.

The improvement of power generation output, that is, the improvement of thermal efficiency is achieved by raising the temperature and pressure at the inlet of the turbine.

This improves the conventional thermal efficiency from 35% to 40%～44%.

System simplification is achieved by the smaller volume per energy of supercritical water compared with conventional BWR coolant condition and due to no difference between steam and water.

This enables the capacity of the main turbine, heat exchanger, and a component smaller than conventional LWR and eliminates the need of re-circulation system, water separator, dryer and/or

steam generator. (show the Fig1)

In addition, this enables RPV, CV, reactor building.

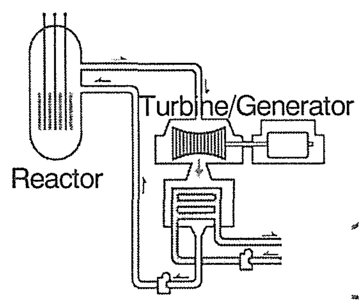


Fig. 1
Supercritical Power Reactor

Mature technology allows the possible use of the considerable success of LWR and supercritical fossil boiler plant.

The flexibility of core design allows the possible design of the fast neutron reactor as well as the thermal reactor due to the heat transfer characteristics of supercritical water.

This SCPR has been developed in another country. In Japan, this development program has been push forward by the joint team, Toshiba, Hitachi, Tokyo University, Kyushu University and Hokkaido University sponsored by IAE.

This development project is 5 year program, which thereafter continues with a 10-15years verification program including a demonstration plant.

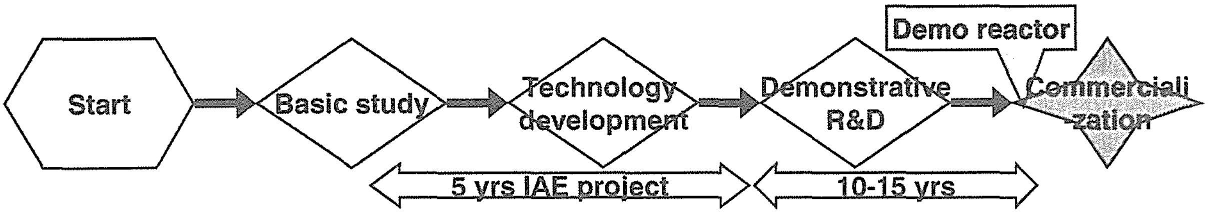


Fig 2 SCPR Development Program

SCPR is an innovative reactor concept. The development program has begun ahead of other countries and now some countries initiating various studies.

SCPR meet the requirement of remarkable advantage of economics and has the potentiality for the fast neutron reactor in view of higher thermal efficiency, simplified system, the use of mature technology, flexible core design.

We would like to promote the SCPR development program in cooperation with other countries as well as domestic organizations concerned.

Third is the reduced-moderation water reactor. This is a light water reactor, highly promising to ensure energy security and reduced waste, which are the original objectives of such development.

(3−3) Resource-Renewable BWR —RBWR−

LWR will play an important role in the future, and more effective use of uranium and plutonium is expected.

RBWR is the reactor based upon conventional LWR technology, which reduces water to fuel ratio and use hard spectrum neutron. That brings breeding ratio of 1.0 by use of LWR and enable to supply the stable energy in the long-term range.

RPWR system architecture is basically same as conventional BWR and has a unique core design and specification.

RBWR is expected to solve the following main issues of the fuel cycle.

- Saving uranium resources
- Effective use of Pu

- Reduction of stock of spent fuel
- Reduction of radioactive waste

Generally, it is necessary to reduce the number density ratio of water to fuel.

RBWR adopts a hexagonal tight lattice and high void fraction which reduce core flow making the most of BWR characteristics and adopts a Y-shape control rod with follower. These lead the breeding ratio of 1.0 to the LWR.

Fuel assembly is composed of a 10.1mm outer diameter fuel rod and a 1.3mm rod gap in the tight hexagonal lattice.

Core is composed of 720 fuel assemblies and 223 control rods arranged among the fuel assemblies.

Conventional LWRs would consume the amount of 1500t of natural uranium by the year 2080. The utilization of conventional LWR and RBWR will allow natural uranium supply to last until 2200. After that, a stable energy supply will be ensured with using depleted uranium without natural uranium for a long time after.

In addition, RPWR is an advantageous reactor for nuclear transformation of minor-actinides in the inside core and for reduction of long-life radioactive waste due to hard neutron spectrum.

(4) Summary

These reactors are being developed jointly with national research institutes, universities, plant makers and utilities.

In addition to these developments in innovative light water reactors that I have introduced, high-temperature gas-cooled reactors and metal-cooled fast reactors are also potential options for the future.

○ Nuclear Energy is indispensable for global and sustainable economic growth

○ Nuclear energy will play an increasingly important role in the stability of future energy supply and for the protection of the global environment.

↓

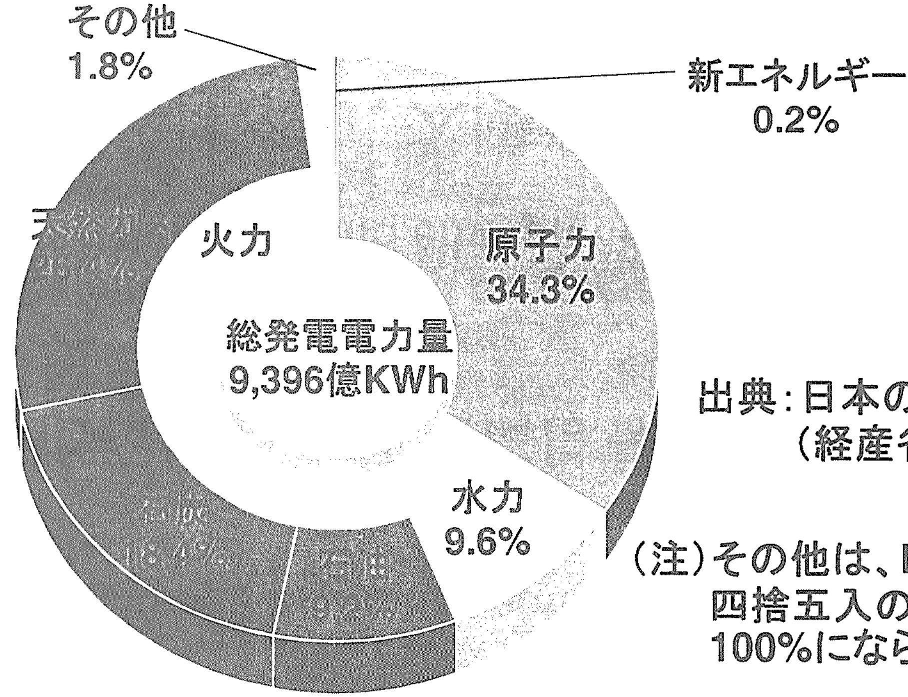
○ We are going to develop and maintain a strong technical base for nuclear energy development in cooperation with government, research institutes, universities and our utility companies.

↓

○In my opinion, nuclear energy will permanently play an important role in improving life for mankind and in issues of environmental protection.

革新型軽水炉の開発

Development of Innovative Light Water Reactors



出典：日本の2000年度実績
（経産省調べ）

（注）その他は、LPG、地熱など。
四捨五入の関係で、合計値は
100%にならない。

三菱重工業株式会社

Company Advisor, Mitsubishi Heavy Industries, Ltd.

饗場　洋一

Yoichi Aeba

原子力発電の必要性
The necessity for nuclear power generation

- 地球環境問題（＝地球温暖化）が浮上
  エネルギーセキュリティと環境問題を同時に解決する必要がある
  The new environmental problem of global warming emerges from the overuse of fossil energy.
  We should have the means to ensure both energy security and global environmental protection.

- 石炭、石油等化石燃料の使用には需給面、環境面から限度がある
  Use of fossil fuels, such as coal and petroleum, will be limited when viewed in terms of supply and demand, and environmental protection.

- 国土の狭い日本では風力、太陽光にも限度がある
  Wind power generation and solar batteries are not expected to play a great role.

↓

- 原子力エネルギーの選択が有望視される
  So nuclear energy is a powerful alternative to fossil energy.

原子力発電の開発課題
The problem of developing nuclear energy.

- 原子力の安全性と経済性
  Safety and cost effectiveness of nuclear energy.

- 地球環境問題の解決と、
  エネルギーセキュリティの確保
  Answers to the question of whether power can solve environmental problems and achieve security.

革新型軽水炉に対する社会のニーズ
The need of society for innovative Light Water Reactors

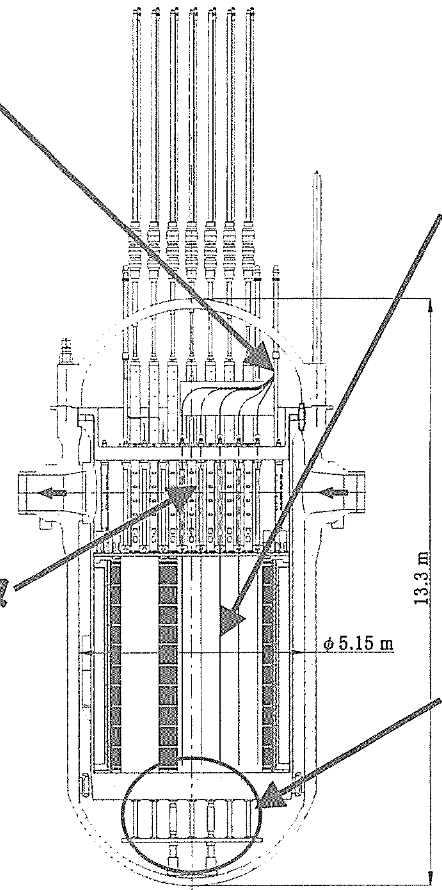
- **高い安全性と信頼性**
  High levels of reliability and safety.
- **他電源に劣らぬ経済性**
  Economically competitive with alternative power sources.
- **将来のエネルギーセキュリティの確保**
  Assuring future energy security.
- **高レベル放射性廃棄物量の低減**
  Reducing the volume of radioactive waste.

APWR+ 原子炉の特徴
Characteristics of APWR+ Reactor

○ 出力：5000MWt（1750MWe）

○ 上部挿入ICIS
Top Inlet ICIS
– RV下部貫通孔なし

○ 長尺14ft. 17×17燃料、257体
Long size 14ft 17×17 fuel assembly
– 長サイクル運転向け低出力密度 16.7 kW/m
Low Core density for long cycle operation



APWR+

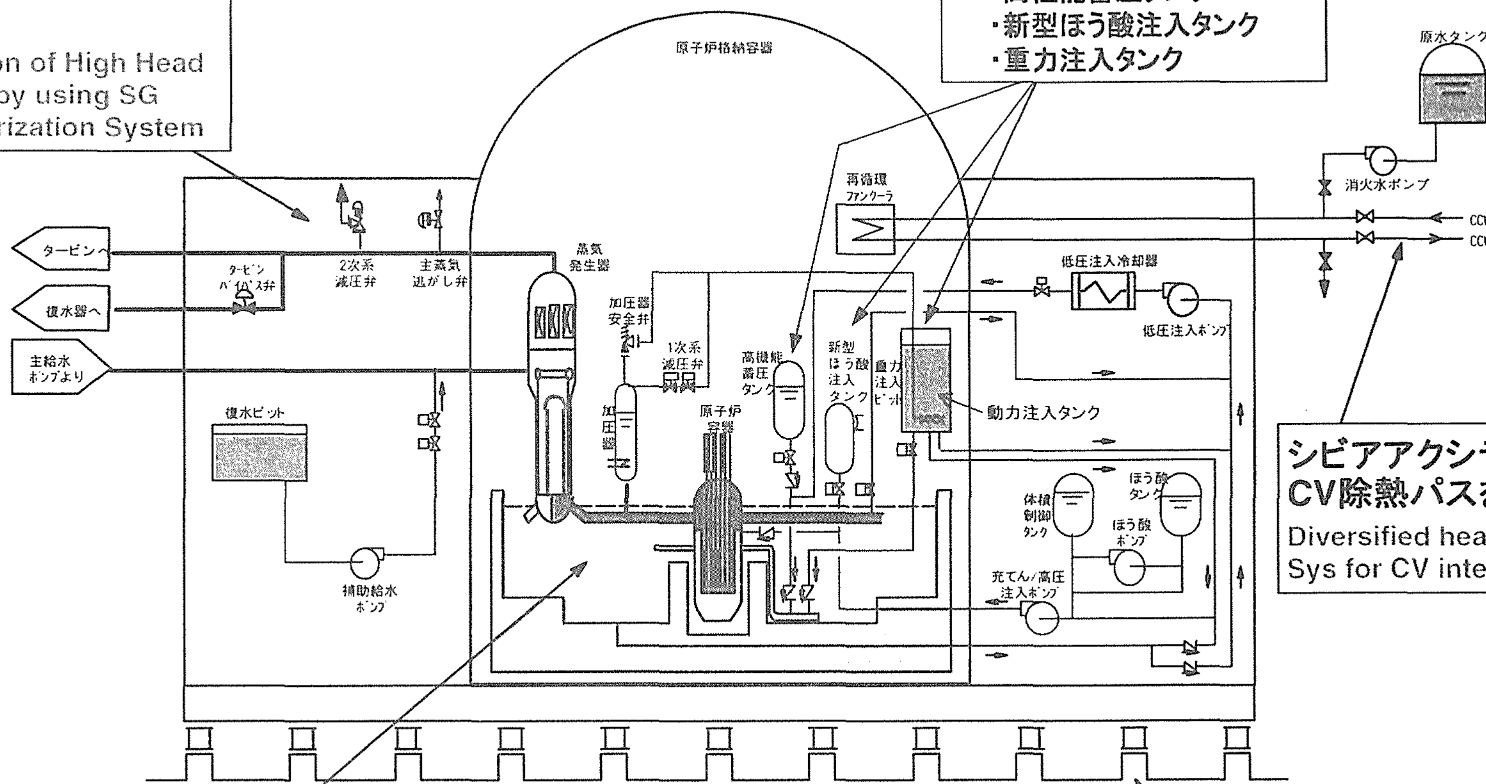
○ 高性能制御棒クラスタ
High performance control Rod
– 濃縮B_4C ＋ AICハイブリット型

○ 簡素な下部炉内構造
Simplified Lower Plenum
– APWRと同等のRVサイズ
Same size as 1500 MWe APWR Reactor Vessel

APWR+ プラントの特徴
Characteristics of APWR+ Plant

SG除熱を活用し、設備簡素化
Elimination of High Head Injection by using SG depressurization System

受動的安全設備の採用
Passive Safety Equipment
- ・高性能蓄圧タンク
- ・新型ほう酸注入タンク
- ・重力注入タンク



シビアアクシデント時CV除熱パスを多様化
Diversified heat removal Sys for CV integrity

事故時RV水没によるCVへの放熱抑制により、CV究極耐力強化
In Vessel Retention for CV integrity

免震設備の採用により耐震信頼性強化
Seismic Reliability by Enhancement seismic isolation system

ABWR改良発展炉（ABWR-Ⅱ）の基本仕様 Basic Specification of ABWR-Ⅱ

簡素化・大容量化による経済性の徹底追求

The Pursuit of Economical Competitiveness by adopting Large Capacity and Simple Components

電気出力：1700MW
Electric Power

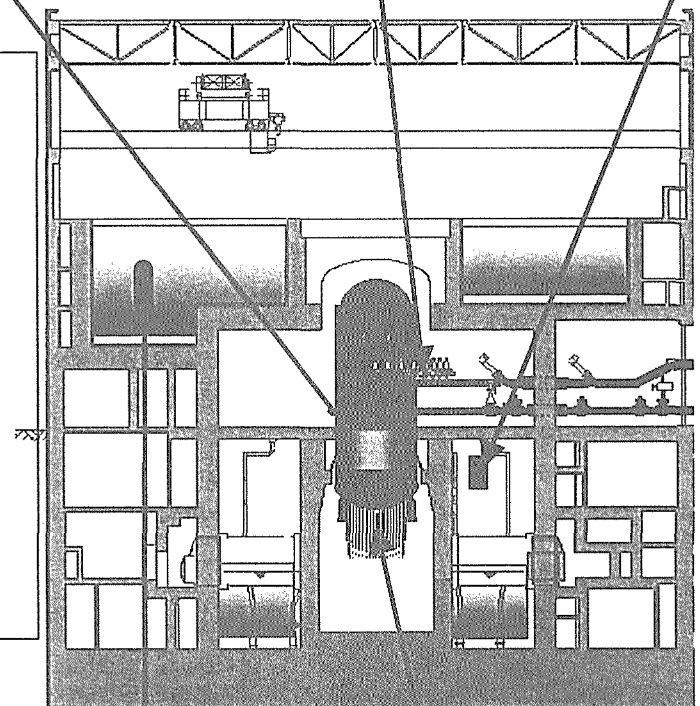
運転期間：18ヶ月
Operation Cycle : 18 months

定検期間：20日
Periodical Inspection : 20 days

建設単価：20%減
Construction Costs : 20% Down

発電単価：25%減
Power Generation Costs : 25% Down

稼働率　：96%以上
Availability Factor : > 96%



大型K格子炉心
Large K-Lattice Core

大容量SRV
Large Capacity SRV

静的水素再結合器
Passive Hydrogen Recombine System

静的崩壊熱除去システム
Passive Residual Heat Removal System

機能別CRD
Functional CRD

新型タービン湿分分離器
Advanced Turbine Moisture Separator

主要性能（Main Features）

・発電コストの低減
Power Generation Costs Reduction

(1)増出力（出力密度増大）
Increase Electric Power(High Power Density)

