OECD Nuclear Energy Agency
International Atomic Energy Agency

ISOE

INFORMATION SYSTEM ON OCCUPATIONAL EXPOSURE

Sixth Annual Report

OCCUPATIONAL EXPOSURES AT NUCLEAR POWER PLANTS

1986-1996

Prepared by

CENTRE D'ÉTUDE SUR L'ÉVALUATION
DE LA PROTECTION DANS LE DOMAINE NUCLÉAIRE

AEN
NEA

International Atomic Energy Agency

Nuclear Energy Agency

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter; Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consist of all OECD Member countries, except New Zealand and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

FOREWORD

In order to facilitate the exchange of techniques and experiences in occupational exposure reduction, the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) launched the Information System on Occupational Exposure (ISOE) on 1 January 1992, after a one year pilot programme. In 1993, an arrangement was agreed between the International Atomic Energy Agency (IAEA) and the NEA by which the IAEA* co-sponsors ISOE inviting those IAEA Member States which are not members of the NEA to participate cost-free in the programme.

This three-level database joins utilities and regulatory agencies throughout the world, providing occupational data for trending, cost-benefit analyses, technique comparison, information exchange, and other analyses following the ALARA principle. In creating the network for the collection of this data, a forum for direct information and experience exchange was also created, thus allowing operational radiation protection professionals, from both utilities and authorities, to freely exchange ideas, views and experience.

This is the Sixth Annual Report produced by the ISOE Programme, and covers the period up to the end of 1996. The analyses presented in this Report focus on the radiological indicators supplied to the NEA 1 database by Participating Utilities.

Based on a decision by the ISOE Steering Group at its 1997 meeting, this report will be the last of its type. With participants now all equipped with a user-friendly database containing this occupational exposure data, it was felt that the Annual Report should focus more on events and overall trends than on data presentation. Periodic reports containing summaries of overall data, or discussing other specific aspects of the ISOE data will be issued, however not necessarily annually. The first new format Annual Report, covering events of 1997, will be issued during the first half of 1998.

This report was prepared by the ISOE European Regional Technical Centre (ERTC), with the assistance of the NEA ISOE Secretariat, and was reviewed and approved by the Members of the ISOE Bureau and Steering Group, who also provided valuable comments. The NEA Secretariat is very grateful to the ERTC for its excellent contribution.

This report is published under the responsibility of the Secretary-General of the OECD. The opinions expressed do not necessarily reflect the point of view of any OECD Member Country or of any international organisation.

The material in this document has been supplied by the authors and has not been edited by the ***IAEA****. The views expressed remain the responsibility of the named authors and do not necessarily reflect those of the government(s) of the designating Member State(s). In particular, neither the IAEA nor any other organisation or body sponsoring this work can be held responsible for any material reproduced in this document.*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The year 1996 was a productive and successful one for the ISOE Programme. In total, as of the end of 1996, the ISOE databases included 399 reactors (365 operating and 34 in cold shutdown or some form of decommissioning) from 24 countries, representing 71 utilities. National regulatory bodies from 21 countries were also participants.

The annual total occupational collective exposure corresponding to reactors in operation has decreased from more than 800 to about 500 man.Sv during the last ten years (1986 to 1996). During the same period the average collective dose per reactor, as well as the average collective dose per TWh produced have also decreased by a factor two, reaching 1.43 man.Sv per reactor and 0.24 man.Sv per TWh produced in 1996. During that period the number of operating reactors has increased by over 25% except for GCRs where a decrease of 40% has been observed.

These trends are observed for most types of reactors and regions, particularly for the collective dose per reactor. The decrease in the average collective dose per unit of energy produced is more significant for BWRs (approximately 60%) than for CANDUs (35%), however the initial level for CANDUs was very low.

It should be noted that in 1996, LWGRs (RBMK), presently represented in the database only by the two units in Lithuania, have an average collective dose per reactor higher than for all other types of reactor (7.55 man.Sv).

The decrease in the total collective dose, despite the increasing number of reactors, is obviously due to the implementation of dose reduction and ALARA programmes, and perhaps also to the lengthening of operating cycles. The larger decrease of dose per reactor and per TWh produced is due to these same factors, but is also related to the introduction of newer reactors, whose ambient radiological environment is improved over older reactors, and which require, for the moment, less maintenance work.

The impacts of the fuel cycle lengthening and reduction of outage duration are highlighted in chapter 5, which discusses principal events. In France, for example, the report states "Future improvements are expected from the extension of the 1300 MW fuel cycles, as well as from the introduction of outages for refueling only". The report from the United States notes "In 1996, nuclear power plants focused on initiatives to reduce refueling outage duration and operating costs". Many other countries also refer to very short outages, such as in Germany in Neckar 2 where the refueling outage for 1996 lasted only 15.2 days.

The average annual collective doses for European PWRs is lower than 1 man.Sv per reactor in Sweden, Belgium and Switzerland. Particularly notable are the results in 1996 in Belgium, where all 7 reactors have had refueling outages, and a steam generator replacement occurred at Doel 4 with excellent dosimetric results (0.63 man.Sv).

One major characteristic of the year 1996 within ISOE is the emphasise put on the impact of good "work management" in order to reduce doses. This is illustrated by two publications issued during that year:

- first, an international Expert Group working within ISOE finalised the report, *Work Management in the Nuclear Power Industry*. The NEA has sold over 1 200 copies of this report, which is now on the process of being translated into several languages; and
- second, in Spain, a report has been developed jointly between authorities and utilities entitled: *"Management of the Optimization of the Radiation Exposure"* to establish the general principles to be considered by companies in the nuclear power industry.

Benchmarking also appears to be one very efficient tool for exposure reduction. This was particularly the case in France where a set of national radiation exposure benchmarks at the job levels is well on the way to completion. This work has been performed in 1996 for all steam generator work and most non destructive tests. Bench-marking appears to also be very popular in the United States, particularly in terms of more global dose indicators such as total site dose.

More classical dose reduction techniques also improved during year 1996: American PWRs implemented new shutdown chemistry protocols to reduce occupational dose by stabilizing radiation fields during refueling outages, and many American BWRs are accelerating plans to implement hydrogen water chemistry and depleted zinc injection to reduce adverse chemical environments for reactor internals and to control radiation fields. Also, noble metals as a protective coating in reactor internals was tested at the Duane Arnold Nuclear Energy Center in Iowa with promising results.

Despite all these efforts, some dose increases have also occurred, for example all Swedish BWRs are now involved in significant modernisation programmes requested by the National Authorities. Some American nuclear power plants were shutdown during much of 1996 for extended maintenance outages (improvements in the material condition of the plants before deregulation) and due to regulatory requirements to reconcile operational practices with design basis analyses and document all modifications prior to restart. Occupational doses have tended to increase in these plants due to more maintenance and inspection activities in controlled areas.

EXPOSÉ DE SYNTHÈSE

1996 a été une année particulièrement productive et efficace pour le programme ISOE. Fin 1996, la base de données ISOE inclut 399 réacteurs (365 en fonctionnement et 34 en arrêt à froid ou en démantèlement) situés dans 24 pays, et appartenant à 71 exploitants. Les autorités nationales de 21 pays participent également à ce programme.

L'exposition collective professionnelle annuelle totale correspondant aux réacteurs en fonctionnement a diminué de plus de 800 homme.Sv à environ 500 homme.Sv pendant ces dix dernières années (de 1986 à 1996). Pendant la même période, la dose collective moyenne par réacteur, comme la dose collective moyenne par TWh produit ont également diminué d'un facteur deux, atteignant 1,43 homme.Sv par réacteur et 0,24 homme.Sv par TWh produit en 1996. Pendant cette période le nombre de réacteurs en fonctionnement a augmenté de plus de 25% excepté pour les réacteurs graphite-gaz où une diminution de 40% a été observée.

On observe ces tendances pour la plupart des types de réacteurs et la plupart des régions, en particulier pour la dose collective par réacteur. La diminution de la dose collective moyenne par unité d'énergie produite est plus importante pour les réacteurs REB (approximativement 60%) et moins importante pour les réacteurs CANDU (35%), toutefois le niveau initial pour ces derniers était très bas.

Il convient de noter qu'en 1996, les réacteurs RBMK, actuellement représentés dans la base de données par deux réacteurs en Lituanie, ont une dose collective moyenne par réacteur plus élevée que les autres types de réacteur (7,55 homme.Sv).

La diminution de la dose collective totale, en dépit du nombre croissant de réacteurs, est évidemment due à la mise en place de programmes de réduction de dose et de programmes ALARA, et peut-être également à l'augmentation de la durée du cycle du combustible. La diminution plus importante de la dose par réacteur et par TWh produit tout en étant due à ces mêmes facteurs, est également liée à l'introduction de nouveaux réacteurs, où l'environnement radiologique est amélioré, et qui exigent, pour le moment, moins de travaux de maintenance que les réacteurs anciens.

L'impact de l'allongement du cycle de combustible et de la réduction de la durée des arrêts est illustré dans le chapitre 5 de ce rapport qui présente les principaux événements de l'année. En France, par exemple, où de « futures améliorations sont attendues de l'extension des cycles de combustible des réacteurs 1300 MW, ainsi que de l'introduction d'arrêts simples pour rechargement ». Les commentaires sur la situation aux États-Unis indique qu' « en 1996, les centrales nucléaires se sont concentrées sur les initiatives pour réduire la durée des arrêts pour rechargement et les coûts d'exploitation ». De nombreux autres pays mentionnent également des arrêts très courts, comme l'Allemagne où l'arrêt pour rechargement à Neckar 2 en 1996 a duré seulement 15,2 jours.

Les doses collectives annuelles moyennes pour les réacteurs REP européens sont inférieures à 1 homme.Sv par réacteur en Suède, en Belgique et en Suisse. Les résultats 1996 sont particulièrement notables en Belgique, où les 7 réacteurs ont eu un arrêt pour rechargement, et où un remplacement de générateur de vapeur a eu lieu à Doel 4 avec d'excellents résultats dosimétriques (0,63 homme.Sv).

Une caractéristique majeure de l'année 1996 au sein du système ISOE est la place accordée à la « gestion du travail » en vue de réduire les doses. Cela est illustré par deux publications :

- en premier lieu, un groupe d'experts internationaux a finalisé le rapport ISOE, *Work Management in the Nuclear Power Industry.* L'AEN a vendu plus de 1 200 copies de ce rapport, qui est maintenant sur le point d'être traduit dans plusieurs langues; et

- en second lieu, en Espagne, un rapport a été réalisé conjointement par les autorités et les exploitants pour définir les principes généraux de gestion à appliquer dans l'industrie nucléaire. Il est intitulé: *Management of the Optimization of the Radiation Exposure.*

Le benchmarking (ou intercomparaison) est aussi apparu comme un outil très efficace pour réduire les expositions. Cela a été en particulier le cas en France où un ensemble de références dosimétriques nationales au niveau des chantiers est en cours d'élaboration. Ces références ont été définies en 1996 pour l'ensemble des travaux sur générateur de vapeur et pour la plupart des contrôles non destructifs. Le benchmarking est également très utilisé aux États-Unis, en particulier en termes d'indicateurs dosimétriques globaux tels que la dose totale du site.

Des techniques plus classiques de réduction de dose ont été également améliorées pendant l'année 1996: les réacteurs REP américains ont mis en oeuvre de nouvelles procédures de contrôle de la chimie du réacteur pour réduire l'exposition professionnelle en stabilisant les débits de dose pendant les arrêts pour rechargement; et de nombreux réacteurs REB américains accélèrent la mise en oeuvre de techniques d'injection d'hydrogène et d'injection de zinc appauvri en vue de réduire les environnements chimiques défavorables pour les internes de réacteur et pour contrôler les débits de dose. En outre, des métaux nobles utilisés comme revêtement sur les équipements des internes de réacteur ont été testés à Duane Arnold Nuclear Energy Center en Iowa avec des résultats prometteurs.

En dépit de tous ces efforts, des augmentations de dose se sont également produites. C'est le cas, par exemple, pour l'ensemble des réacteurs REB suédois qui sont impliqués dans des programmes significatifs de modernisation demandés par les autorités nationales. Quelques centrales nucléaires américaines ont été arrêtées pendant une bonne partie de l'année 1996 pour des arrêts de maintenance prolongés (améliorations des conditions matérielles des centrales avant la "déréglementation" du système électrique de l'État concerné). Ces prolongations d'arrêts ont également été dues à des demandes des autorités sur la concordance, avant tout redémarrage, des pratiques de terrain (procédures réellement réalisées dans les centrales) avec les analyses de base faites à la conception, ainsi que sur la concordance des documents d'exploitation avec les modifications réalisées. Les expositions professionnelles dans ces centrales ont tendance à croître du fait de l'augmentation des travaux de maintenance et des inspections dans les zones contrôlées.

正文摘要

1996年对于ISOE计划来说是富有成果和成功的一年。到1996年年底为止，ISOE数据库总共包括24个国家的399座反应堆（365座正在运行和34座处于冷停堆或某种退役状况），隶属于71个电力公司。21个国家的国家监管组织也是该数据库的参加者。

最近10年（1986年到1996年），相应于正在运行的反应堆的年度集体总职业照射量从800人·希韦特以上减少到的500人·希韦特。同期每个反应堆的平均集体剂量以及生产每万亿瓦小时的平均集体剂量也降低了二分之一，在1996年达到每个反应堆1.43人·希韦特和每万亿瓦小时0.24人·希韦特。在这期间运行的反应堆数增加了25%以上，但GCR除外，这种反应堆运行数减少了40%。

对大多数反应堆类型和地区观察到这种趋势，特别是每座反应堆的集体剂量。生产能源的每座机组的平均集体剂量，对于BWR而言减少的数量比CANDU更大，前者约为60%而后者为35%，不过CANDU的初始水平很低。

还应当注意到，1996年LWGR（RBMK）——目前在数据库中仅有立陶宛两个机组的——每座反应堆的平均集体剂量高于所有其他类型反应堆（7.55人·希韦特）。

尽管反应堆数目不断增加但集体总剂量减少，这显然是由于实施了剂量减少和ALARA计划，或许还因为延长了运行周期。每座反应堆和生产每万亿瓦小时的剂量大幅度减少同样也是因为这些因素，但是也与采用较新型反应堆有关，这些新型反应堆周围的放射性环境比较老的反应堆有所改善，而且目前它们需要比较少的维修工作。

第5章突出了延长燃料循环和减少停堆周期的影响，这一章讨论了一些主要的事件。例如，在法国，报告说“预期将来在1300兆瓦燃料循环的延长以及采用仅为换料而停堆方面进一步加以改进”。美国的报告中指出“1996年，核动力厂着重于……减少换料停堆期和运行费用的主动行动”。许多其他国家也提到了非常短的停堆期，例如在德国的内卡2号机组，1996年换料停堆仅用了15.2天。

欧洲PWR的年平均集体剂量，在瑞典、比利时和瑞士是每座反应堆低于1人·希韦特。特别值得注意的是1996年比利时的结果，在那里总共7座反应堆都

换料停堆，而且在多伊尔4号机组还更换了蒸汽发生器，其剂量测量结果却非常低（0.63人·希韦特）。

1996年ISOE内的一个主要特点是把重点放在为减少剂量进行良好的“工作管理”的效果上。这一年间印发的两份出版物说明了这一点：

- 第一个出版物是ISOE内的国际专家工作组完成了报告“**核动力工业工作管理**”。这份报告NEA已经销售了1200本以上，现在正被译成多种语文；
- 第二个出版物是西班牙文的，是由各国主管部门和电力部门联合编写的一份报告，题为“**辐射照射最佳化管理**”，目的是制订供核动力工业各公司考虑的一般原则。

确定基准水平看来也是降低照射的一种非常有效的方法。法国是一个具体事例，在那里即将完成一系列有关不同工作水平的国家辐射照射基准水平。1996年对所有蒸汽发生器工作和大多数无损检验方面都进行了这项工作。建立基准水平看来在美国也很受欢迎，特别是就更加普遍的剂量指标例如现场总剂量而言。

1996年期间更经典的剂量减少技术也有改善：美国的PWR执行了新的停堆化学程序，通过稳定换料停堆期间的辐射场来减少职业照射，美国的许多BWR加快了计划，实行轻水化学和贫化锌注入以减小反应堆内部件的有害化学环境和控制辐射场。在爱荷华的Duane Arnold核能中心还试验用贵金属作反应堆内部构件的保护涂层，取得了有希望的结果。

尽管作了这一切努力，仍然还发生了某些剂量增加的情况。例如瑞典的所有BWR现在都参与国家当局要求的巨大现代化计划。美国的某些核动力厂由于延长维护性停堆期（解除监管前，动力厂的材料状况方面的改善）和由于监管要求在重新启动前必须使运行实践与设计基准分析和文件所有的修改相一致，1996年大部分时间处于停堆状况。由于被控制地区更多的维护和检查活动，这些动力厂的职业剂量有增加的趋势。

ZUSAMMENFASSENDE ÜBERSICHT

1996 war ein produktives und erfolgreiches Jahr für des ISOE-Programm. In Summe umfaßte die ISOE-Datenbank Ende 1996 399 Reaktoren aus 24 Ländern (365 in Betrieb und 34 im kalten Stillstand oder einem Stadium der Demontage), wobei 71 Versorungsunternehmen vertreten waren. Nationale Behörden von 21 Ländern zählten ebenfalls zu den Teilnehmern.

Die gesamte jährliche Kollektivdosis für die in Betrieb befindlichen Reaktoren fiel im Verlauf der letzten zehn Jahre (1986 bis 1996) von über 800 auf etwa 500 Pers.Sv. Im gleichen Zeitraum sind sowohl die mittlere Kollektivdosis pro Reaktorblock als auch die mittlere Kollektivdosis pro erzeugter TWh um einen Faktor zwei auf einen Wert von 1,43 Pers.Sv pro Reaktorblock und 0,24 Pers.Sv pro 1996 erzeugter TWh gefallen. Während dieses Zeitraums nahm die Zahl der in Betrieb befindlichen Reaktoren um über 25 % zu, außer bei den GCRs, wo ein Rückgang um 40 % zu beobachten war.

Diese Tendenzen sind für die meisten Reaktortypen und Regionen zu beobachten, besonders für die Kollektivdosis je Reaktor. Die Abnahme der mittleren Kollektivdosis pro erzeugter Energie ist signifikanter bei den SWR (etwa 60 %) als für die CANDUs (35 %), allerdings war das Ausgangsniveau der CANDUs schon sehr niedrig.

Es ist anzumerken, daß 1996 für LWGRs (RBMK), derzeit nur durch die beiden Blöcke in Litauen in der Datenbank vertreten, die mittlere Kollektivdosis pro Reaktor höher war als für alle anderen Reaktortypen (7,55 Pers.Sv).

Die Abnahme der Gesamtkollektivdosis, trotz der Zunahme der Zahl der Reaktoren, wird offensichtlich hervorgerufen durch die Einführung von Dosisreduzierungs- und ALARA-Programmen und eventuell auch durch die Verlängerung der Betriebszyklen. Die größere Abnahme der Dosis pro Reaktor und pro erzeugter TWh wird durch die gleichen Faktoren verursacht, ist jedoch auch verbunden mit der Einführung neuerer Reaktoren, deren radiologische Auswirkungen gegenüber den älteren Reaktoren verbessert wurden, die daneben momentan auch weniger Instandhaltungsaufwand benötigen.

Die Einflüsse der Verlängerung der Brennstoffzyklen und der Revisionsverkürzungen werden in Kapitel 5 beleuchtet, wo besondere Gegebenheiten betrachtet werden. Für Frankreich zum Beispiel stellt der Bericht fest, daß "zukünftige Verbesserungen von der Verlängerung der 1300 MW-Brennstoffzyklen erwartet werden, ebenso von der Einführung von Stillständen ausschließlich zum Brennstoffwechsel". Der Bericht der Vereinigten Staaten bemerkt: "1996 konzentrierten sich die Kernkraftwerke auf Anstrengungen zur Reduzierung der Dauer der Brennelementwechsel und der Betriebskosten". Viele andere Länder berichten ebenfalls von sehr kurzen Revisionen wie z. B. in Deutschland bei Neckarwestheim 2, wo der Brennelemntwechsel 1996 nur 15,2 Tage dauerte.

Die mittleren jährlichen Kollektivdosen für europäische DWR liegen in Schweden, Belgien und in der Schweiz unter 1 Pers.Sv pro Reaktor. Besonders bemerkenswert sind die Ergebnisse 1996 aus Belgien, wo alle 7 Reaktoren Brennelementwechsel durchführten und ein

Dampferzeugeraustausch bei Doel 4 mit hervorragenden Dosimetrie-Ergebnissen stattfand (0,63 Pers.Sv).

Ein besonderes Merkmal des Jahres 1996 in ISOE ist die Betonung, die auf den Einfluß von gutem "Workmanagement" zur Dosisreduzierung gelegt wird. Dies wird durch zwei Publikationen, die während des Jahres herausgegeben wurden, verdeutlicht:

- zunächst stellte eine bei ISOE tätige internationale Expertengruppe den Bericht Workmanagement in der Nuklearindustrie fertig. Die NEA hat über 1 200 Exemplare dieses Berichtes verkauft, wobei derzeit die Übersetzung in verschiedene Sprachen läuft; und

- zweitens wurde in Spanien ein Bericht zusammen von Behörden und Betreibern erarbeitet mit dem Titel *Management of the Optimization of the Radiation Exposure* (Handhabung der Optimierung der Strahlenexposition), um die allgemeinen Regeln, die von den Unternehmen der Nuklearindustrie zu berücksichtigen sind, festzulegen.

Benchmarking scheint auch ein sehr effizientes Werkzeug zur Reduzierung der Strahlenexpositon zu sein. Dies war besonders in Frankreich der Fall, wo eine Aufstellung nationaler Strahlenbelastungskriterien (benchmarks) auf Basis der Tätigkeiten kurz vor der Vollendung steht. Diese Arbeit wurde 1996 für alle Arbeiten an Dampferzeugern und bei den meisten zerstörungsfreien Prüfungen durchgeführt. Benchmarking scheint auch in den Vereinigten Staaten sehr üblich zu sein, besonders in Bezug auf mehr globale Dosisindikatoren wie etwa der Standort-Gesamtdosis.

Klassischere Dosisreduzierungstechniken wurden 1996 ebenfalls verbessert: Amerikanische DWR führten neue Chemie-Abfahrportokolle ein, um die tätigkeitsbezogene Dosis durch Stabilisierung der Strahlenfelder während der Brennelementwechsel zu reduzieren. Viele amerikanischen SWR beschleunigen Pläne zur Einführung der Hydrogen-Wasser-Chemie und der Injektion von abgereichertem Zink, um ungünstige chemische Umgebungsbedingungen für die Reaktoreinbauten zu reduzieren und die Strahlenfelder zu beeinflussen. Auch Edelmetallbeläge auf Reaktoreinbauten wurden beim Duane Arnold Nuclear Energy Center in Iowa mit vielversprechenden Ergebnissen getestet.

Trotz all dieser Anstrengungen traten auch einige Dosisanstiege auf, so sind jetzt z. B. alle schwedischen SWR von bedeutenden Modernisierungsprogrammen betroffen, die von den nationalen Behörden gefordert werden. Einige amerikanische Kernkraftwerke wurden 1996 für umfangreiche Instandhaltungsstillstände abgeschaltet (Verbesserungen der materiellen Bedingungen der Anlagen vor der Deregulierung) und wegen Behördenforderungen, die Betriebspraxis mit Ergebnisse von Auslegungs-Basisanalysen abzustimmen und alle Änderungen vor dem Wiederanfahren zu dokumentieren. Die tätigkeitsbezogenen Dosen tendierten in diesen Anlagen wegen umfangreicherer Instandhaltungs- und Prüftätigkeiten im Kontrollbereich nach oben.

