XX CONFERÈNCIA CATALANA PER UN FUTUR SENSE NUCLEARS I ENERGÈTICAMENT SOSTENIBLE

TXERNÒBIL MAI MÉS!

dia 26 d'abril del 2006
a les 18.30h
Auditori del Centre de Cultura Contemporània de Barcelona

VIII Fòrum de l'Energia Sostenible

Dia 27 d'abril del 2006,
a les 11:00 hores
A la Fàbrica del Sol,
Salvat Papasseit 1, La Barceloneta

NUCLEAR? NO GRÀCIES

earth day network

WCRE World Council for Renewable Energy

UAB Universitat Autònoma de Barcelona
Institut de Ciència i Tecnologia Ambientals

Generalitat de Catalunya
Departament de Medi Ambient i Habitatge
Departament de Treball i Indústria
Institut Català d'Energia

Ajuntament de Barcelona

BARNAGEL
Barcelona grup d'energia local

save · agencia

Organització: Grup de Científics i Tècnics per un Futur No Nuclear - GCTPFNN **Entitats col.laboradores:** * ***Organitzacions No Governamentals:*** ADENC - Associació per a la Defensa i l'Estudi de la Natura Alternativa Solidària - Plenty, Alternativa Verda (Organització No Governamental Ecologista), ANG - Associació Naturalista de Girona, Associació Una Sola TerraBrahma Kumaris - Associació Espiritual Mundial, CATAM - Centre d'Acció Territorial Ambiental del Maresme, Centre d'Estudis Joan Bardina, UnescoCAT - Centre UNESCO de Catalunya, Col·lectiu Userda, DEPANA - Lliga per a la Defensa del Patrimoni Natural, EcoConcern, Ecologistes en Acció de Catalunya, EcoMediterrània, Enllaç - Via Fora, Fundació Roca i Galès, Fundació Terra, GDT – Grup de Defensa del Ter, GEA - Associació d'Estudis Geobiològics, GEPEC - Ecologistes de Catalunya, Greenpeace, Justícia i Pau, LIMNOS - Defensa del Patrimoni Natural de Banyoles, Mediterrània: Centre d'Iniciatives Ecològiques, OCUC – Organització de Consumidors i Usuaris de Catalunya, Plataforma Barcelona Sostenible, SCEA - Societat Catalana d'Educació Ambiental, Transforma, WWF - Fons Mundial per la Natura.* ***organitzacions polítiques:*** Els Verds - Alternativa Verda * ***ONG d'energies renovables:*** ADTS – Associació Divulgació Tecnologia Sostenible, APERCA - Associació de Professionals de les Energies Renovables, APPA – Associació de Productors d'Energies Renovables, Ecoserveis, Eurosolar – associació europea per les energies renovables, SEBA - Serveis Energètics Bàsics i Autònoms, WISE - NIRS, World Information Service on Energy - Nuclear Information Resource Service* ***empreses de energies renovables:*** BCN Cambra Logica de Projectes, Ecofys S.L., Ecotecnia S. Coop. C. Ltda., Elektron, GEA Consultors Ambientals, Intiam-Ruai S. Coop. C. Ltda., LKN, Nordex, Tecnopres, TFM - Teulades i Façanes Multifuncionals, Trama Tecnoambiental

VIII FÒRUM DE L'ENERGIA SOSTENIBLE

Dia 27 d'abril del 2006, a les 11:00 hores
A la Fàbrica del Sol, Salvat Papasseit 1, La Barceloneta

Un espai de diàleg i concertació entre els diversos actors en el camp de l'energia.
Un espai per discutir i crear estratègies per fer avançar el nostre país per la via de la sostenibilitat energètica.

ELS FÒRUMS DE L'ENERGIA SOSTENIBLE

Què són?

Els Fòrums de l'Energia Sostenible tracten de l'ús sostenible de l'energia, l'ús dels productes i serveis que ens permeten utilitzar l'energia d'una forma eficient i neta, amb particular èmfasi a l'energia derivada de les fonts renovables i la que aprofita al màxim els recursos energètics, humans i econòmics locals.

A quin públic s'adrecen?

Els Fòrums de l'Energia Sostenible estan oberts a tots els professionals de les energies renovables i també a aquelles persones que des de la seva responsabilitat prenen decisions en el camp de l'energia . L'assistència és gratuïta. Està dirigit específicament als professionals dels productes i serveis d'estalvi energètic i d'ús de les energies renovables: fabricants, dissenyadors, comercials, instal·ladors, mantenidors; a les persones que han de prendre decisions sobre el tema energètic: polítics, directors; als qui poden finançar projectes i/o empreses: bancs, grups d'inversors; als estudiants tècnics: formació professional, enginyeria i arquitectura i al públic usuari d'energia que té una sensibilitat particular pel tema.

Qui els organitza?

Els Fòrums de l'Energia Sostenible els organitza Barcelona Grup d'Energia Local o BarnaGEL, l'agència d'energia independent de l'àrea de Barcelona creada sota el paraigües del programa SAVE de la Comissió Europea. Fins ara BarnaGEL ha organitzat set edicions del Fòrum (març 1998, febrer 1999, abril 2000, abril 2002, abril 2003, abril 2004 i abril 2005)

BARNAGEL
Barcelona grup d'energia local

save · agencia

EL FÒRUM DE L'ENERGIA SOSTENIBLE 2006

TORNEM A SER ACTIUS AVUI PER NO SER RADIOACTIUS DEMÀ

11:00 h. Presentació
Dr. Josep Puig, Barcelona Grup d'Energia Local

11:15 h. Estratègies per fer efectiva la proscripció de l'energia nuclear
Amb la participació de persones del país i de fora amb una gran experiència en fer oposició a la nuclearització i en plantar cara als plans nuclears.

13:30 h. Conclusions i cloenda
Dr. Joaquim Corominas, director d'Ecoserveis

Butlleta d'inscripció

(omplir i enviar abans del 17 d'abril del 2006 a:
barnagel@energiasostenible.org - places limitades.
Inscripcions per rigorós ordre d'arribada de la butlleta)

Nom i Cognoms:

Institució / empresa:

Adreça:

Municipi i codi postal:

Telèfon:

Correu-e:

Web:

Txernòbil

Barcelona Grup d'Energia Local – BarnaGEL
e-mail: barnagel@energiasostenible.org

XX CONFERÈNCIA CATALANA PER UN FUTUR SENSE NUCLEARS I ENERGÈTICAMENT SOSTENIBLE

TXERNÒBIL MAI MÉS!

dia 26 d'abril del 2006

(20è Aniversari de l'accident a la C.N. de Txernòbil)

Auditori del Centre de Cultura Contemporània de Barcelona

NUCLEAR? NO GRÀCIES

earth day network

WCRE World Council for Renewable Energy

XX CONFERÈNCIA CATALANA PER UN FUTUR SENSE NUCLEARS I ENERGÈTICAMENT SOSTENIBLE
(inscrita al DIA DE LA TERRA - 2006)

dia 26 d'abril del 2006
(20è Aniversari de l'accident a la C.N. de Txernòbil)

ENERGIES NETES

NUCLEAR? NO GRÀCIES

TXERNÒBIL MAI MÉS!

Ja fa 20 anys que iniciarem les Conferències Catalanes per un Futur Sense Nuclears, i que des de l'any 1995 se n'anomenen Conferències Catalanes per un Futur Sense Nuclears i Energèticament Sostenibles. Per elles han passat un bon grapat d'especialistes mundials. En elles s'han tractat la problemàtica associada a l'energia nuclear i a la insostenibilitat dels sistemes energètics basats en el malbaratament, la ineficiència i les energies brutes. També en elles s'han presentat alternatives a la insostenibilitat energètica, basades en l'eficiència energètica i les energies renovables. Les Conferències Catalanes per un Futur Sense Nuclears i Energèticament Sostenible continuen la tasca de pressió perquè Catalunya pugui abandonar el malson nuclear i l'addicció als combustibles fòssils i pugui començar a fer via pel camí de la sostenibilitat energètica. Per fer-ho possible hem d'obrir la porta a l'ús generalitzat de les fonts d'energia que flueixen de forma natural per la biosfera: el Sol, el vent, l'aigua, la biomassa, la calor de la terra, etc. combinat amb fer que l'energia es faci servir amb moderació i amb la màxima eficiència, tan a nivell de generació com a nivell d'ús final.

En l'edició d'aquest any, a més a més de recordar l'accident més gran que mai hi ha hagut en una central nuclear, tornem a dedicar la conferència a l'energia nuclear, ara que alguna manaires voldrien veure renéixer l'energia nuclear de les cendres a les que el mercat i la societat van arraconar-la, fa ja alguns anys.

El nou marc energètic liberalitzat hauria de servir no pas per continuar beneficiant aquells sectors econòmics que han fet i continuen fent negocis i diners a costa de la degradació dels sistemes naturals, tot abocant gasos d'efecte hivernacle a l'atmosfera o tot enverinant radioactivament la biosfera. Volem que serveixi perquè la ciutadania pugui exercir, no solament el Dret de captar, aprofitar i utilitzar l'energia del Sol, sinó perquè pugui tenir a l'abast els serveis energètics de qualitat que el Sol ens proporciona. Les energies renovables i netes o 'verdes', entre elles el Sol, són una oportunitat que hem de saber aprofitar i fer-ho amb saviesa.

Auditori del Centre de Cultura Contemporània de Barcelona - CCCB, Montalegre 7, Barcelona. Metro: estacions Catalunya i Plaça Universitat en les línies 1 (vermella), 2 (lila) i 3 (verda) i FGC.

Sessió oberta a càrrecs públics, tècnics, professionals, estudiants, persones actives en grups ecologistes, organitzacions veïnals i públic en general

6'30 h. Obertura:
Dr. Josep Puig,
Portaveu de GCTPFNN

18'45 h. La situació a les zones afectades per l'accident de Txernòbil
Valentina Fiòdorovna Smòlnikova
Directora de la Fundació "Pels nens de Txernòbil"
Fins la seva recent jubilació ha sigut Cap de Pediatria de la Regió de Buda-Koixeliovo, a la província de Gómel, a la República de Belarús (Bielorússia).