(2)プラント設備利用率向上
High Availability Factor

(3)燃料サイクル費低減
Fuel Cycle Costs Reduction

(4)制御棒駆動系員数削減
Reduce the Number of CRDs

・燃料サイクルへの柔軟な対応
Flexibility in Fuel Cycle Strategy

(1)高燃焼度化
High Burn up

(2)運転サイクルの長期化
Long Operation Cycle

(3)MOX燃料利用
Use of MOX Fuel

ABWR改良発展炉（ABWR-Ⅱ）の特徴技術例 Technical Features of ABWR-Ⅱ

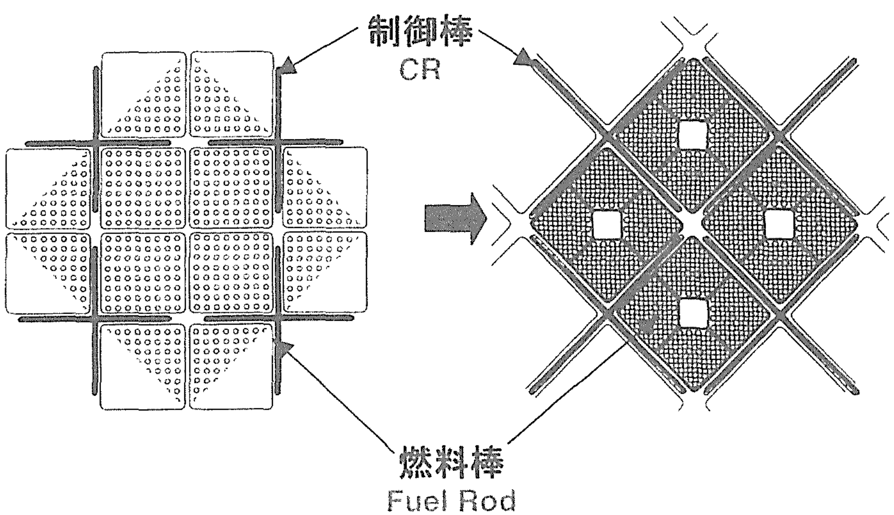
大型K格子炉心
Large K-Lattice Core

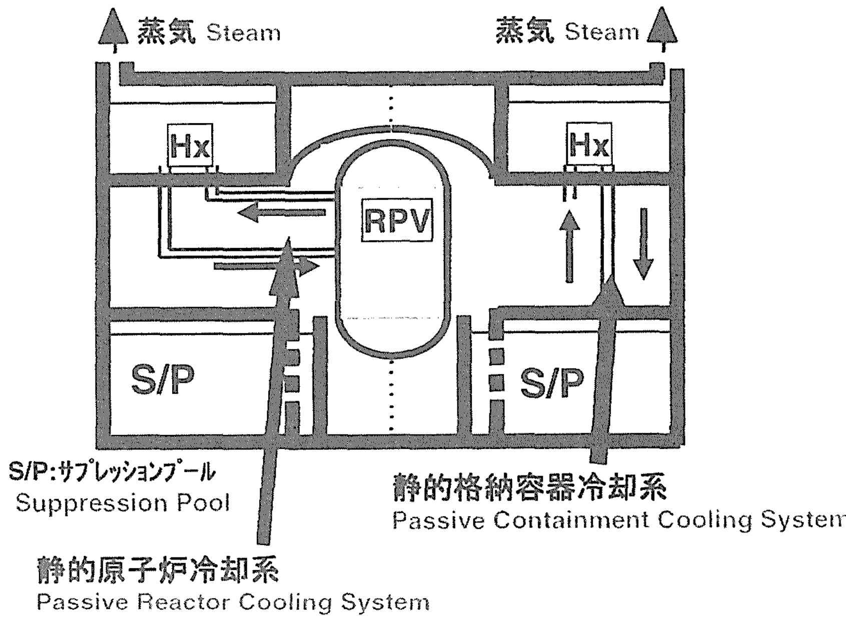
- **大型燃料集合体** Large Fuel Assembly
  - 燃料,減速材の設計自由度増大
    Increase of Design Flexibility for Fuel, Moderator
  - → **炉心設計柔軟性向上** **Increase of Design Flexibility for Core**
- **広翼十字制御棒** Wide Cruciform CR
  - 制御棒価値増大
    Increase of CR Worth
  - → **炉停止余裕向上** **Increase of Shutdown Margin**

静的崩壊熱除去システム
Passive Residual Heat Removal System

- **静的原子炉冷却系** Passive Reactor Cooling System
  - 炉心冷却系のバックアップ
    Backup to the active Core cooling System
- **静的格納容器冷却系** Passive Containment Cooling System
  - 格納容器内圧上昇を抑制
    Remove Decay Heat from PCV

→ **SA時の格納容器過圧防護強化**
Enhance a Protection against PCV Pressurization under SA





開発中の革新型軽水炉
Development of Innovative LWR

	三菱	日立	東芝
小型一体化炉	①IMR	SSBWR	LSBWR
超臨界圧水冷却炉		②SCLWR	
低減速炉	RPWR	③RBWR	

IMR　小型一体炉

SSBWR　小型安全炉

LSBWR　長サイクル小型一体炉

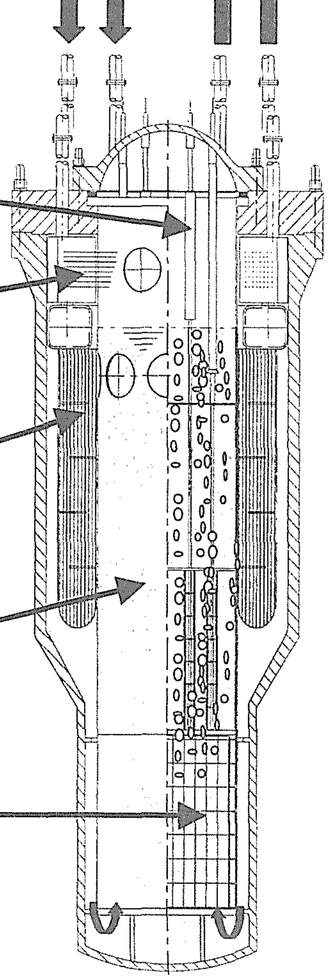
SCLWR　超臨界圧水冷却炉

RPWR　リサイクル型低減速PWR

RBWR　リサイクル型低減速BWR

小型一体炉　原子炉
Integrated Modular Type Reactor

出力：150～300MWe
Electrical output



○ 大型炉に遜色ない高い経済性
Cost Reduction

- 簡素化
  Simplification.
  - 蒸気発生器、制御棒駆動装置内装
    SG, CRDM in Reactor Vessel.
  - 加圧器、1次系配管なし
    Without Pressurizer, Main Coolant Pipe.
- 小型化
  Compact NSSS.
  - 2相自然循環
    Two Phase Natural Circulation
  - 炉心出口高温化(345℃)
    High Core Outlet Temp.

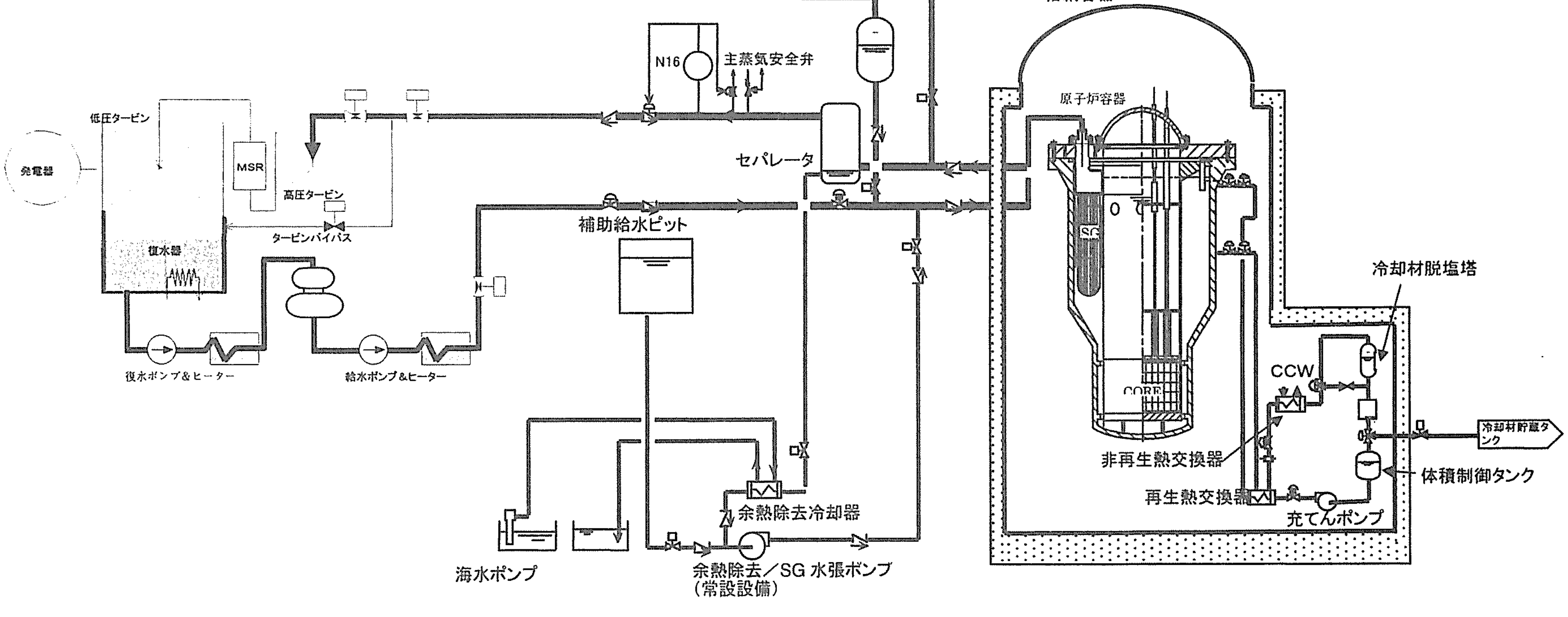
○ 安全性のより一層の向上
Enhanced Safety

- 燃料破損原因排除
  - LOCA、LOF、Ejtなし
    Excluding capability for LOCA, Loss of Flow, Rod Ejection
- パッシブ化
  Passive Safety
  - SGによる事故時直接除熱
    Residual Heat Removal by SG in accident condition

小型一体炉　プラント設備
Integrated Modular Type Reactor Plant

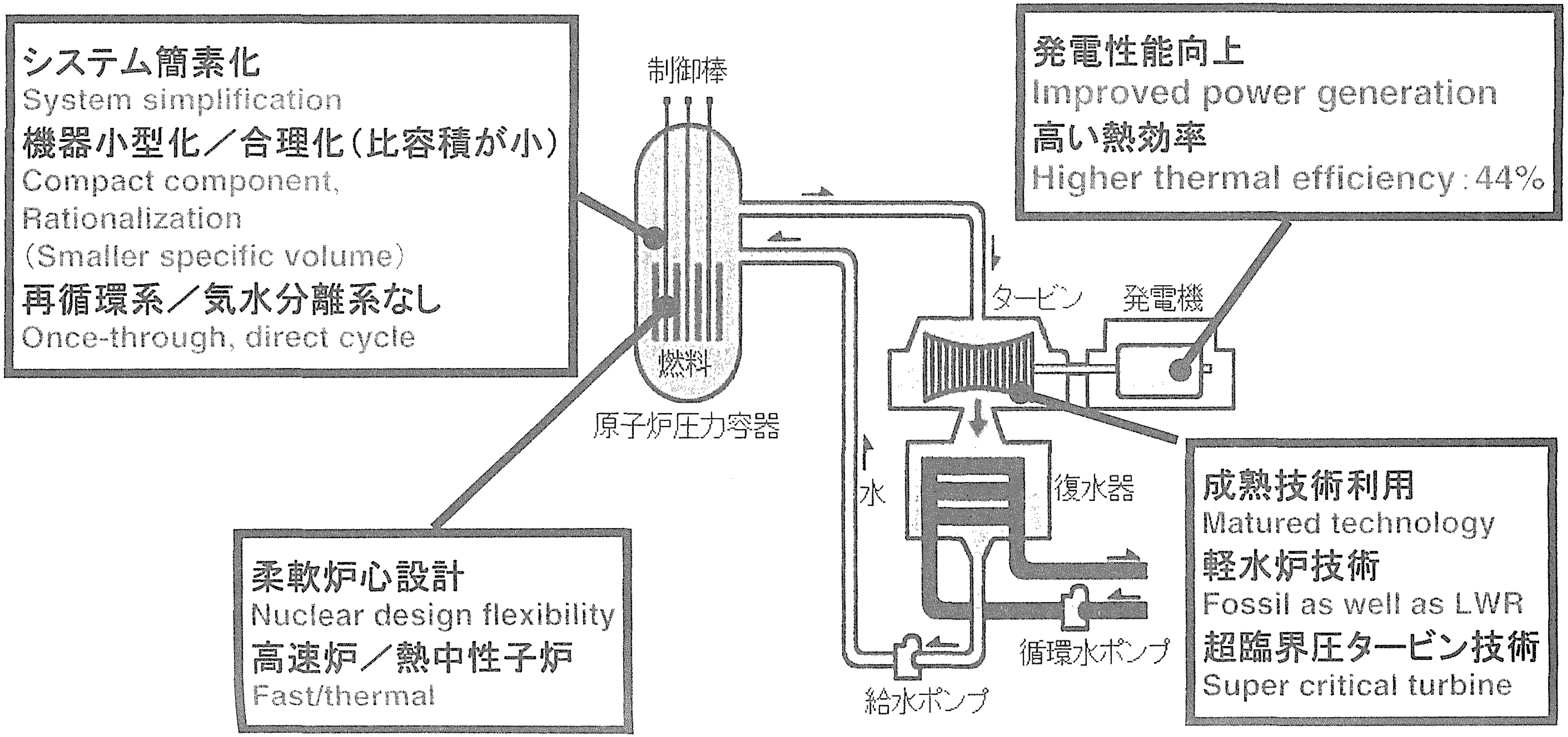
- 経済性
  Cost Reduction
  - 簡素な系統構成
    Simplified System
  - 小型格納容器
    Compact Containment Vessel
  - 標準化、モジュール化短期建設
    Standardization, Modularization
    → Shorten Construction Period.

- 安全性
  Safety Improvement
  - 自立型直接除熱系
    Standalone Residual Heat Removal Sys
  - 外部からの人的支援・電源・水不要
    Unnecessary for Power, Water,
    operational Support from outside.



超臨界圧水冷却炉(SCPR)
Supercritical-water Cooled Power Reactor

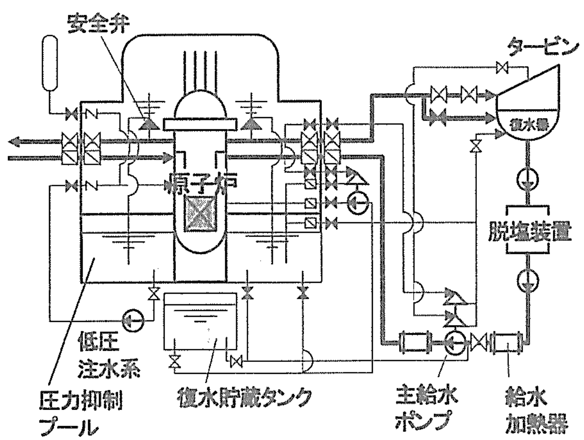
- 目的／Objectives
  - 超臨界圧水技術による軽水炉の経済性向上
  - To improve LWR economy through supercritical-water technology



超臨界圧水冷却炉(SCPR)の開発
Development of Supercritical water Cooled Power Reactor

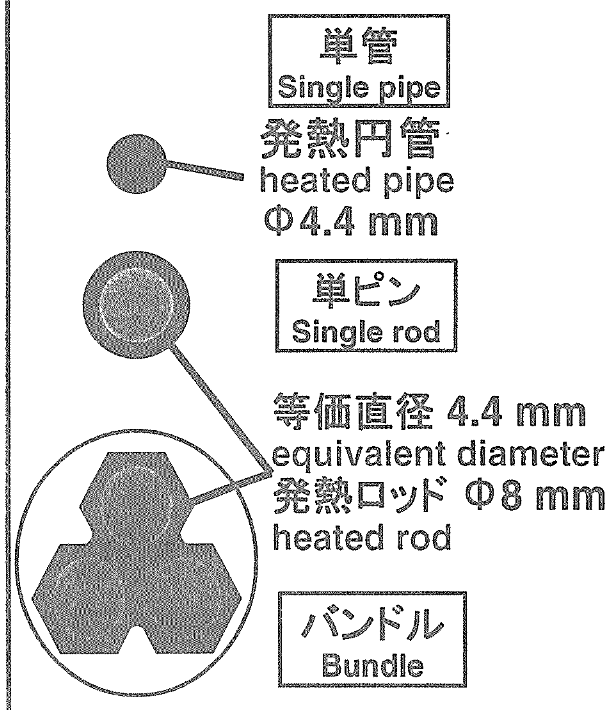
プラント概念設計
Plant conceptual design

- 核熱設計
  Core/fuel design
- 高温構造開発
  High temperature structural design
- タービン系,安全系,建屋設計
  BOP,safety and building design



伝熱流動試験
Thermohydraulics

- 定常・過渡時の伝熱特性把握
  Heat transfer characteristics of steady state and transient conditions



材料・水化学
material and water chemistry

- 既存材料適用性評価
  Evaluation of commercial materials
  - 腐食(SCC)特性
    SCC characteristics
  - 照射(模擬)特性
    Irradiation characteristics
  - 高温強度特性
    High temperature strength characteristics

⇩

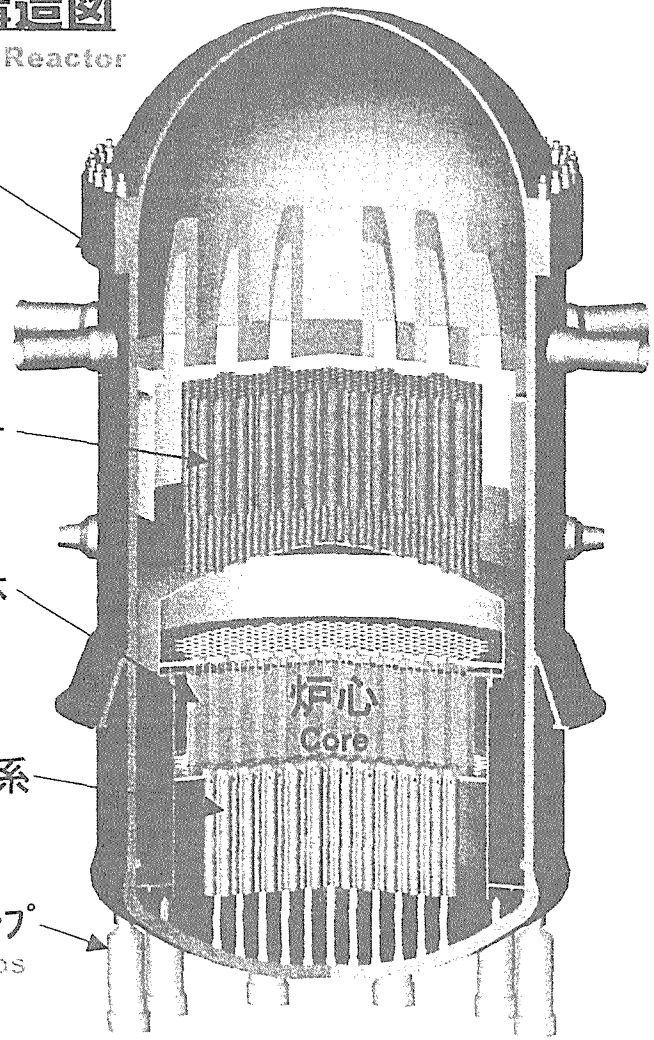
- 有望材の特性改善
  Improvement of promising materials