要約

1996年はISOEプログラムにとって充実した、また成功した年であった。総合的に、1996年末現在、 ISOEデータベースは24カ国から71の電気事業者を擁し、399基の原子炉を包括している（365基が運転中、 34基が冷温停止あるいは廃止処置にある）。また、21カ国からは国の規制当局も参加者となっている。

運転中の原子炉に関する年間の総被ばく線量は、過去10年間(1986-1996)で、800man·Svより多かったのが約500man·Svにまで減少してきている。同期間中に、発電電力量（TWh）あたりの平均線量当量と同様に原子炉あたりの平均線量当量もまた年々規則的に減少してきている。これら２つの指標は過去10年間にわたって半減し、1996年は原子炉あたりで1.43man·Sv、発電電力量（TWh）あたりで 0.24man·Svに達している。その期間中、運転中の原子炉数は25%の増加があった。一方、GCRに関しては40%の減少が見られた。

上記に述べられた傾向は、ほとんどの炉型と地域について見られ、特に原子炉あたりの線量について顕著である。発電電力量あたりの平均線量当量の減少は、CANDUs（35%）よりもBWRs（約60%）の方がより顕著である。しかし、CANDUsの初期の線量レベルは非常に低かった。

1996年において、 LWGRs（RBMK）は、現在データベースでリトアニアの２基のみによって代表されているが、原子炉あたりの平均線量当量は、他の全ての炉型よりも高い(7.55man·Sv)。

原子炉数の増加にも関わらず総線量当量において減少したのは、明らかに線量低減とALARA計画の実施によるものであり、また、おそらく運転サイクルの長期化によるものである。原子炉あたりの線量と発電電力量（TWh）あたりの線量の大幅な減少は、 これらの同じ要因によるものであるが、新しい原子炉、すなわちその放射線環境が旧型の原子炉よりも改良されており、ある期間は必要な保修作業が少ない原子炉の導入もまた影響している。

燃料サイクルの長期化と燃料交換停止期間の短縮の影響は、主要事象について議論している第５章で述べられている。例えば、フランスでは「今後の発展は、燃料交換のみの停止の導入と同様に1300MWクラスでの燃料サイクルの拡大が期待される。」と報告されている。米国からの報告では、「1996年、原子力発電プラントは、燃料交換停止期間短縮と運転コスト縮小の開始に焦点を当てた。」と述べている。非常に短期間の運転停止について言及している国は他にも多く、例えばドイツのNeckar 2では、1996年の燃料交換停止は15.2日を超えなかった。

欧州のPWRに関する年間平均線量当量は、スウェーデン、 ベルギー、スイスにおいて原子炉あたり1man·Svよりも低い。 特に注目すべきなのはベルギーの1996年の結果で、全７基の原子炉が燃料交換停止をしており、また、Doel4号機では蒸気発生器の取替えが行われ、良好な結果（0.63man·Sv）であった。

1996年のISOEでの一つの大きな特徴は、線量低減のための良好な”作業管理”の効果に重点が置かれたことである。これはその年に発行された２つの刊行物によって例証される：

— 第一に、 ISOEの国際的専門家グループが報告書 ”Work Management in the Nuclear Power Industry”を発行した。 NEAはこの報告書を1200部以上販売してきた。今この報告書は数カ国語への翻訳作業過程にある。そして、

－　第二に、スペインでは、規制当局と発電事業者の間で協力して、”Management of the Optimization of the Radiation Exposure ”という題名の報告書を発行した。これは、原子力発電事業に参入している会社による組織によって考慮される一般的原則を確立することを目的としている。

被ばく低減にとって基準付けもまた一つの非常に有効な道具であるように思われる。これは特にフランスにおける場合であるが、作業レベルでの国際的放射線被ばく基準の設置は完成間近である。この作業は全ての蒸気発生器の作業と殆どの非破壊検査について1996年に実施された。基準付けはまた、特にサイト全体の線量といったより大きな線量指標においては、米国でも一般的である。

より基本的な線量低減技術もまた1996年に発展した。アメリカのPWRでは、燃料交換停止期間中に放射線区域を安定することで職業被ばく線量を低減するために、新しい炉停止時水質管理法を実施した。また、アメリカのBWRの多くは、原子炉内部の劣悪な化学環境を低減し、放射線管理区域を管理するために、水素水化学と同位体分離亜鉛注入を実施する計画を進めている。更にまた、原子炉内部の保護コーティングとしての貴金属がIowaのDuane Arnold Nuclear Energy Centerでテストされ、良好な結果であった。

これら全ての努力にも関わらず、線量の増加もいくつか生じた。例えば、スウェーデンの全BWRは現在、国家規制当局から要請された重要な近代化計画に従事している。米国の原子力発電所のいくつかでは、1996年の大半は運転停止であった。これわ長期化された保修停止（規制を解く前にプラントの材料の改良）のため、また基本的な解析の立案と運転訓練を適合させ、運転継続に優先する全ての改造工事を書類で提供するという規制当局の要請のためである。職業被ばく線量は、管理区域におけるより多くの保守作業や検査活動のために、これらのプラントにおいて増加傾向であった。

ОСНОВНЫЕ ИТОГИ

1996 год был для программы ИСПО продуктивным и успешным. В целом по состоянию на конец 1996 года базы данных ИСПО включали в себя данные о 399 реакторах (365 эксплуатируемых и 34 в состоянии холодного останова или в определенном режиме снятия с эксплуатации) из 24 стран, представляющих 71 электроэнергетическую компанию. Участниками являлись также национальные регулирующие органы 21 страны.

Ежегодная суммарная коллективная доза профессионального облучения, связанная с эксплуатируемыми реакторами, сократилась за последние десять лет с более чем 800 чел.Зв до приблизительно 500 чел.Зв (1986 по 1996 годы). За тот же период времени средняя коллективная доза на реактор и средняя коллективная доза на ТВт.ч выработанной электроэнергии также уменьшились в два раза и составили 1996 году 0,43 чел.Зв на реактор и 0,24 чел.Зв на ТВт.ч произведенной электроэнергии. За этот период времени число эксплуатируемых реакторов возросло более чем на 25%, за исключением газоохлаждаемых реакторов (ГОР), число которых сократилось на 40%.

Эти тенденции наблюдаются для большинства типов реакторов и большей части регионов, особенно в отношении коллективной дозы на реактор. Уменьшение средней коллективной дозы на единицу произведенной энергии более значительно для BWR (приблизительно на 60%) по сравнению с реакторами CANDU (35%), хотя первоначальный уровень для CANDU был весьма низким.

Следует отметить, что в 1996 году реакторы РБМК, представленные в настоящее время в базе данных лишь двумя блоками в Литве, имели более высокий средний показатель коллективной дозы на реактор, чем все другие типы реакторов (7,55 чел.Зв).

Уменьшение суммарной коллективной дозы, несмотря на растущее число реакторов, очевидным образом связано с осуществлением программ по снижению доз и программ ALARA и, возможно, также с удлинением эксплуатационных циклов. Более значительное снижение показателей дозы на реактор и на ТВт.ч произведенной электроэнергии обусловлено теми же факторами, однако оно также связано с внедрением новых реакторов, радиационная обстановка на которых улучшена по сравнению с более старыми реакторами и которые в настоящее время требуют меньшего объема технического обслуживания.

Последствия удлинения топливного цикла и сокращения длительности простоев рассматриваются в главе 5, в которой обсуждены основные события. Например, в докладе Франции указывается, что "улучшения в будущем ожидаются в результате увеличения длительности топливных циклов реакторов мощностью 1300 МВт, а также в результате введения остановов реакторов только для перегрузки топлива". В докладе Соединенных Штатов отмечается: "В 1996 году основное внимание на атомных электростанциях было сосредоточено на ... инициативах по сокращению продолжительности остановок для перегрузки топлива и снижению эксплуатационных затрат". Многие другие страны также ссылаются на весьма малую длительность остановок, как, например, в Германии на блоке "Некар 2", где продолжительность остановок для перегрузки топлива в 1996 году составила лишь 15,2 дня.

Средние годовые коллективные дозы для европейских PWR в Швеции, Бельгии и Швейцарии составили менее 1 чел.Зв на реактор. Особенно следует отметить результаты в 1996 году в Бельгии, где на всех семи реакторах имели место остановы для перегрузки топлива, а операция замены парогенератора на блоке "Доэль 4" была проведена с отличными дозиметрическими результатами (0,63 чел.Зв).

Одной из главных характеристик 1996 года в ИСПО является внимание, уделяемое влиянию качественного "управления работами" на снижение доз. Это иллюстрируется двумя публикациями, выпущенными в течение этого года:

- во-первых, международная группа экспертов, работавшая в рамках ИСПО, закончила работу над докладом *"Управление работами в ядерно-энергетической промышленности"*. АЯЭ распродало свыше 1200 экземпляров этого доклада, который в настоящее время переводится на ряд языков; и
- во-вторых, в Испании компетентными органами и энергокомпаниями подготовлен совместный доклад, озаглавленный *"Управление оптимизацией доз облучения"* и устанавливающий общие принципы, которые должны соблюдаться компаниями в ядерно-энергетической промышленности.

Проведение эталонных тестов также, по-видимому, является весьма эффективным средством снижения облучения. Это особенно четко проявляется во Франции, где подходит к завершению разработка комплекса национальных исходных данных для сравнительной оценки облучения на уровнях операций. Эта работа была выполнена в 1996 году для всех работ, связанных с парогенераторами, и для большинства неразрушающих испытаний. Эталонные тесты, по-видимому, также весьма популярны в Соединенных Штатах, особенно в отношении более глобальных индикаторов дозы, таких, как суммарная доза на площадке.

В течение 1996 года были также улучшены более классические методы снижения дозы: на американских PWR осуществлены новые протоколы водно-химического режима при останове в целях снижения дозы профессионального облучения путем стабилизации радиационных полей при остановах для перегрузки топлива, и на многих американских BWR ускоряются планы реализации водородного водно-химического режима и инжекции обедненного цинка в целях снижения воздействия неблагоприятной химической среды на внутренние компоненты реакторов и для контроля радиационных полей. Кроме того, в Ядерно-энергетическом центре Дьюэйна Эрнольда в штате Айова были проведены с многообещающими результатами испытания благородных металлов в качестве защитного покрытия внутренних компонентов реакторов.

Несмотря на все эти усилия, имели также место случаи увеличения доз; например, по требованию национальных компетентных органов на всех шведских BWR осуществляются в настоящее время значительные программы модернизации. Некоторые американские атомные электростанции в течение значительной части 1996 года были остановлены на длительное техническое обслуживание (улучшение состояния материально-технической части станции перед отменой регламентационных ограничений) и в связи с регулирующими требованиями согласовать эксплуатационную практику с данными анализа проектной основы и документировать все изменения перед повторным запуском. На этих станциях имелась тенденция к увеличению доз профессионального облучения в связи с большим объемом инспекционных работ и работ по техническому обслуживанию в контролируемых зонах.

RESUMEN EJECUTIVO

El año 1996 ha sido productivo y de considerable éxito para el Programa ISOE. A finales del año, las bases de datos de ISOE contenían un total de 399 reactores (365 en operación y 34 en parada fría o en alguna etapa de clausura), correspondientes éstos a 24 países y a 71 empresas propietarias. También han participado los organismos reguladores nacionales de 21 países.

La exposición colectiva profesional anual total correspondiente a reactores en operación viene reduciéndose a lo largo de los últimos diez años (de 1986 a 1996), pasando de 800 hombre/Sievert a aproximadamente 500. Durante este mismo período se han reducido de forma sostenida, de un año al siguiente, tanto la dosis colectiva media por reactor como la dosis colectiva media por TWh producido; estos dos indicadores se han reducido por un factor dos en los últimos diez años, alcanzándose en 1996 las cifras de 1,43 hombre/Sievert por reactor y 0,24 hombre/Sievert por TWh producido.

Durante este período el número de reactores en operación ha aumentado entre un cuarto y un tercio, con la excepción de los reactores refrigerados por gas, donde se ha observado una reducción del 40%. Las tendencias descritas anteriormente se pueden observar para la mayoría de los distintos tipos de reactores y regiones, particularmente en lo relativo a la dosis por reactor. La reducción de la dosis colectiva media por unidad de energía producida es más significativa en el caso de los reactores BWR (aproximadamente el 60%) que en el de los de tipo CANDU (35%), si bien es cierto que el nivel inicial para los CANDU era muy bajo.

Conviene subrayar que en 1996 los reactores de tipo LWGR (RBMK), representados actualmente en la base de datos por sólo las dos unidades de Lituania, tienen una dosis colectiva media por reactor más alta que ningún otro tipo de reactor (7,55 hombre/Sievert).

La reducción de la dosis colectiva total, pese al creciente número de reactores, se debe evidentemente a la implantación de programas de reducción de dosis y ALARA, y quizá también al alargamiento de los ciclos de operación. La mayor reducción de la dosis por reactor y por TWh producido se debe a estos mismos factores, aunque también guarda relación con la introducción de nuevos reactores cuyas condiciones radiológicas se ha mejorado con respecto a los reactores más antiguos y que requieren, hasta la fecha, menos trabajos de mantenimiento.

El impacto del alargamiento del ciclo de combustible y de la reducción de la duración de las paradas se subraya en el capítulo 5, que se refiere a los sucesos más importantes. Por ejemplo, y refiriéndose a Francia, el informe dice que "Se esperan mejoras en el futuro debidas a la extensión de los ciclos de combustible de las centrales de 1300 MW y a la introducción de paradas sólo para la recarga de combustible". El informe de Estados Unidos manifiesta que "En 1996, las centrales nucleares se centraron en ... iniciativas para reducir la duración de las paradas para recarga de combustible y los costes de operación". Otros muchos países se refieren a paradas muy cortas, como por ejemplo en la central alemana de Neckar 2, donde la recarga de combustible duró tan sólo 15,2 días en 1996.

Las dosis colectivas anuales medias correspondientes a las centrales PWR europeas son inferiores a 1 hombre/Sievert en Suecia, Bélgica y Suiza. Particularmente llamativos son los resultados belgas para 1996, donde los 7 reactores han experimentado paradas para la recarga del combustible, y se cambiaron los generadores de vapor de Döel 4, con excelentes resultados dosimétricos (0,63 hombre/Sievert).

Una de las principales características de 1996 en el marco de ISOE ha sido el énfasis puesto en el impacto de una "buena gestión del trabajo" en la reducción de las dosis. Esto viene reflejado por dos publicaciones emitidas ese año:

- primero, un Grupo de Expertos internacionales trabajando en el seno de ISOE ha publicado el informe La Gestión del Trabajo en la Industria Nuclear. La AEN ha vendido más de 1 200 copias de este informe, que se está traduciendo actualmente a varios idiomas; y

- segundo, en España se ha elaborado conjuntamente por el Organismo Regulador y las centrales nucleares un informe titulado: La Gestión de la Optimización de la *Exposición a las Radiaciones*, con el fin de establecer los principios generales a considerar por las organizaciones de las empresas participantes en la operación de centrales nucleares.

El Benchmarking también parece una herramienta muy eficaz para la reducción de las exposiciones. Esto ha sido particularmente evidente en Francia, donde está a punto de finalizarse un conjunto nacional de referencias en materia de exposición a las radiaciones para los distintos puestos de trabajo. Esta labor se ha llevado a cabo durante 1996 para todos los trabajos a realizar en los generadores de vapor y para la mayoría de los ensayos no destructivos. Estas referencias también parecen ser muy utilizadas en los Estados Unidos, particularmente en términos de indicadores de dosis más globales, tales como la dosis total para el emplazamiento.

Las técnicas de reducción de dosis más clásicas también han mejorado durante 1996: las centrales PWR estadounidenses han implantado nuevos procesos químicos para condiciones de parada, con el fin de reducir la dosis profesional mediante la estabilización de los campos radiológicos durante las recargas de combustible, y muchas centrales BWR americanas están acelerando sus planes de implantar una química del agua basada en el hidrógeno e inyecciones de zinc empobrecido para reducir los entornos químicos adversos para las partes internas del reactor y controlar los campos de radiación. Asimismo, se ha ensayado el uso de metales nobles como revestimiento protector de las partes internas del reactor en el Centro de Energía Nuclear Duane Arnold, en Iowa, con resultados prometedores.

A pesar de todos estos esfuerzos, se han producido algunos aumentos de dosis, particularmente por ejemplo en todas las centrales BWR suecas, que realizan actualmente programas significativos de modernización, exigidos por las Autoridades Nacionales. Muchas centrales estadounidenses estuvieron paradas durante gran parte de 1996 para trabajos de mantenimiento (mejoras en la condición material de las instalaciones previas a la desregulación) y como consecuencia de requisitos reguladores para acomodar las prácticas operativas con los análisis de base de diseño y documentar todas las modificaciones antes de continuar en operación. En estas centrales ha habido una tendencia al aumento de las dosis profesionales, debido a un mayor número de actividades de mantenimiento e inspección en zonas controladas.

Chapter 1

NEA/IAEA INFORMATION SYSTEM ON OCCUPATIONAL EXPOSURE - ISOE

1.1 The ISOE System during 1996

The year 1996 was a productive and successful one for the ISOE Programme. Participation continued to expand, steps were taken to significantly improve the software used to access occupational exposure data, and a major report on the impact of work management on occupational exposure was issued.

The participants in the ISOE Programme are grouped into four "regions". Originally, these were geographically defined, and included North America, Europe and Asia. After one year of operation of the Programme, however, the IAEA agreed to act as co-sponsor, allowing the participation of authorities and utilities from non-NEA Member countries. These participants then, became the ISOE Programme's fourth "region". The North American region includes Canada, Mexico and the United States of America. The Asian region is comprised of Japan and Korea. The European region consists of all European countries with light water nuclear power plants (Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom). It should be noted that, since the co-sponsorship of the Programme by the IAEA, three countries, Czech Republic, Hungary and Mexico, have become Members of the NEA, thus shifting from the IAEA region to the European region. The IAEA region thus now consists of seven countries: Brazil, China, Lithuania, Romania, Slovak Republic, Slovenia and South Africa. In total, as of the end of 1996, the ISOE databases included information from 399 reactors (365 operating and 34 in cold-shutdown or some form of decommissioning) from 24 countries, representing 71 utilities. National regulatory authorities from 21 countries were also participants. Co-operation with the EC and with WANO also coninues to be a useful addition to the ISOE Programme

During 1996, it was agreed by the ISOE Steering Committee that access to ISOE data, particularly the NEA 1 database containing occupational exposure information, should be improved and modernised. The ISOE Sub-Group on Data Analysis and Technical Guidance was thus charged with overseeing this improvement. The result, attained in early 1998, is that the NEA 1 database is now available in a Microsoft ACCESS environment, and it is planned to move the other two ISOE databases to ACCESS.

One of the most important contributions of ISOE to its users during 1996 was the publication of the report, *Work Management in the Nuclear Power Industry*. This report, prepared by the Expert Group on the Impact of Work Management on Occupational Exposure, has, since its publication, sold over 1 200 copies, and has been a great success among operational radiation protection and outage maintenance personnel, as well as among regulators. The complete approach to the application of work management principles presented in the report, each phase of which is illustrated by numerous hands-on case studies, has proven to be very useful at helping to shorten maintenance outages thus reducing doses and operational costs.

1.2 Characteristics of the ISOE Database

1.2.1 Introduction

In this sixth year of ISOE operation, data for 1996 has been collected for 24 countries. As of the end of 1996, the ISOE database included 399 operating reactors, representing 83% of the operating reactors in the world. The reactor types included in the ISOE database are BWR[1], PWR[2], GCR[3], LWGR[4] and CANDU[5]. This report describes the evolution of the occupational exposure over the last ten years (1986-1996). The data from 1969 to 1985 have been omitted in this report, but are in the database now available on computer diskettes for the users to perform their own analyses.

1.2.2 Characteristics of reactors in operation

The 365 operating reactors (PWR, BWR, CANDU, LWGR and GCR) in the ISOE database as of the end of 1996 included 352 in NEA Member countries and 13 in non-NEA Member countries.

The participation of Lithuania, who joined the Programme during 1996, added a new type of reactor, the LWGR (RBMK) reactors, to the database.

In 1996, the PWR programme had by far the highest number of operating reactors in the ISOE participating countries representing 59% of the total number of reactors, while the BWRs, the GCRs, the CANDUs and the LWGRs represented 24.5%, 10%, 6% and 0.5% respectively.

Nuclear power plant operating experience in the ISOE database has reached, as of the end of 1996, 5791 reactor years. The average age per reactor is 15.9 years (Table 1). Obviously, the average age per type of reactor and per region reflects the previous evolution of the numbers of reactors of the various types. Therefore, GCRs are on average older than PWRs, BWRs, LWGRs and CANDUs. Due to the total number of reactor years of experience, one has to keep in mind that the weight of the large nuclear programmes in the USA, France, Germany, United Kingdom and Japan will have a major influence on trends in total and average collective dose.

---

[1] BWR = Boiling Water Reactor

[2] PWR = Pressurized Water Reactor

[3] GCR = Gas Cooled Reactor

[4] LWGR = Ligth Water cooled Graphite Reactor

[5] CANDU = CANadian Deuterium Uranium

Table 1 Characteristics of reactors operating during 1996 (included in the ISOE database)

Regions	Number of operating reactors	Years of operating experience	Mean age per operating reactor
PWR			
Europe	100	1355	13.6
Asia	33	433	13.1
North America	72	1178	16.4
IAEA	11	119	10.8
All regions	216	3085	14.3
BWR			
Europe	22	390	17.7
Asia	28	388	13.9
North America	39	679	17.4
All regions	89	1457	16.4
GCR			
Europe	34	866	25.5
Asia	1	31	31.0
All regions	35	897	25.6
LWGR			
IAEA	2	23	11.5
All regions	2	23	11.5
CANDU			
Asia	1	14	14.0
North America	22	315	14.3
All regions	23	329	14.3
All types of reactors	**365**	**5791**	**15.9**

1.2.3 Characteristics of reactors definitively shutdown

Table 2 shows the number of definitively shutdown reactors as of 1996 in NEA countries, the corresponding number of years of experience since plant shutdown, and the mean age per reactor at time of shutdown. Based on the 34 shutdown reactors included in the ISOE database, we can see that the GCRs have operated on average longer (22.1 years) than the CANDUs (20 years), PWRs (18.9 years) and BWRs (12.7 years) before being shut down.

Note that in most cases, these reactors had ceased operation for some time prior to the decision being made for their definitive shutdown. In the ISOE database, these pre-decision years of zero production are included in the years of shutdown experience, and are thus not taken into account when calculating mean age per reactor at time of shutdown.

Table 2 Characteristics of definitively shutdown reactors during 1996
(included in the ISOE database)

Regions	Number of reactors definitively shutdown	Years of shutdown experience	Mean age per reactor at time of shutdown
PWR			
Europe	2	14	24.0
North America	6	53	17.2
All regions	8	67	18.9
BWR			
Europe	5	68	11.8
North America	4	53	13.8
All regions	9	121	12.7
GCR			
Europe	14	109	22.8
North America	1	7	13.0
All regions	15	116	22.1
CANDU			
North America	2	22	20.0
All regions	2	22	20.0
All types of reactors	**34**	**326**	**18.7**

Chapter 2

ANNUAL TOTAL COLLECTIVE DOSE

2.1 NEA Trends for reactors in operation

The evolution of total collective dose is presented in Figures 1, 2 and 3. The annual total collective dose has been decreasing through the 1986-1996 period. In spite of the growth in the number of reactors, the implementation of dose reduction programmes has lead to decreases in collective dose.

The reduction of total collective dose since 1986 can be seen for each region and for each reactor type. The largest fraction of this decrease, however, is the result of a decrease of the annual collective doses in the North American and European regions where the largest fractions of ISOE-participating reactors are located.

2.2 1996 in ISOE participating Countries

North America accounts for 46% of the 1996 ISOE participating Countries total collective dose, Europe for 35%, Asia for 15% and ISOE participating Non-NEA Countries for 4% (Figure 4). In 1996, PWRs represent 54% of the total collective dose for all reactors, while the BWRs, CANDUs, LWGRs and the GCRs represent, respectively, 38%, 3%, 3% and 2% (Figure 5).