19'45 h. La situació de l'energia nuclear al món
Mycle Schneider, consultor, Londres

20'30 h. Taula Rodona
amb la participació de Dr. Antoni Lloret, Dr. Marcel Coderch, Dr. Joaquim Corominas, Dr. Pere Carbonell

21'30 h. Cloenda

ORGANITZACIÓ:

Grup de Científics i Tècnics per un Futur No Nuclear – GCTPFNN i World Council for Renewable Energy - WCRE

ENTITATS COL.LABORADORES:

*ORGANITZACIONS NO GOVERNAMENTALS:

- ADENC - Associació per a la Defensa i l'Estudi de la Natura
- Alternativa Solidària - Plenty
- Alternativa Verda (Organització No Governamental Ecologista)
- ANG - Associació Naturalista de Girona
- Associació Una Sola Terra
- Brahma Kumaris - Associació Espiritual Mundial
- CATAM - Centre d'Acció Territorial Ambiental del Maresme
- Centre d'Estudis Joan Bardina
- UnescoCat – Centre Unesco de Catalunya
- Col·lectiu Userda
- DEPANA - Lliga per a la Defensa del Patrimoni Natural
- EcoConcern
- Ecologistes en Acció de Catalunya
- EcoMediterrània
- Enllaç - Via Fora
- Fundació Roca i Galès
- Fundació Terra
- GDT – Grup de Defensa del Ter
- GEA - Associació d'Estudis Geobiològics
- GEPEC – Ecologistes de Catalunya
- Greenpeace
- Justícia i Pau
- LIMNOS - Defensa del Patrimoni Natural de Banyoles
- Mediterrània: Centre d'Iniciatives Ecològiques
- OCUC – Organització de Consumidors i Usuaris de Catalunya
- Plataforma Barcelona Sostenible
- SCEA - Societat Catalana d'Educació Ambiental
- Transforma
- WWF - Fons Mundial per la Natura

ORGANITZACIONS POLÍTIQUES:

- Els Verds - Alternativa Verda

ONG D'ENERGIES RENOVABLES:

- ADTS – Associació Divulgació Tecnologia Sostenible
- APERCA - Associació de Professionals de les Energies Renovables
- APPA – Associació de Productors d'Energies Renovables
- Ecoserveis
- Eurosolar – associació europea per les energies renovables
- SEBA - Serveis Energètics Bàsics i Autònoms
- WISE - NIRS, World Information Service on Energy - Nuclear Information Resource Service

EMPRESES D' ENERGIES RENOVABLES:

- BCN Cambra Lògica de Projectes
- Ecofys S.L.
- Ecotècnia S. Coop. C. Ltda.
- Elektron
- GEA Consultors Ambientals
- Intiam-Ruai S. Coop. C. Ltda.
- LKN
- Nordex
- Tecnopres
- TFM - Teulades i Façanes Multifuncionals
- Trama Tecnoambiental

UAB
Universitat Autònoma de Barcelona
Institut de Ciència i Tecnologia Ambientals

Ajuntament de Barcelona

Generalitat de Catalunya
Departament de Medi Ambient i Habitatge
Departament de Treball i Indústria
Institut Català d'Energia

VINTÉ ANIVERSARI DE LA
CATÀSTOFE DE TXERNÒBIL

XX CONFERÈNCIA CATALANA PER UN FUTUR SENSE NUCLEARS I ENERGÈTICAMENT SOSTENIBLE

Barcelona, 26 d'abril del 2006

VIII FÒRUM DE L'ENERGIA SOSTENIBLE

Barcelona, 27 d'abril del 2006

TXERNÒBIL MAI MÉS!

Índex

Web del GCTPFNN: http://www.energiasostenible.org

1.- INTRODUCCIÓ.

Ja fa 20 anys que iniciarem les Conferències Catalanes per un Futur Sense Nuclears, i que des de l'any 1995 se n'anomenen Conferències Catalanes per un Futur Sense Nuclears i Energèticament Sostenibles. Per elles han passat un bon grapat d'especialistes mundials. En elles s'han tractat la problemàtica associada a l'energia nuclear i a la insostenibilitat dels sistemes energètics basats en el malbaratament, la ineficiència i les energies brutes. També en elles s'han presentat alternatives a la insostenibilitat energètica, basades en l'eficiència energètica i les energies renovables. Les Conferències Catalanes per un Futur Sense Nuclears i Energèticament Sostenible continuen la tasca de pressió perquè Catalunya pugui abandonar el malson nuclear i l'addicció als combustibles fòssils i pugui començar a fer via pel camí de la sostenibilitat energètica. Per fer-ho possible hem d'obrir la porta a l'ús generalitzat de les fonts d'energia que flueixen de forma natural per la biosfera: el Sol, el vent, l'aigua, la biomassa, la calor de la terra, etc. combinat amb fer que l'energia es faci servir amb moderació i amb la màxima eficiència, tan a nivell de generació com a nivell d'ús final.

En l'edició d'aquest any, a més a més de recordar l'accident més gran que mai hi ha hagut en una central nuclear, tornem a dedicar la conferència a l'energia nuclear, ara que alguna manaires voldrien veure renéixer l'energia nuclear de les cendres a les que el mercat i la societat van arraconar-la, fa ja alguns anys.

El nou marc energètic liberalitzat hauria de servir no pas per continuar beneficiant aquells sectors econòmics que han fet i continuen fent negocis i diners a costa de la degradació dels sistemes naturals, tot abocant gasos d'efecte hivernacle a l'atmosfera o tot enverinant radioactivament la biosfera. Volem que serveixi perquè la ciutadania pugui exercir, no solament el Dret de captar, aprofitar i utilitzar l'energia del Sol, sinó perquè pugui tenir a l'abast els serveis energètics de qualitat que el Sol ens proporciona. Les energies renovables i netes o 'verdes', entre elles el Sol, són una oportunitat que hem de saber aprofitar i fer-ho amb saviesa.

La voluntat del GCTPFNN no és cap altre que fer possible que Catalunya abandoni el mal son que l'ha portat a ser depenent de l'energia nuclear i dels combustibles fòssils, fonts d'energia vinculades a les guerres i generadores de sistemes de domini sobre la humanitat i els sistemes naturals. Obrir la porta a un sistema energètic eficient, net i renovable és l'objectiu de les Conferències que des de fa 20 anys organitzem anualment.

2.- OBERTURA.

Dr. Josep Puig
Portaveu del GCTPFNN

3.- The World Nuclear Industry Status Report 2004

Mycle Schneider, Paris
&
Antony Froggatt, London
Independent Consultants

THE WORLD NUCLEAR INDUSTRY STATUS REPORT 2004

by

Mycle Schneider, Paris
&
Antony Froggatt, London,

Independent Consultants

Brussels, December 2004

Commissioned by the Greens-EFA Group in the European Parliament

The Greens | European Free Alliance
in the European Parliament

Note: This document can be downloaded for free from the website of the Greens-EFA Group in the European Parliament at:

http://www.greens-efa.org/pdf/documents/greensefa_documents_106_en.pdf

For questions and comments please contact:

Michel Raquet
Energy Adviser
Greens / EFA
European Parliament
PHS 06C69
Rue Wiertzstraat
B-1047 Brussels
Phone: +32.2.284.23.58
E-mail: mraquet@europarl.eu.int
Web: www.greens-efa.org

To contact the authors:

Mycle Schneider Consulting
45, Allée des deux cèdres
91210 Draveil (Paris)
France
Phone: +33-1-69 83 23 79
Fax: +33-1-69 40 98 75
E-mail: mycle@wanadoo.fr

Antony Froggatt
53a Nevill Road
N16 8SW London
UK
Phone: +44-207-923 04 12
Fax: +44-207-923 73 83
E-mail: a.froggatt@btinternet.com

Table of Contents

4.- Nuclear Power: The Energy Balance

Jan Willem Storm van Leeuwen
and
Philip Smith
The Netherlands

Nuclear Power: the Energy Balance

Introduction: General principles of sustainability; Summary of the costs of nuclear energy

Jan Willem Storm van Leeuwen and Philip Smith

Two debatable claims

The nuclear industry claims that nuclear power is a sustainable energy source and further that it produces negligible amounts of CO_2. These claims are highly debatable. Obviously, no source of energy that is derived from mining a resource in the earth's crust can be sustainable. Yet the sustainability of nuclear power is espoused by many in, and connected to, the nuclear industry. The main object of the five chapters comprising this document is to show that nuclear power not only

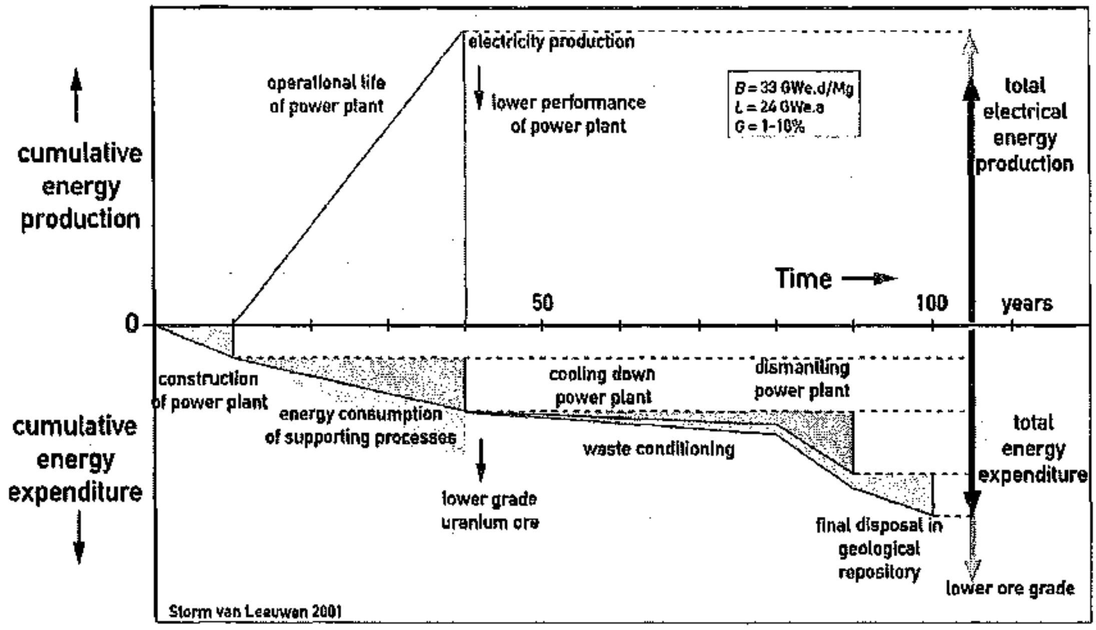


Figure 1. Schematic representation of the energy production and energy costs of nuclear power as a function of time.

leads to the production of far from a negligible amount of CO_2, but also, that it is most certainly not a sustainable energy source. This is underlined by the fact that if the known uranium resources were used to exhaustion, the total electrical energy produced would only amount to the present day world wide electrical energy use in less than a decade (this is shown quantitatively in Chapter 2). This limitation is masked at the present time by the fact that the electrical energy produced by nuclear reactors comprises only some two to three percent of the total useful energy consumption in the world, and there are still large deposits of uranium, with rich ore grades. If large numbers of nuclear reactors were to be built in order to satisfy the growing demand for electricity, the reserves of high grade ore would be rapidly exhausted, leaving immense amounts of low-grade ores over, most of which would cost more energy to utilize (if one includes all of steps of the fuel life cycle) than the reactors would deliver in the form of electricity.

The claim that nuclear energy does not cause CO_2-emission may sound plausible because the operation of the reactor itself does not produce CO_2. This is true, but it is a misleading half-truth. We will show in this study that there are large energy costs involved in producing electrical energy by nuclear power plants. Under present conditions that means burning fossil fuel, with the resulting emission of CO_2. The details will be found below, and the total CO_2-emission will be compared with the emission that would be produced by a gas-burning power plant with the same output. If all of the contributions are taken into account, a nuclear plant fueled with high-grade ores causes the emission of between one-fifth and one-third of the CO_2 produced by a gas-burning plant. But this relatively favourable ratio only holds as long as there are rich uranium ores available. When these are exhausted, the use of leaner ores for the operation of nuclear plants will lead to the production of more CO_2 than gas-burning plants. In the long run, nuclear power is therefore not a solution to the CO_2-emission problem.