⇩

- SCPR炉心用材料の最適化
  Optimization of materials for SCPR core

日立低減速炉(RBWR)の基本仕様
Basic Specification of RBWR

原子炉構造図
Structure of Reactor



RBWR : Resource-Renewable BWR

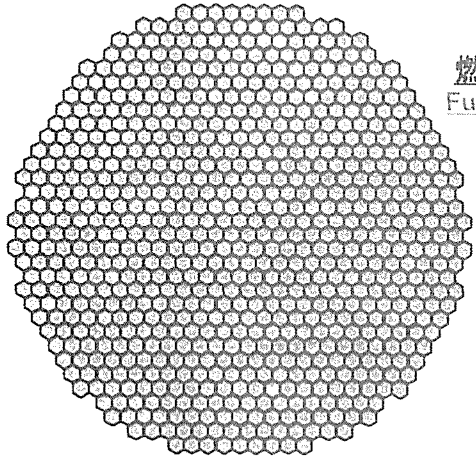
項目 Item	単位 Unit	RBWR
電気出力 Electric Power	MWe	1356
原子炉圧力 Reactor Pressure	MPa	7.2
炉心外接半径 Core Outer Radius	m	2.88
燃料集合体数 Number of Fuel Bundles	-	720
平均燃焼度 Average Fuel Exposure	GWd/t	50
有効炉心長 Core Active Height	m	1.15
炉心流量 Core Coolant Flow	10^4 t/h	3.2
炉心出口クォリティ Core Exit Quality	%	28
炉心平均ボイド率 Average Void Fraction	%	59
炉心圧力損失 Core Pressure Drop	MPa	0.16
増殖比 Breeding Ratio	-	1.01

日立低減速炉（RBWR）の特長
Characteristics of RBWR

BWRの特長を活用して高転換率達成：
High Breeding Ratio utilizing BWR's Characteristics:

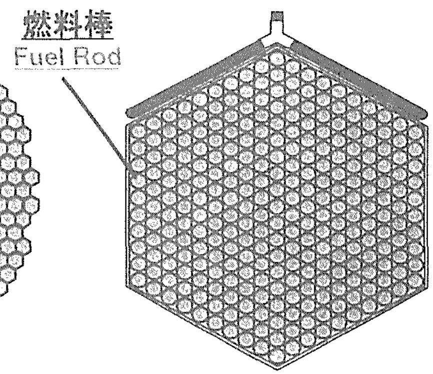
水対燃料比の低減
Reduction of Water to Fuel Ratio

- 稠密六角格子
  Hexagonal Tight Lattice
- 高ボイド率（低炉心流量）
  High Void Fraction(Low Core Flow)
- フォロアー付き制御棒
  Control Rod with Follower



燃料集合体　720本
Fuel Bundles
制御棒　223本
Control Rods

炉　心
Core

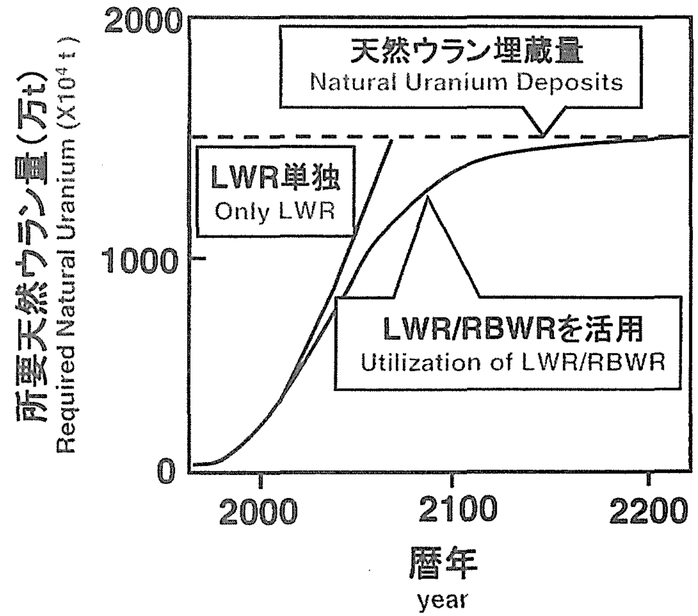


外径　10.1mm
Outer Diameter
間隙　1.3mm
Rod Gap

燃料集合体
Fuel Bundle

- エネルギー長期安定供給
  Sustainable Long Term Energy Supply
- 長寿命放射性廃棄物の有効利用
  Effective Utilization of Long-lived Radioactive Waste

軽水により転換比1.0を達成
Breeding Ratio of 1.0 by use of Light Water



まとめ
Summary

- 世界経済の持続的発展にはエネルギーの安定的供給が必要
  Nuclear energy is indispensable for global and sustainable economic growth.

- エネルギーの安定供給と地球環境保護には
  原子力エネルギーの役割が今後ますます重要
  Nuclear energy will play an increasingly important role for the stability of future energy supply and environmental protection.

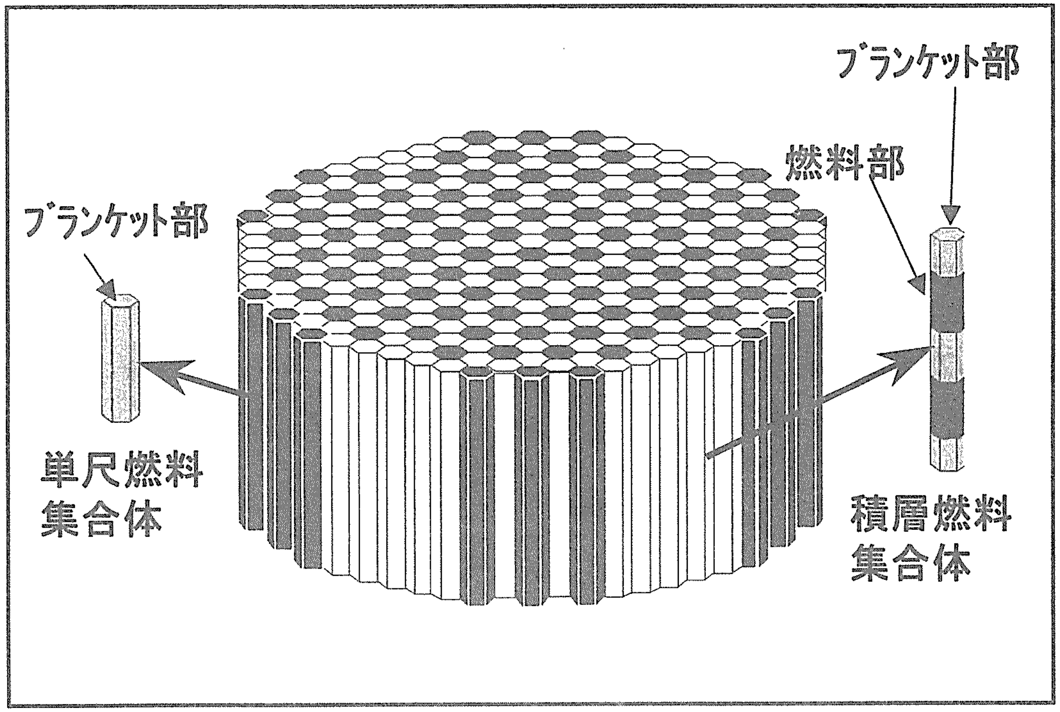
- 国、研究機関、大学、ユーザーとの連携により
  原子力開発技術基盤を維持・発展
  We are going to develop and maintain a strong technical base for Nuclear Energy Development in cooperation with government, research institutes, universities and out utility companies.

人類の永遠の発展と地球環境保護に貢献するために
原子力エネルギーの利用が重要

In my opinion, Nuclear Energy will permanently play an important role in improving life for mankind and in the matter of environmental protection.

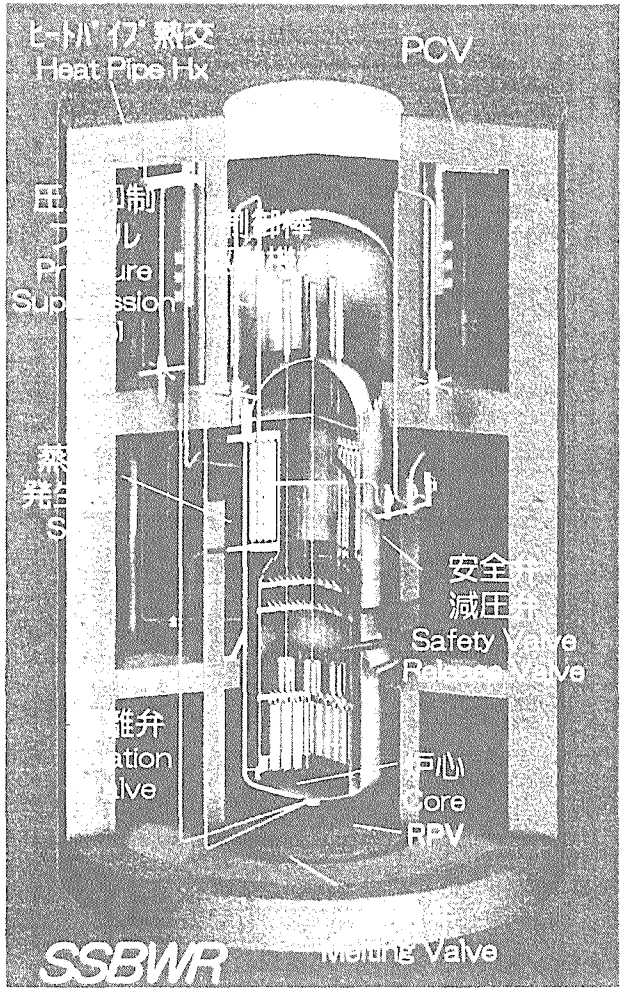
炉概念：リサイクル型PWR (RPWR)

- PWR炉心を稠密格子MOX炉心に置き換え、重水冷却材の採用によりFBR並みの転換比を実現
- FBRの導入が遅れた場合、PWR技術に立脚した環境負荷低減型の炉の導入が可能



項　目	単位	RPWR
電気出力	MWe	1200
原子炉圧力	MPa	15.5
炉心外接円半径	m	2.45
燃料集合体数（シード/ブランケット）	体	210／103
平均燃焼度（シード＋内部ブランケット）	GWd/t	40
有効炉心長（ブランケット含む）	m	
シード燃料集合体		2.5
ブランケット燃料集合体		1.1～1.2
炉心流量	10^4 t/h	8.04
炉心圧力損失	MPa	0.27
転換比（核分裂性Pu残存比）		
軽水炉取出Pu燃料		1.07
自己リサイクルPu燃料		1.11

革新的小型安全炉—SSBWR— Innovative Safe & Simplified BWR



SSBWR : Safe & Simplified BWR

■ 安全性 Safety

・事故時の公衆退避不要を目指した受動安全系
Passive Safety System for Removal of Public Evacuation in case of Accident

・ボイド係数～ゼロの安定炉心
Enhanced Stability by zero Void Reactivity

・大口径配管を排除し大LOCAなし
Confined Primary Loop without Large LOCA

■ 核不拡散性 Non-Proliferation of Nuclear Materials

・運転サイクル20年,炉容器一体交換の高い核不拡散性
Combined Replacement of Core & RPV by 20 years Operating Cycle

■ 多目的熱利用 Multi-Purpose Thermal Utilization

・コンパクトな間接サイクルシステム
Compact Indirect Cycle

■ 経済性 Cost Reduction

・動的機器削減,簡素化BOP系,超短期工法等の優れた経済性
Reduction of Active Components, Simplification of BOP, Sort Construction Period

（株）東芝

超長期運転・簡素化

小型化によるスケールデメリットを克服して安心感が得られるプラントとし、超長期運転サイクル、簡素化システム、静的安全系を備える超長期運転・簡素化小型 BWR（LSBWR: Long Operating Cycle Simplified BWR）を開発している。LSBWR の特徴を図1に示す。

原子力プラントの経済性は、スケール効果により小型炉の方が厳しくなる。これを克服するため、小型炉ゆえの量産効果と以下の革新技術を採用する。

(1) 技術上の革新技術　4～15 年以上の超長期運転炉心を開発し、稼働率向上・運転保守の軽減、使用済み燃料の発生量を低減する。

(2) 設計上の革新技術　大幅簡素化設計として、原子炉建屋・タービン建屋一体化、燃料プール等の削除（8年以上の長期運転の場合のオプション）、静的安全系（静的格納容器冷却系、重力落下式注水系、静的水素処理）を採用する。

(3) 製造上の革新技術　全免震方式の船殻構造建屋・PCVとし、モジュール構成化と工場一貫生産方式による工程短縮、経済性向上を目指す。

安全で安心できるプラントとしては、ノーベントを目指し、静的安全系（静的格納容器冷却系、重力落下式注水系、静的水素処理）の採用による信頼性の向上を図る。SA対応としては、内蔵上部挿入 CRD の採用により、原子炉圧力容器下部を外部から冷却して IVR (In Vessel Retention)を達成する。尚、LSBWR では、自然循環、内蔵上部挿入 CRD 等により保有水量が増加し、冷却材喪失事故確率が大幅に低減している。

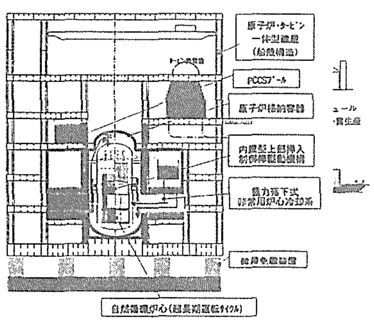


図1　超長期運転・簡素化 BWR　長期運転サイクル、システム簡素化、工場一貫生産等によりスケールデメリットを克服する。
The characteristics of Long Operationg Cycle Simplified BWR

（株）東芝

革新的リサイクルシステム BARS

低減速スペクトルBWRのひとつに革新的リサイクルシステム(BARS;BWR with Advanced Recycle System)がある[1]。革新的リサイクルシステムは図1に示すように、低減速スペクトルBWRに簡素で低コストなプルトニウム(Pu)リサイクル方式である乾式再処理、振動充填燃料の技術を組み合わせてBWRによりPuをマルチリサイクルするものである。低減速スペクトルBWRではマイナーアクチナイド(MA)などが混入してもリサイクルされるPu組成への影響が小さいためMAが混入する乾式再処理と組み合わせが可能である。また乾式再処理によるPuは振動充填燃料で高い充填密度を得やすい粒径分布を持つ特長がある。さらに低減速スペクトルBWRは既存のBWRの炉心部を大きな改造なしに低減速型の炉心に置換して利用できる利点も有る。

図2は大型2倍バンドル型の稠密格子燃料集合体を配置した炉心の例を示しており、制御棒の間隔は既存のBWRと同じである。低減速スペクトルBWRでは一般にボイド係数を負に維持することが炉心設計上の重要な課題となるため短尺炉心などの設計上の工夫が必要となるが、BARSでは図3に示すストリーミングチャンネルを一部の集合体に適用して中性子の漏洩を調整して負を維持する設計を採用している。

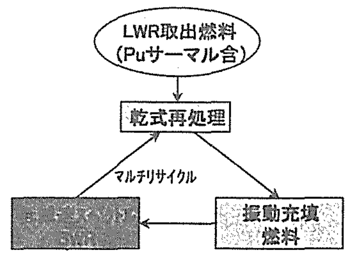


図 1 革新的リサイクルシステム
(BARS)

参考文献：

(1) HIRAIWA, K., et.al. "BARS: BWR WITH ADVANCED RECYCLE SYSTEM", Proc. of the Workshop on Advanced Water Reactors with Innovative Fuels ARWIF-2001, Chester, Oct. ,2000.

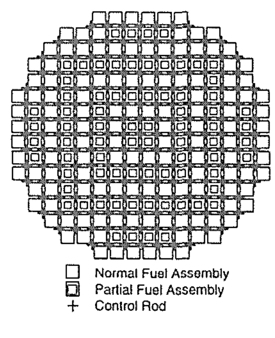


図 2 BARS 炉心配置

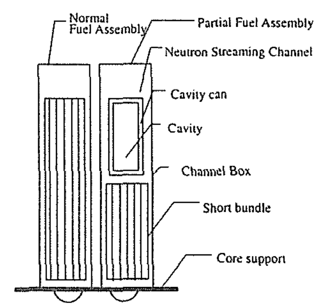


図 3　ストリーミングチャンネル

INTERNATIONAL PROJECT ON INNOVATIVE NUCLEAR REACTORS AND FUEL CYCLES (INPRO)

Poong Eil Juhn
Director
Division of Nuclear Power
International Atomic Energy Agency

SUMMARY

This paper presents the background, objective and status of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) of the International Atomic Energy Agency (IAEA, the Agency). The General Conference of the Agency adopted resolution [GC(44)/RES/21] in September 2000, which has invited "all interested Member States to combine their efforts under the aegis of the Agency in considering the issues of the nuclear fuel cycle, in particular by examining innovative and proliferation-resistant nuclear technology" and has also invited Member States to consider to contribute to a task force on innovative nuclear reactors and fuel cycle [C(44)/RES/22]. In response to this invitation, the IAEA has formulated the INPRO project. The Terms of Reference for INPRO were adopted at the Preparatory Meeting in November 2000, in which more than 40 senior officials from 25 Member States and 4 international organizations were represented. The INPRO Steering Committee, which is the decision and review body on the INPRO project, officially approved the INPRO project at its 1st meeting in May 2001. The General Conference of the Agency in September 2001 adopted another resolution for the Agency to do a role for development of innovative nuclear technology [GC(45)/RES/12, Tab F], which has recognized the unique role that the Agency can play in international collaboration in the nuclear field.

Additional endorsement to support INPRO was made in a UN General Assembly

resolution in December 2001 [UN GA 2001, A/RES/56/94], that again recommended the Agency to do "the unique role that the Agency can play in developing user requirements and in addressing safeguards, safety and environmental questions for innovative reactors and their fuel cycles" and that stressed "the need for international collaboration in the development of innovative nuclear technology".

As of April, 13 Member States and the European Commission have become members of INPRO. In total, 16 cost-free experts being nominated by these Member States and the European Commission are working for INPRO project in the IAEA. Two INPRO Steering Committee meetings were held in 2001 (May and December) and another two meeting are schduled in 2002 to review the progress of INPRO.

The objective of INPRO, which composes of two phases, is to support safe, economic and proliferation resistant use of nuclear technology, in a sustainable manner, to meet the global energy needs in the next 50 years and beyond. The current 1st phase of INPRO is focussing selection of criteria and development of methodologies and guidelines for the comparison of different concepts and approaches, taking into account the compilation and review of such concepts and approaches, and determination of user requirements in the areas of resources,demand and economics; safety; spent fuel and waste; non-proliferation; and environment. Upon completion of the 1st phase of INPRO by the end of 2002, the result will be reported to and discussed at the Agency's "International Conference on Innovative Technologies for Nuclear Reactors and Fuel Cycles" to be organized in 2003. Thereafter, the 2nd phase of INPRO may be initiated to examine the feasibility of commencing an international project on innovative technology development.

1. Introduction

In the next 50 years, the world global energy demands will rise two times while the global electricity demands will be tripled. Currently nuclear power supplies about 16 percent of the world electricity demands.

The long-term outlook for nuclear energy should be considered in the broader perspective of future energy needs and environmental impacts. In order for nuclear energy to play a meaningful role in the global energy supply in the foreseeable future, innovative approaches will be required to address concerns about economic competitiveness, safety, waste and potential proliferation risks.

At the national level, work on evolutionary and innovative approaches to nuclear reactor design and fuel cycle concepts is proceeding in several IAEA Member States. At the international level, IEA, OECD/NEA and the IAEA are co-operating to review ongoing R&D efforts on innovative reactor designs and to identify options for collaboration. The US Department of Energy is promoting the Generation IV International Forum (GIF) initiative, in which both the IAEA and OECD/NEA are participating as observers. The President of the Russian Federation, at the Millennium Summit in 2000, called upon IAEA Member States to join their efforts in creating an innovative nuclear power technology to further reduce nuclear proliferation risks and resolve the problem of radioactive waste.