Figure 1

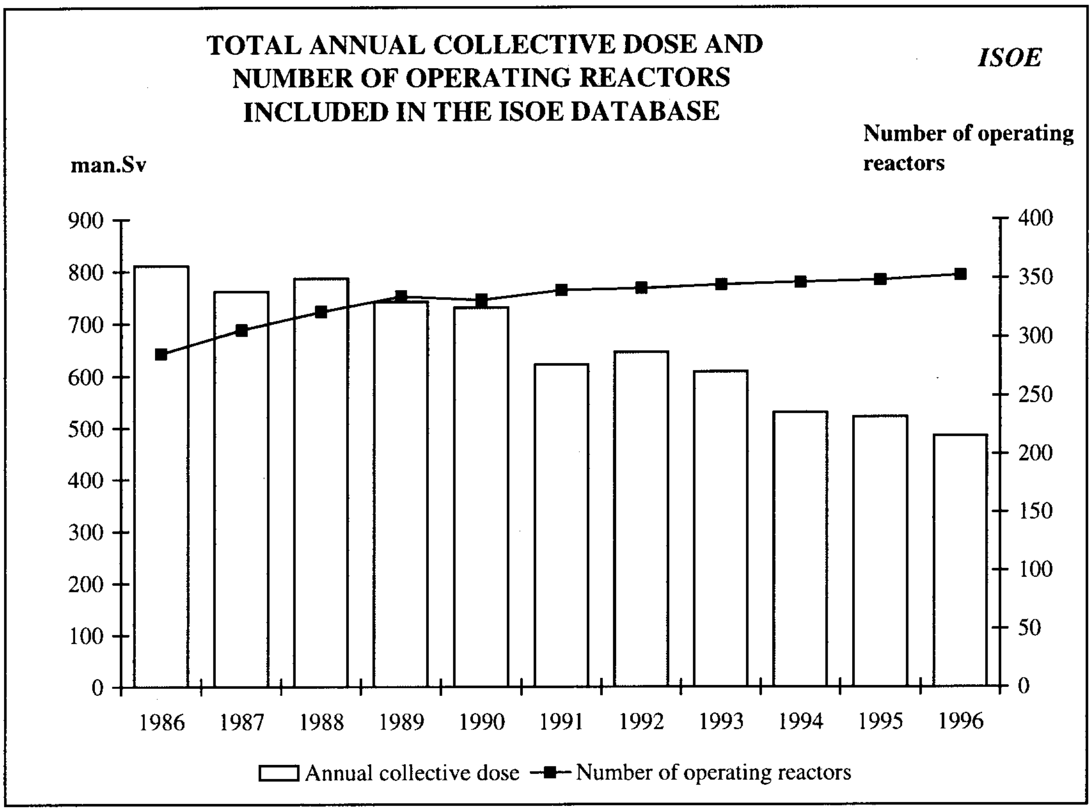


Figure 2

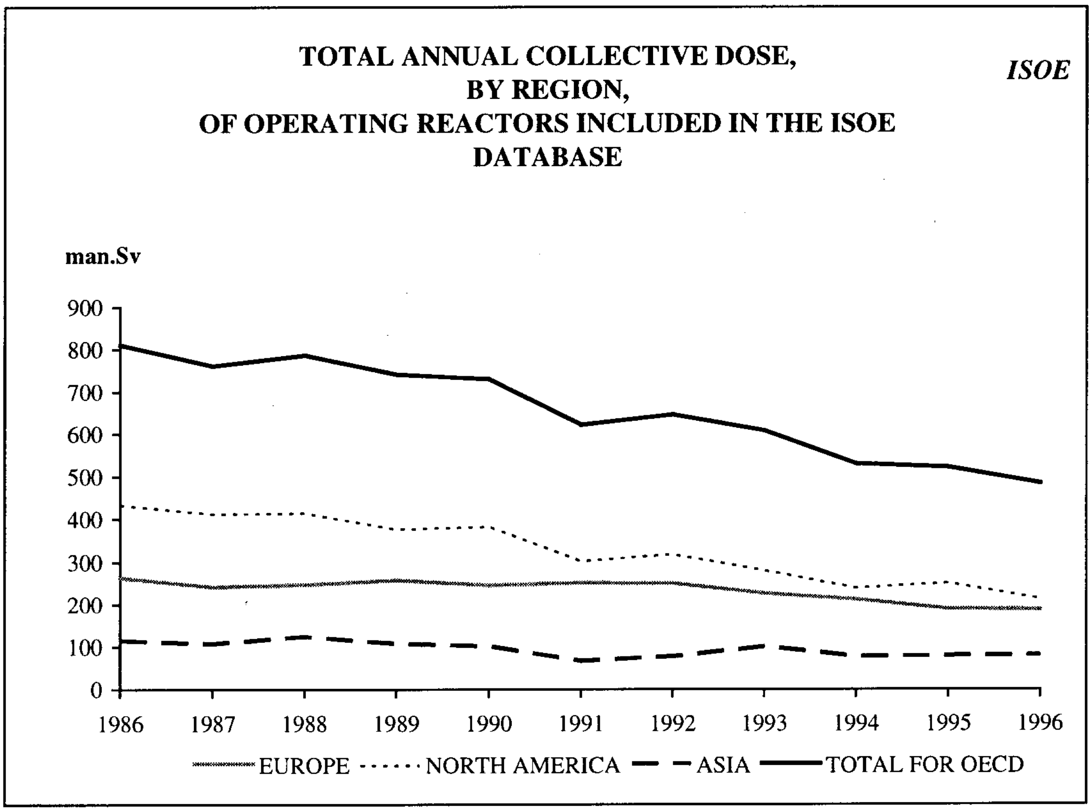
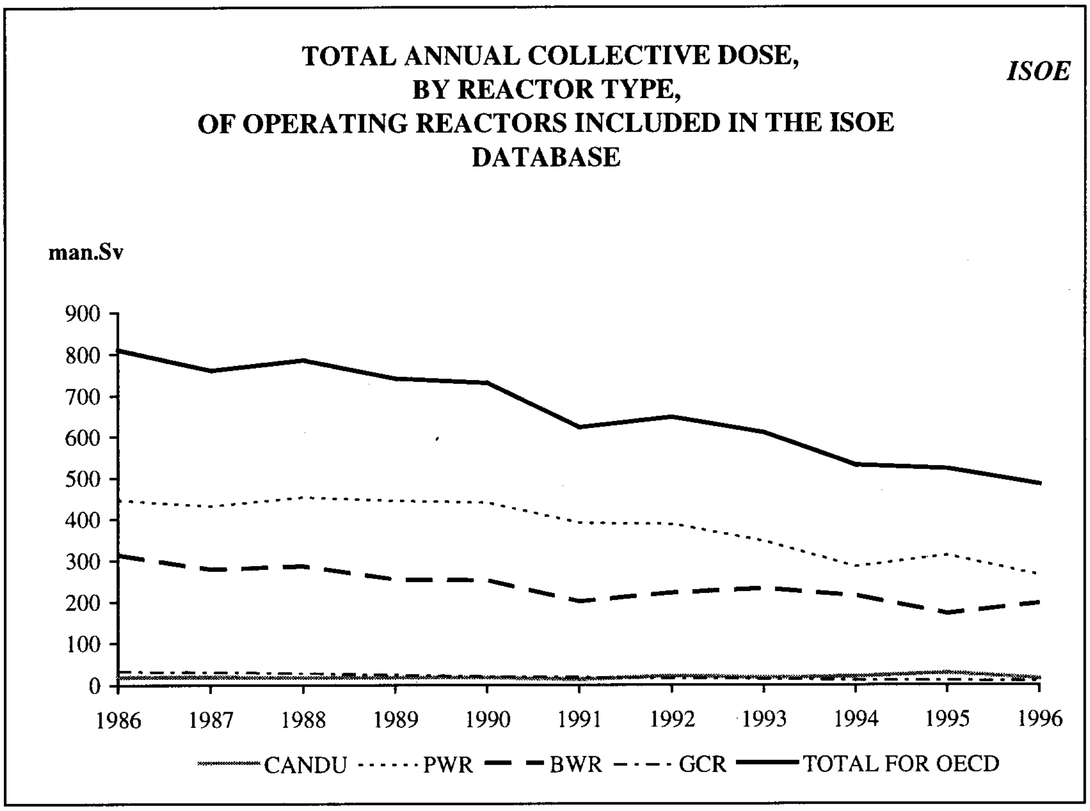
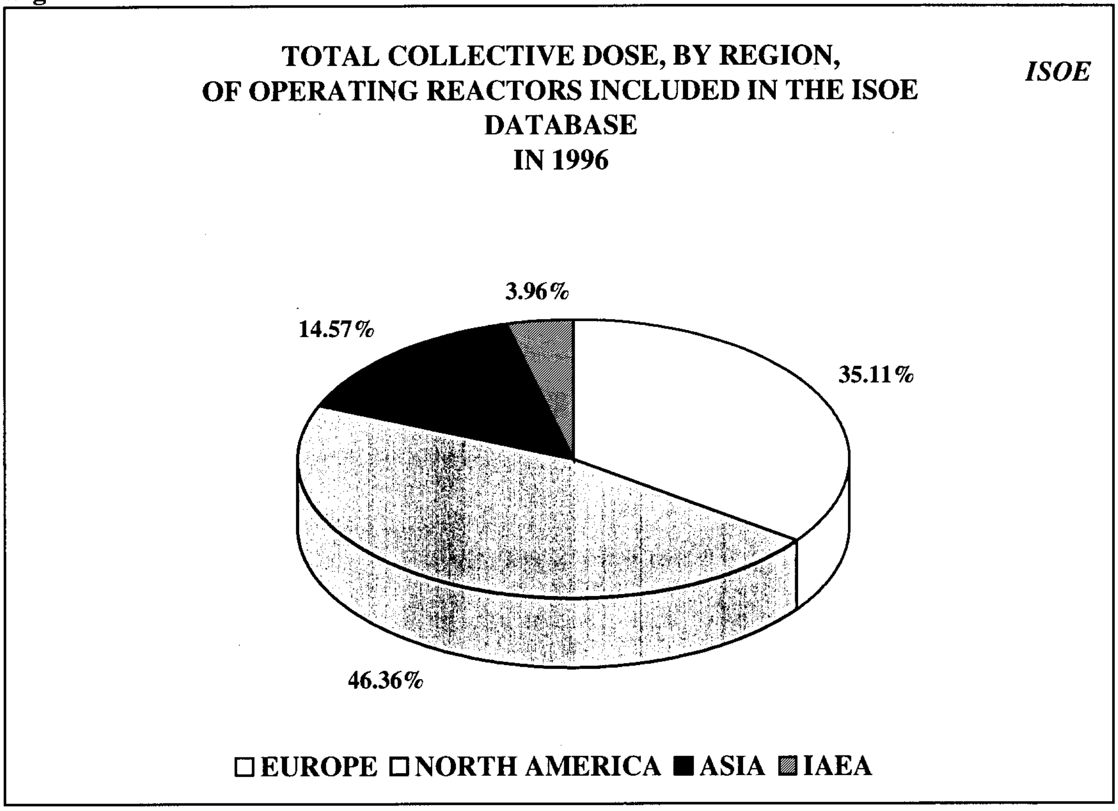


Figure 3



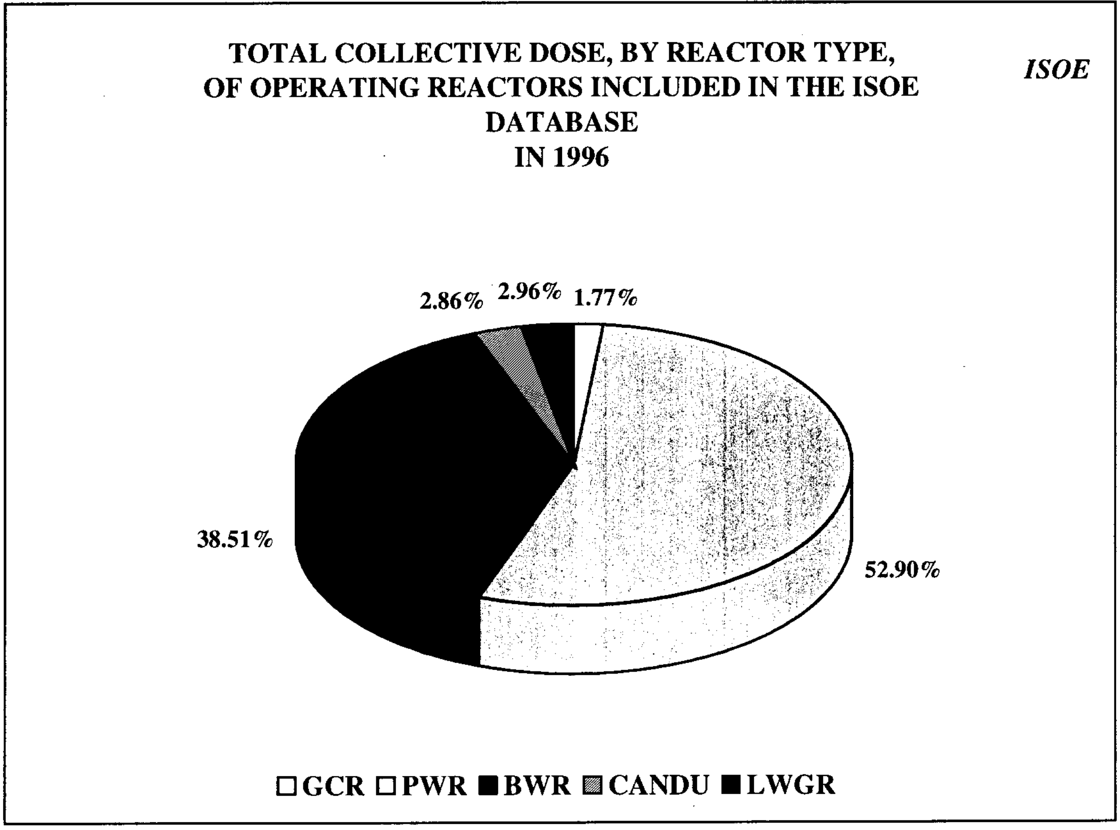
TOTAL ANNUAL COLLECTIVE DOSE, BY REACTOR TYPE, OF OPERATING REACTORS INCLUDED IN THE ISOE DATABASE

Figure 4



TOTAL COLLECTIVE DOSE, BY REGION, OF OPERATING REACTORS INCLUDED IN THE ISOE DATABASE IN 1996

Figure 5



TOTAL COLLECTIVE DOSE, BY REACTOR TYPE, OF OPERATING REACTORS INCLUDED IN THE ISOE DATABASE IN 1996

ANNUAL COLLECTIVE DOSE PER TWH

Table 3 gives the value of the collective dose per unit of gross electric energy produced for the year 1996 by reactor type and by ISOE region. The annual collective dose per TWh has continued to decrease since the last five years, to reach a value of the annual collective dose per TWh of 0.24 in 1996 corresponding to a decrease of 8% as compared with 1995. For BWRs, the ratio increases by 12% in 1996 as compared to 1995. The new type of reactor included in the ISOE database, the Light water graphite-moderated reactors are characterised by a dose to electricity output ratio higher than the other types of reactors, nearly 4.5 times higher than the average ratio for the other four types of reactors in the ISOE database. The evolution of collective dose per unit of electricity produced by region and by reactor type is given in Figures 6 and 7. It can be noticed that the trend for LWGRs does not appear in Figure 7 because historical data for Lithuania were not available at the moment of the ISOE Annual Report elaboration.

Table 3 Annual collective dose per TWh by reactor type and by region in 1996
(in man.Sv/TWh)

Region	BWR	PWR	GCR	CANDU	LWGR	ALL TYPES
Asia	0.26	0.17	0.37	0.62	/	0.22
Europe	0.31	0.20	0.10	/	/	0.21
IAEA	/	0.23	/	/	1.07	0.43
North America	0.49	0.19	/	0.12	/	0.27
TOTAL	0.37	0.20	0.10	0.15	1.07	0.24

Figure 6

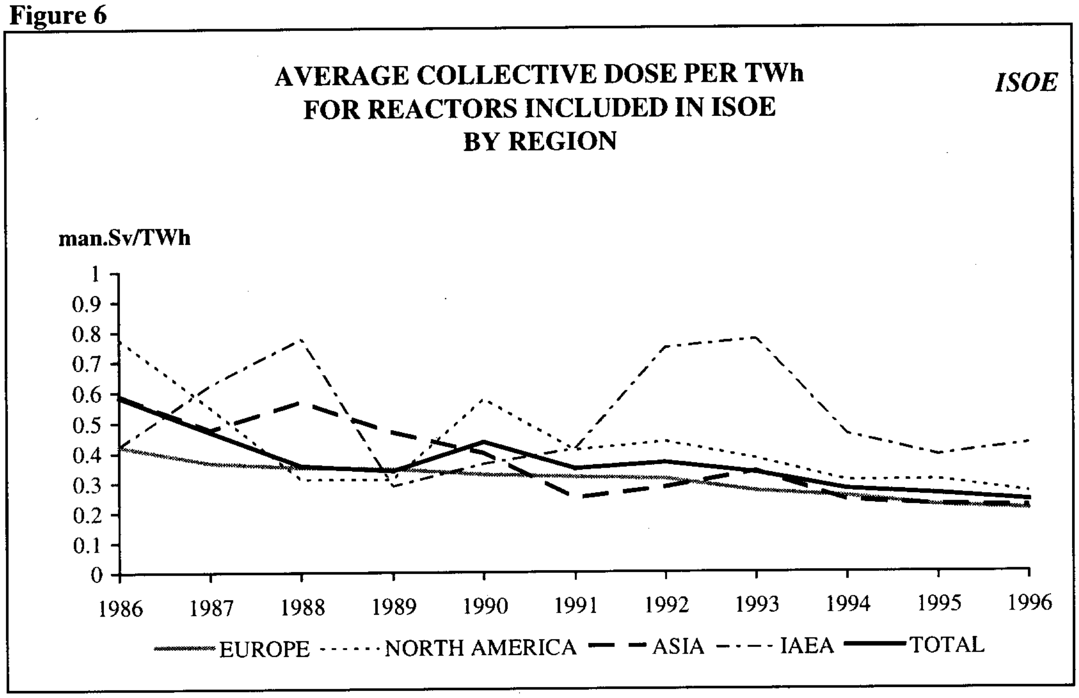
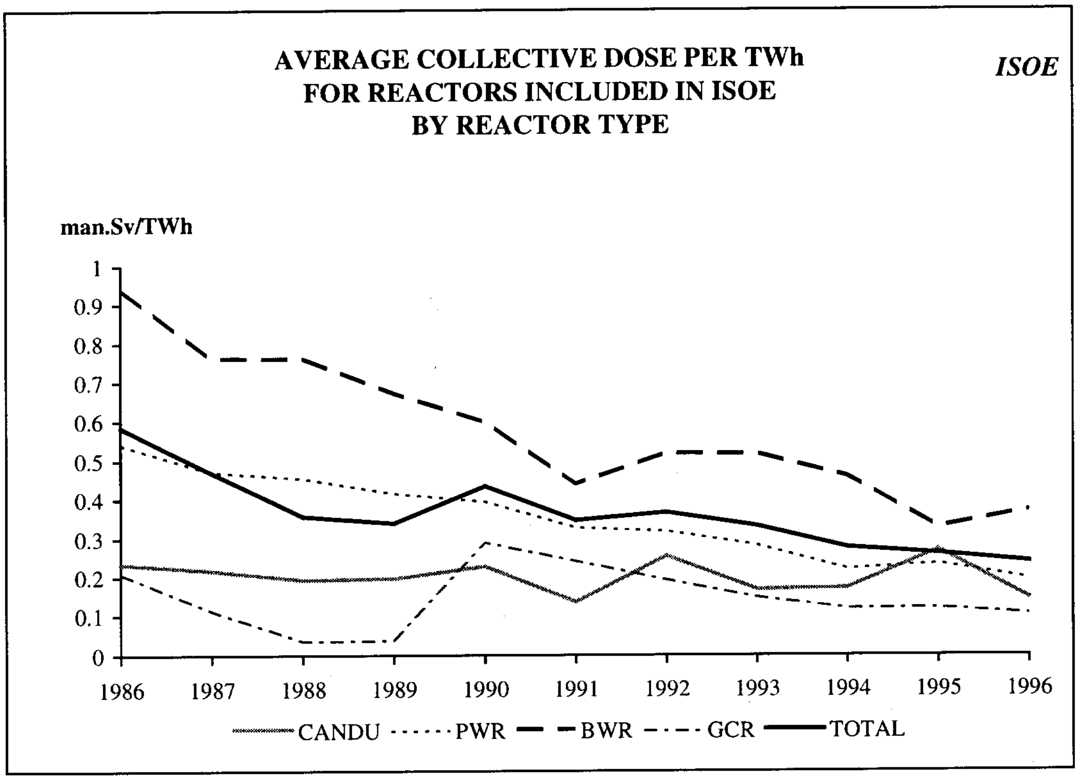


Figure 7



Chapter 4

AVERAGE ANNUAL COLLECTIVE DOSE PER REACTOR

4.1 Evolution by region and by reactor type

The evolution of annual average collective dose per reactor by region and by reactor type from 1986 to 1996 are graphically displayed in Figures 8 and 9.

Regarding average doses data presented in this report, it should be noted that the shifting of countries from the IAEA Region to other regions, as countries that have joined the NEA, will result in average values changing from year to year for the affected regions. This means that average values may change from one year to the next. This is particularly the case for the year 1996 with the addition of Lithuania, operating LWGRs, in this region. The increase of collective dose per reactor for the IAEA region in Figure 8 is mainly due to Lithuania, which has a total collective dose of 15.10 man.Sv for two reactors. All other ISOE Regions have a decreasing trend.

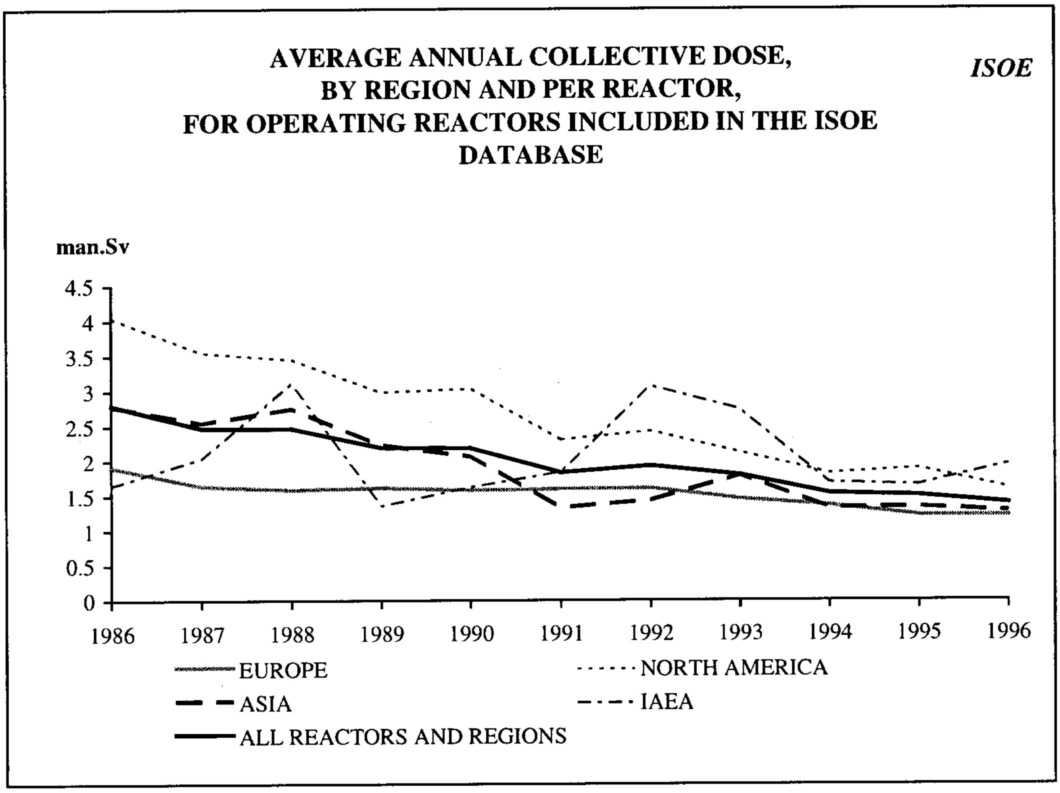
The occupational exposure of PWR, BWR and GCR reactors has also a decreasing trend since 1991.

A significant difference still exists between the regions by type of reactors (Table 4). Figures 10, 11, 12 and 13 show the evolution of the collective dose per reactor in the various regions. The lowest annual collective dose per reactor during the period of this report, from 1986 to 1996, was for GCRs.

Table 4 Average annual collective dose per reactor by type and by region in 1996 (in man.Sv)

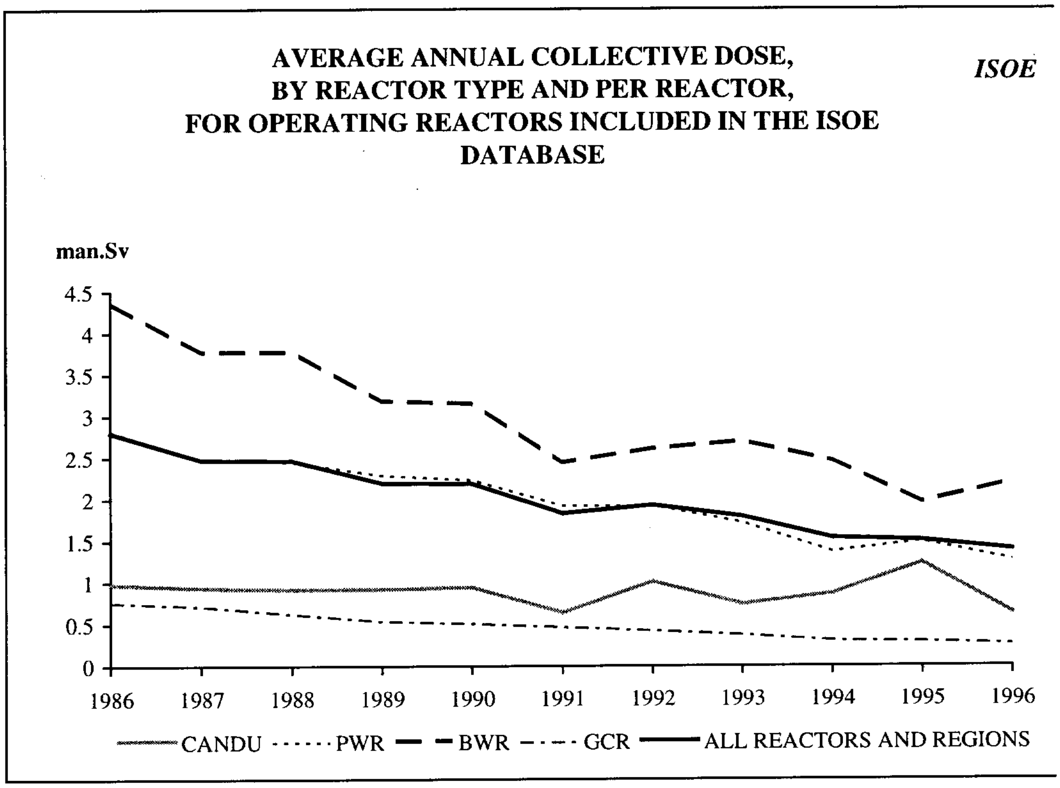
Region	BWR	PWR	GCR	CANDU	LWGR	ALL TYPES
North America	2.80	1.30	/	0.53	/	1.61
Asia	1.60	0.99	0.39	2.99	/	1.28
Europe	1.92	1.38	0.24	/	/	1.21
IAEA	/	0.94	/	/	7.55	1.95
Total	2.21	1.27	0.26	0.63	7.55	1.40