Energy debt

The cause of this little recognized problem of nuclear energy is that it costs energy from other sources (principally produced by burning fossil fuels) to produce nuclear energy. More disturbing is that many of these energy costs only become apparent after a nuclear power station has stopped producing electricity and, so these costs will have to be paid by unborn generations who have not profited from the nuclear-produced energy. These are thus energy debts: debts incurred during its productive lifetime, which our descendants will have to pay. We have made them visible in pictorial form in Figure 1. Here we have represented the cumulative gross electricity production as a triangular area above the base line. The five costs/debts are all shown as dark areas below the base line. These areas are roughly to scale. The actual calculations were made for a rich ore (uranium content = 1%). The area that changes as the ore becomes poorer is indicated. in the diagram. The effect of a less than ideal performance of the plant is also indicated. The time scale is probably not realistic. No large nuclear power plant has ever been dismantled.

Another point that is frequently overlooked, is that nuclear power can only produce electrical energy, whereas most of the energy used by mankind is thermal (heat). Electricity can also be used for this purpose, of course, (one need only think of electrical irons, and ovens, and space heating provided by the degradation of electrical energy to heat by ohmic conversion), one unit of electrical energy can be converted into one unit of thermal energy or one unit kinetic energy.

Methodology

In many industrial cost analyses, monetary units (almost always U.S. dollars) are used. We have chosen, as has been done in most of the analyses in which environmental values are considered, to use units of energy in this analysis because energy is a conserved quantity, whereas money is an arbitrary, and more importantly, a variable measure. Particularly in comparing costs and benefits of various processes the use of a money scale introduces the unpredictable effects of such factors as market prices, cartel price-forming and price regulations. Comparing the dollar costs of two processes is therefore frequently meaningless. But more important than these sources of inaccuracy, the use of monetary units is based on the illusion money is wealth and that compound interest creates wealth. This illusion leads to the use of *discounting* which gives the false impression that the future value of anything goes slowly to zero. This is certainly not true of the riches of the earth, but absolute nonsense when applied specifically to energy. One may counter that at any given moment, a company must choose its course on the basis of the current monetary prices of materials and the current market value of its products. This is not the occasion to enter into an ethical or philosophical discussion, but in our view it is clear enough that it is exactly because of this conventional way of doing business that the planet now stands on the brink of environmental catastrophe. Whether we like it or not, if our civilization to survive, it is imperative that policy choices with long-term consequences no longer be based on quarterly profit figures, but on an analysis of sustainability criteria. How this is to be brought about is not the issue here. The issue is that an honest evaluation of any system used to produce energy (this is the conventional wording - the correct term is to "convert" energy), energy units should be used, both for the production and for the costs.

In the detailed calculations of this document we have determined the energy costs of all of the important constituent steps of the nuclear-energy life cycle. This analysis method, the life-cycle analysis (LCA) is the accepted way of evaluating the performance of complex industrial systems.

Several LCA's of nuclear power plants have been published, particularly during the late 70's and early 80's, as quoted in Storm 1985. After a quiet decade, these LCA's have recently become topical again, e.g. Mortimer [1991a and 1991b], Lako 1995, Uitert 1995, Uchiyama 1995, Orita 1995, Mishra 1995, Bitkolov 1995, Tyner et al. 1988, Dilemma 1999, IAEA TecDoc-753 1994, Proops 2001, Dwarshuis 1992, WNA-11 2005, WNA-critique 2003 and WEC 2004. as a consequence of climate concerns. The nuclear industry claims that its products are CO_2-emission free. This claim is only correct for the nuclear reactor itself. All other processes in the nuclear chain, essential to operating nuclear reactors, do produce CO2. Recent publications claiming low CO_2-emissions for nuclear power as compared with other energy systems, e.g. the studies put together in [IAEA WM 1995], turn out to be oversimplified and incomplete. In order to assess the sustainability of nuclear power, a complete LCA is mandatory.

Our choice of nuclear reactor system and fuel cycle

We have considered in this study only the so-called *once through* use of enriched uranium in a light-water-moderated high-pressure nuclear power reactor (LWR). In this process the uranium fuel used in such a reactor is slightly enriched in the fissionable isotope ^{235}U. When they are "burned up", the fuel elements are stored in water basins for some period, to permit the radioactivity to decline so that they can be transported. The final destination, after conditioning, is an assumed stable geological stratum. The fuel is not reprocessed. The LWR in the once through mode is by far the largest source of nuclear energy, 88% of the power reactors of the world in 2002 (see atw-5 2003 and WNAinfo 2003) are LWR's.

One may ask why we have not chosen to consider the option of fuel reprocessing. In principal, more of the energy of uranium could then be made available. There are some reasons for our choice.

Advantages of recycling nuclear fuel in LWR's are questionable, see e.g. WNAinf13 2003, WNAinf15 2002 and NEA ppr 2003.

Breeder reactors, in fact the breeder cycle, will not become available for large-scale power generation within the next three decades (MIT 2003), see also Chapter 2.

Sustainability criteria

The First Law of Thermodynamics

No source of stored energy obtained from the earth's crust (such as coal, oil, uranium) can correctly be considered sustainable. This is because the First Law of Thermodynamics, i.e. energy cannot be created or destroyed, puts an absolute limit on the energy production. The internal energy in such fuels can be converted to kinetic energy (energy of motion) or electricity. These forms of energy, when used, are converted into heat. Once this has occurred, the heat energy will be dissipated into the environment where it cannot do any more useful work (work is used here in the technical sense of causing something physical to happen). The energy has not disappeared, but it has become degraded to uselessness. Therefore all such "sources" of stored energy will be exhausted eventually. In evaluating the use of such resources it is also important to realize that it costs energy to obtain and use them. At a certain point in the exhaustion of reserves, it will cost more energy to make the remaining part available than is delivered when it is used. Uranium and highly dispersed sources of carbon are examples. The only inexhaustible source of energy, from the point of view of the earth, is light from the sun, which comes from outside the system earth.

More than 90% of the present world energy supply is based on mineral resources and is consequently limited. Substitution of the mineral energy systems by renewable systems based on flow energy, will take decades. So, the basic question is: what role can nuclear power play in the forthcoming decades? This is a First Law problem: how much usable energy can be generated from the known uranium resources?

To answer this question, the net energy obtainable in a nuclear reactor from one kilogram of uranium has to be calculated, and corrected for all of the costs incurred in the life cycle. The total contribution of fission power to the world energy supply can be then calculated from the known uranium resources. This is done in Chapter 2. Evidently, it is too simple to take the theoretical energy content of uranium, which is based on the fission of all atoms in natural uranium: ^{235}U and ^{238}U, or even on the fission of all atoms of ^{235}U (a more modest degree of technological optimism), and on zero energy use of the system needed to convert the fission energy into electricity, from ore body through all of the steps ending in waste disposal. Visions of an unlimited energy supply by fission power ("too cheap to meter") stem from these naive assumptions. But even with breeder systems, only a part of the uranium can be fissioned.

As mentioned, the usable energy content of uranium can only be correctly calculated in an elaborate life-cycle-analysis (LCA), as is done in this report. As it turns out, even if all known uranium reserves are exhausted, the total energy produced (i.e. converted to a usable form) amounts to only a negligible part of the energy which forecasts predict will be needed in the coming decades.

The Second Law of Thermodynamics

A second, and more rigorous, sustainability criterion is provided by the Second Law of Thermodynamics, which states that any conversion of energy in a closed system such as the biosphere, causes an increase of disorder, or chaos. This is illustrated in Figure 2.

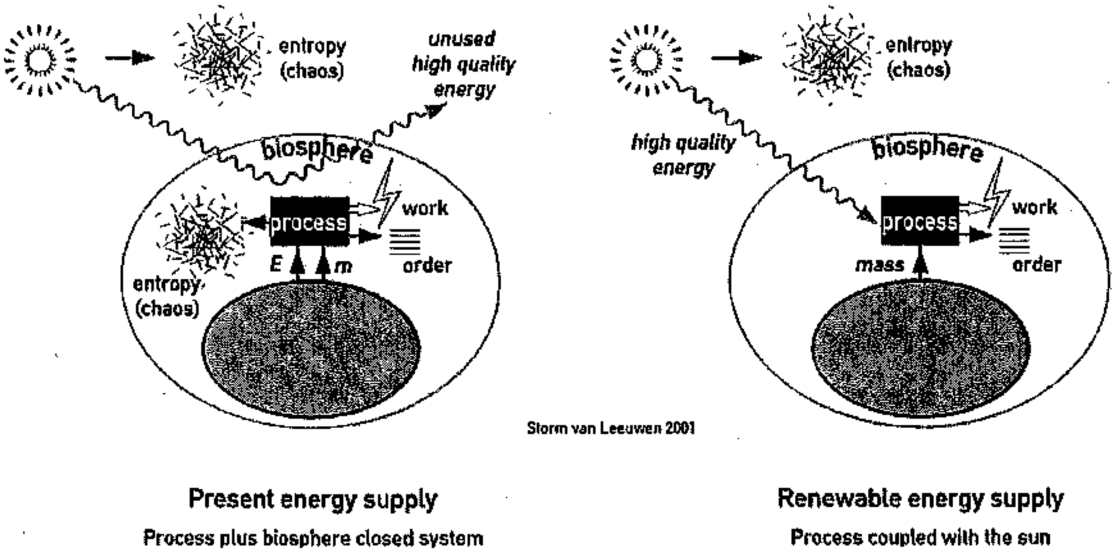


Figure 2. In this figure the fundamental difference between a renewable energy source and one using materials in the crust of the earth s shown schematically. See the text for further explanation.

The drawings in Figure 2 illustrate how the unavoidable entropy (disorder) increase caused by the conversion in the sun of the potential energy of nuclear forces into heat and light remains on the sun. If, however, energy conversion (of resources from the earth's crust) takes place in the biosphere of the earth there must result degradation of the environment. In order to make an honest evaluation of energy conversion under the constraint of environmental sustainability we require in this study that, besides the bare energy costs needed to obtain the energy in the first place, the (energy) costs of repairing this degradation are chalked up as debts against the positive energy made available by the conversion. The costs of nuclear energy in this report are calculated on the basis of this criterion, i.e., that the process itself must provide the extra energy needed to "repair the damage". In particular, it is found that when the richness of available ores drops below a certain critical value, there is no energy surplus to satisfy this criterion. This will occur long before the inevitable exhaustion (prescribed by the First Law) has occurred.

The type of process shown on the right in Figure 2 can, if properly done, provide a truly sustainable stream of useful energy. That is why we stated above that the sustainability criterion prescribed by the Second Law is more rigorous than the criterion of availability of energy sources, laid down by the First Law. The increase of entropy resulting from this conversion occurs on the sun. Only the energy of light is exported to the earth. This is energy with an essentially zero entropy-content. It is important to recognize that it is just exactly this cleanness that was a necessary condition for the birth of life on earth. Taken individually, life processes also produce an increase of entropy, but over billions of years, due to its *self-organizing* capacity, life on the planet developed a closed cycle. All of its detriments are recycled (or rather *were*, before fossil fuels entered the picture) using the clean energy from the sun, and the total entropy in a closed natural life-cycle does not increase with time.

As stated, the existence of life on earth was only possible because of the immense stream of low-entropy energy from the sun, and its evolution up to today probably could not have taken place if were not for the sequestration, by life processes themselves during eons in the past, of a vast amount of carbon in calcareous rocks and burnable carbon and hydrocarbons. This sequestration removed almost all of the CO_2 from the atmosphere, and led to its present composition in which existing life forms can live. In Kyoto, almost ten years ago (1997) this was, to a certain extent, recognized. Disregard of the agreements reached there could have disastrous consequences. Mankind is literally "playing with fire."