The General Conference of the IAEA adopted resolution in September 2000, which has invited "all interested Member States to combine their efforts under the aegis of the Agency in considering the issues of the nuclear fuel cycle, in particular by examining innovative and proliferation-resistant nuclear technology" [GC(44)/RES/21] and invited Member States to consider to contribute to a task force on innovative nuclear reactors and fuel cycles [GC(44)/RES/22]. In response to this invitation, the IAEA initiated the "International Project on Innovative Nuclear Reactors and Fuel Cycles", INPRO.

At a meeting of senior officials from 25 Member States and 4 international organizations in November 2000, the objectives and conditions of this project were discussed and the Terms of Reference for INPRO were adopted.

Additional endorsement to support INPRO was made in a UN General Assembly resolution in December 2001 [UN GA 2001, A/RES/56/94], that again recommended the Agency to do "the unique role that the Agency can play in developing user requirements and in addressing safeguards, safety and environmental questions for innovative reactors and their fuel cycles" and that stressed "the need for international collaboration in the development of innovative nuclear technology".

2. Objectives of INPRO

The objectives of INPRO, as defined in the Terms of Reference, are to:

- Help to ensure that nuclear energy is available to contribute in fulfilling, in a sustainable manner, energy needs in the 21st century. Energy scenarios for the period envisaged will be determined by an expected transformation of the energy sector in the light of limited fossil fuel supplies and potential climate change; new applications such as hydrogen as an energy carrier and seawater desalination for the production of potable water will have to be considered.

- Bring together all interested Member States, both technology holders and technology users, to consider jointly the international and national actions required to achieve desired innovations in nuclear reactors and fuel cycles that use sound and economically competitive technology, and are based – to the extent possible – on systems with inherent safety features and minimize the risk of proliferation and the impact on the environment. The unique mandate of the IAEA in the area of safeguards helps to ensure that the issue of non-proliferation will be considered at every stage of INPRO.
- To create a process that involves all relevant stakeholders that will have an impact on, draw from, and complement both the activities of existing institutions and ongoing initiatives at national and international levels.

3. Organizational Structure

According to the Terms of Reference of INPRO the framework for implementation of the

INPRO project consists of the Steering Committee (SC) and an International Co-ordinating Group (ICG).

The SC is composed of INPRO members, who are senior officials from Member States that participate through provision of extra-budgetary resources (fund or cost free experts) and observers, who are representatives from interested Member States and international organizations, to participate only in SC meetings. IAEA project management is also represented. The SC meets as appropriate to provide overall guidance, advise on planning and methods of work and review the results achieved. Two SC meetings were held in 2001 (May and December) and the next one is scheduled on 29-31 May 2002.

An ICG is comprised with cost free experts from participating Member States. The function of an ICG is to co-ordinate and implement the INPRO project on the basis of experts' work in Member States;

Technical consultant meetings, in which experts from non-member INPRO countries are often invited, are convened as appropriate to consider specific subjects and tasks.

The IAEA provides with project management, administrative and technical support.

4. INPRO membership

As of April 2002, the European Commission and the following 13 countries have become members of INPRO: Argentina, Brazil, Canada, China, Germany, India, Republic of Korea, Russian Federation, Spain, Switzerland, The Netherlands and Turkey. In total, 16 cost-free experts being nominated by their respective governments and the European Commission are working for INPRO project at the IAEA. These experts have broad expertise in the areas of nuclear energy and fuel cycle technology, nuclear safety, economics and nuclear non-proliferation, and form the ICG. Together with the IAEA Secretariat, the ICG has the principal operational responsibility for the implementation of INPRO.

INPRO is implemented using mostly extra-budgetary resources offered by interested Member States.

5. INPRO Phases

According to the Terms of Reference of INPRO, INPRO has timewise two phases (Phase I and Phase II).

Phase I of INPRO was initiated in May 2001. During Phase I, work is subdivided in two sub phases:

Phase IA (in progress): Selection of criteria and development of methodologies and guidelines for the comparison of different concepts and approaches, taking into account the compilation and review of such concepts and approaches, and determination of user requirements.

Phase IB (to be started after Phase IA is completed): Examination of innovative nuclear energy technologies made available by Member States against criteria and requirements. This examination will be co-ordinated by the Agency and performed with participation of Member States based on the user requirements and methodologies established in Phase IA.

For the first phase (Phase I), the following task groups were established:

Resources, Demand and User requirements for Economics;

User requirements for the Environment, Fuel cycle and Waste;

User requirements for Safety;

User requirements for Non-proliferation;

User requirements for crosscutting issues and
Criteria and Methodology.

Upon successful completion of Phase I, the result will be informed to the IAEA sponsored International Conference on Innovative Nuclear Technologies to be held in 2003. The preparatory meeting for this International Conference on Innovative Nuclear Technologies is scheduled on 27-28 May 2002. Taking into account advice from the SC, and with the approval of participating Member States, Phase II of INPRO may be initiated, which will direct to:

- Examining in the context of available technologies the feasibility of commencing an international project;

- Identifying technologies, which might be appropriate for implementation by Member States in such an international project.

6. Co-ordination with other Initiatives

INPRO seeks to interact with other national and international stakeholder and initiatives to ensure effective co-ordination and co-operation in a complementary manner, e.g. with the Generation IV International Forum (GIF). The result of the Three-Agency Study named "Innovative Nuclear Reactor developments – Opportunities for International Co-operation", which has been jointly conducted by IEA, OECD/NEA and IAEA has been agreed to be provided to INPRO as the joint input by all three participating Agencies. In GIF, the IAEA is represented, as an observer, at the Policy and Experts Group, and IAEA experts participate in the technical meetings of GIF.

7. Conclusions

Following an invitation expressed in two resolutions by the IAEA General Conference in 2000, INPRO was officially launched in May 2001.

At the General Conference in 2001, first progress was reported, and the General Conference adopted a resolution on "Agency Activities in the Development of Innovative Nuclear Technology", giving INPRO a broad basis of support. Additional endorsement came in a UN General Assembly resolution in December 2001.

In it's current Phase IA, INPRO is focussing on the demand side for nuclear energy in the 2050 timeframe. To that end, INPRO is developing user requirements in various subject areas, such as economics, environment, safety and non-proliferation.

INPRO is open to all interested IAEA Member States and international organizations; as of April 2002, the European Commission and 13 IAEA Member States have become a member of INPRO.

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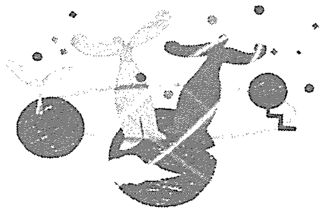
(社)日本原子力産業会議　年次大会

高速増殖炉サイクルシステム実用化戦略調査研究からの展望



平成14年4月24日

核燃料サイクル開発機構

相澤　清人

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21世紀の社会的要請

消費から調和型利用への転換

環境保全

資源高効率利用

再生可能エネルギーへの転換

- 地球環境保全(廃棄物の低減、CO_2削減など)
- エネルギー供給の長期持続
- (発展途上国での)大幅なエネルギー需要の伸び
- 不確実性と変化への柔軟な対応

高水準の安全性

エネルギー多様化

市場競争力

環境破壊、資源枯渇、リスク増加をともなわず、安心感をもって長期に亘りエネルギー供給可能なシステム

・省資源・環境調和を効率的に実現する革新技術
・市場導入を刺激する革新技術

1

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21世紀の原子力サイクルに求められる要件と技術

要件	必要な技術
●環境保全 ・廃棄物の発生量の低減 ・廃棄物の毒性低減	・FPの回収・分離・減容・変換 ・再処理量の低減（高燃焼度、高出力密度、高熱効率） ・ MAの分離・回収・燃焼
●資源高効率利用	・TRUの高回収 ・高燃焼度・高熱効率
● 再生可能エネルギー	・ニーズに応じた柔軟な増殖性の確保
● 高水準の安全性	・受動的安全特性の活用
● エネルギーの多様化	・多目的利用（水素製造・熱利用・分散電源・淡水化等）
● 市場競争力 ・経済性の向上 ・核拡散抵抗性の向上	・システムとしての合理化・簡素化・高性能化 ・低除染燃料サイクル・高燃焼度・高熱効率 ・Puを単独で扱わない ・核不拡散制度との適合性（核物質管理が容易） ・需給量に応じたPu利用（Pu蓄積量の最小化）

2

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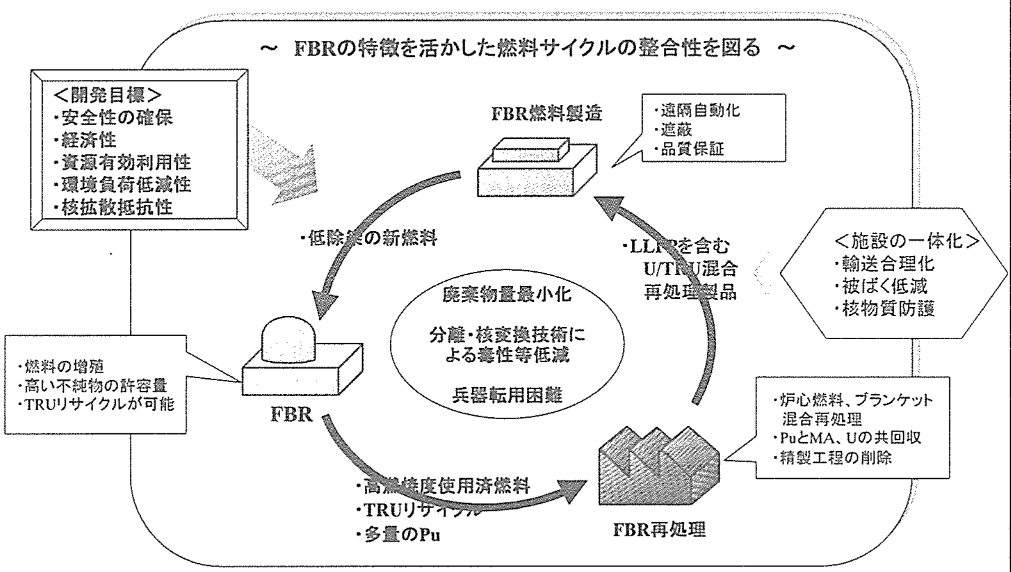
FBRサイクルの基本的な考え方



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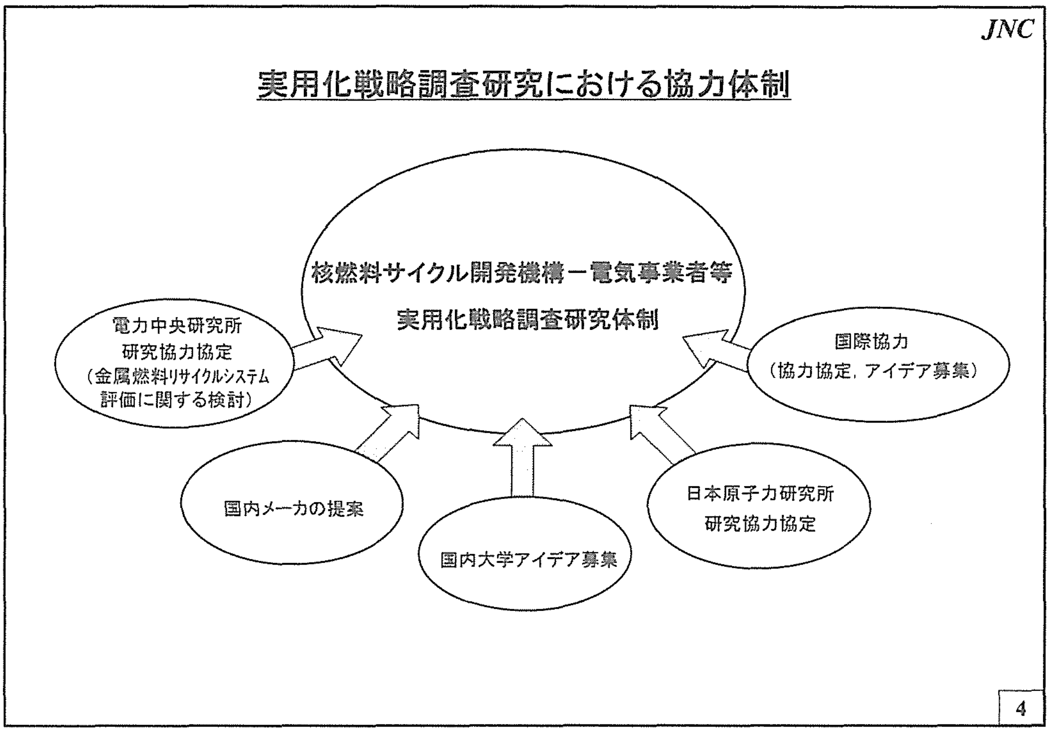
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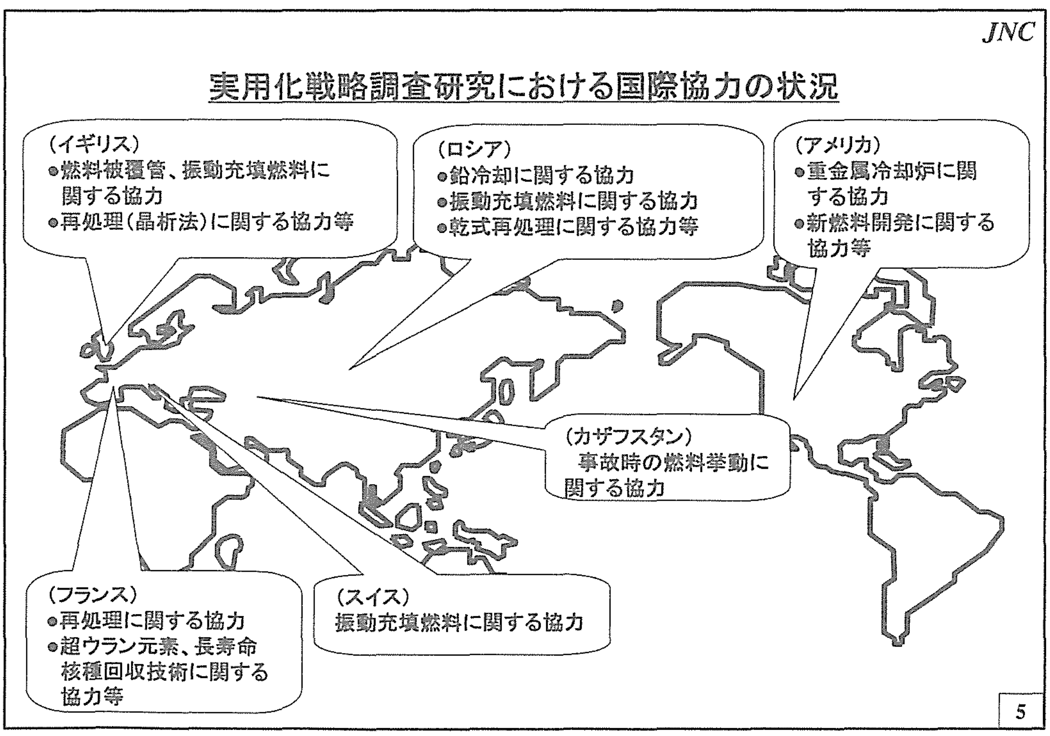
実用化戦略調査研究における協力体制
核燃料サイクル開発機構－電気事業者等
実用化戦略調査研究体制
電力中央研究所
研究協力協定
（金属燃料リサイクルシステム
評価に関する検討）
国際協力
（協力協定，アイデア募集）
国内メーカの提案
国内大学アイデア募集
日本原子力研究所
研究協力協定
4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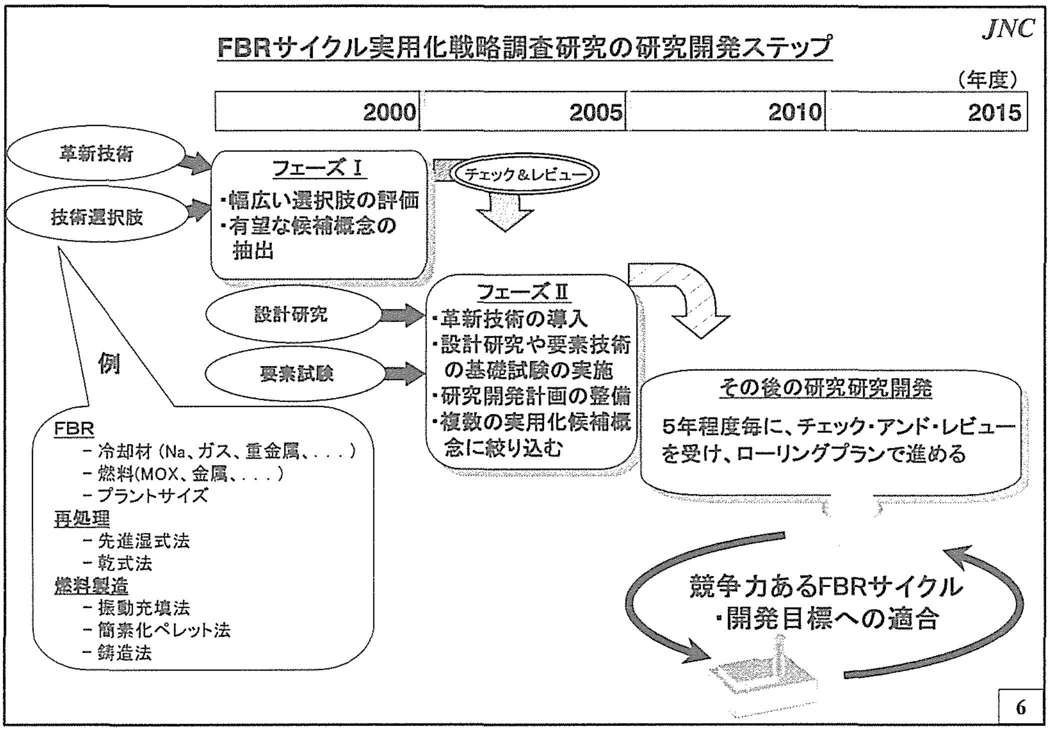
実用化戦略調査研究における国際協力の状況
（イギリス）
●燃料被覆管、振動充填燃料に
関する協力
●再処理（晶析法）に関する協力等
（ロシア）
●鉛冷却に関する協力
●振動充填燃料に関する協力
●乾式再処理に関する協力等
（アメリカ）
●重金属冷却炉に関
する協力
●新燃料開発に関する
協力等
（カザフスタン）
事故時の燃料挙動に
関する協力
（フランス）
●再処理に関する協力
●超ウラン元素、長寿命
核種回収技術に関する
協力等
（スイス）
振動充填燃料に関する協力
5



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実用化戦略調査研究の目的

目的

- 革新技術の導入
- 設計研究や要素技術の基礎試験の実施
- 研究開発計画の整備
- 複数の実用化候補概念に絞り込む

- ステップごとにチェック・アンド・レビューを受けつつ、社会的状況の変化に応じ柔軟に進める
- 実用化候補概念として、有望な候補に絞り込む
  - ・要素技術開発と概念設計を進め、定量的な評価を行う
  - ・FBRと燃料サイクルとの整合性、及び放射性廃棄物の処理処分との整合性を図る
- 競争力あるFBRサイクルの技術体系整備に向け、すでに作成済みの開発計画（ロードマップ）を精査していく