Figure 8



AVERAGE ANNUAL COLLECTIVE DOSE, BY REGION AND PER REACTOR, FOR OPERATING REACTORS INCLUDED IN THE ISOE DATABASE

Figure 9



AVERAGE ANNUAL COLLECTIVE DOSE, BY REACTOR TYPE AND PER REACTOR, FOR OPERATING REACTORS INCLUDED IN THE ISOE DATABASE

Figure 10

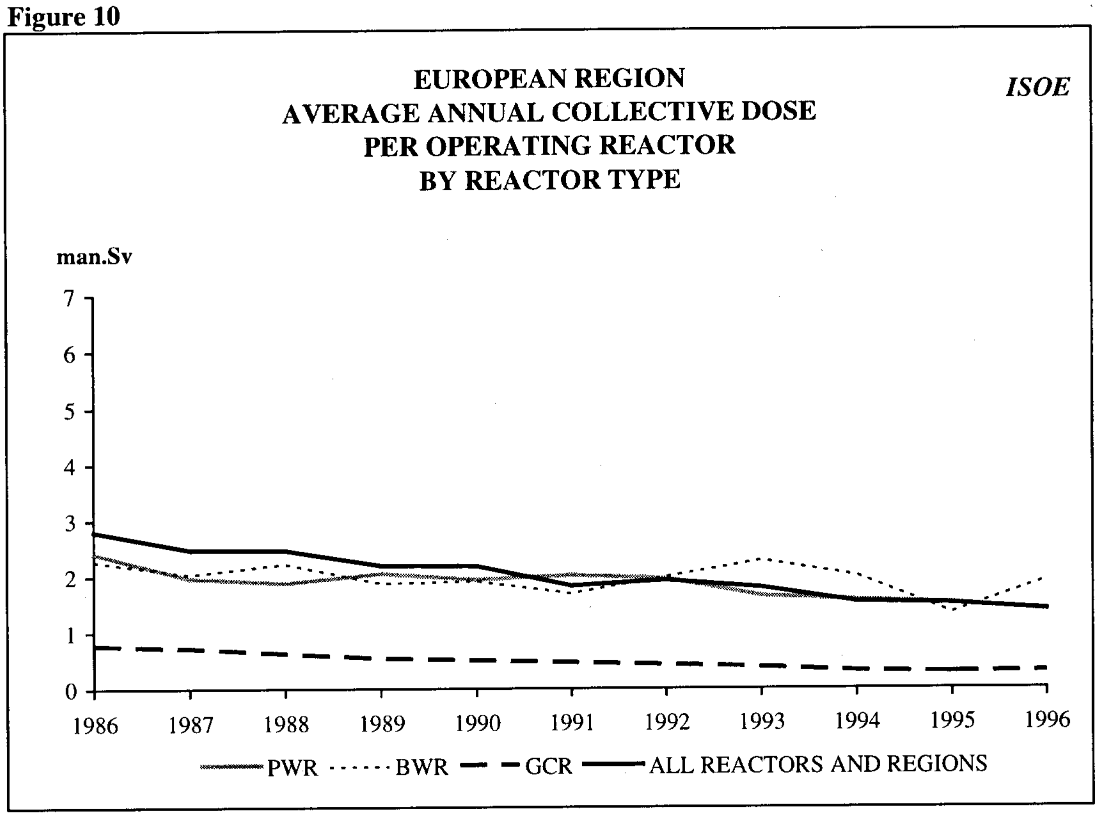


Figure 11

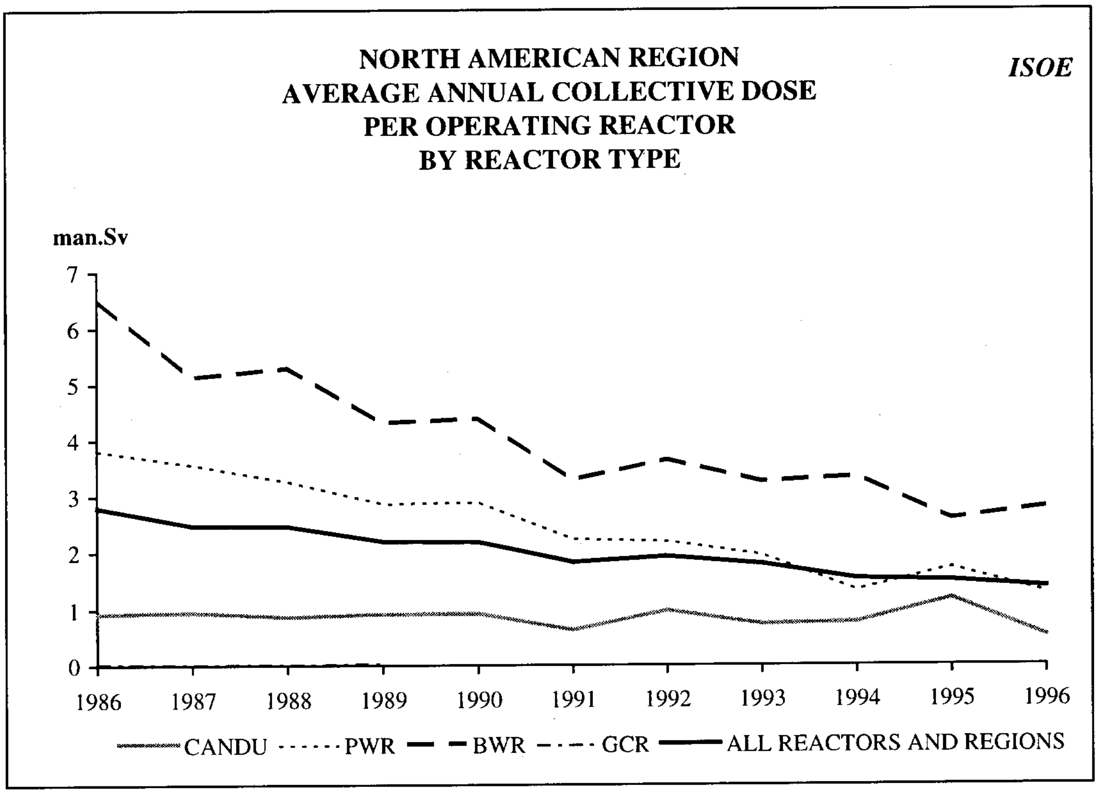


Figure 12

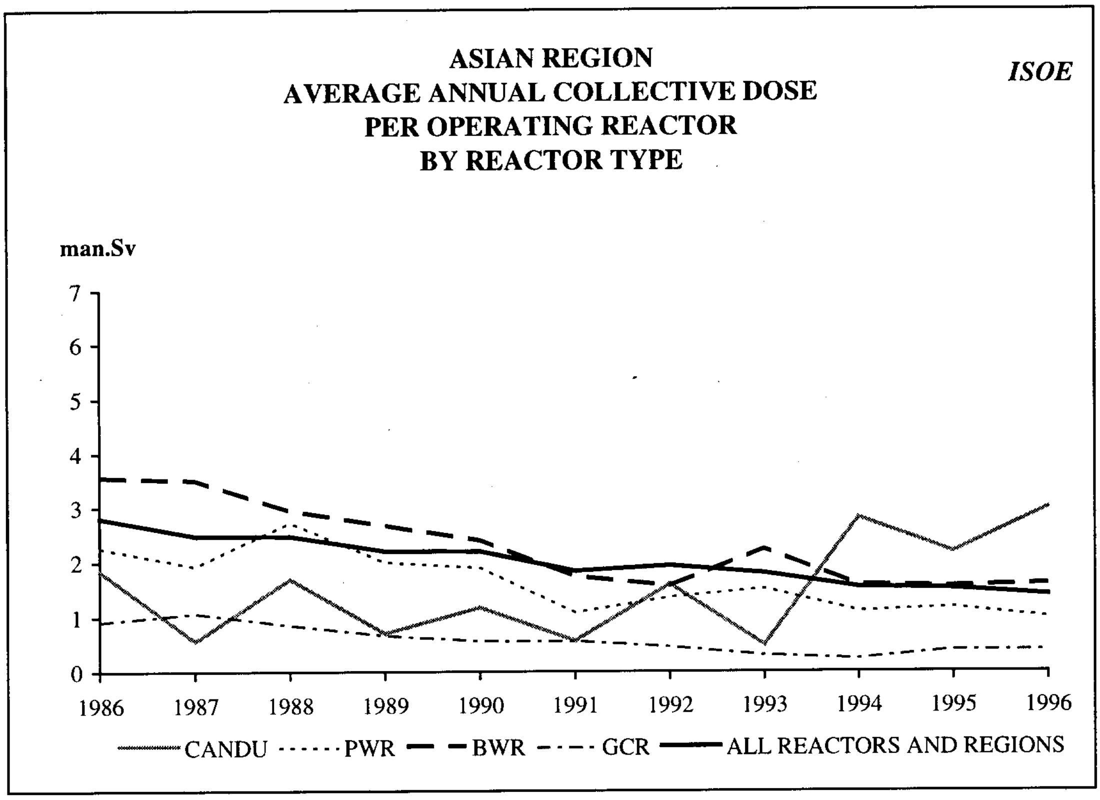
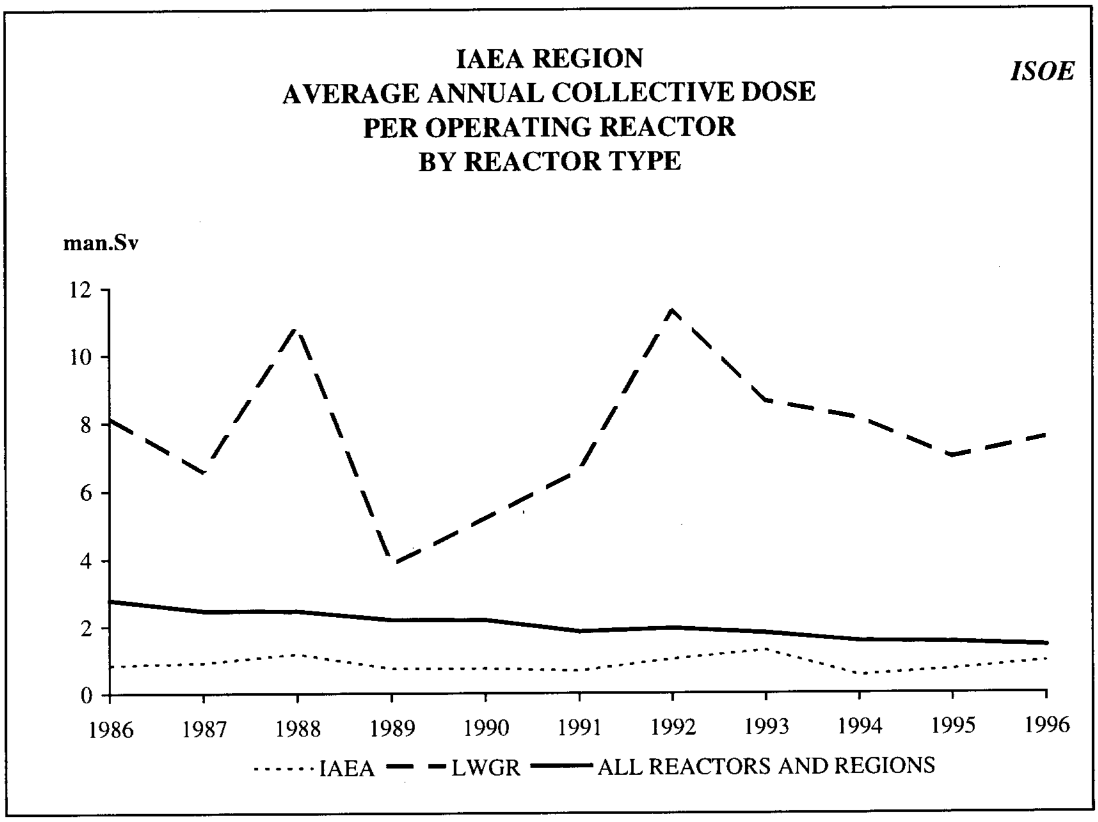


Figure 13



4.2 Evolution by country for operating reactors

The 1996 average annual collective dose per reactor for PWRs, BWRs, GCRs, CANDUs and LWGRs in the different countries under study are presented in Table 5. Figures 14 to 25 show the evolution of the average exposure per reactor by type of reactor for each country. Generally speaking for countries with a significant number of reactors, the average collective doses for BWRs are higher than those for PWRs, GCRs and CANDUs.

In some countries, average annual collective doses per reactor increased significantly during 1996. This can be seen for CANDU reactors in Korea; for PWRs in Finland, Hungary, Brazil, South Africa, Slovak Republic and Slovenia, and for BWRs in Finland, Mexico, Spain and Sweden. In all other participating countries, average annual collective doses per reactor remained stable or decreased during 1996. Chapter 5 discusses some of the reasons behind these dose increases and decreases.

Since 1994, European PWR average annual collective doses have been lower than 1 man.Sv in Sweden, Belgium and Switzerland. Particularly notable are the results in 1996 in Belgium, where all 7 reactors have had a refueling outage, and a steam generator replacement occurred at Doel 4 with excellent dosimetric results (0.63 man.Sv).

The increase of European BWR average collective dose is mainly due to increases in Spain and in Sweden. The results in Spain, operating a small number of reactors, are impacted by the number of reactors which have had a refueling outage: in 1996, the 2 BWRs have had an outage (none in 1995). In Sweden, the increase is due to the increase of safety requirements (material testing) for Barsebäck 1 and 2, and modernising projects for Oskarshamn 2. It is important to note that, for the past few years, all Swedish BWRs are concerned by significant modernising programmes requested by the National Authorities and that, other modernising projects are currently in the planning stage and will be implemented in the near future.

In the United States, collective doses have been decreasing for both PWR and BWR. This is particularly noticeable for American PWRs, where the average annual collective dose per reactor has dropped 25% from 1995 to 1996.

It should be noted that in 1996, LWGRs (RBMK), that are for the moment only corresponding in the data base to the units located in Lithuania, have an average collective dose per reactor higher than for the other types of reactor (7.55 man.Sv).

Table 5 Average annual collective dose per operating reactor by type for a number of countries in 1996 (in man.Sv)

Country	PWR	BWR	CANDU	GCR	LWGR
Belgium	0.92				
Brazil	1.34				
Canada			0.53		
China	0.74				
Czech Republic	0.36				
Finland	1.32	0.84			
France	1.59				
Germany	1.66	1.43			
Hungary	0.63				
Japan	1.04	1.60		0.39	
Korea	0.88		2.99		
Lithuania					7.55
Mexico		8.08			
Netherlands	1.11	0.99			
Slovak Republic	0.68				
Slovenia	1.79				
South Africa	1.11				
Spain	1.47	3.36			
Sweden	0.66	2.33			
Switzerland	0.71	1.68			
United Kingdom	0.53			0.25	
USA	1.30	2.52			

Figure 14

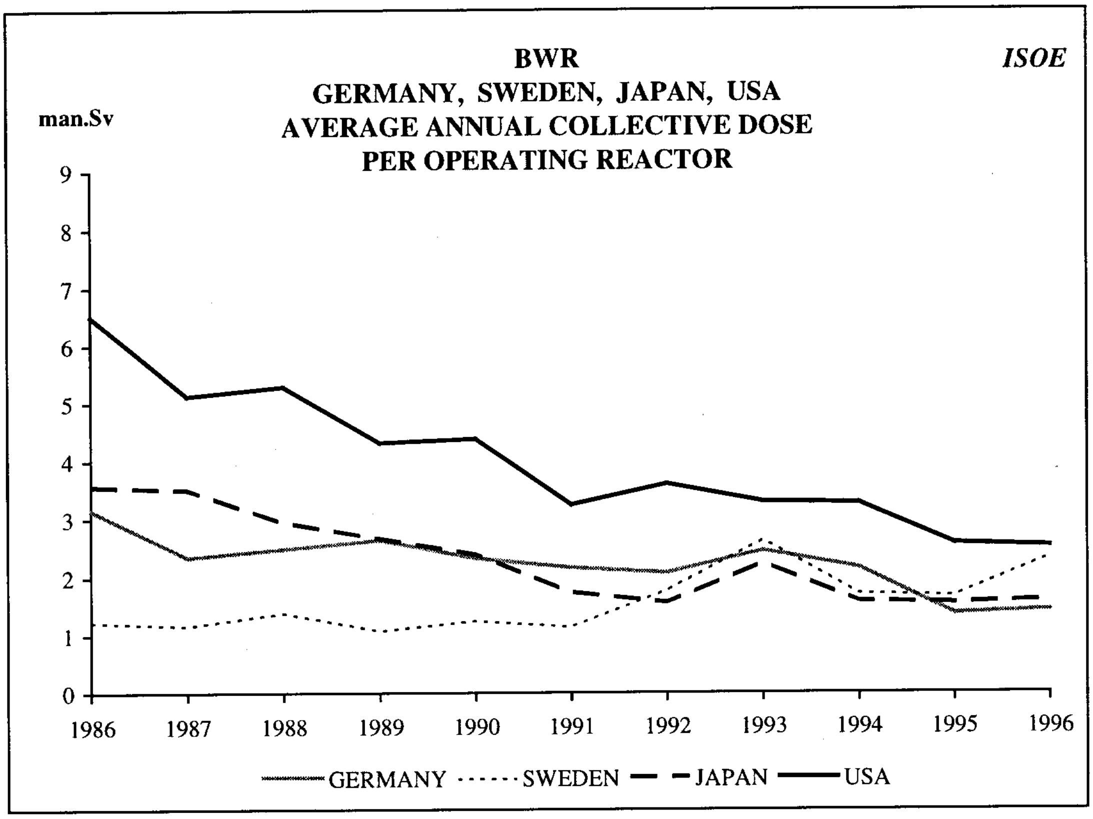


Figure 15

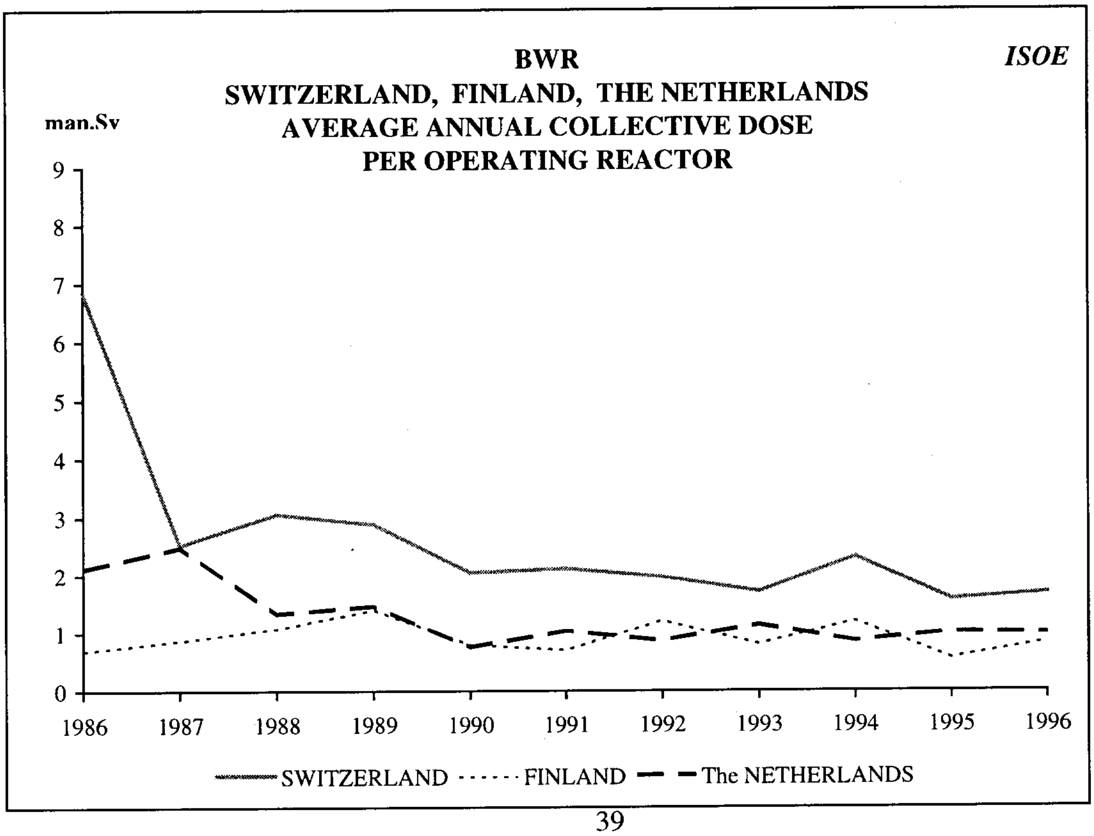


Figure 16

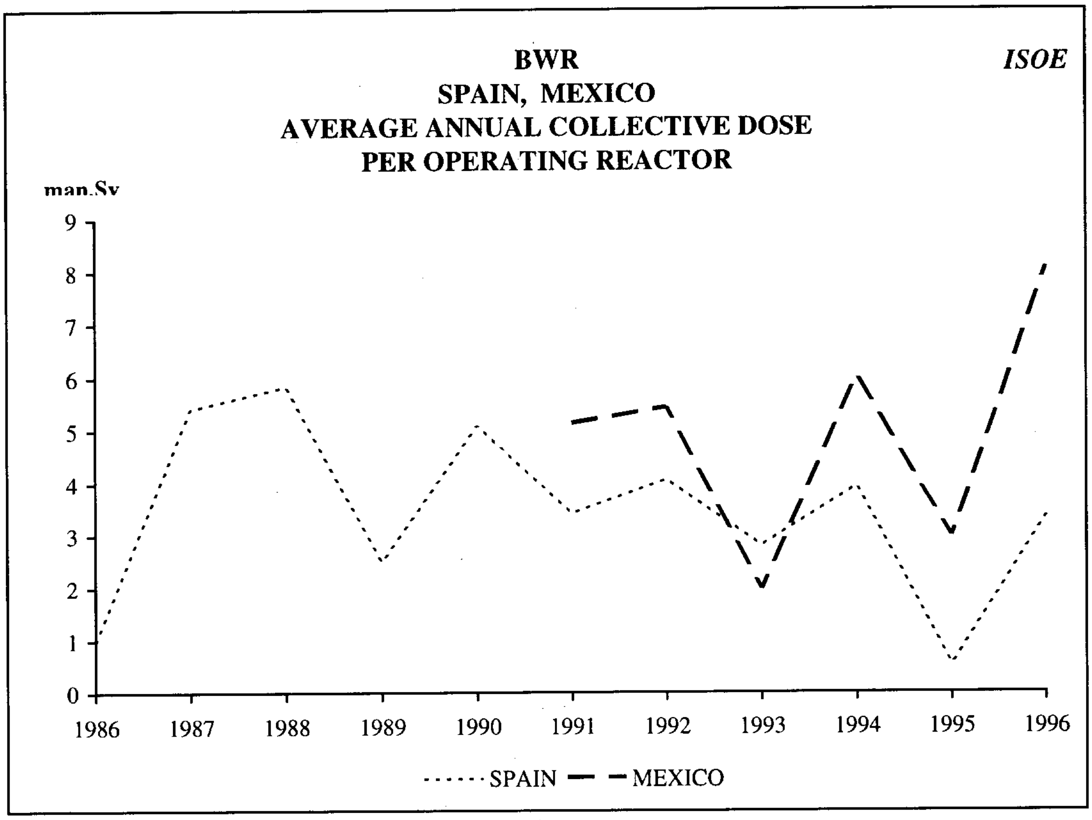

BWR
SPAIN, MEXICO
AVERAGE ANNUAL COLLECTIVE DOSE
PER OPERATING REACTOR
ISOE
man.Sv
9
8
7
6
5
4
3
2
1
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
SPAIN
MEXICO