An idealized picture of a process taking place on earth, but using the clean energy from the sun, is

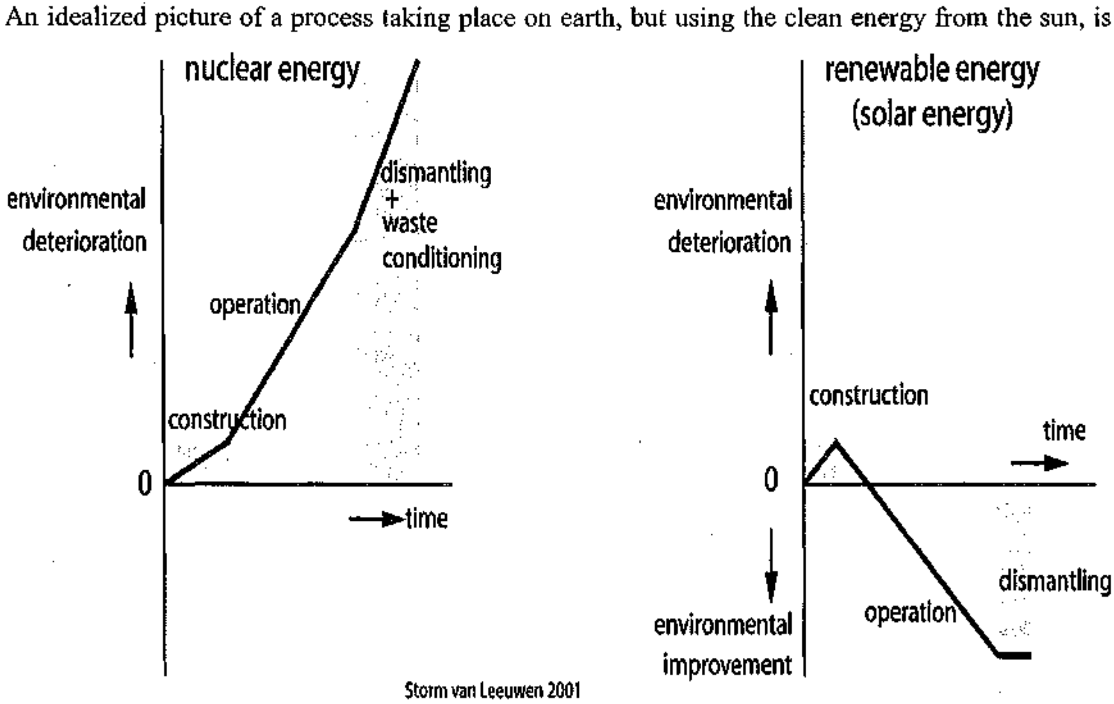


Figure 3. In this figure the difference in the environmental effects of nuclear power and an energy system operating on solar energy is shown. Nuclear energy is generated from resources within the biosphere, so all entropy of the conversion process flows into the biosphere. More entropy means deterioration of the environment. In case of solar energy systems, the entropy of the energy generating process remains on the sun. Solar electricity can be used to lower the entropy of the biosphere and thus improving the quality of the environment.

as shown in Figure 3, and compared with the use of nuclear energy. The basic difference in the environmental effects between the present means of energy production and a sustainable one, using energy from the sun is illustrated.

The factual foundations of these calculations

The calculations of this report are based on the data to be found in the references. Since an elaborate study in 1982 [Storm, 1982], few new data have become available on most parts of the nuclear process chain, especially the head of the chain. More recent studies, see above, use partly the same references as [Storm, 1982]; hardly any more recent data are used. In this revised version we only refer to the primary references. Evidently, the specific energy uses of the processes in the nuclear chain have not changed significantly since 1982. The present study differs from many other studies in that the energy expenditure and net energy production of the full nuclear process chain are calculated as a function of the operating time (T_{100}), measured in full-power years. In other studies a fixed operating time is assumed, mostly an optimistic high estimate of 30 to 40 years with high load factors of 0.7 - 0.8. These high values are not substantiated by the statistics of the present nuclear power plants in the world. The actual performance of the ~400 operating reactors is treated in details in Chapter 3, where it is shown empirically that 24 full-power years is the longest lifetime that may be expected as an average for all reactors of the world.

What are sustainable energy sources?

Physically speaking, the only sustainable energy source to which we have access on earth is the sun. Energy obtained from terrestrial sources will always be exhausted eventually. The sun, on a much larger time scale than we can imagine, will continue to provide a tremendous source of ultra-clean energy. Up to the time when the burning of fossil fuels began, mankind (as well as all life on earth) was entirely dependant upon this solar energy. What are the criteria that an energy source must satisfy in order to be labelled as sustainable? There are two. One must know how much energy is available (physical sustainability) from a source as well as the effects of its use on the environment (environmental sustainability).

Physically unsustainable energy sources

Fossil fuel is obviously not a sustainable source of energy. As mentioned, a finite amount was deposited in the earth's crust many millions of years ago, and will therefore be exhausted someday unless we stop burning the different forms in which it occurs. The same is true of nuclear energy, but even more so, since the total useable energy reserves of uranium are small compared to the energy reserves in fossil fuels. So, even leaving aside the multitude of other problems connected with the use of nuclear energy, it turns out, as was argued above, that it can in no way be considered as the solution to the long-term energy problem. But even in the short term, as we will show below, except in the exceptional case that rich uranium ores are available, it hardly provides more energy than would be obtained from burning the fossil fuels directly. If low-grade ores were to be utilized, a nuclear power plant would actually provide less useful (electrical) energy than one would get by just burning the fossil fuels themselves.

Environmentally unsustainable energy sources

Nor from the viewpoint of environmental sustainability can we consider the burning of fossil fuel sustainable. Burning fossil fuels produces the "greenhouse gas" CO_2. This gas probably constitutes a danger for humankind on a shorter, much more urgent, time scale than the exhaustion of the fuels themselves. Although it is not absolutely certain, as time passes it appears more and more likely that the immense amount of CO_2-emission in today's industrial society will lead to irreversible global warming. Only a few degrees of global warming would lead to unparalleled disruption of the climate and the disappearance of vast areas of habitable land under the sea. If we were to wait until it is proven beyond doubt that the CO_2 produced by human activities will lead to global warming, it would be too late to reverse the process.

Proceeding on the basis of the best available scientific opinions it was, as stated above, agreed upon in the international conference in Kyoto in 1997 that the world must reduce the use of this source of energy as much as possible. The limits set at the time for the reduction of emissions were quite inadequate, it is true. But at least a beginning was made. As we have remarked, the sequestration of CO_2 from the atmosphere in the form of coal, oil, calcareous rock, etc. was probably essential for the creation of the closed cycle of life on earth. Humanity has broken this cycle open by burning fossil fuels in immense amounts. *Caveat!*

Based upon the false claim that nuclear power is free from CO_2-emission, and therefore environmentally sustainable, the nuclear industry claims that nuclear power should be classified as a Clean Development Mechanism (CDM). It would then be eligible for the transfer of low-CO_2-emission technology from North to South. As we have argued, this claim is based upon a distortion of the facts. As explained, it is true that the operation of a nuclear power plant does not in itself lead to CO_2-emission. However, large amounts of energy are needed in order to build the plant, in order to mine, refine, and enrich the uranium fuel, in order to condition and sequestrate the radioactive waste as well as the depleted uranium, and finally in order to dismantle the plant. Most of this energy must be obtained by burning fossil fuels, and, as we have noted, a great deal of this fossil-fuel energy will be needed *after* the power plant has reached the end of its useful life.

But needed it will be, if one is to classify nuclear energy as environmentally sustainable (in the sense of "weak" sustainability, by which we mean that as long as the raw materials are not exhausted, the process does not permanently damage the environment) and therefore it must be, from the beginning, chalked up to an *energy debt* inherent in the building and operation of a nuclear power plant. It is a distortion of the facts to pretend that this energy debt, that can at present only be paid by burning fossil fuels, does not exist. This will be shown in detail below. It must be understood that an energy debt is quite a different thing than a money debt. Money is only worth what people think it is worth. No amount of money placed in the bank can be used to "buy" energy when the sources are exhausted. The laws of physics are inexorable. Money can be "made", but energy cannot be made. On the basis of calculations, using information from the nuclear industry, we can conclude that nuclear power, besides obviously not being a sustainable energy source, is not a solution to the problem of global warming.

Reducing the use of fossil fuels must be seen today as having the highest priority, and it is important to expose false solutions toward reaching this goal. We proceed below to show in this study that nuclear power is not a viable way to substantially reduce CO_2-emission except in the very short term, i.e. as long as very rich uranium ores are not exhausted. It is no exaggeration to say that nuclear power can only exist because it is fueled by fossil fuels. If the fossil fuels are gone, nuclear energy will also have to disappear.

The energy costs and the energy debts of nuclear power

Our point of departure in the calculations, the results of which are sketched below and quantitatively calculated in the following chapters, is that no permanent environmental degradation may take place as the result of its use. This criterion has been applied to all phases of the "life cycle" of a nuclear reactor.[1] This is no small matter, and we hasten to explain our choice. We are quite aware of the fact that in practically all modern technological processes the environment is to some extent adversely affected. So why do we take such a strict view, and how would the conclusions we reach be affected if we were to take a more tolerant attitude? One reason for strictness is that between that and a total abandonment of any protection of the environment there are myriad levels of protection that one could demand, and that for each step one would have to justify the particular choice made. Our strict choice leads to the easiest conceptual picture. We have made one exception to this policy, and that is in the dismantling of the reactor. We present both the results of including and of neglecting this very large energy cost, i.e. debt. It is conceivable that society will decide to leave no longer useful reactors intact, but simply totally isolated from the environment, instead of painstakingly dismantling them and sequestering the radioactive detritus in stable geological strata, a course that would show responsibility toward future generation. A policy of simply abandoning them would lead to an apparent substantial lowering of the energy debts of nuclear energy. Apparent, because the costs will reappear later, in a time in which there are no fossil fuels are available to provide environmental protection. This poisoning of the environment would indeed result in more "efficient" nuclear power, in the sense that the present cost items would be lower, the momentary energy efficiency higher.

[1] With one exception: the tritium formed in the cooling water of a nuclear reactor by neutron capture in deuterium ("heavy" hydrogen). At present this is simply released into the biosphere. We do not know how serious this is as a hazard to life, nor do we have enough information to calculate the energy cost of sequestering it. What can be said is that tritium does not "belong" in the environment (except in minute amounts formed by cosmic rays in the atmosphere), but due to lack of information we cannot draw any conclusions about the damage caused by the release of large amounts to the biosphere. The same holds true on radioactive carbon C-14.

Summary of the cost items of nuclear energy

The most important energy costs of a power plant itself, up to the end of its useful lifetime, are:

i the energy costs of building and operating the plant itself ;

ii the energy costs of mining and refining the uranium in the ores, and

iii the energy costs of enrichment of the uranium and fabrication of the fuel elements;

iv operating and maintenance costs (including refurbishment of the plant itself);

The second of these depends sensitively on the richness of the ore, and for poor ores will, if the use of nuclear energy continues, become very high. In fact it will rise so high that nuclear power no longer produces more energy than is needed to keep it going (and pay its debts). In other words, the point is reached when ores become so poor that one would get more energy out of burning the fossil fuel directly than by following the roundabout path of using fossil fuels to build, operate, and fuel a nuclear power plant. This is an important fact, because by far the largest part of the uranium reserves are found in very poor reserves – reserves that can not properly be labelled ores, since they can deliver no energy above that required for their use.