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実用化戦略調査研究の開発目標

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- **安全性**
  - 取り扱い物質の特性(科学的活性度、毒性など)やプロセス条件(運転温度など)を踏まえた安全対策
  - FBRサイクルの導入リスクが、社会にすでに存在するリスクに比べて十分小さい
    - 原子炉　・炉心損傷に至る恐れのある事象の発生を防止するとともに、その発生を仮定しても炉容器 または格納施設内で収束
    - 燃料サイクル　・臨界安全、閉じ込め機能の確保
- **経済性**
  - 将来の軽水炉に比肩する発電単価の達成
  - 世界に通用するコスト競争力の確保
    - より一層の物量削減
    - 海外調達、など
- **環境負荷低減性**
  - 長寿命核種(TRUおよびLLFP)の燃焼または分離変換による地層処分への負荷軽減
  - 運転・保守および廃止措置にともなう廃棄物の発生量低減
- **資源有効利用性**
  - 優れた中性子経済を活用し持続的に核燃料を生産
    - TRU燃料の多重リサイクル
    - 軽水炉TRUのリサイクル
  - エネルギー源としての多様なニーズへの対応
    - 水素製造、海水淡水化、熱供給、分散電源など
- **核拡散抵抗性**
  - 核物質防護および保障措置への負荷軽減(単体プルトニウムが純粋な状態で存在しないこと、など)
  - 核不拡散性制度の運用の効率化(遠隔保守・監視、自動化技術など)

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実用化戦略調査研究の主な設計要求(1/2)

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FBRシステム(基幹電源)

発電単価	：4.0円/kWh (建設単価　20万円/kWe相当)
連続運転期間	：13ヶ月以上
建設工期	：目標値として、大型炉42ヶ月、 中型モジュール炉36ヶ月
増殖性能	：低除染TRU燃料を前提に、FP核変換を行なう場合、増殖比1.0以上 目標値として、増殖比1.2以上、 複利システム倍増時間30年以下
TRU燃焼	：低除染TRU燃料を前提に、FBRマルチリサイクル及び長期貯蔵軽水炉使用済燃料を視野に入れたサイクルを考慮
FP核変換	：I，Tc
放出放射能	：現行軽水炉の申請書記載値と同等以下
安全性	：受動安全機能、再臨界回避 炉心損傷頻度10^{-6}/炉年未満

⟺

燃料サイクルシステム

燃料サイクル費	：1.1円/kWh以下 (再処理費　27万円/kgHM、燃料製造費16万円/kgHM 相当)
稼働率	：200日/年
建設工期	：60ヶ月
U, Puの回収率	：99%以上(サイクル全体として)
分離対象核種	：I, Tc, Cs, Sr, Mo, Pd
放出放射能	：現行軽水炉燃料サイクル施設の申請書記載値と同等以下
安全性	：軽水炉燃料サイクルと同等 施設内での放射性物質の大規模漏えいの発生頻度の目標値として10^{-6}/年・プラント以下(暫定)

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実用化戦略調査研究の主な設計要求(2/2)

FBRシステム（小型炉）

用途　　　　:分散電源（発電単価　5.5円/kWh）
　　　　　　発電以外としての小型炉の特性を活かした利用

燃料交換間隔　: 10年以上（高い内部転換機能を炉心の長寿命化に利用）

建設工期　　: 目標値として、20ヶ月以内

TRU燃焼　　: 低除染TRU燃料を装荷可能とし、サイクルを通じての環境負荷低減をはかる

放出放射能　: 現行軽水炉の申請書記載値と同等以下

安全性　　　: 小型炉の有する固有の安全特性、受動的安全性の活用

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実用化戦略調査研究におけるFBRシステムの検討対象

原子炉型 ＼ 燃料形態				固体燃料					液体燃料
				被覆管燃料			被覆粒子燃料		(U+Pu)
				酸化物	金属	窒化物	酸化物	窒化物	
Na冷却	大型炉			○	○	○			
Na冷却	中小型モジュール炉			○	○	○			
重金属冷却	大型炉（Pb）			○	○	○			
重金属冷却	中小型モジュール炉（Pb, Pb-Bi）			○	○	○			
ガス冷却	大型炉	CO_2ガス炉	蒸気タービン発電	○	○	○			
ガス冷却	大型炉	Heガス炉	蒸気タービン発電	○	○	○			
ガス冷却	大型炉	Heガス炉	ガスタービン発電	○		○	○	○	
ガス冷却	Heガス中小型モジュール炉			○		○	○	○	
水冷却				○					
液体燃料による冷却									○

（注）○は、検討対象を示す

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フェーズⅡにおけるFBRシステムの研究開発

フェーズⅡでは

ソフト
・予備的概念設計
ハード
・枢要技術の要素試験

炉型毎に
ポイントは異なる

小型炉（ナトリウム、鉛ビスマス）
・小型炉の特性を活かした利用形態とシステムの開発

大・中型炉

フェーズⅠ

ナトリウム冷却炉
・目標を概ね達成見通し。
・技術成立性については、知見が十分。
・経済性向上方策等に革新技術を採用。

その他の炉型
・全体概要を把握した。
・基本的な成立性に係る課題を摘出した。

フェーズⅡ

・経済性向上、ナトリウム炉の弱点克服等に向けた設計概念の追求
・主要技術（合体機器，新材料等）の成立性確認

ガス冷却炉
・革新的プラント設計（事故時の炉心除熱等）の追求
・耐高温被ふく材等の課題の解決

重金属冷却炉
革新的プラント設計（炉心性能向上等）の追求
材料腐食対策や耐震性向上等の課題の解決

水冷却炉
稠密炉心の冷却、CDA対策等の課題の解決

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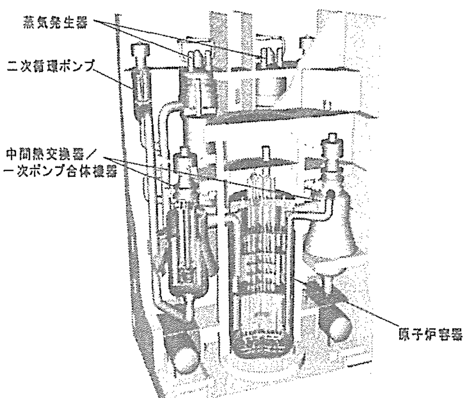
ナトリウム冷却炉（大型・中型モジュール）の技術開発課題



大型ナトリウム冷却ループ型炉の例

平成13年度の主要な検討事項

Na冷却炉の魅力の追求
・LLFP装荷炉心の成立性確認
・長期連続運転の検討（中型炉）
（ MOX燃料：3年、金属燃料：5年を想定）
・直管SG、BOP合理化等の採用検討（中型炉）

Na冷却炉の弱点克服
・Na水反応対策の強化：SG水リーク時の破損伝播の局限化方策
・Na漏洩対策の強化：Naバウンダリの二重化、内部の不活性雰囲気化等

今後の技術開発課題

- SASS（Self Actuated Shut Down System）の成立性確認
- 自然循環崩壊熱除去特性の確認
- 再臨界回避に係わる炉内試験の実施（カザフIGR炉）
- 合体機器の成立性確認
- 3次元免震技術の開発
- 新材料（12Cr鋼）の材料データの取得
- 金属燃料の炉内過渡試験の準備（米TREAT炉）
- ODS鋼燃料ピンの先行照射の準備（露BOR-60）

13

現時点におけるFBRシステム技術の評価結果

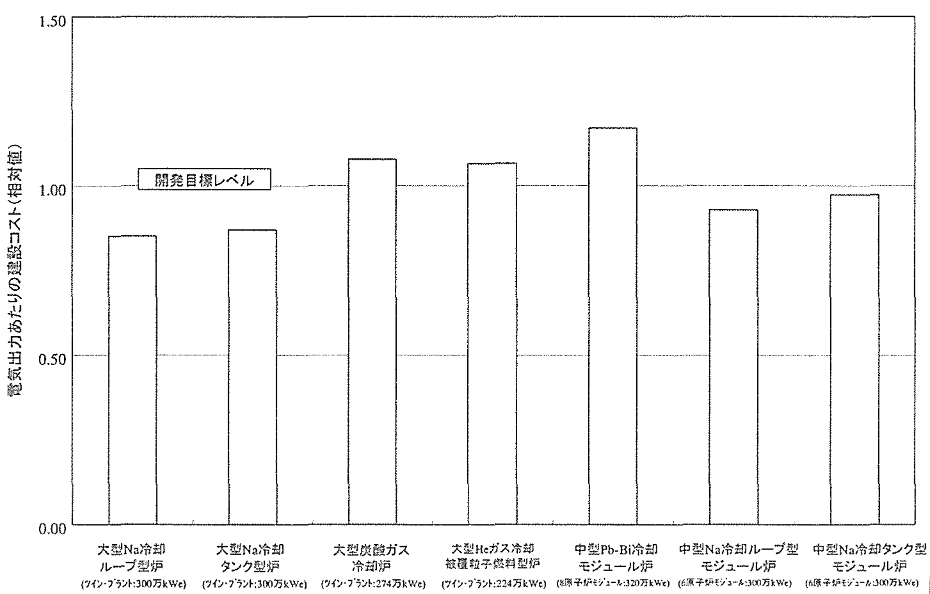
（A: フェーズⅡで検討する技術、 B: フェーズⅡでは実用化戦略調査研究以外の国内外の研究をレビューし、再評価する技術、
C: A及びB以外の技術で検討結果をデータベースとして残す技術、 ー: 検討対象外の技術）

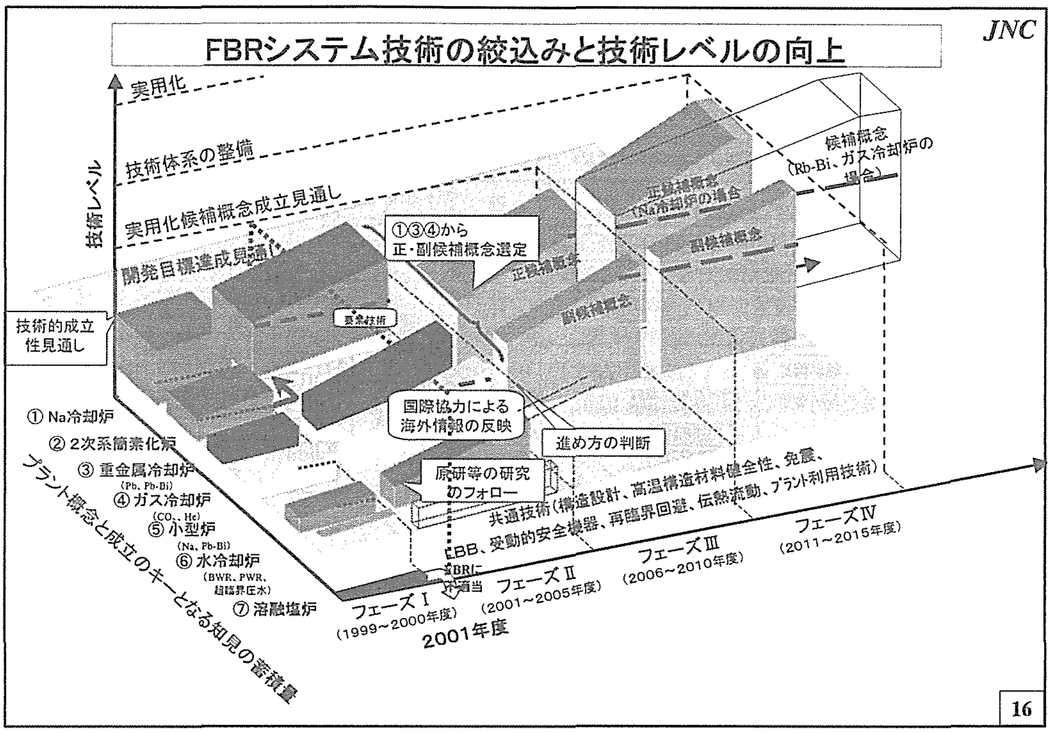
対象技術		炉型評価結果	燃料形態の評価結果		
			MOX	窒化物	金属
Na冷却	大型炉タンク型	B	A	B	A
	大型炉ループ型	A			
	中型モジュール炉	A			
重金属冷却	大型炉(Pb)	C	B	A	A
	中型モジュール炉 (Pb , Pb-Bi)	A			
ガス冷却	CO_2ガス炉(ピン型)	B	B	A	C
	Heガス炉(ピン型)	B			
	Heガス炉 (被覆粒子・分散燃料型)	A			
水冷却	BWR型FBR	A	A	ー	ー
	PWR型FBR	A			
	超臨界圧水型FBR	A			
小型炉	Na炉 注1	A	B	A	A
	重金属炉 注2	A			

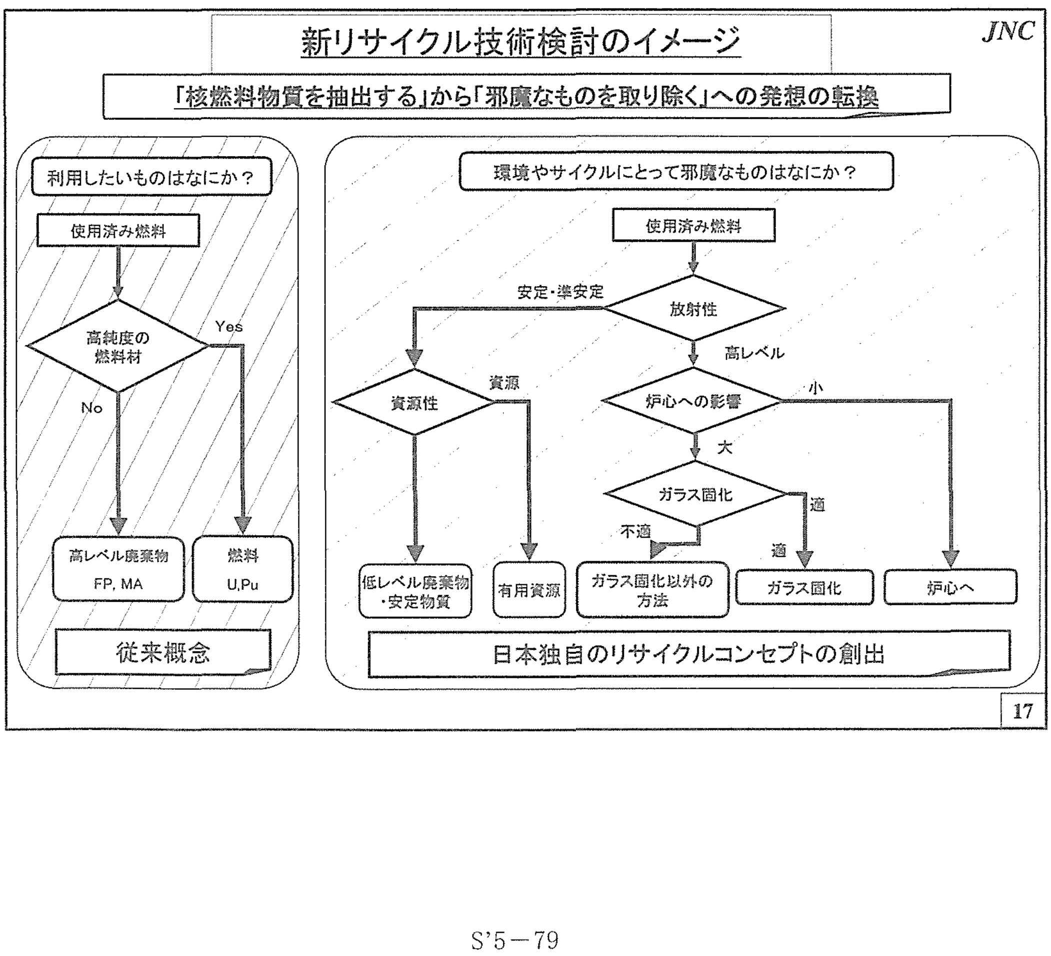
注1） 小型炉のガス炉については、大型炉の検討結果を反映して検討する予定。

注2） 燃料形態の評価は長期運転対応としての評価結果

FBRシステム(各炉概念毎)における概略の建設コスト比較




JNC
FBRシステム技術の絞込みと技術レベルの向上
実用化
技術体系の整備
実用化候補概念成立見通し
開発目標達成見通し
技術レベル
技術的成立性見通し
①③④から
正・副候補概念選定
要素技術
正候補概念
副候補概念
正候補概念（Na冷却炉の場合）
副候補概念
候補概念（Pb-Bi、ガス冷却炉の場合）
国際協力による
海外情報の反映
進め方の判断
原研等の研究のフォロー
共通技術（構造設計、高温構造材料健全性、免震、
FBB、受動的安全機器、再臨界回避、伝熱流動、プラント利用技術）
① Na冷却炉
② 2次系簡素化炉
③ 重金属冷却炉
(Pb、Pb-Bi)
④ ガス冷却炉
(CO₂、He)
⑤ 小型炉
(Na、Pb-Bi)
⑥ 水冷却炉
(BWR、PWR、超臨界圧水)
⑦ 溶融塩炉
プラント概念と成立のキーとなる知見の蓄積量
フェーズⅠ
(1999～2000年度)
2001年度
フェーズⅡ
(2001～2005年度)
フェーズⅢ
(2006～2010年度)
フェーズⅣ
(2011～2015年度)
16


JNC
新リサイクル技術検討のイメージ
「核燃料物質を抽出する」から「邪魔なものを取り除く」への発想の転換
利用したいものはなにか？
使用済み燃料
高純度の燃料材
Yes
No
高レベル廃棄物
FP, MA
燃料
U,Pu
従来概念
環境やサイクルにとって邪魔なものはなにか？
使用済み燃料
放射性
安定・準安定
高レベル
資源性
資源
炉心への影響
小
大
ガラス固化
適
不適
適
低レベル廃棄物
・安定物質
有用資源
ガラス固化以外の方法
ガラス固化
炉心へ
日本独自のリサイクルコンセプトの創出
17

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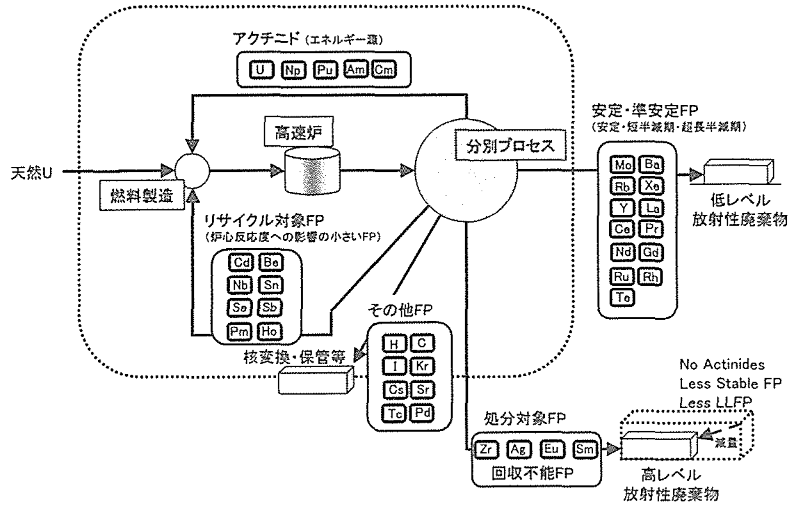
新リサイクルシステムの概念