Figure 17

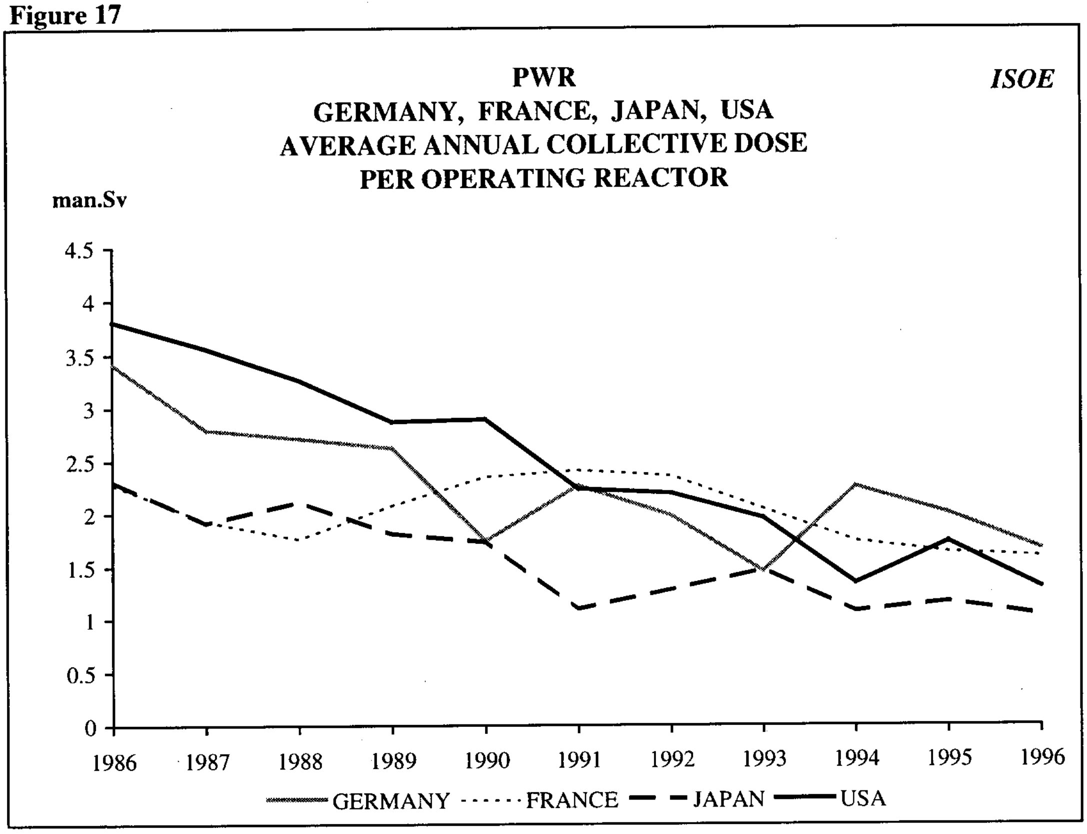


Figure 18

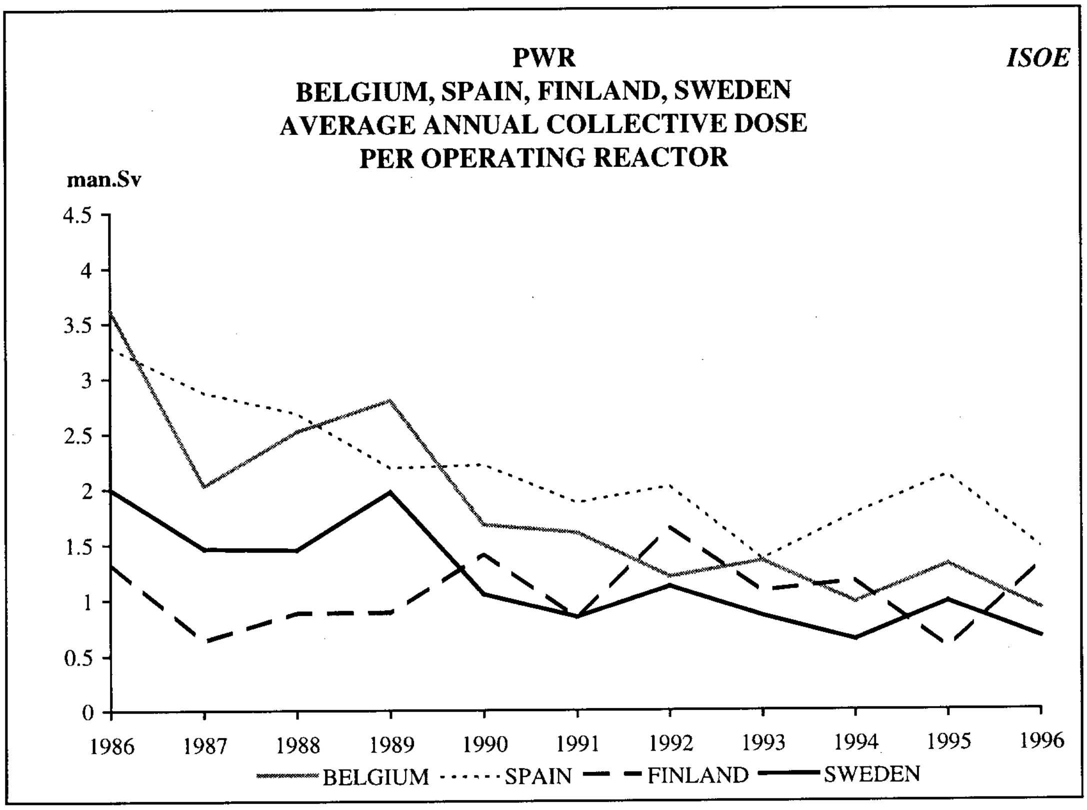


Figure 19

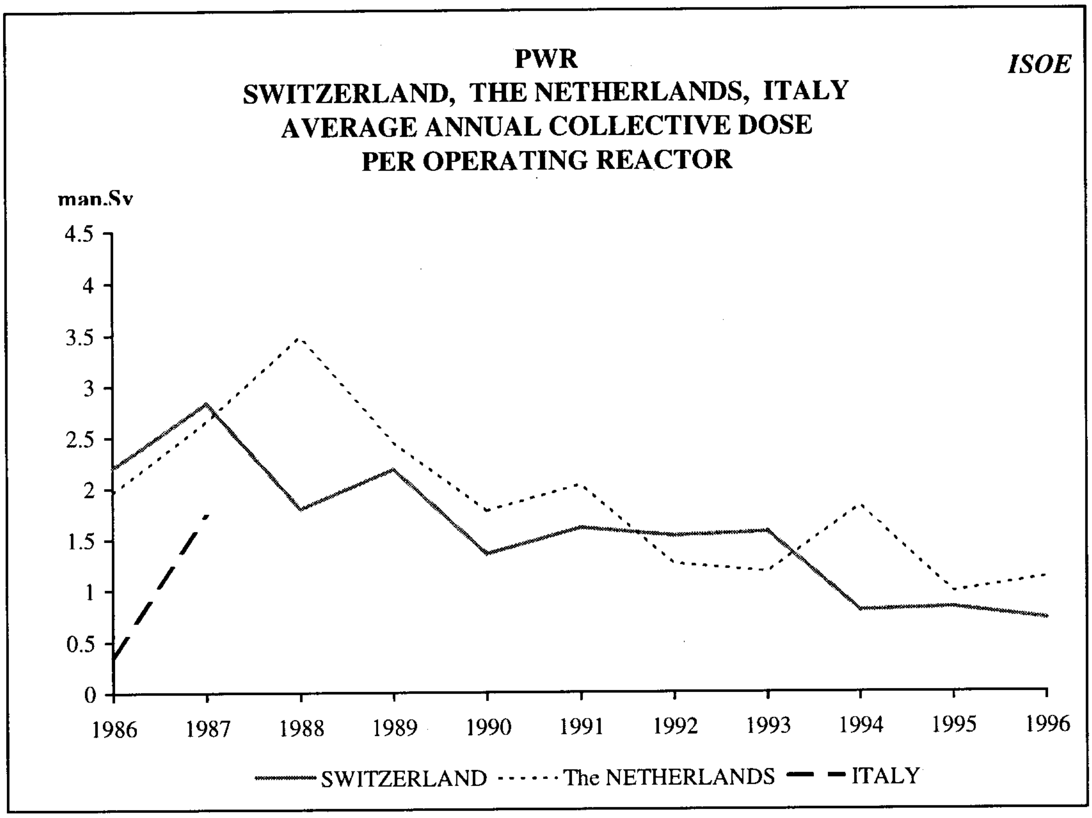


Figure 20

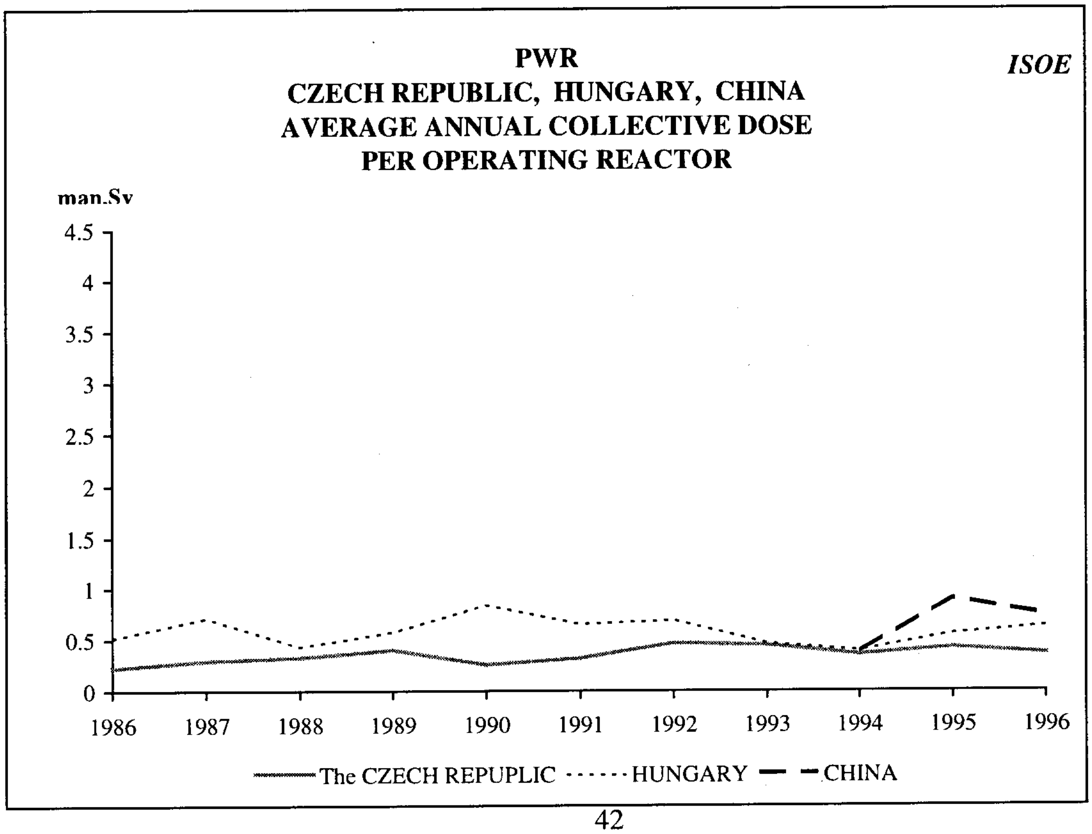


Figure 21

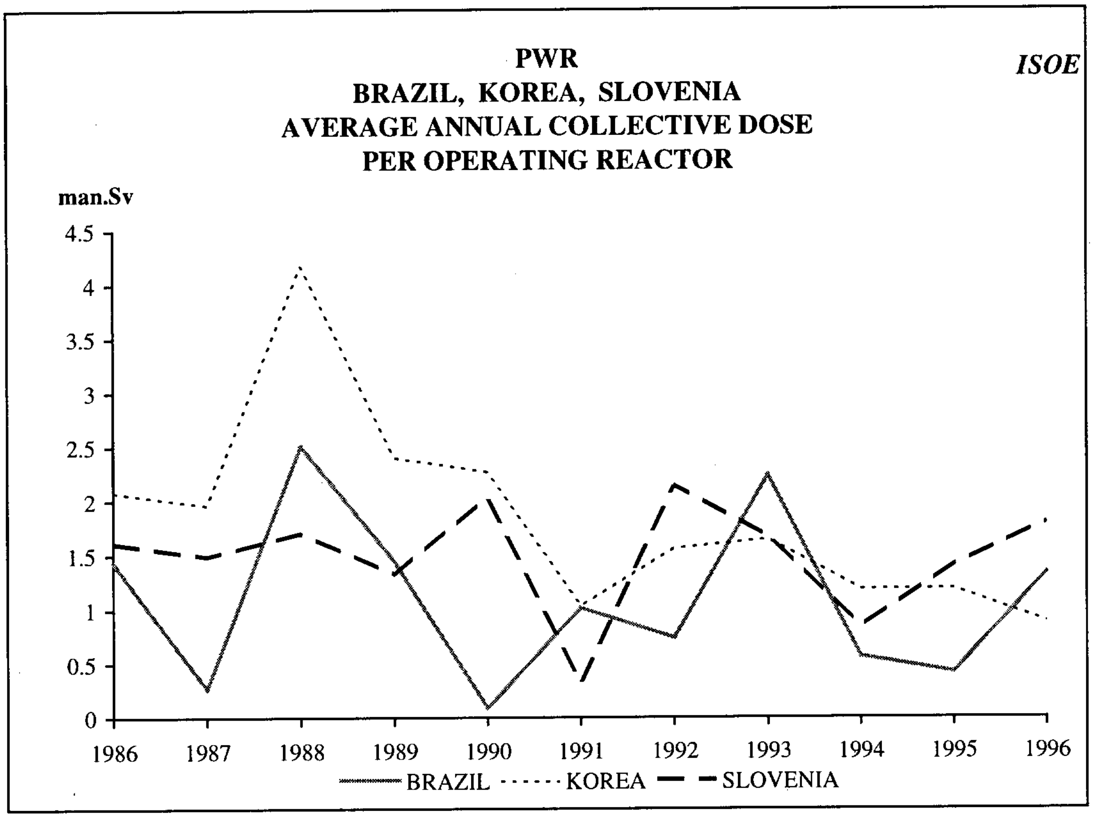


Figure 22

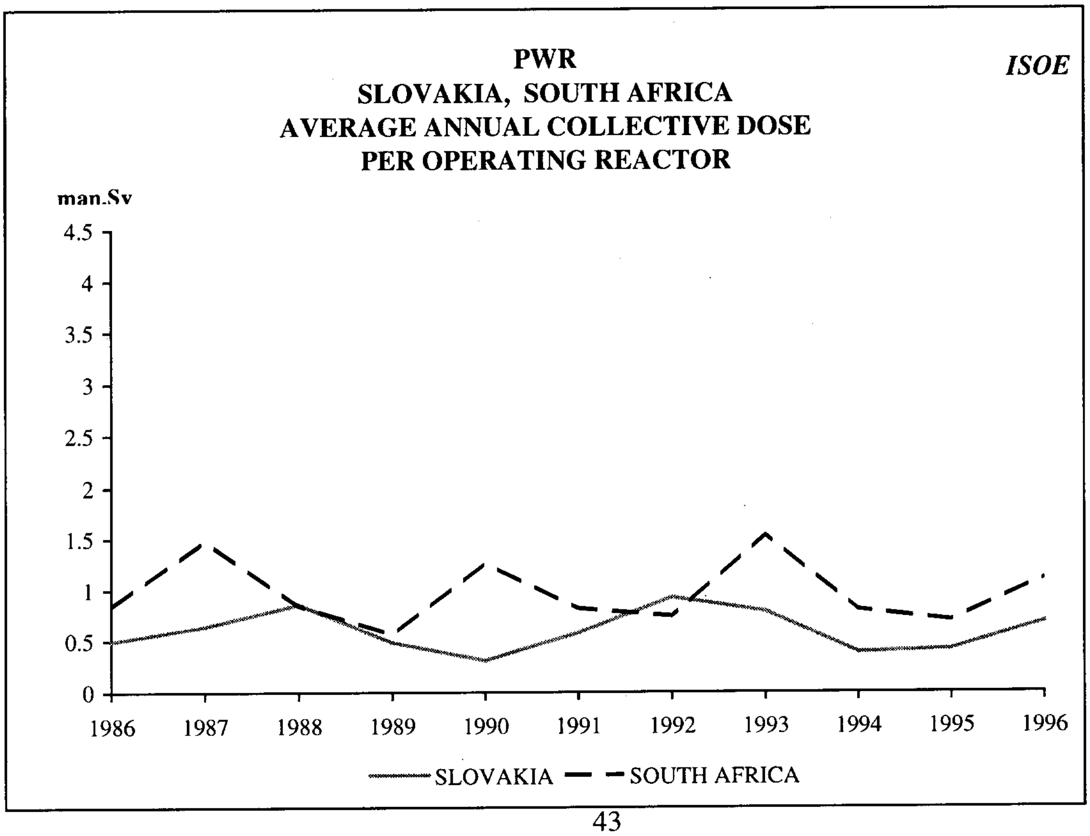


Figure 23

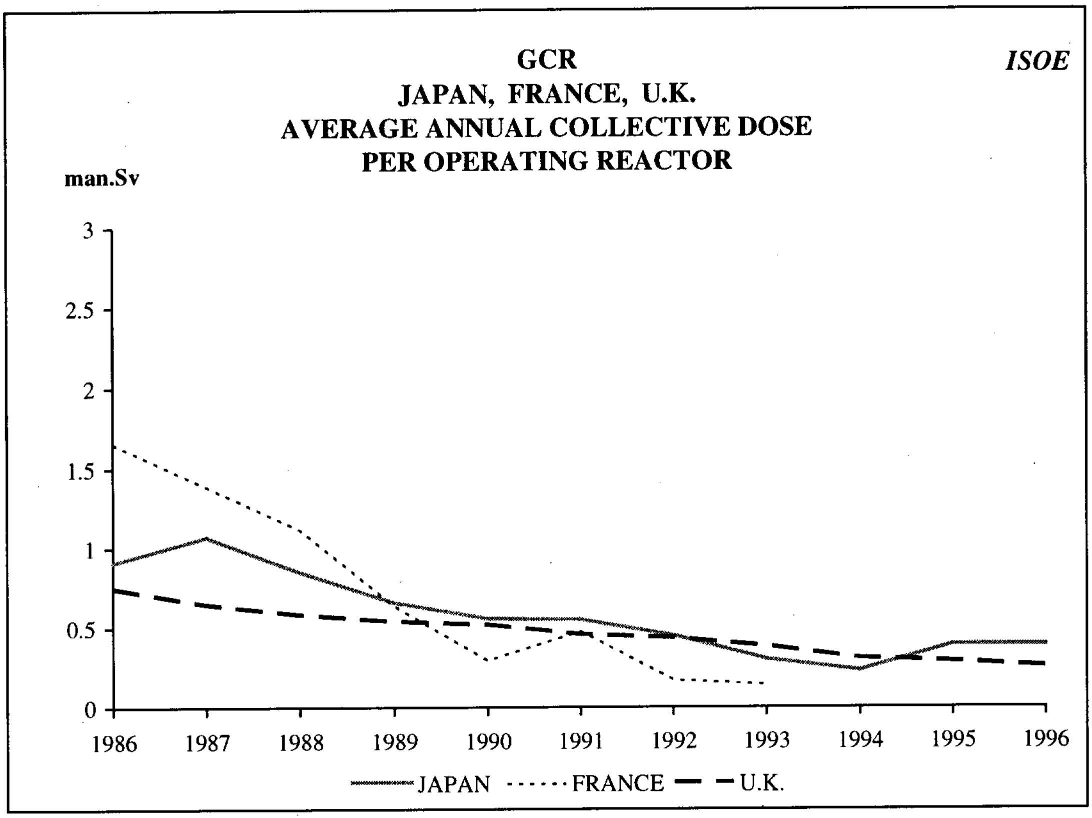


Figure 24

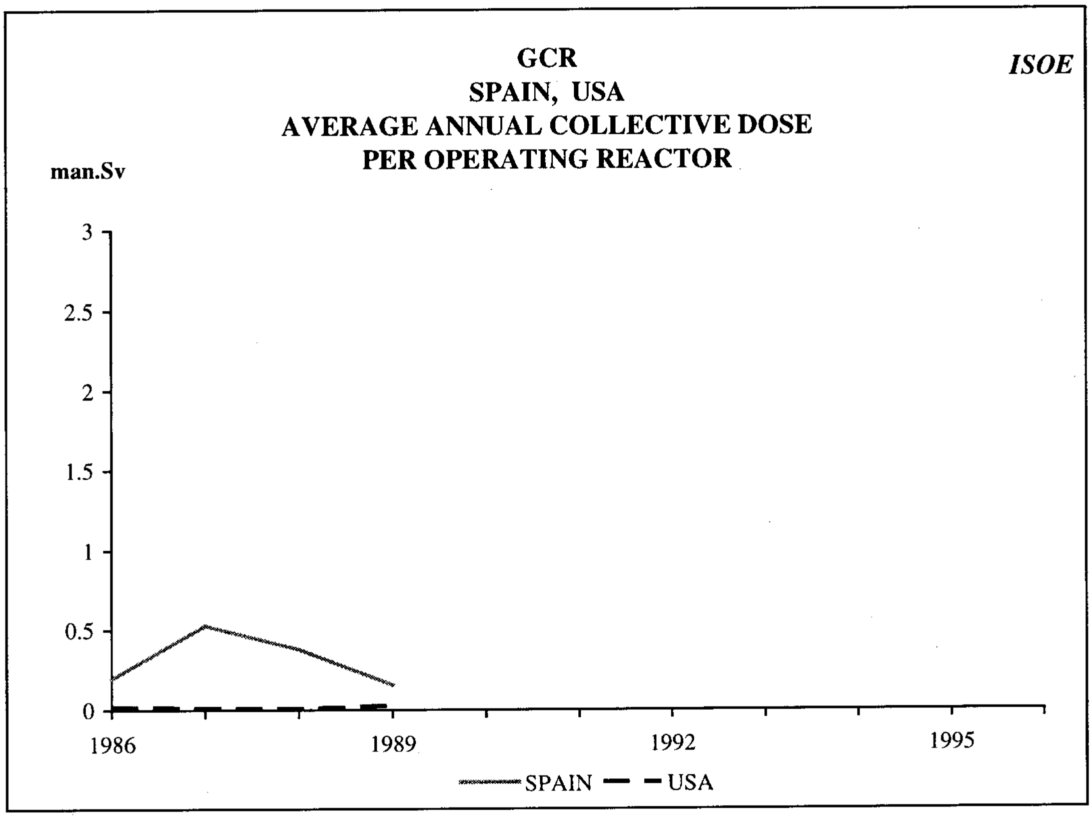
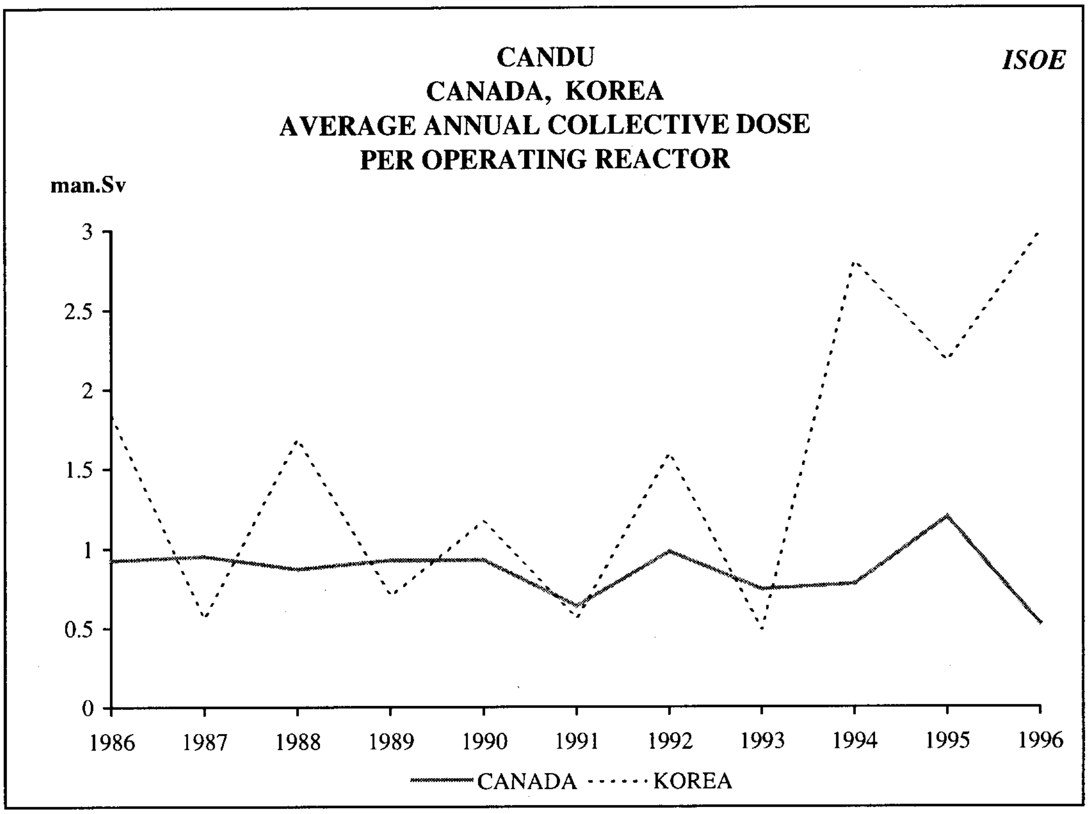


Figure 25


CANDU
CANADA, KOREA
AVERAGE ANNUAL COLLECTIVE DOSE
PER OPERATING REACTOR
ISOE
man.Sv
3
2.5
2
1.5
1
0.5
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
CANADA
KOREA

4.3 Contribution of outside personnel and outages to total collective dose in 1996 for reactors in operation

Table 6 shows the contribution of outside personnel to the total collective dose in 1996 for ISOE-participating Countries. In general, the values for 1996 have not changed significantly from those observed for the previous years. It should be noted that in this context, outside personnel refers to those workers who are not from the plant. This can include contract workers, but also workers from the utility who are not permanently stationed at the site.

The contribution of outside personnel to the total collective dose continues to vary considerably between the countries. For example, for PWRs it is 27% in China and 57% in Switzerland whereas it is 97% in Japan, for BWRs it is 49% in Netherlands, whereas it is 95% in Japan and for CANDUs it is 9% in Canada whereas it is 77% in Korea.

Tables 7 and 8 give the contribution of outages to the total collective dose for operating BWRs and PWRs in 1996 in ISOE participating countries.

Table 6 Contribution of outside personnel to total collective dose for each country and type of reactor in 1996

	Country	Percentage of collective dose received by outside personnel
PWR	Belgium	84%
	Czech Republic	73%
	Finland	79%
	France	79%
	Germany	88%
	Hungary	61%
	Netherlands	80%
	Spain	94%
	Sweden	66%
	Switzerland	50%
	United Kingdom	82%
	EUROPE	81%
	Japan	97%
	Korea	93%
	USA	N.A.
	Brazil	75%
	China[1]	27%
	Slovak Republic	N.A.
	Slovenia	78%
	South Africa	N.A.
BWR	Finland	81%
	Germany	78%
	Netherlands	49%
	Spain[2]	89%
	Sweden[3]	87%
	Switzerland	70%
	EUROPE	82%
	Japan	95%
	Mexico	N.A.
	USA	N.A.
GCR	United Kingdom	N.A.
	Japan	92%
LWGR	Lithuania	34%
CANDU	Canada	9%
	Korea	77%

1. *Data had break down into 3 types of personnel (plant, outside and no breakdown) for 2 reactors. These data has not been considered in the calculation.*
2. *Data had break down into 3 types of personnel (plant, outside and no breakdown) for 2 reactors. These data has not been considered in the calculation.*
3. *Data had no break down into type of personnel for 3 reactors.*

Table 7 Contribution of outages to total collective dose for operating BWRs in 1996

Countries	Contribution of outage dose to total collective dose
Finland	85%
Germany	64%
Netherlands	68%
Spain	82%
Sweden	92%
Switzerland	72%
EUROPE	82%
Japan	?
Mexico	88%
USA	80%

Table 8 Contribution of outages to total collective dose for operating PWRs in 1996

Countries	Contribution of outage dose to total collective dose
Belgium	88%
Czech Republic	86%
Finland	95%
France	84%
Germany	85%
Hungary	95%
Netherlands	78%
Spain	78%
Sweden	78%
Switzerland	80%
United Kingdom	92%
EUROPE	85%
Brazil	95%
China	94%
Japan	?
Korea	69%
Slovak Republic	93%
Slovenia	89%
South Africa	83%
USA	89%

Chapter 5

PRINCIPAL EVENTS OF THE YEAR 1996 AS REPORTED BY PARTICIPANTS

This chapter addresses the principal events, if any, having had an impact on the collective doses of the different countries' with operating nuclear power plants in 1996. This information has been provided directly by the participants.