In Chapter 2 we give the energy costs of mining and milling the uranium fuel for nuclear reactors, as well as the steps leading to the production of fuel elements. But since the environmental destruction becomes gigantic as ores become leaner, in Chapter 4 we consider separately the energy costs of repairing the damage, including sequestration of the highly radioactive spent fuel elements and of depleted uranium, and returning the mining and milling area to "green field" conditions, We realize that it is improbable that mining and milling areas will ever be returned to "green field" conditions. But, in that case, the exposure of life, animal and vegetable, to the radioactive wastes laid bare by these processes will be something that future generations may never forgive us for.

The energy debts incurred by a nuclear power plant have to be paid after the plant has reached the end of its useful life. To summarize, they are:

iv the energy costs of conditioning the extremely radioactive spent fuel elements so that they can be sequestered in a presumably stable geological stratum plus the energy costs of sequestration, Chapter 4);

v the sequestration of depleted uranium left behind by the enrichment (Chapter 4), and

vi the energy costs of dismantling the plant itself, and of sequestering the diverse radioactive detritus (Chapter 3). As mentioned, we have calculated the energy costs of the entire life cycle **with** and **without** including this last energy item.

Paying the costs of the first four categories and paying off the debts in the last three requires the burning of fossil fuels. The burning of the fossil fuel produces CO_2. It is therefore untrue that nuclear energy does not result in CO_2 emission.

Up to the present, none of the debts, incurred in enormous amounts by the existing nuclear power plants, have been paid. For that reason we have had to estimate them. This is difficult because there are few precedents to use in the estimation of the costs of these highly dangerous and costly operations. Not only that, but in the case of the sequestration costs there is reason to doubt that it ever can be done safely. The proposals on how to do it are legion, ranging from the simple to the highly exotic. None may ever turn out to be satisfactory solutions. Here we will assume, nonetheless, that it can, somehow, be done.

Pretending that these debts do not exist does not make them go away. They are not like bad debts that can be simply written off as losses on the ledger. Mankind will have to pay them one day, or pay the consequences of a poisoned environment.

It is important to note that we carry out our calculations, as mentioned, for two cases: the first takes account of all costs and in the second we take all costs into account but leave out the debt of dismantling the reactor system. Specifically, this means in the first case that we assume a debt of 240 PJ (in Chapter 3 this is explained), and in the second we only take account of the building costs, which we estimate to be 80 PJ.

Itemized list of the costs of, and the debts incurred by, the use of nuclear energy.

PROCESS	CHAPTER WHERE THE COST IS DERIVED	ENERGY USED	THERM ELEC RATIC
* MINING AND MILLING,SOFT ORES	Chapter 2, Eq.2.1 -2.2	c = 2.75×10^{-4} PJ/MgU	7.5
* MINING AND MILLING,HARD ORES	Chapter 2, Eq.2.1 -2.2	c = 6.54×10^{-4} PJ/MgU	1.6
CONVERSION TO UF_6	Chapter 2, Eq. 3	1.5×10^{-3} PJ/MgU	27
ENRICHMENT	Chapter 2, Eq. 4.1 - 5.4	*5.5×10^{-3} PJ/Mg SWU	0.51
FUEL-ELEMENT FABRICATION	Chapter 2, Eq. 6	3.8×10^{-3} PJ/MgU	2.5
OPERATE,MAINTAINANCE,UPGRADE	Chapter 3	2.0 PJ/300d	11
MINE AREA CLEANUP	Chapter 4	4.5×10^{-6} PJ/Mg TAILINGS	8.0
SEQUESTERING DEPLETED URANIUM	Chapter 4	1.7×10^{-3} PJ/MgU	22
INTERIM STORAGE SPENT FUEL	Chapter 4	9.3×10^{-3} PJ/MgU	15
CONDITIONING SPENT FUEL	Chapter 4	2.0×10^{-3} PJ/MgU	11
EQUESTERING SPENT FUEL	Chapter 4	1.0×10^{-3} PJ/MgU	8.1
CONDITIONING OPERATIONAL WASTE	Chapter 4	4.4×10^{-1} PJ/300d	10
DISPOSAL OPERATIONAL WASTE	Chapter 4	7.1×10^{-2} PJ/300d	8
DISPOSAL ENRICHMENT WASTE		8.5×10^{-5} PJ/Mg SWU	9.9

* The energy used for mining and milling is found by substituting the ore grade, G, and the value of c in the equation:

$$\frac{c}{0.98-0.0723\times G\times(\log G)^2}$$

* Note that because the standard unit, SWU, is so small we have introduced the unit Mg SWU, that is 1000 times larger.

The derivation of all of these costs are is repeated in Chapter 5, where the references to the literature from which they are derived are also given.

Diverse parameters and quantities (assuming a burnup of 46 GW(th)day/MgHM)

electrical energy produced in full-power 300 days (corresponding to one reload period) 25.92 PJ
number of reloads assumed for a lifetime of 24 full-load years: 28
initial load: 81.2Mg, assay 3.3%, reloads: 20.3 Mg, assay 4.20%
Enrichment: feed assay: 0.71%; tail assay: 0.20%
total mass of natural uranium used in the lifetime of the reactor, 4951.6 Mg
gross lifetime electricity generation,0.1518 PJ/Mg = 151.8 EJ/Tg natural uranium

Nuclear power plant parameters

We assume that the energy is produced in a pressurized water reactor (PWR) based on a "once through" fuel cycle (without reprocessing of spent fuel).

The parameters of the nuclear power plant and its operation, taken as model in this study, are given below. We have assumed that the highest presently used burnup practice (i.e. giving the most energy from the uranium "burned") of 46 GW(th)day/MgU):

net power	$P(e)$ = 1000 MWe
thermal power	$P(th)$ = 3125 MWth
equilibrium discharge batch average burnup	B = 46 GW(th)day/Mg U initial
core specific power	S = 38.5 MW(th)/Mg U initial
first core mass	m_{fc} = 81.2 Mg U
fraction of core replaced in equilibrium reloading	F = 1/4
assay first core	x_{fc} = 3.3% ^{235}U
assay reloads	X_{rel} = 4.2% ^{235}U
full-power time between reloads	D = 300 days = 0.82 full power years

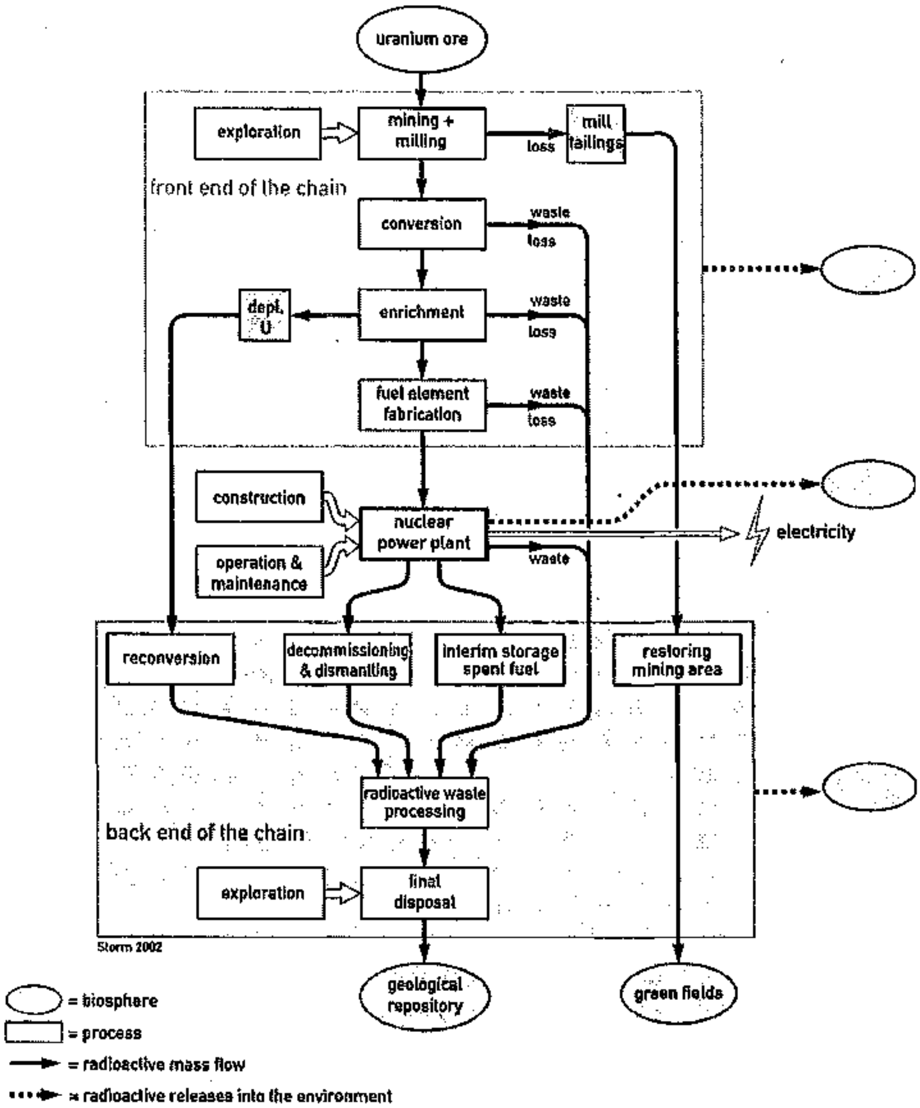
reload mass $m_{rel} = m_{fc} \cdot F = 20.3$ Mg U

$$m_{tot} = m_{fc} + m_{rel} \bullet \left(\frac{T_{100}}{D} - 1 \right), \text{ for } T_{100} \geq D \qquad \text{(Eq. 1)}$$

T_{100} = full-power operating time (years) and m_{tot} = total (enriched) uranium consumption.

References [Jan and Krug, 1995], [Scheidt, 1995], [DOE/EIA, 1997].

In the figure (below) we show schematically all of the elements that we have included in the nuclear-plant process chain.



Nuclear fuel chain PWR once-through

In this figure the entire nuclear chain is illustrated. In the following chapters the various energy costs are calculated.

In Chapter 2 the four boxes (excluding exploration) in the shaded area at the head of the chain are treated. The operation of the reactor itself is analyzed in Chapter 3. The six boxes (excluding exploration) inside the larger box at the tail of the chain comprise the "energy debts". These are the subject of Chapter 4. All of the relevant equations are summarized in Chapter 5.

5.- The role of nuclear power in a low carbon economy

SDC position paper

Sustainable
Development Commission

SDC position paper

The role of nuclear power in a low carbon economy

March 2006

Contents

Page

Contact us

You can contact the Sustainable Development Commission at:

London (main office):
020 7238 4999
enquiries@sd-commission.org.uk
www.sd-commission.org.uk

Edinburgh: 0131 244 0140
Scotland@sd-commission.org.uk
www.sd-commission.org.uk/scotland

Belfast: 02890 257346
N.Ireland@sd-commission.org.uk

Cardiff: 029 2082 6382
Wales@sd-commission.org.uk
www.sd-commission.org.uk/wales

Too often the debate around nuclear is highly polarised, with heavily entrenched positions on both sides. This does not help with a considered analysis of nuclear power, and tends to result in reports that seek to justify a pre-determined position. Such reports are easily dismissed by opponents and will be regarded with suspicion by those that are truly 'neutral'; they are therefore of limited value to the public debate.