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フェーズⅡにおける燃料サイクルシステムの研究開発

フェーズⅡでは

［再処理］
- ・予備的な概念設計
- ・湿式枢要技術に関する小規模ホット試験
- ・湿式代替補完技術の基本特性試験
- ・乾式2方式の要素試験での定量的な比較

［燃料製造］
- ・MOX燃料の高性能化
- ・新型燃料絞り込みの知見収集
- ・金属燃料小規模Pu試験

フェーズI

再処理
- ・幅広い選択肢の調査
- ・施設概念の構築, 経済性概略評価
- ・乾式では3方式→2方式に絞込み

燃料製造
- ・幅広い選択肢の調査
- ・施設概念の構築, 経済性概略評価

フェーズⅡ

湿式再処理
- ・晶析技術, TRU回収技術等のホット試験による先進湿式法の確立
- ・ホット試験による代替補完技術の見極め
  （超臨界流体直接抽出/アミン抽出/イオン交換法）

乾式再処理
- ・小規模Pu試験等による技術的成立性の確認

ペレット法燃料製造
- ・簡素化ペレット技術の開発と低除染TRU含有燃料の製作性見極め

振動充填法燃料製造
- ・ゲル化法, 転動造粒法等の開発と有望な顆粒製造法の選定
- ・ゲル化法, RIAR法等による顆粒を用いた小規模システム試験

鋳造法燃料製造
- ・小規模試験による鋳造技術の見極め

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先進湿式法及び代替補完技術の技術開発課題

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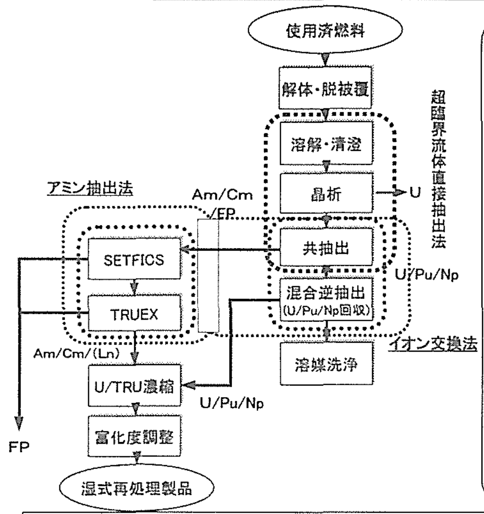

平成13年度における主要な検討事項

[先進湿式法]

・晶析技術に関する実験室規模ホット試験により結晶の生成を確認

・TRU回収技術(SETFICS＋TRUEX)コールド試験でソルトフリー試薬の適用可能性を確認

[超臨界流体直接抽出法]

・超臨界CO_2+TBPと模擬物質によるコールド試験で溶解・抽出反応の促進を確認

[アミン抽出法]

・酸化剤の製品等への移行が少ないことを実験的に確認

[イオン交換法]

・CMPO含浸無機吸着剤のコールド試験でTRU回収の適用性確認

今後の技術開発課題

[先進湿式法]
・晶析技術の確立
・簡素化溶媒抽出技術の確立

[他の代替補完技術]
・CPFでのU／Pu試験による元素挙動・分離性能確認
・代替補完技術の絞込み

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金属電解法再処理法の技術開発課題

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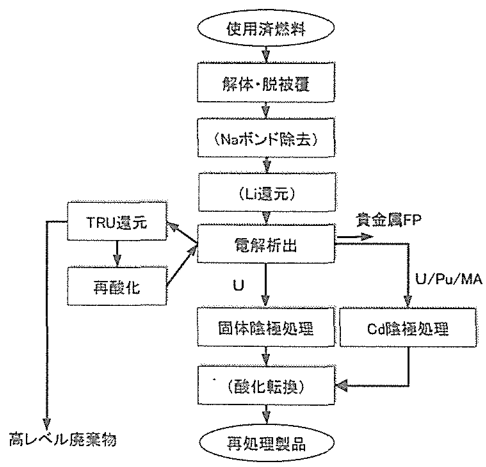

平成13年度における主要な検討事項

・MA入り三元合金燃料を用いた電解精製試験(電中研ーITU)で回収率等の基礎データを取得

・Cd陰極への回収試験において高濃度のHMの回収に成功

・Pu試験のためのグローブボックス整備(JNCー電中研)

今後の技術開発課題

・Pu試験、実使用済燃料試験
・塩廃棄物処理技術の確立
・塩・Cd蒸留分離技術開発
・脱被覆技術の開発

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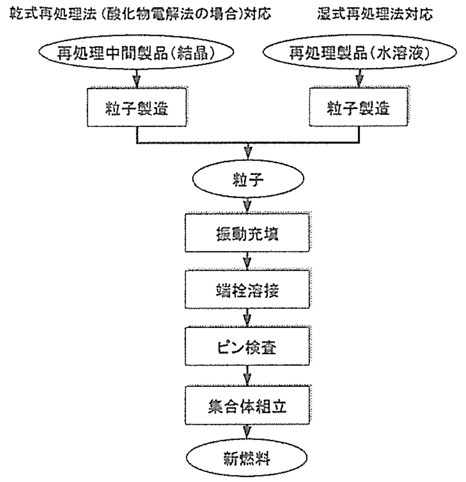
振動充填製造法の技術開発課題



平成13年度における主要な検討事項

- 原料液の温度・濃度などの保持条件の把握
  （湿式対応外部ゲル化）
- 転動造粒法による粒子製造試験において所期の粒子を製造
  （湿式対応硝酸出発乾式法）
- 模擬顆粒や電解法UO_2顆粒による充填試験により目標重点密度を達成
- 燃料輸送時の密度安定性確認試験で偏析が発生しないことを確認

今後の技術開発課題

- 粒子製造候補技術の絞り込み（**外部ゲル化法**、**内部ゲル化法**等から選定）
- ホット試験
- スフェアパック・バイパック（形状模擬MOX）・ペレットの比較照射試験

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現時点における燃料サイクルシステム技術の評価結果

A: フェーズⅡで検討する技術、 B:フェーズⅡでは実用化戦略調査研究以外の国内外の研究をレビューするとともに他の技術とのハイブリッド化の可能性を検討し、再評価する技術、
C: A及びB以外の技術で検討結果をデータベースとして残す技術、 ―: 検討対象外の技術

対象技術 ＼ 燃料形態			MOX	窒化物	金属
再処理	先進湿式法		A	A	―
	乾式	酸化物電解法	A	C	C
		金属電解法	A	A	A
		フッ化物揮発法	B	B	B
燃料製造	簡素化ペレット		A	A	―
	振動充填	湿式法対応	A	A	―
		酸化物電解法対応	A	C	―
		金属電解法対応	A	A	―
		フッ化物揮発法対応	B	B	―
	鋳造法		―	―	A

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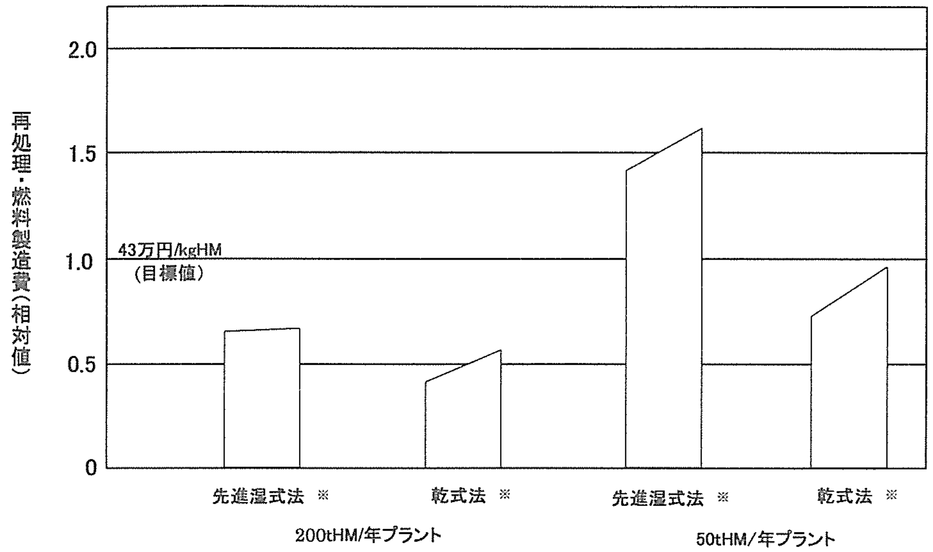
燃料サイクルシステムに関する経済性評価の結果
(引き続きフェーズIIにてコストダウンの評価を実施中)

燃料形態：酸化物燃料、燃焼度：15万MWd/t



※ 各方式において、今後開発課題を達成した時の予想値

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燃料サイクル技術の絞込みと技術レベルの向上

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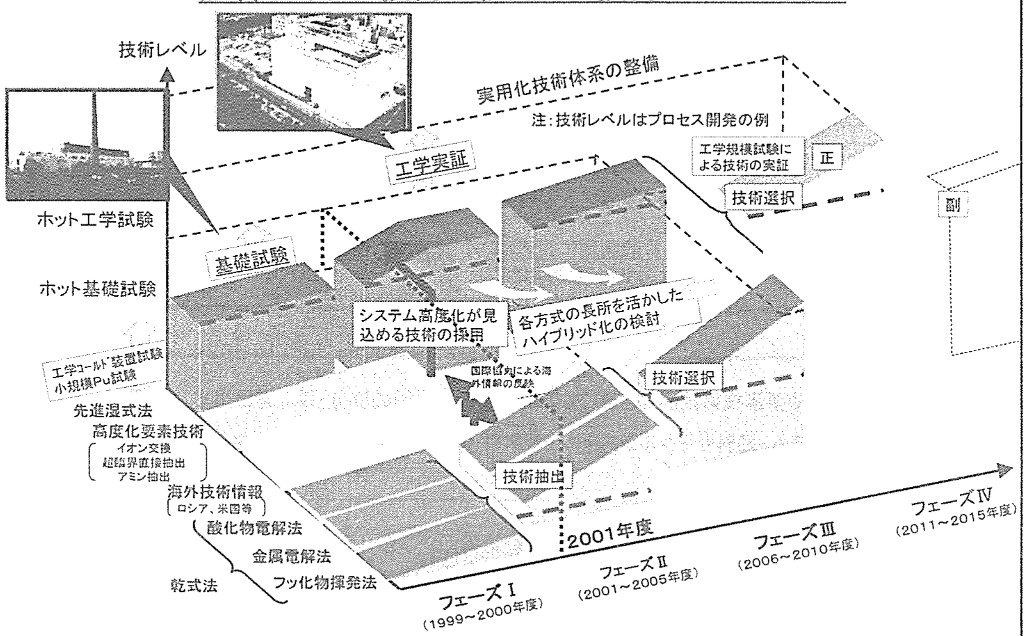

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実用化戦略調査研究の成果の公表状況

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成果の発表・報告

原子力委員会への説明	5, 11月に進捗状況の報告　他　革新炉検討会でも紹介
国際会議	ICONE−9(4月, ニース(仏))
	SMiRT 16 (8月, ワシントン(米))
	Global-2001 (9月, パリ(仏))
	核データ国際会議 (ND-2001) (10月, つくば(日))
	Actinides-2001 (11月, 葉山(日))　他
学会	日本原子力学会誌掲載　9, 10, 11月号
	秋の大会　24件
	春の年会　30件
雑誌等	月間エネルギー　9月号
	原子力eye　9月号
	火力原子力発電 10月特集号　他

知的所有権　平成12年度特許申請　5件
平成13 年度特許申請　5件

主な公開文献等:

1) 核燃料サイクル開発機構,「サイクル機構技報」, No.12別冊, 2001.9
2) 野田宏, 可児吉男,「高速増殖炉サイクルの実用化戦略調査研究」, 原子力学会誌, 43[9],(2001)
3) 野田宏,「高速増殖炉サイクルの実用化戦略調査研究フェーズⅠ成果の概要」, 月刊エネルギー, 34[8], (2001)

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実用化戦略調査研究のこれまでの成果と今後の展開

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検討内容

5つの開発目標(安全性, 経済性, 資源有効利用性, 環境負荷低減性, 核拡散抵抗性)に合致した
プラント概念の検討
研究開発戦略の検討　を実施。

⇩

検討結果

候補とすべき<u>FBR及び燃料サイクルの概念の整理</u>
基幹電源:<u>経済性の見通し</u>
小型炉　:<u>分散電源や多目的利用に相応しい小型炉の特性</u>
燃料サイクルプロセス:<u>適切な組み合わせ</u>

⬇

今後の方向性

- 設計研究や要素技術試験等を通じて革新的技術の一層の開発・導入を目指す。
- FBRシステム・燃料サイクルシステムと放射性廃棄物の処理処分が、全体として整合がとれる技術に統合化。
- 成果:
  - 安全性・経済競合性・環境負荷低減・持続的かつ恒久的な資源確保が可能な<u>FBRサイクルシステムの実用化像の明確化</u>
  - 将来社会の多様なニーズ(分散電源, 多目的利用)に柔軟に応える有望な<u>候補概念の具体化</u>
  - 効果的な<u>研究開発の提示</u>

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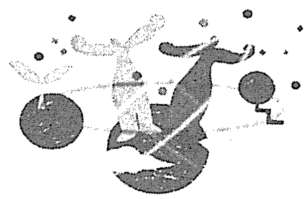
The 35th JAIF Annual Conference

Prospective View from "Feasibility Study on Commercialized FR Cycle Systems"



April 24, 2002

KIYOTO AIZAWA

Japan Nuclear Cycle Development Institute

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Social Needs of the 21st Century

Conversion from Consumption to Environmentally Conscious Utilization

Environmental Preservation

Enhancement of Safety

Efficient Utilization of Resources

Diversification of Energy Sources

Recyclable Energy

Energy-market Competitiveness

- Global Environmental Preservation (Reduction of waste, CO_2 etc.)
- Sustainability of Energy Supplies
- Increase of Energy Demand
- Flexible Response to Uncertainty and Change

A system enabling the long-time supply of energy without environmental disruption, exhaustion of resources or increase of risk.

- Innovative technology efficiently realizing the saving of resources and environmental friendliness
- Innovative technology facilitating commercialization

1

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Needs and Technologies for Nuclear Cycle of the 21st Century

Needs	Technologies
●Environmental Preservation	・Recovery, Volume Reduction, Partitioning and Transmutation of FP
・Reduction of Wastes	・Reduction of Reprocessing Volume (High Burn-up, High Thermal Efficiency)
・Reduction of Waste's Toxicity	・ Recovery and Burning of MA
●Efficient Utilization of Resources	・High Recovery Rate of TRU ・High Burn-up, High Thermal Efficiency
● Recyclable Energy	・Securing of Flexible Breeding Ratio Corresponding to Needs
●Enhancement of Safety	・Enhancement of Passive Safety Features
●Diversification of Energy Sources	・Multi-purpose Use (Production of H_2, Utilization of Thermal Energy, Distributed Power Sources, Desalinization of Sea Water)
● Energy-market Competitiveness	・Rationalization, Simplification, High Efficiency of Systems
・Improvement in Economic Competitiveness	・Low-decontamination Recycle, High Burn-up, High Thermal Efficiency ・No Pure Plutonium in any FR Cycle Process
・Enhancement of Nuclear Non-proliferation	・Conformity with the Non-proliferation System (Easy to Safeguard) ・Pu Utilization Corresponding to Demand (Minimization of Pu accumulation)

2

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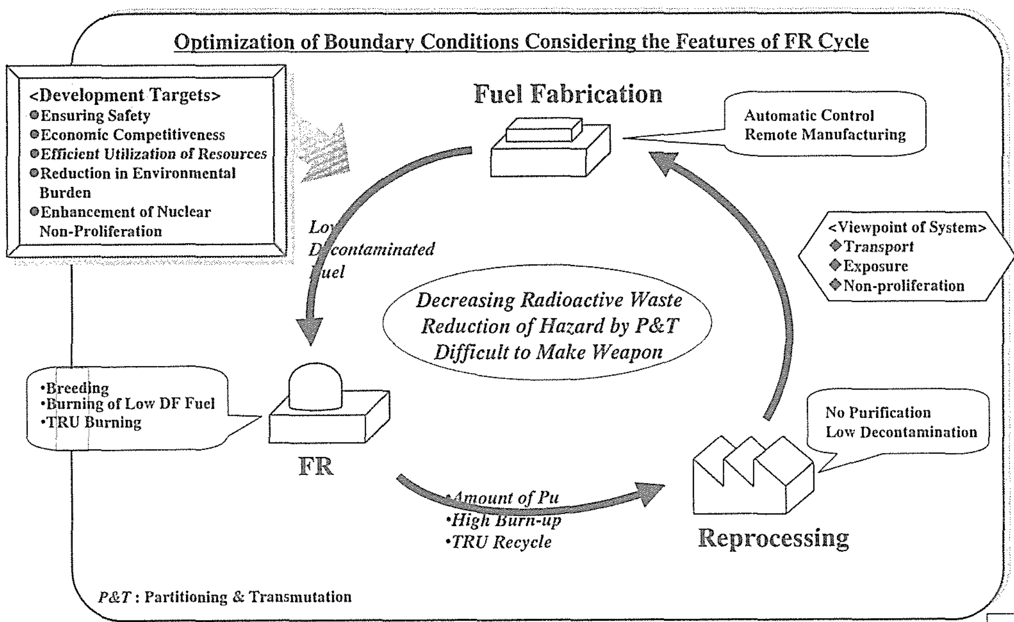
Assessment Philosophy



3

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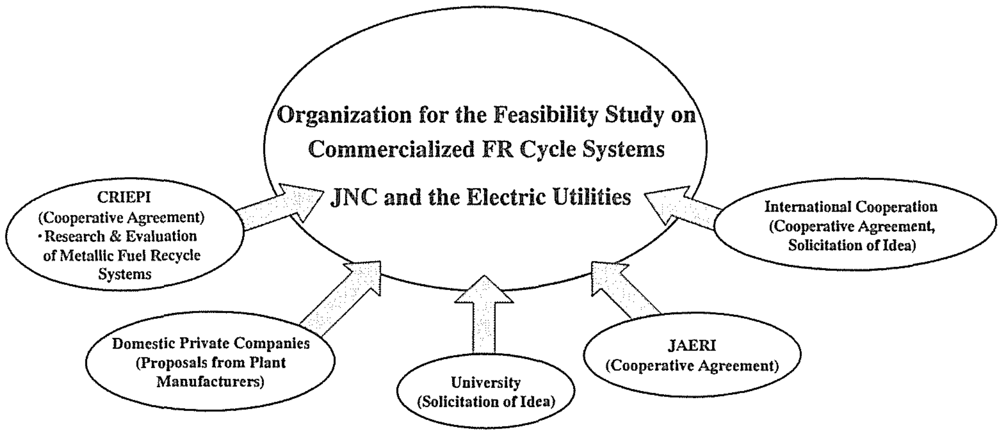
Organization for Carrying out the Feasibility Study on Commercialized FR Cycle Systems