Belgium:

Tihange:

Unit 1: The particular works which caused effects on the dosimetry during the year were the dismantling of a boric acid tank, in the containment (11.3 mSv), finishing of the walkways of the steam generators (20.1 mSv) and the installation of an hydrogen recombiner (7.9 mSv).

Unit 2: The main work was the nickel plating of 600 steam generator tubes (159 mSv) with the plugging of 2 tubes (6.5 mSv) and the examination of the hydraulic seals of the primary pumps (27 mSv).

Unit 3: This unit is preparing the steam generator replacement of next year. The preparation of this operation contributes to a dose of 22.6 mSv. The control and plugging of leaking tubes of these steam generators during two forced shutdown leads to respectively 63.7 and 213 mSv, and 135.7 mSv during the planned outage: this means 41.2% of the total annual dose of the year. On the other hand, some inspections and repair of penetration on the upper side of the reactor vessel head contributes to a dose of 50 mSv.

Doel:

Unit 1 & 2: There were no special events affecting the collective dose.

Unit 3: The principal events were: ASME In Service Inspection of the reactor vessel and a planned cold shutdown for a leak repair job at a reactor head standpipe. These activities lead to collective dose of respectively 0.37 mSv and 24.69 mSv.

Unit 4: During the annual outage, the 3 Steam Generators were replaced, and the total collective dose for this work was 620 mSv. During the annual outage also an ASME In Service Inspection of the reactor vessel and the replacement of the core exit thermocouples were performed; total collective dose for these activities was respectively 3.02 mSv and 11.49 mSv.

Brazil:

The most significant event at the Angra 1 NPP was the refueling outage, including ten year old in service inspection of the reactor vessel internals. The total collective dose for the outage was 1.33 man.Sv with no workers receiving a personal dose above 11.5 mSv.

Canada:

The total annual collective dose for the 22 Canadian CANDU® reactors was 0.53 person.Sv, back down to levels more typical of pas years.

At Ontario Hydro, total collective dose decreased by 36%, at 0.58 person.Sv per reactor. Principle radiological events at each OH station were:

Pickering (0.45 person.Sv/unit):

> Activities at PND were dominated prolonged shutdown to five of the eight units to address specific, non-radiological, work initiatives. Significant radiological jobs at PND-A, consisted of completing repairs to primary heat transport over-pressure relief valves and piping on Unit 2, and shutdown cooling heat exchanger work on Unit 4. On the B side, precautionary repairs to emergency coolant injection check valves on all four units were made. Work in the Unit 6 reactor building to repair high pressure service water valves also contributed to collective dose.

Bruce 'A' (0.66 person.Sv/reactor):

> Unit 1 boiler maintenance cleaning carried over into 1996. Fuel channel inspections at Unit 3 were the other significant radiological work at BAND. Unit 2 was layed up all year.

Bruce 'B' (0.45 person.Sv/reactor):

> There was one planned outage on Unit 7, with a forced outage caused by a stuck fueling machine head also contributing to collective dose.

Darlington (0.28 person.Sv/reactor)

> A major outage on Unit 1 contributed to collectie dose, as did minor boiler repairs on Unit 3, and a fueling machine head getting stuck on a Unit 1 channel.

Internal dose (mainly due to tritium) for 1996 increased slightly at Ontario Hydro, to 24% of the total collective dose. In 1996, the ratio of workers who reeived less than 5 man.Sv went down slightly to 89%.

At Point Lepreau, New Brunswick Power, the 1996 collective dose (0.94 person.Sv), decreased substantially from 1995. The plant recovered from an incident where foreign material was accidentally introduced into the heat transport system. Significant radiological work was done on inspecting heat transport feeder piping (0.15 person.Sv), and inspection and plugging of boiler tubes (0.30 person.Sv).

The Gentilly 2, Hydro Québec, dose decreased substantilly to 1.48 person.Sv (16% internal dose). The 504 workers received an average of 2.93 man.Sv.

Seventy-six percent of the 1996 dose was received during the annual two week outage which consisted of work on a steam generator, fuel channel inspection (SLAR), and F/M gear box maintenance.

China:

Daya Bay NPP:

The principal events occurring at the Daya Bay NPP were the replacement of control rods drive mechanisms.

The replacement work at unit 2 started on January 1st 1996 and ended on January 14th 1996. Fifty eight people were involved in the work. The collective dose was 100.13 man.mSv. The maximum individual dose for this work was 4.36 mSv.

The replacement work at unit 1 started on April 9th 1996 and ended on May 2nd 1996 with a collective dose of 155.01 man.mSv.

The accumulative collective dose of the plant was 1650 man.mSv out of which the dose for the replacement of control rod drive mechanisms was 15.5%.

Qinshan NPP:

The principal event in Qinshan was the refueling outage which lasted 62 days and resulted in a collective dose of 739.24 man.mSv. This represents 94.8% of the collective dose of Qinshan for the year 1996 (779.71 man.mSv).

The main projects during the outages were:

- Steam generator maintenance and inspection: 87.39 man.mSv
- Valve work 44.06 man.mSv

Czech Republic:

The most significant events on NPP Dukovany were refueling outages.

Unit 1: one planned outage, duration of outage: 39 days. Collective dose for outage 0.31 man.Sv. It is 21% contribution to collective dose of NPP Dukovany for the 1996 year.

Unit 2: one planned longer outage, duration of outage: 70 days. Collective dose for outage 0.43 man.Sv. About 30% contribution to collective dose of NPP Dukovany.

Unit 3: one planned outage, duration of outage: 58 days. Collective dose for outage 0.38 man.Sv, about 36% of the collective dose of Unit 3 is traceable to steams. Contribution to collective dose of NPP Dukovany is about 26%.

Unit 4: one planned outage, duration of outage: 39 days. Collective dose for outage 0.13 man.Sv. About 9% contribution to collective dose of NPP Dukovany for the 1996 year.

France:

1) Collective radiation exposure:

Measurements of collective exposure to radiation continued to drop through 1996, which puts EDF well on the way to reaching its year 2000 goal of 1.2 man.Sv per reactor-year.

Future improvements are expected from the extension of the 1300 MW fuel cycles as well as the introduction of outages for refueling only. They should offset any radioactive exposure generated by the second wave of ten-year inspections of the 900 MW series.

The average collective dose per reactor in commercial operation use dropped by nearly 3% in 1996, reaching a level of 1.59 man.Sv, compared to 1.63 man.Sv in 1995.

Sample achievements in the drive to reduce collective radiation exposure: in the last two years the levels observed during reactor vessel opening and closing have been lowered by 22% and 33% for the 900 MW and 1300 MW series respectively.

An example of dosimetric variation observed in 1996 between two reactors in extreme operating conditions: 0.31 man.Sv at Golfech 2, a recent unit, during a "refueling only" outage, against dosimetry of 5.5 man.Sv at Chinon B2, a unit with hot spots, during a ten-year inspection.

Important variations do exist between reactors; improving those units posting the worst results will obviously have a substantial effect on overall gains in future.

2) Personal radiation exposure:

After a period of constant reduction since 1992, the level of radiation exposure sustained by individuals shows contrasting results. The number of workers exposed to an annual dose greater than 30 mSv continued to decrease to a very low level (55 persons). However, the work force subjected to a dose greater than 20 mSv per year has remained stable at 500 persons mark.

We will make a special effort for 1997 so that EDF's target can be achieved, that is to say "no one above 20 mSv by the year 2000, not counting accidents".

Implementation of the ALARA project now underway should soon help this objective to be met.

A special action plan is aimed at reducing personal exposure to radiation. Designed in 1996, this plan addresses all subcontractors operating in controlled areas, targeting specifically the 27 companies who employ close to 90% of the workers registering over 20 mSv per year. The plan calls for the reassignment, whenever necessary, of the most exposed workers to other tasks with a lesser risk of exposure. National and localised communication and coordination, as well as individual monitoring, are already the linchpin in keeping dose rates down, and they will play an increasingly important role in future. Our priority is to monitor the workers in the most sensitive trades, such as pipe insulation, scaffolding or welding.

3) The ALARA project:

Two years after it was launched, the ALARA initiative produced encouraging results. Important milestones were reached in 1996:

- A set of radiation exposure benchmarks for the most vulnerable sites is well on the way to completion. This is a collective achievement, involving every nuclear unit, together with a large number of contractors. The part which concerns steam generator operations (20% of the overall dose) was finalised by the end of 1996. The same applies to most non-destructive tests. For the remaining activities, which represent about 50% of the total dose, partial documentation is available and will be completed in 1997.
- Special groups have been formed within certain corporate units with a view to managing the networks that gather benchmarking data and thereby share and enrich each other's experience. They are tests, Corporate Technical Support, for specialised or generic operations, Corporate Engineering Support for operations and the Engineering groups for any design modifications.
- An analysis of variance between actual and planned dosimetry is now systematically conducted upon every outage.

Germany:

Most outage durations in German NPPs lay in range of 20 to 30 days. The shortest outage was performed in Neckar 2 with 15.2 days, the longest happened in Brünsbuttel (51 days), Krümmel (68 days) and Biblis-B (67 days). The annual collective dose amounted to a normal level in Brünsbuttel and Krümmel whereas in Biblis B the collective dose was 11.69 Sv, 1 Sv of this for plant personnel and 10.69 Sv for contractor personnel. The high dose for Biblis-B was again generated, as in the years before, by extensive inspection and repair work in connection with the detection of corrosion effects at fixing elements in the bearing construction and at some measuring pipes of the main cooling pumps. These findings motivated the local supervision authority to set up extensive questionnaires and requirements lists though the utility had already clarified all factual issues and developed a pertinent repair concept. Corrosion in the piping was caused by chlorine induced stress at parts of the piping where chlorine contenting glutens had been used during the construction phase of the plant. In one case the corrosion resulted in a minor leakage and caused the utility to perform a detailed inspection and cleaning programme in order to avoid further events of this kind.

Throughout the last two years, the radiation protection experts in the power plants studied the methods of a quantitative radiation protection optimisation in the sense of ALARA, based on α-value considerations undertaken on a national and international level. This study resulted in an α-value concept which is presently taken as a test-version in German NPPs on a voluntary basis. Experience feedback will be collected and evaluated in the German radiation protection expert group. Independent of the result, the α-value concept is considered to be one decision criteria amongst the others for the ALARA management which might help to reach a monetary balanced optimum in radiation protection efforts.

Japan:

The first ABWR (1356 MWe): Kashiwazaki-Kariwa No. 6 started commercial operation in November. The second ABWR (1356 MWe): Kashiwazaki-Kariwa No. 7 also started test operation and reached first criticality in November. Genkai No. 4 (PWR, 1180 MWe) started test operation and reached first criticality in October.

Speaking with the total collective dose for the FY 1996, the value for 23 PWRs was 23.82 person.Sv and the value for 28 BWRs was 44.79 person.Sv. And then, the whole value was 68.99 person.Sv for all commercial reactors including GCR that was marked by a little increase from the previous year. The average collective dose per reactor for all commercial reactors was 1.33 person.Sv that was the same as the previous year.

On the other hand, during the periodical inspections ended in FY 1996, the average collective dose was 1.61 person.Sv for PWRs and 2.25 person.Sv for BWRs, and was marked by the increase from the previous year on the whole. The main factor of those results, especially for BWRs, was the increase of the amount of improvement work.

Lithuania:

The principal events which have affected the collective dose during 1996 at the Ignalina NPP were:

Unit 1:

Dismantling of the drum-separator water balance pipes (0.747 man.Sv).
Repair of the primary system valves (0.397 man.Sv).
Repair of the weld defects of the primary system pipes d = 800 mm (0.641 man.Sv).
Repair of the weld defects of the drum-separator water balance pipes (0.198 man.Sv).
Repair of the weld defects of the drum-separator branch pipes (0.107 man.Sv).
Flaw detection of the primary system metal structures (0.128 man.Sv).
Modernisation of the reactor steam and gas discharge system (1.325 man.Sv).
Insulation works (0.135 man.Sv).

Unit 2:

Dismantling of the drum-separator water balance pipes (0.617 man.Sv).
Repair of the primary system valves (0.129 man.Sv).

Repair of the weld defects of the primary system pipes d = 800 mm (0.549 man.Sv).
Repair of the weld defects of the drum-separator branch pipes (0.035 man.Sv).
Flaw detection of the primary system metal structures (0.148 man.Sv).
Modernisation of the reactor steam and gas discharge system (0.858 man.Sv).
Insulation works (0.089 man.Sv).

The collective dose after implementation of this work during the maintenance period of unit 2 is 2.425 man.Sv. This means 52% of the total dose during outage of unit 2 in 1996 and 16% of the annual dose of the Ignalina NPP's personnel, including contractors.

Mexico:

In 1996, there were two long outages: 89 days for unit 1 and 85 days for unit 2; critical path in both cases: thorough turbine inspection and blade replacement.

Romania:

Cernavoda Unit 1 went into commercial operation on 2 December 1996.

Slovak Republic:

At the Bohunica NPP there are 4 PWR reactors in operation. The main contribution to the collective dose was caused by the activities during the planned outages. Most of these activities were carried out after the long term plan of control and maintenance. However, there were also some reconstruction activities, for example, installation of the upper feedwater distribution system into steam generators. In the year 1996 there were the standard outages (duration 45 and 46 days) at two of the reactors. At two reactors there were large outages (planned for every three years) with a wider programme for quality control including control of the reactor vessel (duration 78 and 79 days).

During the long term outage at unit 2 (78 days) an extensive volume of modifications was performed. The most significant collective dose received was due to the modification of the steam generators blow down pipelines - 229.34 mSv. During the regular outages work was done on exchanging the feedwater distribution pipes inside the steam generators Nos. 34, 41 and 43, with the collective doses 22.49 mSv, 40.76 mSv and 57.62 mSv respectively.

The highest collective dose during outages results from removal and assembling of devices (27%) and by quality control and testing (17%). In 1996 the workers received 30% of the collective dose during outages from activities on steam generators, 25% of the collective effective dose from activities on reactors and 34% from activities on primary coolant pipes, radwaste and control of the integrity of the fuel cladding. The most exposed work function groups in 1996 were the welders and mechanics of special maintenance, quality controllers and primary circuit operators. The collective doses are higher than in 1995 in both NPPs because of large outages on two reactors.

Bohunica NPP:

Unit 1: no special events.

Slovenia:

Krsko NPP:

Radiological performance indicators for the year 1996 were:

- Collective radiation exposure 2.01 man.Sv.
- Maximum individual dose 16.85 mSv.
- Average individual dose 2.26 mSv.

The collective dose is at the maximum acceptable level (from 1.5 to 2 man.Sv). The average value over the past 5 years is 1.61 man.Sv. The goal is set at 1.5 man.Sv. During the refueling outage (at the end of the 13th fuel cycle) there was maintenance work due to the steam generator tube sleeving which contributed a major additional dose of 0.53 man.Sv. The total number of steam generator tube sleeves installed was 488. The specific activities were also the removal of a stuck reactor vessel head bolt and the removal of foreign material from the reactor vessel bottom. This material was mainly tailings from previous steam generator deplugging activities which had triggered some fuel failures.

The total collective dose from the refueling outage was 1.58 man.Sv. The plant was disconnected from the grid for 65 days. Reactivation of steam generator tubes provided 13.15% of plugged tubes instead of 17.29%. With these conditions and based on the projected degradation of the tubes, the power level can be at 100% for the next 4 years before both steam generators are replaced.

The modification was started which will provide lower doses to waste processing personnel and radioactive waste volume reduction using a drying process of the evaporator bottom and resins.

South Africa:

In South Africa, nuclear power is produced by two PWR units at Koeberg Nuclear Power Station. For the year 1996, major dose contributions were from refueling Outage 108 (48 days), with a total dose of 869.7 mSv and Outage 207 (51 days) with a dose of 897.3 mSv. Outage durations are planned to be reduced to 26 days by the year 1999.

Highlights were the fact that no personnel were exposed above 15 mSv for 1996, and only three were exposed to more than 10 mSv. ALARA planned a total dose for the station of 2400 mSv, with an actual dose of 2219.4 mSv total.

Major dose contribution were as follows:

- Lagging replacement on steam generators, 207: 52.55 mSv.
- Lagging replacement in reactor building, 207: 41.55 mSv.

- Maintenance work in reactor cavity, 207: 35.30 mSv.
- Steam generators sludge lancing, 207: 35.25 mSv.
- Install and remove SG nozzle dams, 108: 42.05 mSv
- B service of active valves, 108: 45.35 mSv.

Spain:

The total collective dose for the Spanish NPPs is distributed as follow:

- 7 PWR reactors: 10.29 man.Sv (1.47 man.Sv / reactor)
- 2 BWR reactors: 5.37 man.Sv (2.69 man.Sv / reactor)

It is appropriate to underline:

- A report has been elaborated jointly between the Regulatory Body and the NPPs: *"Management of the Optimization of the Radiation Exposure"*. The objective of this report is to establish the general principles to be considered by the organisation of the companies participating in the exploitation of the nuclear power plants, in order to manage the optimisation of the expositions to the ionizing radiations.

- Singular projects at Ascó II NPP:

  - Steam Generators Replacement: 1.58 man.Sv
  - RTD's Bypass Replacement: 0.29 man.Sv
  - Others Modifications: 0.91 man.Sv

These projects have involved the 75% of the total collective dose.

- Singular projects at Almaraz I NPP:

  - Steam Generators replacement: 1.56 man.Sv
  - RTD's Bypass Replacement: 0.37 man.Sv
  - Head Closure Vessel Replacement: 0.29 man.Sv

These projects have involved the 58% of the total collective dose.

- Cofrentes NPP has been involved for several years in an outage re-engineering project which results in a set of one long and one short refueling outage every three years. During 1996 the first short refueling outage was performed in 19 days 15 hours against the 20 days scheduled. This success permitted to have 1.35 Sv for the outage and 1.81 Sv collective dose for the whole year (outage and operation).

- The main contributions to the refueling outage collective dose (4.17 man.Sv) are the following:

  - The source term increased between 20-30% because of the Hydrogen injection.
  - Modification of the Clean-up system (replacement of the heat exchangers): 0.69 man.Sv.
  - Maintenance and modifications works in mean steam isolator valves: 0.69 man.Sv.

- Replacement of the rods of 2 recirculation valves: 0.13 man.Sv.

Without taking into account this modifications, the 1996 results are comparable with the 1994 refueling outage results (3.36 man.Sv), that was one of the best records in Sta. M^a de Garoña NPP.

Sweden:

The last years levelling trend for occupational exposures in Swedish BWR nuclear power stations is changed into a rather upgoing trend. Of the work contributions to the increase in occupational exposures the most significant events appears as follow:

Barsebäck: Refueling outage for both units was prolonged for the same reason by 31 respective 44 days. This due to cracks in weldings, found during routine inspections, in the residual or shutdown heat removal system. Resulting in replacement of pipings, pumps and suspensions. The total outage dose increased a bit over 50% from original budget. Personnel categories mainly effected by the dose increase due to unplanned work activities was the mechanical team. But also the insulation, inspection and decontamination/cleaning teams were effected as well by increased personnel dose.

Forsmark: Unit 1 and 2 are undergoing a modernisation program to secure future power production and therefore the dose budget is a bit higher than for previous years. The dose target for 1996 was 1.1 and 1.2 man.Sv per unit 1 and 2. Unit 2, overwrite their target by 25%, mainly caused by measures taken, due to crack indications found on both the RPW head and the residual or shutdown heat removal system. About 40% of the collective dose for both unit 1 and 2 is traceable to steam and turbine systems. Where the reason is increased dose rate caused by high moisture content in the steam. Unit 3 had a normal refueling outage period with no exceptionals. The dose target, set to 1.3 man.Sv for the year, was underpassed by 0.1 man.Sv.

Oskarshamn: Occupational exposure for all three units in Oskarshamn was 9,1 man.Sv. About 6% of total reported occupational exposure for 1996 was acquired during unit 1's outage period, prolonging 64 days into the year of 1997. All three units are undergoing continuos modernisation to secure future safe power production. Commonly this year's outage was modification of residual or shutdown heat removal system. With replacement of isolation valves and operating devices as well as optimisation of system piping in order to reduce future inspections.

Unit 1, most significant work contribution to dose, about 30%, was according to authorities directions an increased inspection programme of the recirculation system and the shroud head. Unit 2, modernisation by replacement of all cablings as well as conduits and to protect cable and switch cabinets against water level movements inside containment. Quite a large task that contributed to around 40% of unit 2s total collective dose of 5.4 man.Sv. Unit 3 outage was prolonged by eight days due to unplanned modification of core spray system attachment inside RPV. This work contributed to a collective dose increase by about 40%.

Ringhals: Unit 1, about 25% of total refueling outage collective dose contributes to preparatory work for the modernisation program starting at 1997 years outage. A modernisation program that includes replacement of connections, pipings and stellite valves in the recirculation system and the residual or shutdown heat removal system. As well as decontamination of those systems using LOMI method.

The trend for occupational exposures in Swedish PWR nuclear power stations is heading down. For this years work contributions to the occupational exposures some of the most significant events was:

Ringhals: Unit 2, reactor vessel head replacement, due to cracks found in the 1992 years control rod penetrations. Work contribution to personnel dose was around 40% of total refueling outage collective dose. Dose rates in the steam generator channel heads, replaced in 1989, seems to have reached a steady state at a low level.

Unit 3, a 23 days short refueling outage period with no exceptionals. Dose rate in the SG channel heads, one year after replacement, was considered low.

Unit 4, had a normal 28 days refueling outage without any exceptionals. The dose rates in the steam generators (not replaced) are stable and still very low.

Switzerland:

Power production and refueling outages

Each of the five Swiss NPP's at four sites had a normal refueling outage of standard duration. No really large maintenance or modification work was scheduled at any plant, resulting in a new record low set of collective doses for the calendar year:

Plant	*Person-Sv*
Beznau I	0.52
Beznau II	0.68
Mulheberg	1.40
Gösgen	0.92
Leibstadt	1.96

The highest individual dose accumulated in Swiss NPP's was 15.2 mSv; showing that the Swiss legal limit of 20 mSv in 1996 again posed no significant problem.

Developments in 1996

No significant regulation or safety requirement modifications were undertaken. With the Swiss constitutional 10 years nuclear moratorium still running, no planning for new plants could be undertaken but also no shutdown considerations for the mid term future were followed.

Mid term developments

The start-up at the building site for national intermediate waste storage site (at Wuerenlingen; adjoining the site of the research institute PSI and near the Beznau NPP) for all types of waste was not influenced by the moratorium.

The only significant new mid term work planned is the steam generator replacement scheduled for 1999 at Beznau II.

United States:

In 1996, nuclear power plants in the USA focused on work management initiatives to reduce refueling outage duration and operating costs. This focus was developed due to company-wide programs to prepare for de-regulation and competition in the US energy market over the next several years. Also, the success of specific US nuclear plants, *e.g.*, Limerick and Peach Bottom, in achieving shorter refueling outages for the past several cycles stimulated other US plants to achieve similar outage goals. Recognizing the benefits of international cooperation one reason for Limerick's and Peach Bottom's success in achieving shorter refueling outages was the adoption of European approaches to work management and plant maintenance.

The US plants with the shortest outages in 1996 are as follow :

Power plant	*Days*	*man-mSv*
Limerick, Unit 1 (1R06)	24.8	1529
Peach Bottom, Unit 2	19.45	1320
South Texas, Unit 1	22.6	1136

Some US nuclear power plants were shutdown for much of 1996 for extended maintenance outages (improvements in the material condition of the plants before deregulation) and due to regulatory requirements policy to reconcile operational practices with design basis analyses and document prior to continued operations. An increasing trend in occupational dose was observed in these plants due to more maintenance and inspection activities in the radiological areas of the plants.

PWR Highlights

US pressurized water reactors implemented new shutdown chemistry protocols to reduce occupational dose by stabilizing radiation fields during refueling outages. Steam generator replacements continued in the US, both in actual execution and in development of future steam generator replacement plans. Point Beach Unit 1 started their steam generator replacement outage in the forth quarter of 1996 and finished in 1997. The total dose for Point Beach Unit 1 for the steam generator replacement was 1880 person-mSv.

Commonwealth Edison Company's Byron Nuclear Power Station developed plans to replace steam generators in 1997 for Unit 2. The feasibility of steam generator replacement for Commonwealth Edison Company's Zion Nuclear Power Station was studied in 1996.

BWR Highlights

The US Boiling Water Reactor experience in 1996 included increased inspections of reactor vessel internals for cracks. Many US plants are accelerating plans to implement hydrogen water chemistry and depleted zinc injections to reduce adverse chemical environments for reactor internals and to control radiation fields. Also, noble metals as a protective coating in reactor internals was tested at the Duane Arnold Nuclear Energy Center in Iowa with promising results.

Health Physics Initiatives

Two technical topics being addressed by utility and regulatory health physicists in 1996 were skin dose limits for hot particles and effective dose equivalence studies. Research studies were sponsored by industry and regulatory agencies to study dose effects of hot particles on pigs skin. A scientific report is being prepared by the National Council on Radiation Protection (NCRP). Opportunities for regulatory relief of hot particle skin dose limits will be evaluated following the release of the NCRP report.