Our stand-alone evidence base is published alongside this paper, as a separate resource.

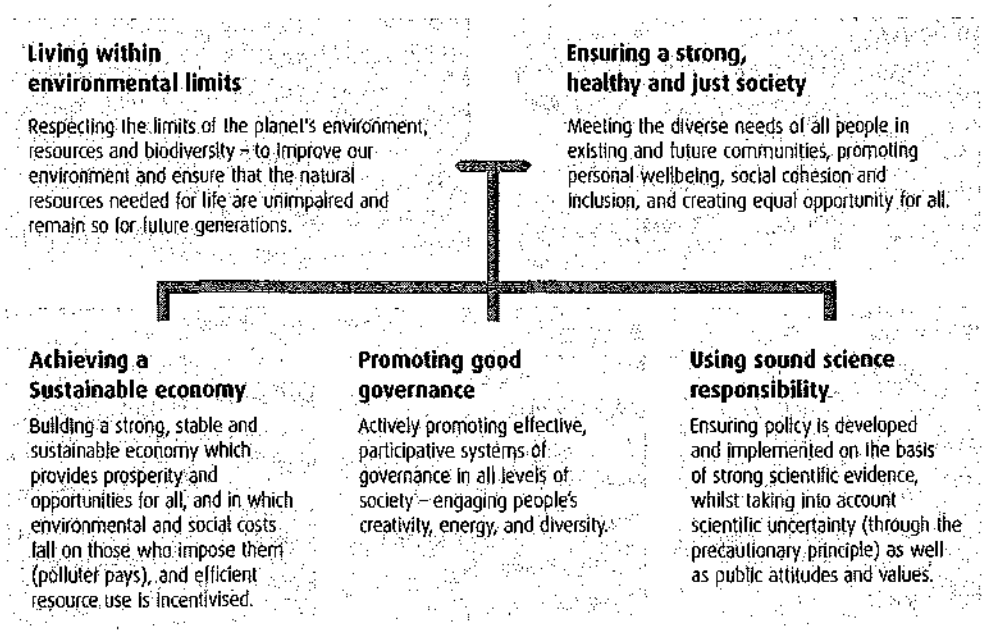
1.5 Our approach

In March 2005 the UK Government and the Devolved Administrations jointly published a shared framework for sustainable development, *'One future – different paths'*, in which five new principles of sustainable development were agreed across Government for all policy development, delivery and evaluation – see Figure 1. Based on these principles, the UK Government published its Sustainable Development Strategy, *'Securing the future'* to guide its policy-making process across different departments. We have therefore examined new nuclear development against these five principles.

In this paper we have not followed the five principles slavishly, as some are more significant for the nuclear issue than others. We have dealt with 'environmental limits' and 'sound science' together; we have looked in considerable depth at 'sustainable economy'; we have covered 'good governance' in relation to public engagement and in conjunction with 'a healthy and just society'.

In examining the evidence base, and taking into account the context of the five principles and the 2006 Energy Review, we have

Figure 1: UK sustainable development principles



Securing the Future – delivering UK sustainable development strategy prepared this paper following extensive discussions at the Commissioner level with the following questions as our framework:

A. If we replace or expand our nuclear electricity generating capacity, what is the public good for the environment? (Living within environmental limits and using sound science responsibly)

> Is nuclear a truly low carbon technology, taking into account a full lifecycle analysis?

> What contribution can it make in combating climate change?

> What are the waste and decommissioning implications, and how will they be dealt with?

> What are the wider environmental impacts – in the UK and overseas?

B. What is the public good for our economy? (Achieving a sustainable economy)

> What are the total costs of nuclear power over the lifetime of planning through construction and operation to decommissioning and disposal of waste?

> What are the implications for security of supply?

> How would new nuclear capacity be delivered in the context of the UK's energy market?

> Is the lack of appetite for new nuclear power a case of market failure? Does the current market structure need reform?

> What are the implications for alternatives to nuclear power?

C. How is the public good best served in the decision-making process for new nuclear and how does it contribute to social well-being? (Good governance; strong, healthy and just society)

> How should policy on nuclear power be developed to assure public confidence?

> What are the implications of a UK decision for overseas governance issues of the nuclear supply and waste disposal chains?

> What are the implications of a decision on nuclear for planning and licensing conditions?

> What are the health implications of a new nuclear programme?

> What are the security risks associated with a new-build programme and how are these best managed?

> What are the risks associated with nuclear proliferation and how are these best managed?

2. Sustainable Development Analysis

This section will look at the case for nuclear power based on three areas of analysis, and using the five principles of sustainable development. The analysis below draws exclusively on the SDC's evidence base, which consists of eight separate reports that are published alongside this paper.

2.1 Environment

2.1.1 Low carbon status[2]

No energy technology is currently carbon free. Even renewable technologies will lead to fossil fuels being burnt at some point in their construction due to the high levels of fossil fuel usage in almost every transport mode and industrial process, including electricity generation. For example, wind turbines are built of steel, and fossil fuels are therefore consumed in their construction either directly, during manufacture, and also from petroleum usage when the parts are transported to the construction site. However, the fossil fuel used over the life of the turbine is 'repaid' in less than 10 months, as the turbines themselves generate zero carbon energy[3].

Nuclear power stations are no different, with large up-front energy requirements during construction[4], although this is balanced by the high power output of each plant. However, nuclear differs from many renewables in its requirement for mined fuel (uranium ore). Although the total volume of fuel used is low compared to the volumes of fossil fuel required in gas or coal plants, uranium mining and the subsequent fuel processing is an energy intensive activity that must be included for full lifecycle emissions analysis. Decommissioning and waste activities are also likely to require energy inputs, and therefore their long-term impact on nuclear power's CO_2 emissions will depend on the carbon intensity of future energy supplies.

Our evidence shows that taking into account the emissions associated with plant construction and the fuel cycle, the emissions associated with nuclear power production are relatively low, with an average value of 4.4tC/GWh, compared to 243tC/GWh for coal and 97tC/GWh for gas[5].

However, emissions from decommissioning and the treatment of waste also need to be assessed but this is difficult for two main reasons:

- **in the UK, decommissioning of existing plant is highly complex and involves plant that was not designed with decommissioning in mind**
- **the UK has not decided on its approach to waste management, which makes it difficult to assess the associated CO_2 emissions.**

The carbon impact associated with the 'back-end' of the nuclear fuel cycle is spread across all of the UK's nuclear power plants (active and decommissioned) and includes all of the electricity generated over their lifetime. Newly commissioned plants are likely to have lower lifecycle carbon emissions than for previous reactor designs, because of improvements in plant design (for example, smaller size, and improved thermal efficiency and use of fuel), and because new plant is designed so that it can be dismantled and decommissioned more easily.

A number of commentators have expressed concerns that any move to low-grade uranium ores could substantially increase the carbon intensity of nuclear power. Our evidence on uranium resource availability[6] shows that predicting if and when this might happen is very difficult to do with any accuracy. Resource availability is discussed in more detail below, but it is by no means certain that all the high grade ores have been discovered, and any increase in the price of uranium could trigger renewed interest in uranium prospecting.

It is worth noting that the CO_2 emissions associated with many of the construction inputs into a nuclear power plant could be subject to emissions trading schemes, depending on their country of origin. This presents a possible solution to the lifecycle emissions problem if

[2] Paper 2 – *Reducing CO_2 emissions: nuclear and the alternatives*
[3] Sustainable Development Commission (2005). *Wind Power in the UK.*
[4] In addition to carbon emissions from the production of concrete.
[5] These figures are for carbon (C) rather than CO_2. They have been converted from the data used in our evidence base by multiplying the CO_2 figures by 12/44.

as many of the inputs as possible could be brought within a comprehensive emissions trading regime. This could be achieved directly, by including those industries that supply nuclear plants, or indirectly by requiring carbon certificates for the calculated carbon value of imported inputs.

In the long-term, the move towards a low carbon economy more generally should lead to a reduction in the emissions from nuclear-related activities, but this will depend to a large extent on the uptake of low carbon technologies in the relevant sectors (e.g. mining, and fuel processing).

Our evidence leads us to conclude that nuclear power can currently be considered a low carbon technology, but that a number of concerns remain over its long-term energy requirements from 'back-end' liabilities, and the potential impact of increasing the use of low-grade uranium ores. The priority should be to internalise any outstanding carbon costs as far as possible so that it competes equally with other low carbon technologies.

In our analysis of the possible contribution of nuclear power to reducing CO_2 emissions, the lifecycle emissions from nuclear power are not included. This allows a fairer comparison with other low carbon technologies, all of which will have some associated emissions.

2.1.2 Climate change benefits[7]

In the 2003 Energy White Paper, the Government outlined its long-term objective to cut CO_2 emissions by 60% from 1990 levels by 2050, with significant progress by 2020. On the basis of this goal we have assessed the potential contribution nuclear electricity generation could make to reducing CO_2 emissions over the long-term, based on two scenarios for nuclear new-build.

Nuclear power currently makes up around 20% of UK electricity, and around 8% of total UK energy supply. Electricity generated from nuclear power currently displaces around 14 million tonnes of carbon (MtC) per year, with a range of 7.95MtC to 19.9MtC (depending on whether it is assumed to displace coal or gas-fired electricity generation). This is equivalent to around 9% of total UK CO_2 emissions in 2004 (with a range of 5-12.6%).

As the large range in these figures illustrates, the actual contribution of nuclear power to reducing CO_2 emissions depends heavily on what type of plant, or fuel, it displaces. If the fuel is carbon intensive, such as coal, then the savings are large, but if nuclear were to displace a low carbon technology, such as wind power, then there may be no carbon saving. The DTI currently assumes that the standard least-cost comparison plant is gas CCGT (combined cycled gas turbine). This seems a reasonable assumption over the next 20 years, although in reality this is very dependent on gas and carbon prices.

Our evidence assumes that new-build nuclear plant would displace new-build gas CCGT plant, which has an emissions level of around 90tC/GWh – i.e. if nuclear plant is not built then gas CCGT would be built instead. The case is similar for renewables, which at present are displacing output from old coal and possibly gas plant, but in the long-term would most likely displace new-build gas CCGT. There is no overlap between nuclear and renewables, or any other low carbon technology, and until the combined capacity of such technologies is very high (which is not a realistic prospect for many decades based on current trends), they are all likely to result in CO_2 savings from the displacement of gas plant.

Our evidence looks at two scenarios for nuclear new-build above our current baseline of declining capacity: replacement of existing plant (10GW), and an expansion that would roughly double current capacity (20GW).

It is important to note that there are constraints on how quickly a replacement or expansion of nuclear capacity could be constructed. Our replacement and expansion scenarios assume a maximum build rate of 1GW per year starting in 2015, which would deliver 10GW by 2024, with a similar rate of new-build under the expansion scenario delivering a further 10GW by 2034.

Although the build rate may be faster during 2024-2034 (for example as lessons learned from early projects are applied to later ones), it may equally be more protracted between 2005 and 2024 (for example due to licensing and planning problems, opposition from the public, or problems of supply if several countries demand new orders from a limited number of suppliers). We note that Britain has no recent track record of nuclear plant construction, and the most likely reactor designs would be imported.