4

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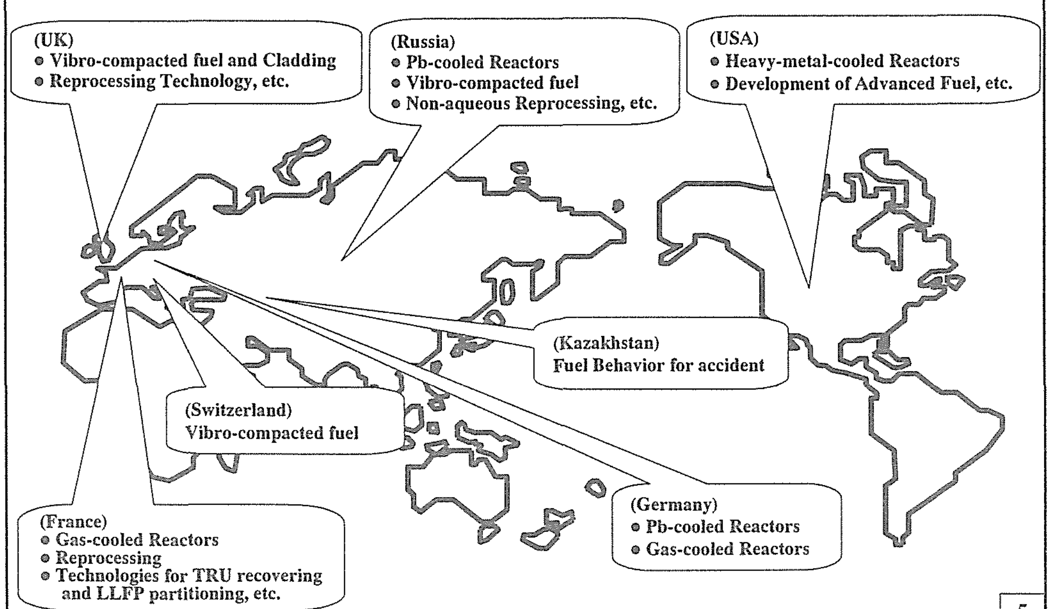
Current International Cooperation



5

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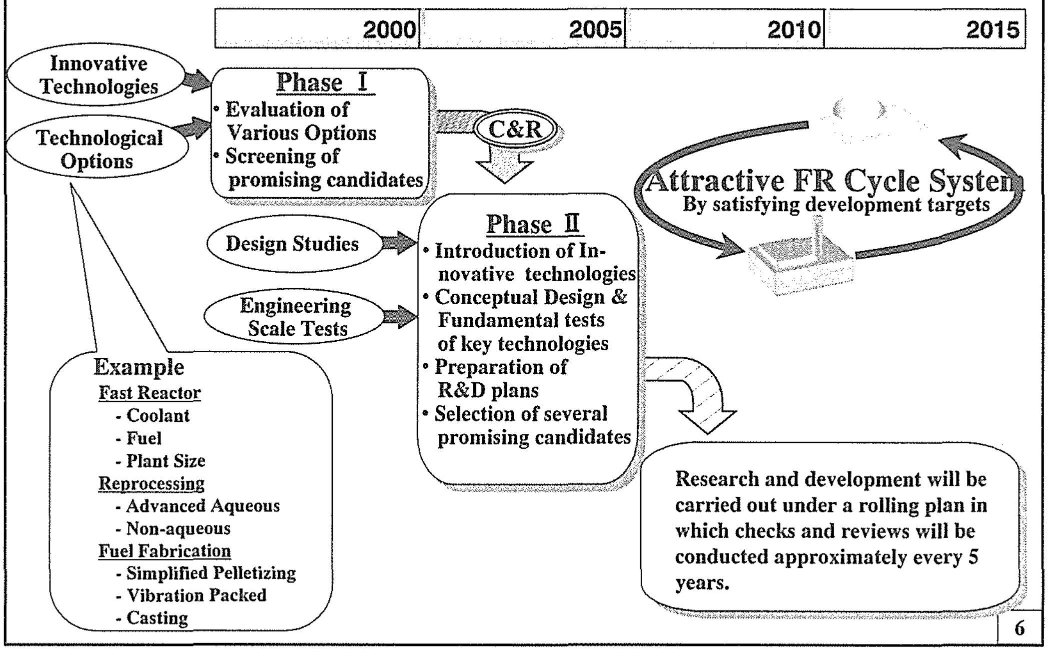
Development of the FR Cycle System



6

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Purposes of the Feasibility Study on Commercialized FR Cycle Systems

Purposes

- Introduction of innovative technologies
- Conceptual Design and Fundamental tests of key technologies
- Preparation of R&D plans
- Selection of several promising candidates

- Step-by-step check & review and flexible promotion of research corresponding to social conditions
- Selection of several promising candidates
  - Conceptual design, elemental technology development and quantitative evaluations
  - Consistency with FR, fuel cycle and disposal of the radioactive waste
- Detailed examination of established R&D plans (Road map) to realize FR cycle engineering scheme

7

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Development Targets of the Commercialized FR Cycle Systems

Ensuring Safety

- ◆ Prevention of Reactor Core Damage

Economic Competitiveness

- ◆ Competitive with Future LWRs and Other Electric Power Sources
- ◆ Cost which the world accepts

Reduction in Environmental Burden

- ◆ TRUs Burning and LLFPs Transmutation
- ◆ Reduction of Radioactive Waste

Efficient Utilization of Resources

- ◆ Burning and Breeding

Enhancement of Nuclear Non-Proliferation

- ◆ No Pure Plutonium in any FR Cycle Process
- ◆ Enhanced Design for Non-proliferation of the Plant

8

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Major Design Targets of FR Cycle System (1/2)

FR System (Base Power)

Electricity Generation Cost	: 4.0yen/kWh (Equivalent to Reactor Construction Cost 0.20 Million yen/kWe)
Operation Cycle	: More than 13 months
Construction Period	: As a goal, Large-scale : 42 months Medium-scale Modular Type : 36 months
Breeding Ratio	: Above 1.2 *In the case of FP Transmutation : Above 1.0* System Doubling Time : Less than 30 years
TRU Burning	: Consideration of FR multi-recycle and long-term storage of LWR spent fuel
FP Transmutation	: I, Tc
Radioactive Release	: Equivalent or less than Present LWR Application
Safety	: Passive Safety, Re-criticality free, Core damage frequency less than 10^{-6}/ry

⟺

Fuel Cycle System

Fuel Cycle Cost	: Less than 1.1yen/kWh [Equivalent to 0.43 Million yen/kgHM]
Availability Factor	: 200 days/y
Construction Period	: 60 months
U, Pu Recovery Rate	: More than 99%
Partitioning FPs	: I, Tc, Cs, Sr, Mo, Pd
Radioactive Release	: Equivalent or less than Present LWR Reprocessing Facility Application
Safety	: Same as LWR Fuel Cycle Large-scale Radioactive Leakage in *the facility less than 10^{-6}/y*

9

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Major Design Targets of FR Cycle System (2/2)

FR System (Small-scale Reactor)

Use	: Distributed power supply (Electric power cost 5.5 yen /kWh) The usage which it made use of the characteristics of the small type reactor except for electric power generation.
Fuel exchange interval	: More than 10 years (High conversion ratio is used for lengthening the core life.)
Construction Period	: As a goal , within 20 months
TRU Burning	: Low-decontamination TRU fuel can be loaded and Reduction of environmental burden through the cycle is aimed.
Release of radioactivity	: Equivalent or less than Present LWR application value.
Safety	: Passive safety and safety character of small type reactor.

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Evaluation of FR System Technology

(○: Screened technology to be studied)

Technology \ Fuel Type			Solid Fuel					Liquid Fuel
			Pin Type			Coated Particle		U + Pu
			MOX	Metal	Nitride	MOX	Nitride	
Na	Large-scale Type		○	○	○			
Na	Medium-scale Modular Type		○	○	○			
Heavy Metal	Large-scale Type (Pb)		○	○	○			
Heavy Metal	Medium, Small-scale Modular Type (Pb, Pb-Bi)		○	○	○			
Gas	Large-scale Type	CO_2 Gas- cooled, Steam Turbine	○	○	○			
Gas	Large-scale Type	He Gas-cooled, Steam Turbine	○	○	○			
Gas	Large-scale Type	He Gas-cooled, Gas Turbine	○		○	○	○	
Gas	Medium, Small-scale Modular Type (He)		○		○	○	○	
Water (Heavy Water) cooled Type			○					
Liquid Fuel Type								○

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R&D of FR Cycle System in Phase II

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Phase II

Software
- Preliminary conceptual design

Hardware
- Fundamental tests of key technologies

Key points vary among reactor types

Small-scale Reactor (Sodium, Pb-Bi)
- Development of utilization schemes and systems based on the characteristics of a small-scale reactor

Phase I — **Large / Medium-scale Reactor** — **Phase II**

Sodium-cooled Reactor
- Development targets are expected to be obtained.
- Knowledge on technological feasibility is sufficient.
- Innovative technology to realize economic competitiveness is adopted.

⇒

- Clarification of conceptual design to enhance economic competitiveness and overcome drawbacks of the sodium-cooled reactor
- Confirmation of feasibility of key technologies (integration of facilities and new materials, etc.)

Other Types of Reactor
- The outline of the entire system is clarified.
- Issues affecting fundamental feasibility of technologies are clarified.

⇒

Gas-cooled Reactor
- Adoption of innovative plant design (heat removal in the accident, etc.)
- High-temperature resist cladding material

Heavy-metal-cooled reactor
- Adoption of innovative plant design (improvement of core performance, etc.)
- Clarification of solutions to such issues as countermeasures for material corrosion and enhancement of seismicity, etc.

Water-cooled Reactor

Clarification of solutions to such issues as cooling of dense core and CDA countermeasures, etc.

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The Progress of Study on Sodium-cooled Reactor
(Large-scale , Medium-scale modular type)

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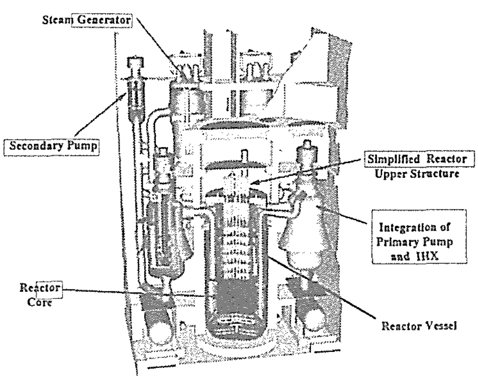

The example of the Sodium-cooled Large-scale Loop-type Reactor

Major Study Items in 2001

Enhancement of the attractive merits of Sodium-cooled Reactor
- Confirmation of the feasibility of LLFP loaded core
- Study on long core cycle length. (Medium-sized reactor) (MOX fuel : 3 years, Metal fuel : 5 years)
- Adoption of straight tube type SG , BOP rationalization, etc. (Medium-sized reactor)

Conquest of the drawback of Sodium-cooled Reactor
- Enhancement of Sodium-Water reaction countermeasure :
  - Localization of propagation of water tube failures in SG.
- Enhancement of Sodium leak countermeasure :
  - Double boundary structure for all sodium boundary with inert gas circumstances

Key Issues for Future Development
- Confirmation of feasibility of SASS (Self Actuated Shut Down System) by in-pile test
- Confirmation of the natural circulation decay heat removal performance
- Confirmation of Re-criticality Free core concept by in-pile test (IGR: Kazakhstan)
- Confirmation of feasibility of the Integration of components
- Development of three-dimensional seismic-isolation technology
- Data collection of strength of new material (12Cr Steel)
- In-pile transient test of Metal Fuel (TREAT: USA)
- Irradiation test of ODS Cladding Fuel pins (Joyo: Japan, BOR-60: Russia)

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Evaluation Result of FR System Technology

A : Screened technology to be studied in the Phase II
B : Technology to be revaluated in the Phase II by reviewing results of other studies in Japan and overseas
C : Scope of the study in the Phase I except A and B
—: Out of scope in the Phase I

Reactor System		Evaluation of Reactor Type	Evaluation of Fuel Type		
			MOX	Nitride	Metal
Sodium	Large-scale Tank Type	B	A	B	A
	Large-scale Loop Type	A			
	Medium-scale Modular Type	A			
Heavy Metal	Large-scale	C	B	A	A
	Medium-scale Modular Type (Pb-Bi)	A			
Gas	CO_2 Gas-cooled (Pin Type Fuel)	B	B	A	C
	He Gas-cooled (Pin Type Fuel)	B			
	He Gas-cooled (Coated Particle Fuel)	A			
Water	BWR System	A	A	—	—
	PWR System	A			
	Supercritical Pressure	A			
Small-scale *1 *2	Sodium-cooled	A	B	A	A
	Heavy Metal-cooled	A			

*1) As for the Gas-cooled reactor of the Small-scale reactor, the evaluation result of the Large-scale reactor will be reflected.

*2) The evaluation of the fuel type is a result as a dealing with the long-term operation.

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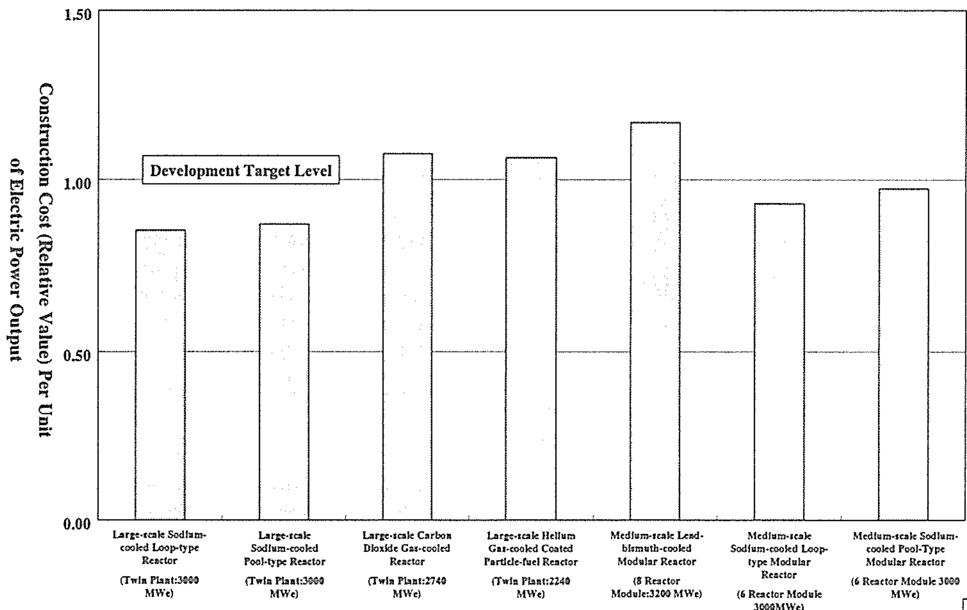
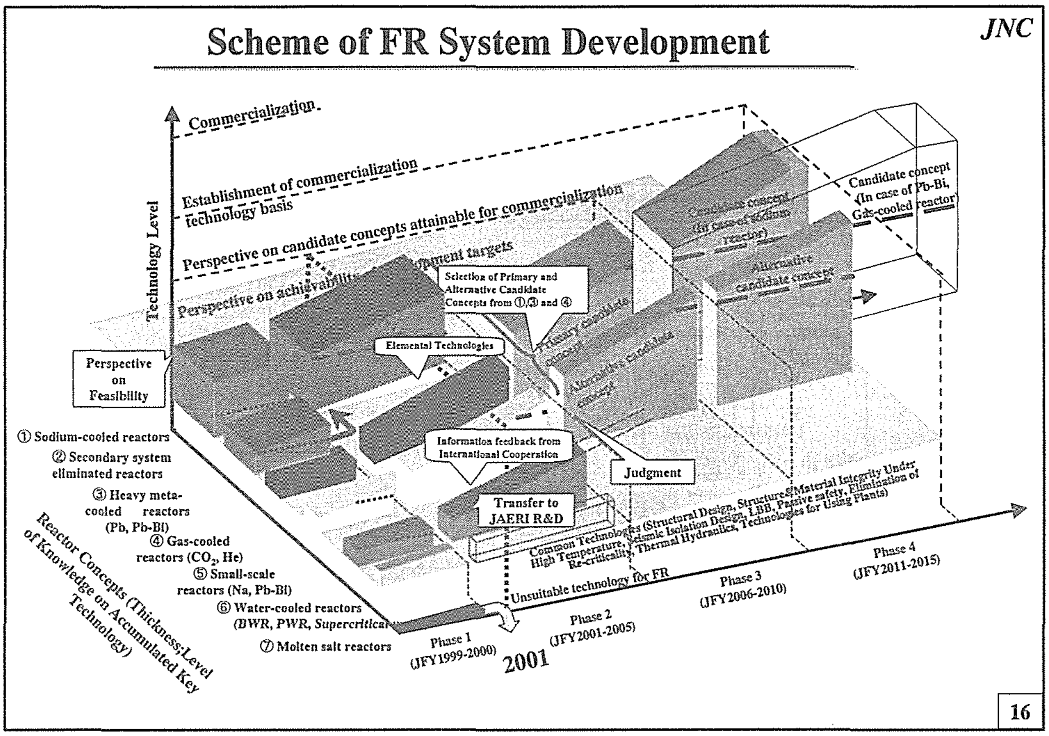
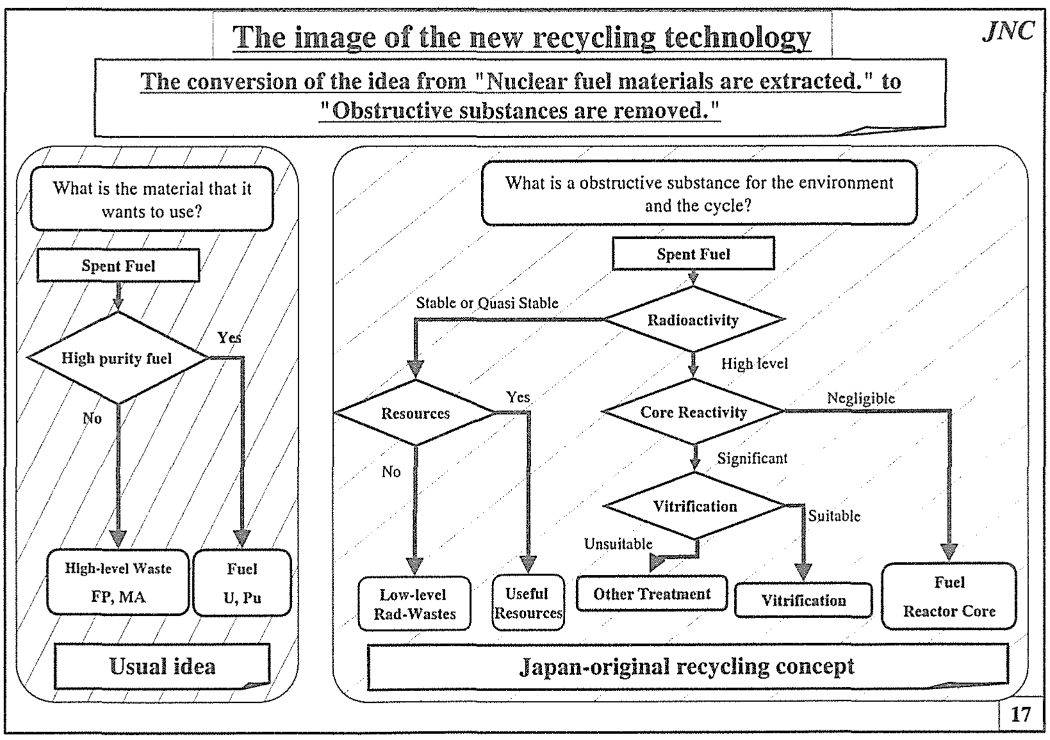
Comparison of Approximate Construction Cost Estimation among the Reactor Concepts Studied