Effective dose equivalence studies have been conducted by Texas A & M University using Monte Carlo computer analysis. Results of the studies show that placement of a single dosimetry badge on the front upper body of an occupationally exposed worker provides adequate monitoring for the worker's dose. Implementation of these concepts will reduce the need to issue multiple badge dosimetry packets to workers assigned to activities in radiation areas of the power plant.

US utilities are implementing remote monitoring systems for key in-plant work areas such as refueling floor, BWR drywell and radwaste areas. The worker is outfitted with several electronic dosimeters which are capable of remotely transmitting their readouts to centralized health physics control points. The control points are equipped with closed circuit video monitors and electronic dosimeter readout monitors to track several crews dose accumulation. Cellular phones/radios are also provided to facilitate communication between the workers and the health physics control technicians. Remote monitoring programs reduce the number of health physics technicians needed in field, potential provides closer supervision of work in radiation areas and reduces person rem for the work force (*e.g.*, health physics technicians).

LIST OF ISOE PUBLICATIONS

ANNUAL REPORTS

- Nuclear Power Plant Occupational Exposures in OECD Countries 1969-1991, (ISOE First Annual Report, OECD Nuclear Energy Agency, June 1993).
- Nuclear Power Plant Occupational Exposures in OECD Countries 1969-1992, (ISOE Second Annual Report, OECD Nuclear Energy Agency, May 1994).
- Occupational Exposures at Nuclear Power Plant 1969-1993, (ISOE Third Annual Report, OECD Nuclear Energy Agency, May 1995).
- Occupational Exposures at Nuclear Power Plant 1969-1994, (ISOE Fourth Annual Report, OECD Nuclear Energy Agency, May 1996).
- Occupational Exposures at Nuclear Power Plant 1969-1995, (ISOE Fifth Annual Report, OECD Nuclear Energy Agency, May 1997).

EXPERT GROUP REPORTS

Work Management in the Nuclear Power Industry — ISOE Expert Group on the Impact of Work Management on Occupational Exposure, OECD Documents, 1997.

TOPICAL SESSIONS PROCEEDINGS

- Fuel Failures – Steam generator Replacements, First ISOE Topical Sessions, OECD, Paris, December 1994.

- Electronic Dosimetry – Chemical Decontamination, Second ISOE Topical Sessions, OECD, Paris, November 1995.

- Primary Water Chemistry and its Effects on Dosimetry – ALARA Training & Tools Third ISOE Topical Sessions, OECD, Paris, October 1996.

REGIONAL TOPICAL SESSION PROCEEDINGS

- NARTC Workshop, Orlando, USA, 1997.

INFORMATION SHEETS

From the Asian Regional Technical Centre:

- Japanese Dosimetric Results: FY 1994 data – Asian ISOE Information Sheet No. 1, October 1995.
- Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1994 – Asian ISOE Information Sheet No. 2, October 1995.
- Japanese Dosimetric Results: FY 1995 data – Asian ISOE Information Sheet No. 3, July 1996.
- Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1995 – Asian ISOE Information Sheet No. 4, July 1996.
- Japanese Dosimetric Results: FY 1996 data – Asian ISOE Information Sheet No. 3, September 1997.
- Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1996 – Asian ISOE Information Sheet No. 4, September 1997.

From the European Regional Technical Centre:

- Occupational Exposure and Steam Generator Replacement
  CEPN ISOE Information Sheet No. 1, April 1994.
- The influence of reactor age and installed power on collective dose: 1992 data
  CEPN ISOE Information Sheet No. 2, May 1994.
- First European Dosimetric Results: 1993 data
  CEPN ISOE Information Sheet No. 3, June 1994.
- Preliminary European Dosimetric Results for 1994
  CEPN ISOE Information Sheet No. 4, June 1995.
- Overview of the first three Full System Decontamination
  CEPN ISOE Information Sheet No. 6, April 1996.
- Preliminary European Dosimetric Results for 1995
  CEPN ISOE Information Sheet No. 7, June 1996.
- Reactor Vessel Closure Head Replacement
  CEPN ISOE Information Sheet No. 9, December 1996.
- Preliminary European Dosimetric Results for 1996
  CEPN ISOE Information Sheet No. 10, June 1997.
- “Annual individual doses distributions: data available and statistical biases”.
  CEPN ISOE Information Sheet No. 11, September 1997.
- “Occupational exposure and reactor vessel annealing”.
  CEPN ISOE Information Sheet No. 12, September 1997.

From the IAEA, Non-NEA Members Regional Technical Centre:

- ISOE Expert meeting
  IAEA ISOE Information Sheet No. 1, October 1995.

From the North American Regional Technical Centre:

- Swedish Approaches to Radiation Protection at Nuclear Power Plants
- NARTC site visit report by Peter Knapp, July 1996.

OTHER PUBLICATIONS

- “The International System on Occupational Exposure, ISOE – Status and Results for 1995”, T. Lazo, Proceedings of the IRPA9 International Congress on Radiation Protection, Vienna,
- 14-19 April 1996.
- “The International ISOE Programme – ISOE Asian Regional Technical Center Activities”, H. Kawaguchi, Y. Shibata, N. Aiyoshi, Proceedings of the IRPA9 International Congress on Radiation Protection, Vienna, 14-19 April 1996.
- “The International ISOE Programme – ISOE European Regional Technical Centre Activities”, L. D'Ascenzo, P. Crouail *et al.*, Proceedings of the IRPA9 International Congress on Radiation Protection, Vienna, 14-19 April 1996.
- “The International ISOE Programme – ISOE North American Regional Technical Center Activities”, D. Miller, Proceedings of the IRPA9 International Congress on Radiation Protection, Vienna, 14-19 April 1996.
- “The International ISOE Programme – ISOE IAEA Technical Centre Activities”, M. Gustafsson, Proceedings of the IRPA9 International Congress on Radiation Protection, Vienna, 14-19 April 1996.

Additionally, for publicising the ISOE Program:

- NEA/IAEA Information System on Occupational Exposure leaflet, OECD Nuclear Energy Agency, April 1996.

FOR FURTHER INFORMATION, PLEASE CONTACT:

ISOE Secretariat

Dr. Ted LAZO, OECD/NEA, France
Tel: +33 1 45 24 10 45
Fax: +33 1 45 24 11 10
E-mail: lazo@nea.fr

Mr. Geoffrey WEBB, IAEA, Austria
Tel: +43 1 20 60 227 21
Fax: +43 1 20 607
E-mail: G.Webb@iaea.org

BUREAU

Chairman

Dr. David W. MILLER, University of Illinois, USA
Tel: +1 217 935 8881 ext. 3880
Fax: +1 217 935 4632
E-mail: dwmphd@aol.com

Chairman-Elect

Mr. Pio CARMENA SERVERT, UNESA, Spain
Tel: +34 1 567 4963
Fax: +34 1 567 4986
E-mail: nuclear@unesa.es

Vice-chairman

Mr. Peter KAPTEINAT, VGB, Germany
Tel: +49 201 81 28 248
Fax: +49 201 81 28 321
E-mail: kraemerp@msn.com

Vice-chairman

Mr. Thommy GODAS, SSI, Sweden
Tel: +46 8 729 7244
Fax: +46 8 729 7108
E-mail: thommy.godas@ssi.se

REGIONAL TECHNICAL CENTRES

Asia (ARTC)

Mr. Hiroshi KAWAGUCHI, NUPEC, Japan
Tel: +81 3 5470 5504
Fax: +81 3 5470 5524
E-mail: kawaguchi@nupec.or.jp

Europe (ERTC)

Dr. Christian LEFAURE, CEPN, France
Tel: +33 1 46 54 79 08
Fax: +33 1 40 84 90 34
E-mail: lefaure@cepn.asso.fr

Non-NEA members (IAEA-RTC)

Ms. Monica GUSTAFSSON, IAEA, Austria
Tel: +43 1 20 60 227 25
Fax: +43 1 20 607
E-mail: M.Gustafsson@iaea.org

North America (NARTC)

Mr. William GREEN, Illinois Power Company, USA
Tel: +1 217 362 7478
Fax: +1 217 362 7475
E-mail: direality@aol.com

ANNEX 1

PARTICIPANTS IN THE NEA INFORMATION SYSTEM ON OCCUPATIONAL EXPOSURE IN 1996

as of October 1997

UTILITIES

Operating Reactors

Country	Utility	Plant Name
Belgium	– Electrabel	Doel 1, 2, 3, 4 Tihange 1, 2, 3
Brazil	– Furnas Centrais Eletricas SA	Angra 1
Canada	– Ontario Hydro	Bruce A1, A2, A3, A4 B5, B6, B7, B8 Pickering A1, A2, A3, A4 B1, B2, B3, B4 Darlington 1, 2, 3, 4
	– Hydro Québec	Gentilly 2
	– New Brunswick Electric Power Company	Point Lepreau
China	– Guangdong Nuclear Power Joint Venture Co., Ltd	Guangdong 1, 2
	– Qinshan Nuclear Power Co.	Qinshan 1
Czech Republic	– Electrostation Dukovany	Dukovany 1, 2, 3, 4
Finland	– Imatran Voima Oy	Loviisa 1, 2
	– Teollisuuden Voima Oy	Olkiluoto 1, 2
France	– Electricité de France	Belleville 1, 2 Blayais 1, 2, 3, 4 Bugey 2, 3, 4, 5 Cattenom 1, 2, 3, 4 Chinon B1, B2, B3, B4 Cruas 1, 2, 3, 4 Dampierre 1, 2, 3, 4 Fessenheim 1, 2 Flamanville 1, 2 Golfech 1, 2 Gravelines 1, 2, 3, 4, 5, 6 Nogent 1, 2 Paluel 1, 2, 3, 4 Penly 1, 2 Saint-Alban 1, 2 Saint Laurent B1, B2 Tricastin 1, 2, 3, 4

Country	**Utility**	**Plant Name**
Germany	– Energie-Versorgung Schwaben AG (EVS)	Obrigheim
	– Badenwerk AG (BW)/EVS	Philippsburg 1, 2
	– Bayernwerk AG (BAG)	Grafenrheinfeld
	– BAG/Isar-Amperwerk AG (IAW)	Isar 1
	– Ostbayrische Energieversorgungs-AG/ Stadtwerke München (BAG/IAW/OBAG/SWM)	Isar 2
	– PreussenElektra AG (PE)	Unterweser Brokdorf Stade•
	– Neckarwerke AG, TWS Stuttgart	Gemeinschschafts - Kernkraftwerk Neckar, Neckarwestheim (GKN) 1, 2
	– Hamburgische Elektricitäts-WerkeAG (HEW)	Brunsbüttel
	– HEW and PE	Krümmel,
	– RWE Energie AG	Biblis A, B Mülheim-Kärlich
	– Kernkraftwerke Gundremmingen Betriebsgesellschaft mbH (KGB)	Gundremmingen B, C
	– Vereinigte Elektrizitätswerke Westfalen AG (VEW)	Emsland
	– Gemeinshaftskernkraftwerk Grohnde GMBH	Grohnde
Hungary	– Magyar Vilamos M vek Rt.	PAKS 1, 2, 3, 4
Japan	– Hokkaido Electric Power Co.	Tomari 1, 2
	– Touhoku Electric Power Co.	Onagawa 1, 2
	– Tokyo Electric Power Co.	Fukushima Daiichi 1,2,3,4,5,6 Fukushima Daini 1,2,3,4 Kashiwazaki Kariwa 1,2,3,4,5,6,7
	– Chubu Electric Power Co.	Hamaoka 1, 2, 3, 4
	– Hokuriku Electric Power Co.	Shika
	– Kansai Electric Power Co.	Mihama 1, 2, 3 Takahama 1, 2, 3, 4 Ohi 1, 2, 3, 4
	– Chugoku Electric Power Co.	Shimane 1, 2
	– Shikoku Electric Power Co.	Ikata 1, 2, 3
	– Kyushu Electric Power Co.	Genkai 1, 2, 3, 4 Sendai 1, 2
	– Japan Atomic Power Co.	Tokai 1, 2 Tsuruga 1, 2
	– Power Reactor and Nuclear Fuel Development Corporation (PNC)	Fugen ATR

Country	**Utility**	**Plant Name**
Korea	– Korean Electric Power Corp.	Wolsong 1 Kori 1, 2, 3, 4 Uljin 1, 2 Yonggwang 1, 2, 3, 4
Lithuania	– Minatomenergoprom	Ignalina 1, 2
Mexico	– Comisiòn Federal de Electricidad	Laguna Verde 1, 2
Netherlands	– N.V. EPZ	Borssele
Romania	– National Electricity Company	Cernavoda 1
Slovak Republic	– Electrostation Bohunica	Bohunica 1, 2, 3, 4
Slovenia	– Nuklearna Elektrana Krsko	Krsko 1
South Africa	– Eskom	Koeberg 1, 2
Spain	– UNESA	Almaraz 1, 2 Asco 1, 2 Cofrentes Santa Maria de Garona Trillo Vandellos 2 Jose Cabrera
Sweden	– Barsebäck Kraft AB	Barsebäck 1, 2
	– Forsmarks Kraftgrupp AB	Forsmark 1, 2, 3
	– OKG AB	Oskarshamn 1, 2, 3
	– Vattenfall AB	Ringhals 1, 2, 3, 4
Switzerland	– Kernkaftwerk Leibstadt AG (KKL)	Leibstadt
	– Forces Motrices Bernoises (FMB)	Muhleberg
	– Nordostschweizerische kraftwerke AG (NOK)	Beznau 1, 2
	– Kernkaftwerk Gosgen-Daniken (KGD)	Gosgen

Country	**Utility**	**Plant Name**
United Kingdom	– Nuclear Electric	Sizewell B
United States	– Arizona Public Service Co.	Palo Verde 1, 2, 3
	– Baltimore Gas & Electric	Calvert Cliffs 1, 2
	– Boston Edison Company	Pilgrim 1
	– Carolina Power and Light	H. B. Robinson 2
	– Commonwealth Edison Co.	Braidwood 1, 2 Byron 1, 2 Dresden 2, 3 LaSalle County 1, 2 Quad Cities 1, 2 Zion 1, 2
	– Consumers Energy Company	Palisades 1
	– General Public Utilities,	TMI 1 Oyster Creek 1
	– Illinois Power Co.	Clinton 1
	– Indiana and Michigan Power Company	D.C. Cook 1, 2
	– New York Power Authority	Indian Point 3
	– Pacific Gas and Electric Company,	Diablo Canyon 1, 2
	– Pennsylvania Power & Light	Susquehanna 1, 2
	– PECo Energy	Limerick 1, 2 Peach Bottom 2, 3
	– South Carolina Electric & Gas	Virgil C. Summer 1
	– Southern California Edison	San Onofre 2, 3
	– Texas Utilities	Comanche Peak 1, 2
	– Wisconson Electric Power Co.	Point Beach 1, 2

UTILITIES

Definitively Shutdown Reactors

Country	**Utility**	**Plant Name**
France	– Electricité de France	Bugey 1 Chinon A1, A2, A3 Chooz A St. Laurent A1, A2
Italy	– Ente Nazionale per l'Energia Elettrica	Caorso Garigliano Latina (GCR) Trino
Germany	– PreussenElektra AG (PE)	Würgassen
Netherlands	– NCGKN	Dodewaard
Spain	– UNESA	Vandellos 1
United States	– Southern California Edison	San Onofre 1,
	– General Public Utilities,	TMI 2
	– Commonwealth Edison Co.	Dresden 1
	– Pacific Gas and Electric Company	Humboldt Bay 1
	– PECo Energy	Peach Bottom 1

REGULATORY AUTHORITIES

Belgium	Service de la Sécurité Technique des Installations
Brazil	National Nuclear Energy Commission
Canada	Atomic Energy Control Board (AECB)
China	China National Nuclear Corporation (CNNC)
Czech Republic	State Office for Nuclear Safety
Finland	Säteilyturvakeskus (STUK)
France	Ministère du travail, et des affaires sociales, Represented by the Office de Protection contre les Rayonnements Ionisants (OPRI)
Germany	Bundesministerium Für Umwelt, Naturschutz und Reactorsicherheit
Italy	Agenzia Nazionale per la Protezione dell'Ambiente (ANPA)
Japan	Science and Technology Agency (STA), and Agency of Natural Resources and Energy of the Ministry of International Trade and Industry (MITI)
Korea	Ministry of Science and Technology (MOST) Korea Institute of Nuclear Safety (KINS)
Mexico	Comision Nacional de Seguridad Nuclear y Salvaguardias
Netherlands	Ministerie van Sociale Zaken en Werkgelegenheld
Romania	National Commission for Nuclear Activities Control
Slovak Republic	State Health Institute
Slovenia	Slovenian Nuclear Safety Administration (SNSA)
Spain	Consejo de Segurigad Nuclear
Sweden	Statens strålskyddsinstitut (SSI)
Switzerland	Office Fédéral de l'Énergie, Division principale de la Sécurité des Installations Nucléaires, DSN
United Kingdom	Nuclear Installations Inspectorate
United States	Nuclear Regulatory Commission (NRC)

ISOE REGIONAL TECHNICAL CENTRES

European Region (ERTC)	Centre d'étude sur l'évaluation de la protection dans le domaine nucléaire (CEPN), Fontenay-aux-Roses, France
Asian Region (ARTC)	Nuclear Power Engineering Corporation (NUPEC), Tokyo, Japan
North American Region (NARTC)	University of Illinois, Champagne-Urbanna, Illinois, U.S.A.
Non-NEA Countries (IAEARTC)	International Atomic Energy Agency (IAEA), Vienna, Austria

COUNTRY – REGIONAL TECHNICAL CENTRE AFFILIATIONS

Country	**Regional Technical Centre**
Belgium	ERTC
Brazil	IAEARTC
Canada	NARTC
China	IAEARTC
Czech Republic	ERTC
Finland	ERTC
France	ERTC
Germany	ERTC
Hongary	ERTC
Italy	ERTC
Japan	ARTC
Korea	ARTC
Lithuania	IAEARTC
Mexico	NARTC
Netherlands	ERTC
Romania	IAEARTC
Slovak Republic	IAEARTC
Slovenia	IAEARTC
South Africa	IAEARTC
Spain	ERTC
Sweden	ERTC
Switzerland	ERTC
United Kingdom	ERTC
United States	NARTC

INTERNATIONAL COOPERATION

- European Commission (EC)
- World Association of Nuclear Operators, Paris Centre (WANO PC)

Participation Summary

Operating Reactors Participating in ISOE

Country	PWR	BWR	PHWR	GCR	LWGR	Total
Belgium	7	–	–	–	–	7
Brazil	1	–	–	–	–	1
Canada	–	–	22	–	–	22
China	3	–	–	–	–	3
Czech Republic	4	–	–	–	–	4
Finland	2	2	–	–	–	4
France	54	–	–	–	–	54
Germany	14	6	–	–	–	20
Hungary	4	–	–	–	–	4
Japan	23	28	–	1	–	52
Korea	10	–	1	–	–	11
Lithuania	–	–	–	–	2	2
Mexico	–	2	–	–	–	2
Netherlands	1	1	–	–	–	2
Slovak Republic	4	–	–	–	–	4
Slovenia	1	–	–	–	–	1
South Africa	2	–	–	–	–	2
Spain	7	2	–	–	–	9
Sweden	3	9	–	–	–	12
Switzerland	3	2	–	–	–	5
United Kingdom	1	–	–	–	–	1
United States	26	15	–	–	–	41
Total	**170**	**67**	**23**	**1**	**2**	**263**

Operating Reactors Not Participating in ISOE but Included in the ISOE Data Base

Country	PWR	BWR	PHWR	GCR	LWGR	Total
United Kingdom	–	–	–	34	–	34
United States	46	22	–	–	–	68
Total	**46**	**22**	**-**	**34**	**-**	**102**

Total Number of Operating Reactors Included in the ISOE Data Base

	PWR	BWR	PHWR	GCR	LWGR	Total
Total	**216**	**89**	**23**	**35**	**2**	**365**

Definitively Shutdown Reactors Participating in ISOE

Country	PWR	BWR	PHWR	GCR	Total
France	1	–	–	6	7
Italy	1	2	–	1	4
Germany	–	1	–	–	1
United States	2	2	–	1	6
Total	**4**	**5**	–	**8**	**18**

Definitively Shutdown Reactors Not Participating in ISOE but Included in the ISOE Data Base

Country	PWR	BWR	PHWR	GCR	Total
Canada	–	–	2	–	2
Germany	–	2	–	–	2
United Kingdom	–	–	–	6	6
United States	4	2	–	1	7
Total	**4**	**4**	**2**	**7**	**17**

Total Number of Definitively Shutdown Reactors Included in the ISOE Data Base

	PWR	BWR	PHWR	GCR	Total
Total	**8**	**9**	**2**	**15**	**35**

Number of Utilities Officially Participating:	71
Number of Counries Officially Participating:	24
Number of Authorities Officially Participating:	21

ANNEX 2

1986-1996 DATA FOR OPERATING REACTORS PER COUNTRY, REGION AND TYPE OF REACTOR

1986-1996 data for operating reactors :

- by country and type of reactors,
- by region and type of reactors,
- by type of reactors for all NEA reactors.

Note that this year, for the first time, reactors which have been definitively shutdown and gas cooled reactors are included in this Report. The following historical tables have thus been adjusted, with respect to those published in last year's ISOE Annual Reports, to include these new classes of reactors. In the case of reactors which are definitively shutdown, these reactors and their doses are included in these historical records only for those years in which the reactors were operating.

- BELGIUM, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	7	39.37	25.29	0.64	3.61
1987	7	41.92	14.21	0.34	2.03
1988	7	43.09	17.63	0.41	2.52
1989	7	41.16	19.59	0.48	2.80
1990	7	42.72	11.73	0.27	1.68
1991	7	42.86	11.23	0.26	1.60
1992	7	43.46	8.45	0.19	1.21
1993	7	41.93	9.43	0.22	1.35
1994	7	40.62	6.84	0.17	0.98
1995	7	41.36	9.20	0.22	1.31
1996	7	43.34	6.42	0.15	0.92

- BRAZIL, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	0.14	1.44	9.95	1.44
1987	1	0.97	0.27	0.28	0.27
1988	1	0.61	2.51	4.08	2.51
1989	1	1.85	1.45	0.78	1.45
1990	1	2.26	0.09	0.04	0.09
1991	1	1.44	1.02	0.70	1.02
1992	1	1.75	0.74	0.42	0.74
1993	1	0.41	2.24	5.43	2.24
1994	1	0.06	0.56	10.23	0.56
1995	1	2.52	0.42	0.17	0.42
1996	1	2.43	1.34	0.55	1.34

- CANADA, CANDU -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	18	74.62	16.71	0.22	0.93
1987	19	80.60	18.13	0.22	0.95
1988	18	85.58	15.73	0.18	0.87
1989	18	83.23	16.72	0.20	0.93
1990	18	73.36	16.73	0.23	0.93
1991	19	88.38	12.15	0.14	0.64
1992	20	78.26	19.62	0.25	0.98
1993	22	94.57	16.42	0.17	0.75
1994	22	110.65	17.12	0.15	0.78
1995	22	100.29	26.28	0.26	1.19
1996	22	95.23	11.59	0.12	0.53

- CHINA, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986					
1987					
1988					
1989					
1990					
1991					
1992					
1993					
1994	3	13.08	1.17	0.09	0.39
1995	3	12.84	2.69	0.21	0.90
1996	3	14.76	2.22	0.15	0.74

- CZECH REPUBLIC, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	3	6.15	0.67	0.11	0.22
1987	4	10.70	1.17	0.11	0.29
1988	4	11.82	1.31	0.11	0.33
1989	4	12.42	1.60	0.13	0.40
1990	4	12.59	1.02	0.08	0.25
1991	4	12.13	1.27	0.10	0.32
1992	4	12.25	1.87	0.15	0.47
1993	4	12.63	1.79	0.14	0.45
1994	4	12.98	1.42	0.11	0.35
1995	4	12.23	1.69	0.14	0.42
1996	4	12.85	1.45	0.11	0.36

- FINLAND, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	2	11.74	1.37	0.12	0.69
1987	2	11.80	1.73	0.15	0.87
1988	2	11.93	2.14	0.18	1.07
1989	2	11.30	2.80	0.25	1.40
1990	2	12.05	1.58	0.13	0.79
1991	2	12.05	1.40	0.12	0.70
1992	2	12.04	2.41	0.20	1.20
1993	2	12.25	1.60	0.13	0.80
1994	2	12.16	2.39	0.20	1.20
1995	2	11.68	1.10	0.09	0.55
1996	2	11.85	1.68	0.14	0.84

- FINLAND, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	2	7.04	2.64	0.37	1.32
1987	2	7.57	1.27	0.17	0.64
1988	2	7.34	1.76	0.24	0.88
1989	2	7.50	1.78	0.24	0.89
1990	2	6.90	2.82	0.41	1.41
1991	2	7.18	1.68	0.23	0.84
1992	2	6.96	3.29	0.47	1.64
1993	2	7.36	2.16	0.29	1.08
1994	2	6.97	2.33	0.33	1.17
1995	2	6.80	1.13	0.17	0.57
1996	2	7.18	2.64	0.37	1.32

- FRANCE, GCR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	2	4.71	3.31	0.70	1.66
1987	4	6.54	5.56	0.85	1.39
1988	4	9.33	4.47	0.48	1.12
1989	4	6.15	2.56	0.42	0.64
1990	3	3.15	0.88	0.28	0.29
1991	2	4.00	0.95	0.24	0.48
1992	2	2.59	0.34	0.13	0.17
1993	1	1.64	0.14	0.09	0.14