Detailed analysis, and a full explanation of the assumptions used, is given in our evidence base. However, it is clear that the nuclear contribution to a 2020 CO_2 reduction target would be limited, with the full carbon benefits occurring over the following decades. To avoid any uncertainties over the build rate, the emissions savings figures for the total capacity installed under each scenario should be used.

These show that a replacement programme consisting of 10GW of new nuclear capacity would displace 6.7 MtC, which represents a 4% cut in CO_2 emissions from 1990 levels (165.1MtC). An expansion programme would double these figures, with 20GW delivering around 13.4MtC of emissions savings, equal to an 8% cut in emissions.

[6] Paper 8 – *Uranium resource availability*

[7] Paper 2 – *Reducing CO_2 emissions: nuclear and the alternatives*

6.- The Other report on Chernobyl (TORCH)

Ian Fairlie
and
David Sumner
UK

THE OTHER REPORT ON CHERNOBYL (TORCH)

AN INDEPENDENT SCIENTIFIC EVALUATION OF HEALTH AND ENVIRONMENTAL EFFECTS 20 YEARS AFTER THE NUCLEAR DISASTER PROVIDING CRITICAL ANALYSIS OF A RECENT REPORT BY THE INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA) AND THE WORLD HEALTH ORGANISATION (WHO)

AUTHORS Ian Fairlie, PhD, UK. David Sumner, DPhil, UK
AFTERWORD Prof. Angelina Nyagu, Ukraine

Berlin, Brussels, Kiev, April 2006

COMMISSIONED BY Rebecca Harms, MEP, Greens/EFA in the European Parliament
WITH THE SUPPORT OF The Altner Combecher Foundation

The Greens | EFA
in the European Parliament

Acknowledgements

This report was financed by Rebecca Harms, MEP, of the Greens/EFA Party in the European Parliament and the Altner-Combecher Foundation.
The publishers are grateful in particular to Herr Günter Altner, Frau Altner and Herr Graf Hatzfeldt for their support.

The authors thank Dr M DeCort of DG-TREN of the European Commission for permission to reproduce plates from the Atlas of Caesium Deposition on Europe after the Chernobyl Accident (1998) EUR Report 16733. Office for Official Publications of the European Communities, Luxembourg. The authors also thank Dr Y Demidchik for permission to reproduce figure 4.2.

The authors thank Dr K Baverstock, Professor Y Dubrova, U Fink and Dr W Neumann for their helpful comments on drafts of the report. The authors also thank Dr E Cardis, Dr GN Kelly, Dr E Lyman, Professor A Nyagu, Dr T Ruff, M Schneider, J Simmonds and others for their helpful information. They also thank Margit Göbel, Silke Malorny and Anna Turmann for their expert administrative help.

Any errors, of course, remain the sole responsibility of the authors.

Table of Contents

Foreword by Rebecca Harms

„There are two compelling reasons why this tragedy must not be forgotten. First, if we forget Chornobyl, we increase the risk of more such technological and environmental disasters in the future. Second, more than seven million of our fellow human beings do not have the luxury of forgetting. They are still suffering, every day, as a result of what happened 14 years ago. Indeed, the legacy of Chernobyl will be with us, and with our descendants, for generations to come."

Kofi Annan
UN Secretary General in April 2000

"We did not yet possess a system of imagination, analogies, words or experiences for the catastrophe of Chernobyl."

Svetlana Alexiyevich
Writer from Belarus

In August 1986, four months after the Chernobyl disaster, Morris Rosen, head of the Division of Nuclear Safety of the Vienna based International Atomic Energy Agency (IAEA), declared: "Even if there was a Chernobyl type accident every year, I would still consider nuclear power an interesting type of energy production".[1] After a gigantic explosion and a ten day blazing fire had spread two hundred times the amount of radioactivity of the combined releases of the Hiroshima and Nagasaki bombs all over the planet, after the evacuation of over one hundred thousand people, the IAEA's chief nuclear safety officer considered an annual repetition of such a catastrophe an acceptable hypothesis. This man was the most powerful person in the IAEA on the issue of nuclear safety between 1981 and 1996, when he retired from his position then as Assistant Director General for Nuclear Safety. Breathtaking.

Rosen's post-Chernobyl declaration sheds a particular light on the mission statement of the IAEA, which stipulates that the Agency "develops nuclear safety standards and, based on these standards, promotes the achievement and maintenance of high levels of safety in applications of nuclear energy, as well as the protection of human health and the environment against ionizing radiation". Frightening.

When the IAEA in September 2005 released two reports on the environmental effects (coordinated by the IAEA) and health impacts (coordinated by the World Health Organisation - WHO) of the Chernobyl accident, numerous people and NGOs were suspicious about intentions and content. The IAEA is not neutral. Its primary role, as defined on its website, is "to promote safe, secure and peaceful nuclear technologies". The IAEA led interagency cooperation with the WHO is not a coincidence. An 1959 agreement between both organisations stipulates: "Whenever either organization proposes to initiate a program or activity on a subject in which the other organization has or may have a substantial interest, the first party shall consult the other with a view to adjusting the matter by mutual agreement." The term is well chosen: "adjusting the matter".

For the Swiss medical doctor Michel Fernex, the consequences are straight forward: "This Agreement explains why the WHO action plan for Chernobyl, IPHECA[2], launched as late as 5 years after the catastrophe, was designed by the IAEA, it explains why the proceedings of the WHO Chernobyl Conference (Geneva 1995) were never published, and why the inter-agency UN report on Chernobyl[3] still indicates, against all evidence, that Chernobyl caused 32 deaths, 200 irradiated and 2,000 thyroid cancers (in children and teenagers only), those being the IAEA and UNSCEAR[4] figures, and not those of WHO and OCHA[5]."

[1] Le Monde, 28 August 1986
[2] International Programme on the Health Effects of the Chernobyl Accident
[3] dated 6 February 2002
[4] United Nations Scientific Committee on the Effects of Atomic Radiation
[5] United Nations Office for the Coordination of Humanitarian Affairs

On 5 September 2005 an IAEA press release entitled "Chernobyl: The True Scale of the Accident", stated: "A total of up to four thousand people could eventually die of radiation exposure from the Chernobyl nuclear power plant (NPP) accident nearly 20 years ago, an international team of more than 100 scientists has concluded."
The IAEA statement was widely disseminated by the international media and raised an outcry amongst independent experts and environmental organisations that considered that the release scandalously downplayed the true scale of the disaster. However a solid scientific critique was missing.

I decided to commission an independent analysis of the IAEA/WHO reports in order to clarify the science basis for the assertions. You are holding the result of the study, **The Other Report on Chernobyl or TORCH**, by Ian Fairlie and David Sumner, in your hands. It becomes clear from their conclusions that the IAEA had indeed issued a seriously misleading statement about the WHO findings on health impact that forecasts, rather than 4,000, close to 9,000 excess cancer deaths. However, other evaluations estimate the death toll from cancer alone to between 30,000 and 60,000, most of them *outside* the most intensely affected countries Ukraine, Belarus and Russia. In fact, the TORCH report also shows that more radioactivity was released from the reactor than previously thought and that more than half of the fallout came down in Europe outside the former Soviet Republics.

The excellent Afterword from renowned Ukrainian expert Prof. Angelina Nyagu, President of the Kiev based association "Physicians of Chernobyl", reveals a number of additional issues that were not the focus of the main report but highlight the scale of the ongoing drama. Ukrainian experts estimate, for example, that the economic damage to Ukraine will be $200 billion until 2015. In comparison, Ukraine's GDP in 2001 was $37 billion. In 1992 Ukraine spent 15% of its State budget dealing with the aftermath of Chernobyl. While the figure has dropped to 5% in recent years, there are many issues that remain unresolved. Some of these are extremely urgent, including the fact that close to 10,000 people continue to live in zones of compulsory evacuation.

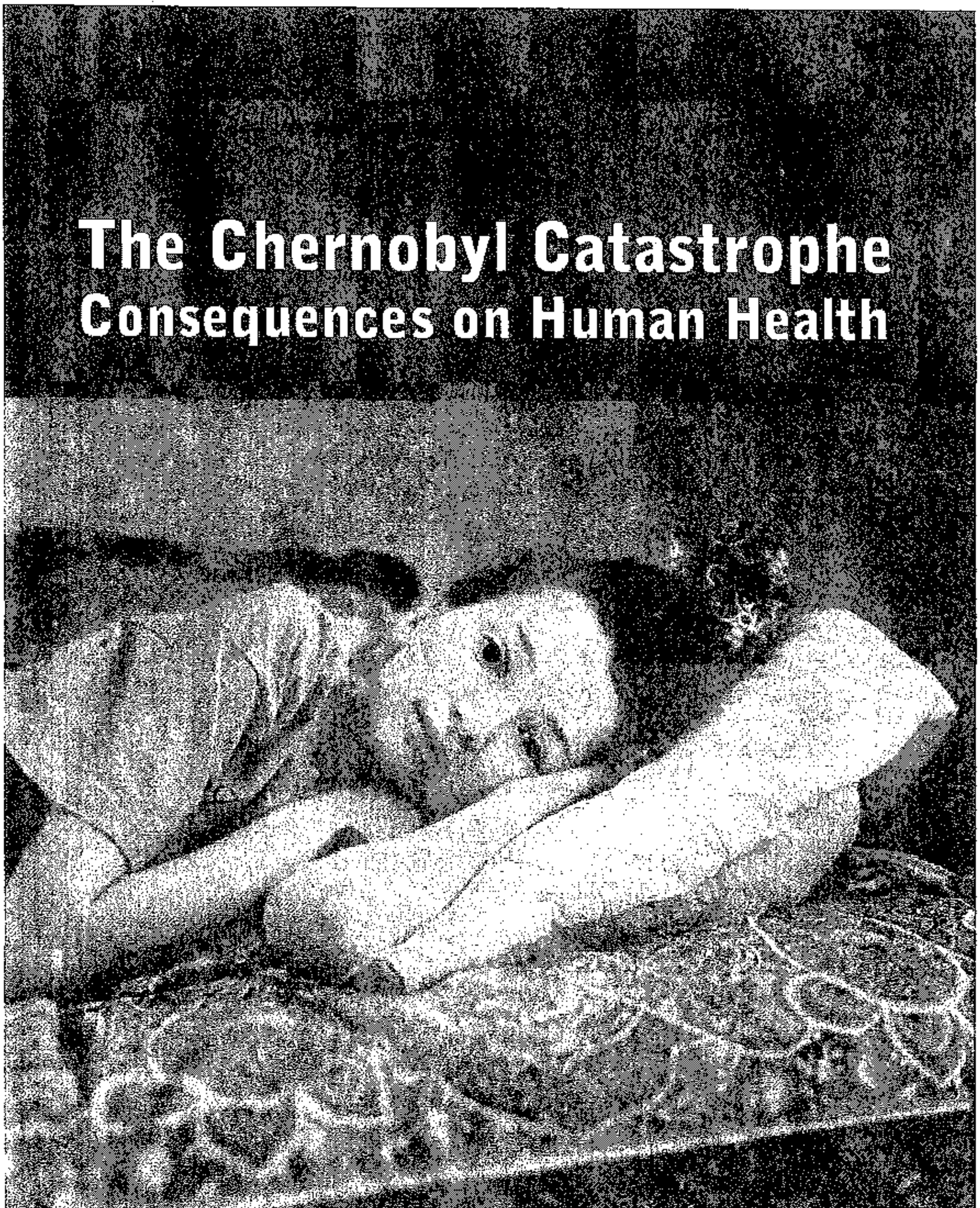
The present report cannot make up for the 20 years of systematic downplaying, secrecy, misinformation and misunderstanding of the effects of the Chernobyl catastrophe. But it does make a significant contribution to the better understanding of what is at stake when the nuclear industry and its lobby as well as some political leaders want us to agree to a new round of nuclear folly. It is stunning to what extent the energy sector, in East and West, has never experienced its Perestroïka, has never been exposed to Glasnost. It is the responsibility of political leaders to take up the debate on energy policy and, beyond the commemorations of the 20th anniversary of what will remain an ongoing disaster, guarantee a truly democratic decision making process that takes into account the experiences from the past in order to design a sustainable energy future for all.