15


Scheme of FR System Development
JNC
Commercialization
Establishment of commercialization technology basis
Perspective on candidate concepts attainable for commercialization
Perspective on achievability of development targets
Technology Level
Perspective on Feasibility
Selection of Primary and Alternative Candidate Concepts from ①,③ and ④
Elemental Technologies
Primary candidate concept
Alternative candidate concept
Candidate concept (In case of sodium reactor)
Alternative candidate concept
Candidate concept (In case of Pb-Bi, Gas-cooled reactor)
Information feedback from International Cooperation
Judgment
Transfer to JAERI R&D
① Sodium-cooled reactors
② Secondary system eliminated reactors
③ Heavy metal-cooled reactors (Pb, Pb-Bi)
④ Gas-cooled reactors (CO_2, He)
⑤ Small-scale reactors (Na, Pb-Bi)
⑥ Water-cooled reactors (BWR, PWR, Supercritical)
⑦ Molten salt reactors
Reactor Concepts (Thickness:Level of Knowledge on Accumulated Key Technology)
Unsuitable technology for FR
Phase 1 (JFY1999-2000)
Phase 2 (JFY2001-2005)
Phase 3 (JFY2006-2010)
Phase 4 (JFY2011-2015)
2001
16


The image of the new recycling technology
JNC
The conversion of the idea from "Nuclear fuel materials are extracted." to "Obstructive substances are removed."
What is the material that it wants to use?
Spent Fuel
High purity fuel
Yes
No
High-level Waste FP, MA
Fuel U, Pu
Usual idea
What is a obstructive substance for the environment and the cycle?
Spent Fuel
Radioactivity
Stable or Quasi Stable
High level
Resources
Yes
No
Core Reactivity
Negligible
Significant
Vitrification
Suitable
Unsuitable
Low-level Rad-Wastes
Useful Resources
Other Treatment
Vitrification
Fuel Reactor Core
Japan-original recycling concept
17

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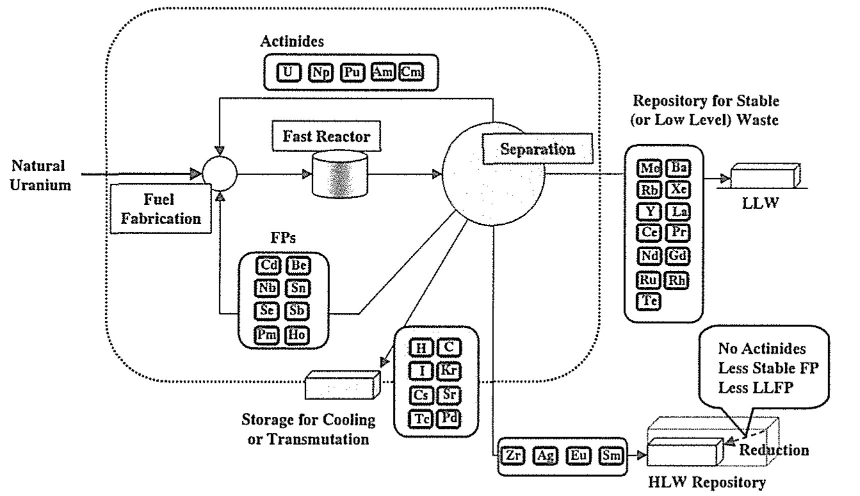
Material Flow in "New Concept"



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R&D of Fuel Cycle System in Phase Ⅱ

Phase Ⅱ

Reprocessing
- Preliminary conceptual design
- Small-scale Hot test of Aqueous Reprocessing key technology
- Fundamental tests of Auxiliary Alternative Processing for Aqueous Reprocessing Method
- Quantitative evaluation of the feasibility of two Non-aqueous Reprocessing Methods

Fuel fabrication
- High-performance MOX fuel
- Gathering of the knowledge necessary for the selection of Advanced Fuel Options
- Small-scale Pu tests of metal fuel

Phase Ⅰ

Reprocessing
- Research of candidates
- Conceptual facilities design, Evaluation of economic competitiveness
- Screening of non-aqueous reprocessing methods: 3 →2

Fuel Fabrication
- Research of candidates
- Conceptual facilities design, Evaluation of economic competitiveness

Phase Ⅱ

Aqueous Reprocessing
- Establishment of Advanced Aqueous Method by Crystallization technology, Hot test of TRU recovery technology, etc.
- Confirmation of Auxiliary Alternative Processing technology by Hot test (Supercritical fluid Direct Extraction Method / Amine Extraction Method / Ion Exchange Method)

Non-aqueous Reprocessing
- Confirmation of technological feasibility by small-scale test such as Pu test

Pelletizing Method of Fuel Fabrication
- Confirmation of Simplified pelletizing technology development and production of Low-decontamination TRU fuel

Vibration Compaction Method of Fuel Fabrication
- Development of Gelation, Rolling Granulation Method and Selection of Promising Granule Production Method
- Small-scale system tests using granule by gelation and RIAR method

Casting Method of Fuel Fabrication
- Confirmation of Casting technology by small-scale test

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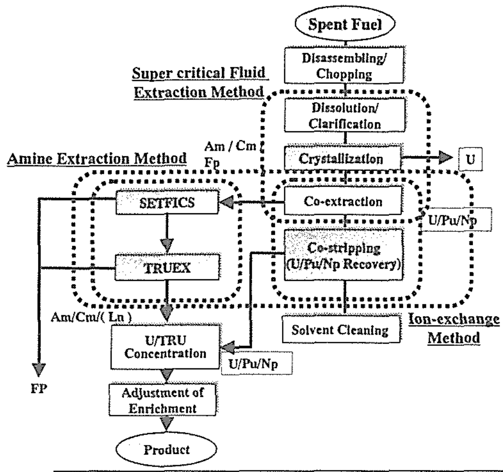
The Progress of Study on Advanced Aqueous Method and Other Alternative / Supplementary Aqueous Technologies



Major Study Items in 2001

[Aqueous process]

- Development of crystallization process : Small scale U, Pu test
- Development of TRU recovery process : SETFICS+TRUEX cold tests

[Supercritical fluid extraction process]

- Cold test with supercritical CO_2, TBP and imitated FPs

[Amine extraction process]

- Experiments on migration of oxidizing agent

[Ion-exchange process]

- Cold tests using adsorbent impregnated with CMPO

Key Issues for Future Development

[Advanced Aqueous Method]

- Verification of **Crystallization method**
- Verification of **Simplified extraction method**

[Other Alternative / Supplementary Technologies]

- U/Pu tests at CPF (Chemical Processing Facility)
- Selection of an alternative method

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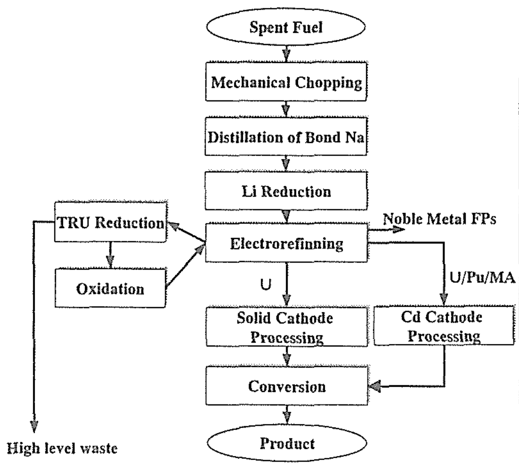
The Progress of Study on Metal Electrorefining Method



Major Study Items in 2001

- Electrowinning test with U and Pu (CRIEPI-ITU)
- High efficient recovery of HM into Cd cathode
- Setting up of glove boxes for Pu test Pu (JNC-CRIEPI)

Key Issues for Future Development

- Pu tests, hot tests
- Salt waste treatment technique
- Separation of salt and Cd
- Decladding technique

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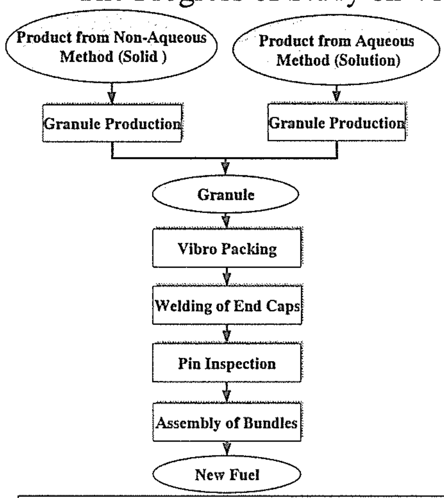
The Progress of Study on Vibration Compaction Method



Major Study Items in 2001

- Gelation tests for external gelation method
- Granulation test for rolloing granulation method
- Vibro-packing tests with imitated granules or electrowon UO_2 granules
- Verificarion on column stability under transportation

Key Issues for Future Development

- Selection of the most appropriate particle fabrication method from internal gelation, external gelation and rolling granulation methods
- Fabrication tests with Pu
- Irradiation test of MOX and Np-MOX fuel / PIE (HFR: PSI cooperation)

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Evaluation Result of FR Fuel Cycle System Technology

A : Screened Technology to be Studied in the Phase Ⅱ
B : Technology to be Revaluated in the Phase Ⅱ by Reviewing Results of Other Studies in Japan and Abroad Evaluation of FR Fuel Cycle System Technology
C : Scope of the Study in the Phase Ⅰ except A and B
—: Out of Scope in the Phase Ⅰ

Technology \ Fuel Type			MOX	Nitride	Metal
Reprocessing	Aqueous Method		A	A	—
	Non-aqueous Method	Oxide Electrowinning	A	C	C
		Metal Electrorefining	A	A	A
		Fluoride Volatility Method	B	B	B
Fuel Fabrication	Pelletizing Method		A	A	—
	Vibration Compaction	Gelation Method	A	A	—
		Oxide Electrowinning Compatible	A	C	—
		Metal Electrorefining Compatible	A	A	—
		Fluoride Volatility Method Compatible	B	B	—
	Casting		—	—	A

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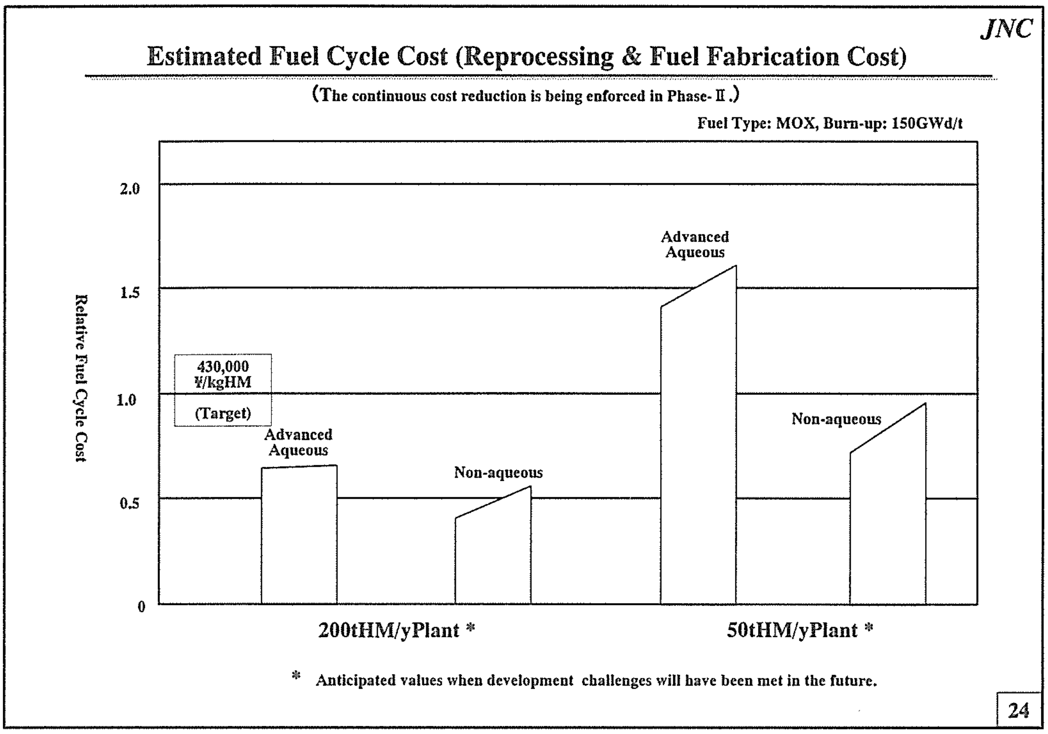
JNC
Estimated Fuel Cycle Cost (Reprocessing & Fuel Fabrication Cost)
(The continuous cost reduction is being enforced in Phase-Ⅱ.)
Fuel Type: MOX, Burn-up: 150GWd/t
Relative Fuel Cycle Cost
2.0
1.5
1.0
0.5
0
430,000 ¥/kgHM
(Target)
Advanced Aqueous
Non-aqueous
Advanced Aqueous
Non-aqueous
200tHM/yPlant *
50tHM/yPlant *
* Anticipated values when development challenges will have been met in the future.
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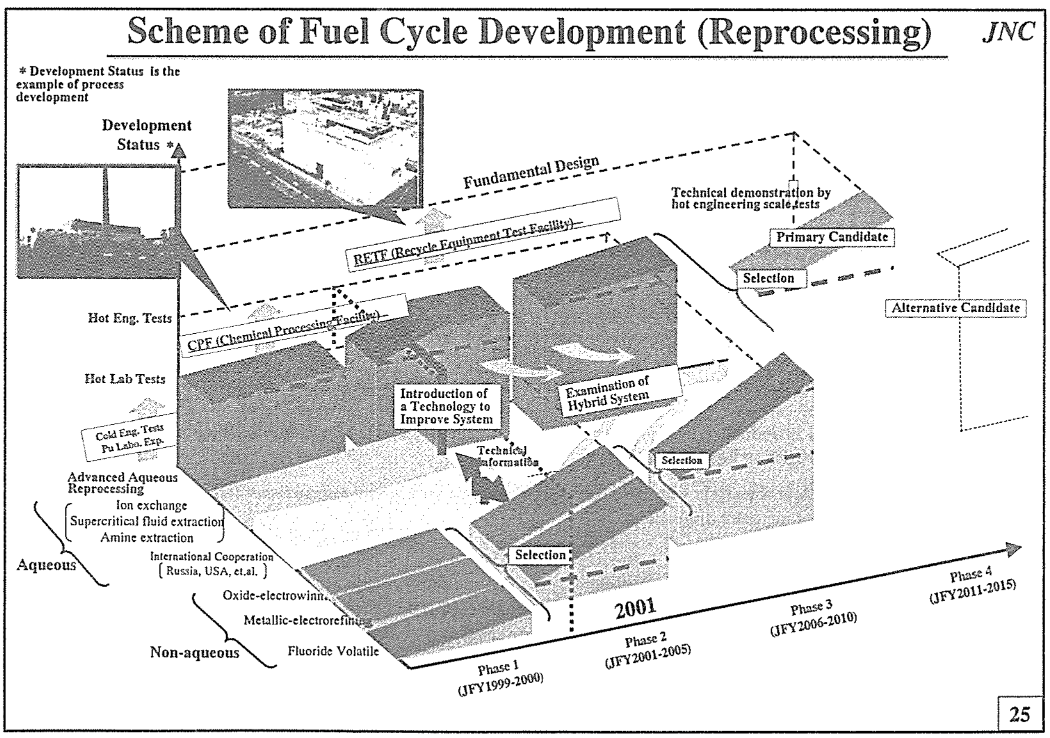
Scheme of Fuel Cycle Development (Reprocessing)
JNC
* Development Status is the example of process development
Development Status *
Fundamental Design
Technical demonstration by hot engineering scale tests
RETF (Recycle Equipment Test Facility)
Primary Candidate
Selection
Alternative Candidate
Hot Eng. Tests
CPF (Chemical Processing Facility)
Hot Lab Tests
Introduction of a Technology to Improve System
Examination of Hybrid System
Cold Eng. Tests
Pu Labo. Exp.
Technical information
Selection
Advanced Aqueous Reprocessing
Ion exchange
Supercritical fluid extraction
Amine extraction
Aqueous
International Cooperation
(Russia, USA, et.al.)
Selection
Oxide-electrowinning
Metallic-electrorefining
Non-aqueous
Fluoride Volatile
2001
Phase 1 (JFY1999-2000)
Phase 2 (JFY2001-2005)
Phase 3 (JFY2006-2010)
Phase 4 (JFY2011-2015)
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Publication of the Results

Report of the Results

Atomic Energy Commission

International Conference — ICONE-9 (April, Nice in France)
SMiRT 16 (August, Washington D.C. in USA)
Global-2001 (September, Paris in France)
Nuclear Data International Conference (ND2001) (October, Tsukuba)
Actinides-2001 (November, Hayama)

Atomic Energy Society of JAPAN — Journal No. 9, 10, 11
Fall Meeting : 24
Annual Meeting : 30

Patents — Application for Patents in 2000 : 5 applications
in 2001 : 5 applications

References

1) JNC Technical Review No.12 Separated Volume. 2001.9
2) H. Noda, Y. Kani "Feasibility Studies on Commercialized Fast Reactor Cycle System", Journal of the Atomic Energy Society of Japan, p.18, 43[9], (2001)
3) H. Noda "Results of Feasibility Studies on Commercialized Fast Reactor Cycle System", Energy, p.55, 34[8], (2001)

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Current Status and Future Development of FS

Studies of the Plant Concepts and R&D Strategy Suitable for the Five Development Targets
(Safety, Economic Competitiveness, Effective Utilization of Resources, Nuclear Non-proliferation)

⇩

Results of Studies

Classification of promising candidate concepts for FR and Fuel cycle system

- Reactor for Base Load Power : Prospects for economic competitiveness
- Small-scale Reactor : Characteristics of a small-scale reactor suitable for distributed power and multi-purpose utilization
- Fuel Cycle Process : Adequate Combination Schemes

⬇

Future Aims

- Development and Introduction of innovative technologies, intensive design efforts for candidate systems with experimental activities on key technologies
- An integrated system consistent with the FR system, Fuel cycle system and radioactive waste management (treatment and disposition)
- Results:
  - Clarification of FR cycle system technologies to ensure safety, economic competitiveness, reduction in environmental burden and sustainable utilization of resources
  - Concretization of the most promising candidate concept that flexibly meets the needs of the future society (distributed power, multipurpose utilization)
  - Presentation of effective R&D plans