- FRANCE, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1985	32	197.78	61.57	0.31	1.92
1986	38	235.37	86.64	0.37	2.28
1987	44	255.05	84.89	0.33	1.93
1988	47	261.91	82.80	0.32	1.76
1989	49	295.25	101.70	0.34	2.08
1990	49	300.33	115.12	0.38	2.35
1991	52	324.99	125.28	0.39	2.41
1992	52	330.41	122.53	0.37	2.36
1993	53	364.17	108.44	0.30	2.04
1994	54	358.48	93.83	0.26	1.74
1995	54	375.17	88.05	0.23	1.63
1996	54	393.6	85.91	0.22	1.59

- GERMANY, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	7	50.14	22.07	0.44	3.15
1987	7	50.82	16.41	0.32	2.34
1988	7	47.52	17.41	0.37	2.49
1989	7	47.28	18.46	0.39	2.64
1990	7	43.72	16.23	0.37	2.32
1991	7	47.17	15.10	0.32	2.16
1992	7	46.95	14.50	0.31	2.07
1993	7	37.79	17.10	0.45	2.44
1994	7	35.56	15.07	0.42	2.15
1995	6	45.09	8.22	0.18	1.37
1996	6	46.72	8.60	0.18	1.43

- GERMANY, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	9	65.56	30.70	0.47	3.41
1987	11	78.53	30.73	0.39	2.79
1988	13	96.59	35.24	0.36	2.71
1989	13	92.27	34.09	0.37	2.62
1990	14	103.52	24.38	0.24	1.74
1991	14	100.28	31.67	0.32	2.26
1992	14	111.89	27.66	0.25	1.98
1993	14	115.63	20.27	0.18	1.45
1994	14	115.18	31.51	0.27	2.25
1995	14	109.87	27.96	0.25	2.00
1996	14	115.77	23.30	0.20	1.66

- HUNGARY, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	2	6.66	1.04	0.16	0.52
1987	3	9.88	2.14	0.22	0.71
1988	4	13.45	1.73	0.13	0.43
1989	4	13.89	2.31	0.17	0.58
1990	4	13.73	3.36	0.24	0.84
1991	4	13.73	2.60	0.19	0.65
1992	4	13.96	2.75	0.20	0.69
1993	4	13.80	1.87	0.14	0.47
1994	4	14.05	1.58	0.11	0.39
1995	4	14.03	2.23	0.16	0.56
1996	4	12.82	2.53	0.20	0.63

- ITALY, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	5.46	2.25	0.41	2.25

- ITALY, GCR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	1.19	0.29	0.25	0.29

- ITALY, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	2.11	0.31	0.15	0.31
1987	1	0.17	1.75	10.05	1.75

– JAPAN, BWR –

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	18	87.15	64.17	0.74	3.57
1987	18	100.30	63.14	0.63	3.51
1988	19	99.04	55.99	0.57	2.95
1989	21	95.20	55.96	0.59	2.66
1990	21	115.35	50.19	0.44	2.39
1991	21	119.41	36.51	0.31	1.74
1992	24	117.69	37.59	0.32	1.57
1993	25	133.36	55.60	0.42	2.22
1994	26	147.24	41.15	0.28	1.58
1995	26	163.58	40.41	0.25	1.55
1996	28	171.01	44.79	0.26	1.60

– JAPAN, GCR –

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	0.92	0.91	0.99	0.91
1987	1	0.79	1.07	1.36	1.07
1988	1	0.84	0.85	1.01	0.85
1989	1	0.77	0.66	0.86	0.66
1990	1	0.95	0.56	0.59	0.56
1991	1	0.89	0.55	0.62	0.55
1992	1	1.08	0.45	0.42	0.45
1993	1	0.00	0.30		0.30
1994	1	0.98	0.23	0.23	0.23
1995	1	0.88	0.39	0.44	0.39
1996	1	1.05	0.39	0.37	0.39

- JAPAN, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	16	78.79	36.90	0.47	2.31
1987	16	85.52	30.61	0.36	1.91
1988	17	77.74	35.91	0.46	2.11
1989	17	85.89	30.77	0.36	1.81
1990	18	85.11	31.19	0.37	1.73
1991	19	91.87	20.80	0.23	1.09
1992	20	97.83	25.50	0.26	1.28
1993	21	106.50	30.75	0.29	1.46
1994	22	115.59	23.55	0.20	1.07
1995	22	123.89	25.52	0.21	1.16
1996	23	123.40	23.82	0.19	1.04

- KOREA, CANDU -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	4.74	1.84	0.39	1.84
1987	1	5.52	0.56	0.10	0.56
1988	1	4.73	1.69	0.36	1.69
1989	1	5.41	0.71	0.13	0.71
1990	1	5.11	1.17	0.23	1.17
1991	1	5.42	0.56	0.10	0.56
1992	1	5.18	1.60	0.31	1.60
1993	1	5.99	0.49	0.08	0.49
1994	1	4.91	2.80	0.57	2.80
1995	1	4.97	2.17	0.44	2.17
1996	1	4.83	2.99	0.62	2.99

- KOREA, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	5	22.48	10.40	0.46	2.08
1987	6	32.52	11.76	0.36	1.96
1988	7	35.37	29.24	0.83	4.18
1989	8	41.95	19.18	0.46	2.40
1990	8	47.78	18.13	0.38	2.27
1991	8	50.89	8.28	0.16	1.03
1992	8	51.35	12.46	0.24	1.56
1993	8	52.14	13.13	0.25	1.64
1994	8	53.40	9.48	0.18	1.18
1995	9	58.99	10.69	0.18	1.19
1996	10	68.18	8.85	0.13	0.88

- LITHUANIA, LWGR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	9.88	8.14	0.82	8.14
1987	2	9.18	13.12	1.43	6.56
1988	2	12.81	21.80	1.70	10.90
1989	2	16.65	7.73	0.46	3.87
1990	2	17.03	10.39	0.61	5.20
1991	2	17.00	13.13	0.77	6.57
1992	2	14.64	22.63	1.55	11.32
1993	2	12.26	17.25	1.41	8.63
1994	2	7.71	16.24	2.11	8.12
1995	2	11.82	13.93	1.18	6.96
1996	2	14.14	15.10	1.07	7.55

- MEXICO, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986					
1987					
1988					
1989					
1990					
1991	1	4.24	5.14	1.21	5.14
1992	1	3.92	5.44	1.39	5.44
1993	1	4.92	1.96	0.40	1.96
1994	1	4.24	6.03	1.42	6.03
1995	2	7.85	5.93	0.76	2.96
1996	2	7.88	16.16	2.05	8.08

- NETHERLANDS, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	0.43	2.12	4.91	2.12
1987	1	0.44	2.49	5.72	2.49
1988	1	0.46	1.34	2.92	1.34
1989	1	0.38	1.46	3.81	1.46
1990	1	0.43	0.76	1.75	0.76
1991	1	0.43	1.03	2.40	1.03
1992	1	0.44	0.86	1.97	0.86
1993	1	0.46	1.13	2.48	1.13
1994	1	0.42	0.85	2.05	0.85
1995	1	0.42	1.01	2.40	1.01
1996	1	0.42	0.99	2.35	0.99

- NETHERLANDS, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	3.78	1.96	0.52	1.96
1987	1	3.12	2.66	0.85	2.66
1988	1	3.22	3.48	1.08	3.48
1989	1	3.63	2.45	0.67	2.45
1990	1	3.07	1.77	0.58	1.77
1991	1	2.90	2.02	0.70	2.02
1992	1	3.36	1.25	0.37	1.25
1993	1	3.49	1.17	0.34	1.17
1994	1	3.53	1.82	0.51	1.82
1995	1	3.60	0.97	0.27	0.97
1996	1	3.52	1.11	0.32	1.11

– SLOVAK REPUBLIC, PWR –

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	4	11.72	1.97	0.17	0.49
1987	4	11.51	2.57	0.22	0.64
1988	4	11.47	3.44	0.30	0.86
1989	4	12.16	1.94	0.16	0.49
1990	4	12.04	1.24	0.10	0.31
1991	4	11.69	2.31	0.20	0.58
1992	4	11.05	3.70	0.34	0.93
1993	4	11.02	3.15	0.29	0.79
1994	4	12.14	1.54	0.13	0.39
1995	4	11.44	1.66	0.14	0.41
1996	4	11.26	2.73	0.24	0.68

- SLOVENIA, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	4.02	1.61	0.40	1.61
1987	1	4.49	1.49	0.33	1.49
1988	1	4.14	1.70	0.41	1.70
1989	1	4.69	1.33	0.28	1.33
1990	1	4.62	2.03	0.44	2.03
1991	1	4.95	0.31	0.06	0.31
1992	1	3.97	2.14	0.54	2.14
1993	1	3.96	1.67	0.42	1.67
1994	1	4.61	0.84	0.18	0.84
1995	1	4.78	1.40	0.29	1.40
1996	1	4.56	1.79	0.39	1.79

- SOUTH AFRICA, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	2	9.32	1.69	0.18	0.85
1987	2	6.60	2.96	0.45	1.48
1988	2	11.10	1.69	0.15	0.85
1989	2	11.73	1.14	0.10	0.57
1990	2	8.94	2.52	0.28	1.26
1991	2	9.70	1.64	0.17	0.82
1992	2	9.88	1.49	0.15	0.75
1993	2	7.75	3.07	0.40	1.54
1994	2	10.28	1.61	0.16	0.81
1995	2	11.92	1.40	0.12	0.70
1996	2	12.37	2.22	0.18	1.11

- SPAIN, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	2	10.50	1.93	0.18	0.97
1987	2	9.87	10.82	1.10	5.41
1988	2	10.25	11.68	1.14	5.84
1989	2	11.01	4.99	0.45	2.49
1990	2	10.02	10.20	1.02	5.10
1991	2	11.13	6.85	0.62	3.42
1992	2	10.83	8.13	0.75	4.07
1993	2	11.11	5.59	0.50	2.79
1994	2	10.55	7.88	0.75	3.94
1995	2	12.47	1.03	0.08	0.52
1996	2	11.31	6.71	0.59	3.36

- SPAIN, GCR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	3.08	0.20	0.06	0.20
1987	1	3.13	0.53	0.17	0.53
1988	1	3.16	0.38	0.12	0.38
1989	1	2.54	0.16	0.06	0.16

- SPAIN, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	5	23.88	16.42	0.69	3.28
1987	5	28.21	14.35	0.51	2.87
1988	6	33.87	16.11	0.48	2.69
1989	7	42.58	15.35	0.36	2.19
1990	7	44.24	15.52	0.35	2.22
1991	7	44.45	13.12	0.30	1.87
1992	7	44.94	14.14	0.31	2.02
1993	7	44.46	9.56	0.21	1.37
1994	7	44.78	12.38	0.28	1.77
1995	7	42.50	14.85	0.35	2.12
1996	7	45.01	10.29	0.23	1.47

- SWEDEN, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	9	53.26	11.06	0.21	1.23
1987	9	50.48	10.47	0.21	1.16
1988	9	51.48	12.47	0.24	1.39
1989	9	49.74	9.71	0.20	1.08
1990	9	49.85	11.21	0.22	1.25
1991	9	56.67	10.31	0.18	1.15
1992	9	44.31	15.94	0.36	1.77
1993	9	44.12	23.58	0.53	2.62
1994	9	51.89	15.42	0.30	1.71
1995	9	51.21	15.05	0.29	1.67
1996	9	54.70	20.94	0.38	2.33

- SWEDEN, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	3	16.70	5.99	0.36	2.00
1987	3	16.88	4.39	0.26	1.46
1988	3	17.93	4.35	0.24	1.45
1989	3	15.86	5.92	0.37	1.97
1990	3	18.34	3.15	0.17	1.05
1991	3	20.09	2.53	0.13	0.84
1992	3	18.17	3.36	0.18	1.12
1993	3	16.47	2.56	0.16	0.85
1994	3	20.32	1.91	0.09	0.64
1995	3	18.10	2.93	0.16	0.98
1996	3	19.84	1.98	0.10	0.66

- SWITZERLAND, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	2	9.82	13.67	1.39	6.84
1987	2	10.36	5.05	0.49	2.52
1988	2	10.00	6.13	0.61	3.06
1989	2	10.17	5.76	0.57	2.88
1990	2	10.61	4.09	0.39	2.05
1991	2	9.99	4.23	0.42	2.12
1992	2	10.49	3.93	0.37	1.97
1993	2	10.44	3.42	0.33	1.71
1994	2	10.14	4.63	0.46	2.31
1995	2	10.88	3.14	0.29	1.57
1996	2	10.89	3.36	0.31	1.68

- SWITZERLAND, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	3	12.65	6.60	0.52	2.20
1987	3	12.55	8.51	0.68	2.84
1988	3	12.69	5.38	0.42	1.79
1989	3	12.59	6.54	0.52	2.18
1990	3	12.99	4.06	0.31	1.35
1991	3	12.91	4.82	0.37	1.61
1992	3	12.92	4.58	0.35	1.53
1993	3	12.87	4.69	0.36	1.56
1994	3	14.11	2.37	0.17	0.79
1995	3	13.86	2.46	0.18	0.82
1996	3	14.13	2.12	0.15	0.71

- UNITED KINGDOM, GCR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	36	57.14	27.00	0.47	0.75
1987	36	54.11	23.38	0.43	0.65
1988	38	60.02	22.27	0.37	0.59
1989	39	70.17	21.17	0.30	0.54
1990	36	65.66	18.74	0.29	0.52
1991	36	69.77	16.51	0.24	0.46
1992	34	77.51	14.83	0.19	0.44
1993	34	89.76	12.98	0.14	0.38
1994	34	88.96	10.41	0.12	0.31
1995	34	83.80	9.71	0.12	0.29
1996	34	86.01	8.65	0.10	0.25

- UNITED KINGDOM, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986					
1987					
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995	1	5.11	0.03	0.01	0.03
1996	1	8.48	0.53	0.06	0.53

- USA, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	30	106.01	195.15	1.84	6.51
1987	33	132.50	169.39	1.28	5.13
1988	34	146.39	179.87	1.23	5.29
1989	36	153.68	155.48	1.01	4.32
1990	36	179.35	157.80	0.88	4.38
1991	37	194.39	120.05	0.62	3.24
1992	37	180.65	133.09	0.74	3.60
1993	37	193.67	121.91	0.63	3.29
1994	37	193.93	121.00	0.62	3.27
1995	37	216.70	95.15	0.44	2.57
1996	37	213.85	93.19	0.44	2.52

- USA, GCR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	85.40	0.02	0.00	0.02
1987	1	208.22	0.01	0.00	0.01
1988	1	718.18	0.01	0.00	0.01
1989	1	576.25	0.03	0.00	0.03

- USA, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	58	292.29	220.93	0.76	3.81
1987	63	326.69	224.15	0.69	3.56
1988	67	376.45	218.70	0.58	3.26
1989	71	390.70	203.81	0.52	2.87
1990	72	411.37	207.99	0.51	2.89
1991	74	454.72	165.22	0.36	2.23
1992	73	469.37	160.00	0.34	2.19
1993	72	447.91	140.50	0.31	1.95
1994	72	478.47	96.24	0.20	1.34
1995	72	494.35	124.56	0.25	1.73
1996	72	487.57	93.65	0.19	1.30

- ASIA, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	21	101.27	47.30	0.47	2.25
1987	22	118.04	42.37	0.36	1.93
1988	24	113.11	65.15	0.58	2.71
1989	25	127.85	49.95	0.39	2.00
1990	26	132.89	49.32	0.37	1.90
1991	27	142.76	29.08	0.20	1.08
1992	28	149.18	37.96	0.25	1.36
1993	29	158.64	43.88	0.28	1.51
1994	30	168.99	33.03	0.20	1.10
1995	31	182.88	36.21	0.20	1.17
1996	33	191.58	32.67	0.17	0.99

- ASIA, ALL TYPES OF REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	41	194.08	114.22	0.59	2.79
1987	42	224.65	107.14	0.48	2.55
1988	45	217.72	123.68	0.57	2.75
1989	48	229.23	107.27	0.47	2.23
1990	49	254.30	101.24	0.40	2.07
1991	50	268.49	66.70	0.25	1.33
1992	54	273.13	77.60	0.28	1.44
1993	56	298.00	100.27	0.34	1.79
1994	58	322.12	77.21	0.24	1.33
1995	59	352.31	79.18	0.22	1.34
1996	63	368.47	80.83	0.22	1.28

- EUROPE, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	24	141.35	54.46	0.39	2.27
1987	23	133.76	46.96	0.35	2.04
1988	23	131.65	51.16	0.39	2.22
1989	23	129.87	43.19	0.33	1.88
1990	23	126.68	44.06	0.35	1.92
1991	23	137.43	38.92	0.28	1.69
1992	23	125.06	45.78	0.37	1.99
1993	23	116.17	52.42	0.45	2.28
1994	23	120.72	46.25	0.38	2.01
1995	22	131.76	29.56	0.22	1.34
1996	22	135.90	42.28	0.31	1.92

- EUROPE, GCR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	40	66.11	30.80	0.47	0.77
1987	41	63.78	29.47	0.46	0.72
1988	43	72.52	27.12	0.37	0.63
1989	44	78.86	23.89	0.30	0.54
1990	39	68.81	19.62	0.29	0.50
1991	38	73.77	17.46	0.24	0.46
1992	36	80.11	15.17	0.19	0.42
1993	35	91.41	13.12	0.14	0.37
1994	34	88.96	10.41	0.12	0.31
1995	34	83.80	9.71	0.12	0.29
1996	34	86.01	8.65	0.17	0.30

- EUROPE, PWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	74	419.26	178.30	0.43	2.41
1987	84	464.58	166.06	0.36	1.98
1988	90	501.89	169.81	0.34	1.89
1989	93	537.15	191.31	0.36	2.06
1990	94	558.42	182.91	0.33	1.95
1991	97	581.51	196.23	0.34	2.02
1992	97	598.31	189.87	0.32	1.96
1993	98	632.81	161.93	0.26	1.65
1994	99	631.01	155.98	0.25	1.58
1995	100	642.62	151.52	0.24	1.52
1996	100	676.53	138.27	0.20	1.38

Czech Republic and Hungary have been added in the European region.

- EUROPE, ALL TYPES OF REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	138	626.72	263.56	0.42	1.91
1987	148	662.13	242.49	0.37	1.64
1988	156	706.06	248.08	0.35	1.59
1989	160	745.88	258.38	0.35	1.61
1990	156	753.91	246.59	0.33	1.58
1991	158	792.72	252.61	0.32	1.60
1992	156	803.48	250.81	0.31	1.61
1993	156	840.38	227.46	0.27	1.46
1994	156	840.69	212.64	0.25	1.36
1995	156	858.18	190.78	0.22	1.22
1996	156	898.44	189.19	0.21	1.21

- NORTH AMERICA, BWR -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	30	106.01	195.15	1.84	6.51
1987	33	132.50	169.39	1.28	5.13
1988	34	146.39	179.87	1.23	5.29
1989	36	153.68	155.48	1.01	4.32
1990	36	179.35	157.80	0.88	4.38
1991	38	198.63	125.19	0.63	3.29
1992	38	184.56	138.53	0.75	3.65
1993	38	198.59	123.87	0.62	3.26
1994	38	198.17	127.03	0.64	3.34
1995	39	224.55	101.34	0.45	2.60
1996	39	221.72	109.35	0.49	2.80

- NORTH AMERICA, ALL TYPES OF REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	107	558.33	432.81	0.78	4.04
1987	116	748.01	411.68	0.55	3.55
1988	120	1326.60	414.31	0.31	3.45
1989	126	1203.87	376.04	0.31	2.98
1990	126	664.08	382.52	0.58	3.04
1991	131	908.23	302.56	0.33	2.31
1992	131	732.20	318.15	0.43	2.43
1993	132	741.08	280.79	0.38	2.13
1994	132	787.29	240.39	0.31	1.82
1995	133	819.19	251.79	0.31	1.89
1996	133	804.53	214.59	0.27	1.61

- ALL BWR REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	72	334.51	313.78	0.94	4.36
1987	74	366.56	279.49	0.76	3.78
1988	76	377.07	287.02	0.76	3.78
1989	80	378.76	254.63	0.67	3.18
1990	80	421.39	252.05	0.60	3.15
1991	82	455.48	200.62	0.44	2.45
1992	85	427.31	221.90	0.52	2.61
1993	86	448.13	231.88	0.52	2.70
1994	87	466.13	214.43	0.46	2.46
1995	87	519.88	171.04	0.33	1.97
1996	89	528.63	196.42	0.37	2.21

- ALL CANDU REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	19	79.36	18.55	0.23	0.98
1987	20	86.13	18.69	0.22	0.93
1988	19	90.32	17.42	0.19	0.92
1989	19	88.65	17.42	0.20	0.92
1990	19	78.47	17.90	0.23	0.94
1991	20	93.79	12.71	0.14	0.64
1992	21	83.44	21.22	0.25	1.01
1993	23	100.57	16.91	0.17	0.74
1994	23	115.56	19.92	0.17	0.87
1995	23	105.27	28.45	0.27	1.24
1996	23	100.06	14.58	0.15	0.63

- ALL GCR REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	42	152.43	31.73	0.21	0.76
1987	43	272.80	30.55	0.11	0.71
1988	45	791.54	27.97	0.04	0.62
1989	46	655.88	24.57	0.04	0.53
1990	40	69.76	20.18	0.29	0.50
1991	39	74.67	18.01	0.24	0.46
1992	37	81.19	15.62	0.19	0.42
1993	36	91.41	13.42	0.15	0.37
1994	35	89.94	10.64	0.12	0.30
1995	35	84.68	10.10	0.12	0.29
1996	35	87.06	9.04	0.10	0.26

- ALL PWR REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	161	838.03	453.23	0.54	2.82
1987	177	932.89	439.87	0.47	2.49
1988	189	1018.78	463.00	0.45	2.45
1989	197	1086.12	450.92	0.42	2.29
1990	200	1130.54	446.09	0.39	2.23
1991	206	1206.77	395.81	0.33	1.92
1992	206	1243.51	395.90	0.32	1.92
1993	207	1262.53	356.43	0.28	1.72
1994	212	1318.63	290.98	0.22	1.37
1995	214	1363.35	319.86	0.23	1.49
1996	216	1401.08	274.88	0.20	1.27

- NON-NEA, PWR REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	8	25.20	6.70	0.27	0.84
1987	8	23.58	7.28	0.31	0.91
1988	8	27.33	9.34	0.34	1.17
1989	8	30.42	5.86	0.19	0.73
1990	8	27.86	5.88	0.21	0.73
1991	8	27.78	5.28	0.19	0.66
1992	8	26.65	8.07	0.30	1.01
1993	8	23.17	10.13	0.44	1.27
1994	11	40.16	5.73	0.14	0.52
1995	11	43.49	7.57	0.17	0.69
1996	11	45.39	10.30	0.23	0.94

- NON-NEA, LWGR REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	1	9.88	8.14	0.82	8.14
1987	2	9.18	13.12	1.43	6.56
1988	2	12.81	21.80	1.70	10.90
1989	2	16.65	7.73	0.46	3.87
1990	2	17.03	10.39	0.61	5.20
1991	2	17.00	13.13	0.77	6.57
1992	2	14.64	22.63	1.55	11.32
1993	2	12.26	17.25	1.41	8.63
1994	2	7.71	16.24	2.11	8.12
1995	2	11.82	13.93	1.18	6.96
1996	2	14.14	15.10	1.07	7.55

- NEA, ALL TYPES OF REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	286	1379.13	810.58	0.59	2.83
1987	306	1634.79	761.31	0.47	2.49
1988	321	2250.38	786.07	0.35	2.45
1989	334	2178.98	741.69	0.34	2.22
1990	331	1672.29	730.34	0.44	2.21
1991	339	1802.93	621.87	0.34	1.83
1992	341	1808.80	646.56	0.36	1.90
1993	344	1879.46	608.52	0.32	1.77
1994	346	1950.09	530.24	0.27	1.53
1995	348	2029.68	521.89	0.26	1.50
1996	352	2071.44	484.61	0.23	1.38

- NON-NEA, ALL TYPES OF REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	9	35.08	14.84	0.42	1.65
1987	10	32.76	20.40	0.62	2.04
1988	10	40.14	31.14	0.78	3.11
1989	10	47.07	13.59	0.29	1.36
1990	10	44.89	16.27	0.36	1.63
1991	10	44.78	18.41	0.41	1.84
1992	10	41.28	30.70	0.74	3.07
1993	10	35.43	27.38	0.77	2.74
1994	13	47.86	21.97	0.46	1.69
1995	13	55.31	21.50	0.39	1.65
1996	13	59.53	25.40	0.43	1.95

- ALL TYPES OF REACTORS -

YEAR	NUMBER OF REACTORS IN OPERATION	GROSS PRODUCTION (TWh)	ANNUAL TOTAL COLLECTIVE DOSE (man.Sv)	AVERAGE COLLECTIVE DOSE PER TWH (man.Sv/TWh)	AVERAGE COLLECTIVE DOSE PER REACTOR (man.Sv)
1986	295	1414.21	825.42	0.58	2.80
1987	316	1667.55	781.71	0.47	2.47
1988	331	2290.51	817.21	0.36	2.47
1989	344	2226.05	755.28	0.34	2.20
1990	341	1717.18	746.61	0.43	2.19
1991	349	1847.71	640.28	0.35	1.83
1992	351	1850.08	677.26	0.37	1.93
1993	354	1914.89	635.90	0.33	1.80
1994	359	1997.96	552.21	0.28	1.54
1995	361	2084.99	543.38	0.26	1.51
1996	365	2130.97	510.02	0.24	1.40