The aftermath of the Chernobyl disaster is far from mitigated. Not even on a technical level. The conditions at the reactor site, in particular concerning spent fuel and waste management at the other three Chernobyl units, represent significant additional risks to be solved under very difficult radiological conditions. However, nuclear waste and contamination in many other places around the world from activities often decades ago still await a costly solution. Nobody can guarantee that another accident of Chernobyl dimensions or worse won't happen tomorrow. In most countries a large majority of the people do not want any more nuclear power plants. It is about time that industrial, economic and political leaders listen. No more Chernobyl.

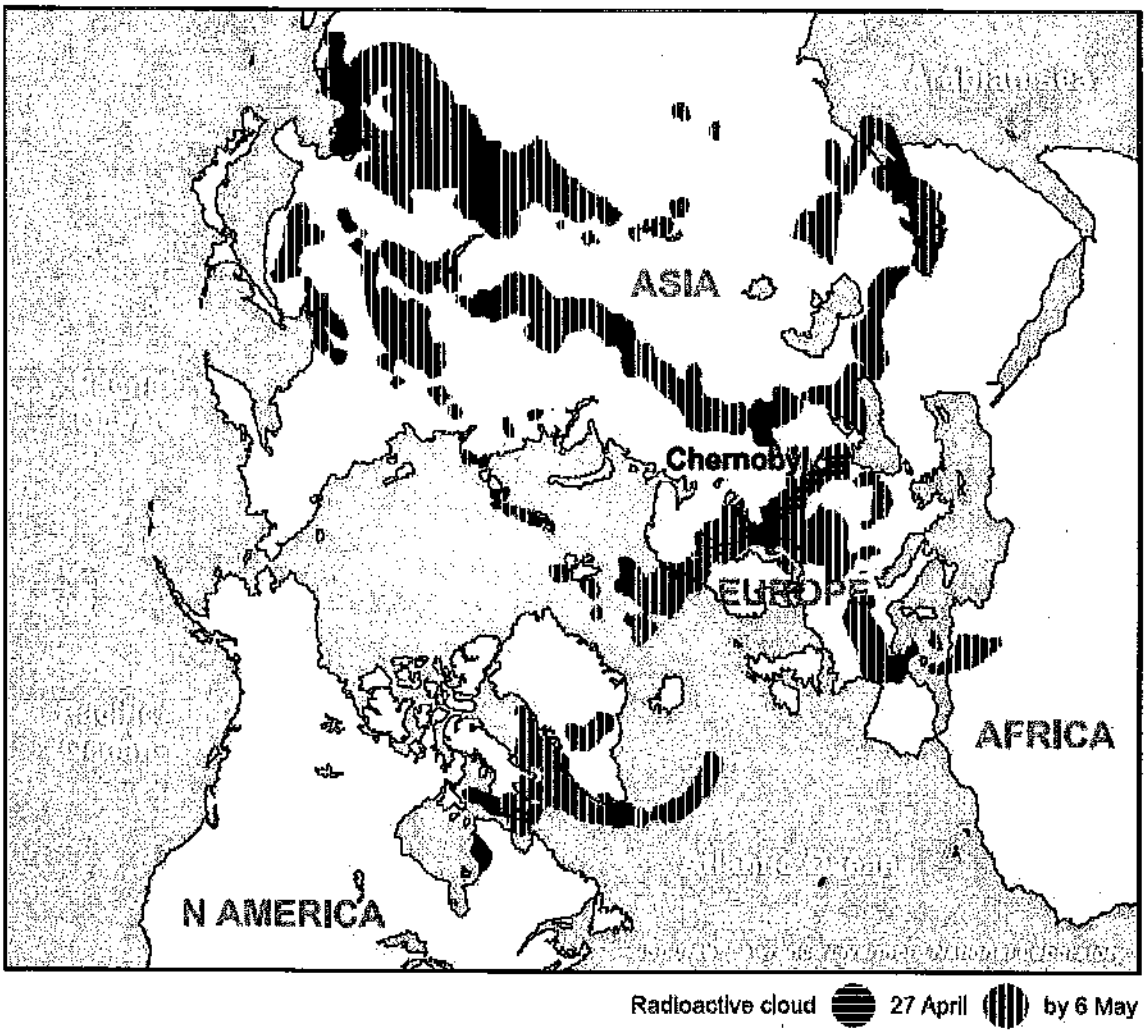
7.- The Chernobyl Catastrophe. Consequences on Human Health

Greenpeace
Amsterdam, The Netherlands

The Chernobyl Catastrophe
Consequences on Human Health



GREENPEACE 2006



ISBN 5-94442-013-8

April 2006

Greenpeace greatly appreciates the noted submissions of the following contributing authors of this report and the contributions of those individuals that made this publication possible.

General Editorship: A. Yablokov, I. Labunska, I. Blokov

This report was edited by Dr. David Santillo (UK), Dr. Paul Johnston (UK), Ruth Stringer (UK) and Tony Sadownichik (the Netherlands/Canada).

List of authors in alphabetical order:

Antipkin Yu.G., Institute of Paediatrics, Obstetrics and Gynaecology, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3

Arabskaya L.P., Institute of Paediatrics, Obstetrics and Gynaecology, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3

Bazyka D.A., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3

Blokov I.P., Greenpeace International - Chapter 1 and 2

Burlak G.F., Ministry of Health of Ukraine, Kiev, Ukraine – Chapter 3

Burlakova E.B., Institute of Biochemical Physics, Moscow, Russia – Chapter 1

Buzunov V.A., In-t of radiological hygiene and epidemiology, Research Center for Radiation Medicine, Kiev – Chapter 3

Cheban A.K., "Physicians of Chernobyl" Association, Kiev, Ukraine – Chapter 2 and 3

Dashkevich V.E., In-t of paediatrics, obstetrics and gynaecology Academy of Medical Sciences, Kiev, Ukraine – Chapter 3

Diomina, E.A., Institute of Experimental Pathology, Oncology and Radiobiology, Kiev, Ukraine – Chapter 3

Druzhina M.A., Institute of Experimental Pathology, Oncology & Radiobiology, Kiev, Ukraine – Chapter 3

Fedirko P.A., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3

Fedorenko Z., Institute of Oncology, Academy of Medical Sciences, Kiev, Ukraine – Chapter 2

Fuzik M., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 2

Geranios A., Department of Nuclear Physics and Elementary Particles, University of Athens, Greece – Chapter 4

Gryshchenko V., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 2

Gulak G.L., Institute of Oncology, Academy of Medical Sciences, Kiev, Ukraine – Chapter 2

Komissarenko I.V., Institute of Endocrinology and Metabolism, Academy of Medical Sciences, Kiev, Ukraine – Chapter 2

Kovalenko A.Ye., Institute of Endocrinology and Metabolism, Academy of Medical Sciences, Kiev, Ukraine – Chapter 2

Khudoley V.V., N.N.Petrov Research Institute of Oncology, Saint Petersburg, Center of Independent Environmental Expertise, Russian Academy of Sciences St.Petersburg, Russia - Chapters 1 and 2

Lipskaya A.I., Institute of Experimental Pathology, Oncology & Radiobiology, National Academy of Sciences, Kiev, Ukraine – Chapter 3
Loganovsky K.N., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3
Malko M.V., Joint Institute of Power and Nuclear Research, National Academy of Sciences of Belarus, Belarus - Chapters 1 and 2
Misharina Zh.A., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3
Naboka M.V., Department of Eco-hygienic investigations of the Radioecological Centre of the National Academy of Sciences of the Ukraine, Kiev, Ukraine – Chapter 3
Nyagu A.I., "Physicians of Chernobyl", International Journal of Radiation Medicine, Kiev, Ukraine – Chapter 3
Okeanov E.A., A.D. Sakharov International State Environment University, Minsk, Belarus - Chapter 1 and 2
Omelyanets N.I., Laboratory of Medical Demography, Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 2
Oradovskaya I.V., Immunology Institute of the Russia Ministry of Public Health, Moscow, Russia – Chapter 3
Pilinskaya M.A., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3
Pintchouk L.B., Institute of Experimental Pathology, Oncology & Radiobiology, National Academy of Sciences, Kiev, Ukraine – Chapter 3
Prysyazhnyuk A., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 2
Rjazskay E.S., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3
Rodionova N.K., Institute of Experimental Pathology, Oncology & Radiobiology, National Academy of Sciences, Kiev, Ukraine – Chapter 3
Rymyantseva G.M., V.P. Serbskiy V.P., Scientific-Research Institute of Social and Legal Psychiatry, Moscow, Russia - Chapter 3
Rybakov S.I., Surgical Department, Institute of Endocrinology and Metabolism Academy of Medical Sciences, Kiev, Ukraine – Chapter 2
Schmitz-Feuerhake I., Department of Physics, University of Bremen, Germany (retired) – Chapter 4
Serkiz Ya.I., Institute of Experimental Pathology, Oncology & Radiobiology, National Academy of Sciences, Kiev, Ukraine – Chapter 3
Shestopalov V.M., Radioecological Centre, National Academy of Sciences of the Ukraine, Kiev, Ukraine – Chapter 3
Skvarskaya E.A., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3
Slipenyuk K., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 2
Stepanova E.I., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3
Sushko V.A., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3
Tararukhina O.B., Russian Scientific Radiology Centre, Moscow, Russia – Chapter 3
Tereshchenko V.P., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3

Usatenko V.I., National Commission of Radiation Protection of Ukraine, Kiev, Ukraine – Chapter 1
Vdovenko V.Yu., Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine – Chapter 3
Wenisch A., Austrian Institute of Applied Ecology, Vienna, Austria – Chapter 4
Yablokov A.V., Russian Academy of Sciences, Russia – Chapters 1,2,3,4
Zubovsky G.A, Russian Scientific Center of Roentgenoradiology, Moscow, Russia – Chapter 3

The preparation and organization of this report was by Iryna Labunska (Greenpeace International Science Unit) and Ivan Blokov (Greenpeace International)

Materials for this report were collected and translated by Eugeniy Lobanov (Belarus), Maryna Karavai (Belarus), Vladimir Tchouprov (Russia), Irina Mikituk (Ukraine), Olga Sologub (Ukraine), and Victor Sologub (Ukraine).

We also would like to extend special thanks to:

Prof. Antipkin Yu.G., Director of the Institute of Paediatrics, Obstetrics and Gynaecology, Academy of Medical Sciences, Kiev, Ukraine

Prof. Bebeshko V.G., Director of the Research Centre for Radiation Medicine, Academy of Medical Sciences, Kiev, Ukraine

Prof. Tronko N. D., Director of the Institute of Endocrinology and Metabolism, Academy of Medical Sciences, Kiev, Ukraine

Note: In the report units of measurement were used as presented in submitted documents.