INSTITUTE FOR ENERGY AND ENVIRONMENTAL RESEARCH

6935 Laurel Avenue, Suite 201
Takoma Park, MD 20912

Phone: (301) 270-5500
FAX: (301) 270-3029
e-mail: ieer@ieer.org
http://www.ieer.org

DECLARATION OF DR. ARJUN MAKHIJANI REGARDING SAFETY AND ENVIRONMENTAL SIGNIFICANCE OF NRC TASK FORCE REPORT REGARDING LESSONS LEARNED FROM FUKUSHIMA DAIICHI NUCLEAR POWER STATION ACCIDENT[1]

I, Arjun Makhijani, declare as follows:

Introduction and Statement of Qualifications

1. I am President of the Institute for Energy and Environmental Research ("IEER") in Takoma Park, Maryland. Under my direction, IEER produces technical studies on a wide range of energy and environmental issues to provide advocacy groups and policy makers with sound scientific information and analyses as applied to environmental and health protection and for the purpose of promoting the understanding and democratization of science. A copy of my curriculum vita is attached.

2. I am qualified by training and experience as an expert in the fields of plasma physics, electrical engineering, nuclear engineering, the health effects of radiation, radioactive waste management and disposal (including spent fuel), estimation of source terms from nuclear facilities, risk assessment, energy-related technology and policy issues, and the relative costs and benefits of nuclear energy and other energy sources. I am the principal author of a report on the 1959 accident at the Sodium Reactor Experiment facility near Simi Valley in California, prepared as an expert report for litigation involving radioactivity emissions from that site. I am also the principal author of a book, *The Nuclear Power Deception: U.S. Nuclear Mythology from Electricity "Too Cheap to Meter" to "Inherently Safe' Reactors"* (Apex Press, New York, 1999, co-author, Scott Saleska), which examines, among other things, the safety of various designs of nuclear reactors.

3. I have written or co-written a number of other books, reports, and publications analyzing the safety, economics, and efficiency of various energy sources, including nuclear power. I am also the author of *Securing the Energy Future of the United States: Oil, Nuclear and Electricity*

[1] Task Force Review (*Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident*, Nuclear Regulatory Commission, July 12, 2011, at http://pbadupws.nrc.gov/docs/ML1118/ML111861807.pdf)

Vulnerabilities and a Post-September 11, 2001 Roadmap for Action (Institute for Energy and Environmental Research, Takoma Park, Maryland, December 2001). In 2004, I wrote "Atomic Myths, Radioactive Realities: Why nuclear power is a poor way to meet energy needs," *Journal of Land, Resources, & Environmental Law,* v. 24, no. 1 at 61-72 (2004). The article was adapted from an oral presentation given on April 18, 2003, at the Eighth Annual Wallace Stegner Center Symposium entitled, "Nuclear West: Legacy and Future," held at the University of Utah S.J. Quinney College of Law. In 2008, I prepared a report for the Sustainable Energy & Economic Development (SEED) Coalition entitled *Assessing Nuclear Plant Capital Costs for the Two Proposed NRG Reactors at the South Texas Project Site.*

4. I am generally familiar with the basic design and operation of U.S. nuclear reactors and with the safety and environmental risks they pose. I am also generally familiar with materials from the press, the Japanese government, the Tokyo Electric Power Company, the French government safety authorities, and the U.S. Nuclear Regulatory Commission ("NRC") regarding the Fukushima Daiichi (hereafter Fukushima) accident and its potential implications for the safety and environmental protection of U.S. reactors. I have also read *Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-chi Accident*, July 12, 2011 (hereafter the "Task Force Review"), published by the NRC.

5. On April 19, 2011, I prepared a declaration stating my opinion that although the causes, evolution, and consequences of the Fukushima accident were not yet fully clear a month after the accident began, it was already presenting new and significant information regarding the risks to public health and safety and the environment posed by the operation of nuclear reactors. My declaration was submitted to the NRC by numerous individuals and environmental organizations in support of a legal petition to suspend licensing decisions while the NRC investigated the regulatory implications of the Fukushima accident. Emergency Petition to Suspend All Pending Reactor Licensing Decisions and Related Rulemaking Decisions Pending Investigation of Lessons learned From Fukushima Daiichi Nuclear Power Station Accident (April 14-18, 2011). In my declaration I also stated my belief that the integration of new information from the Fukushima accident into the NRC's licensing process could affect the outcome of safety and environmental analyses for reactor licensing and relicensing decisions by resulting in the denial of licenses or license extensions or the imposition of new conditions and/or new regulatory requirements. I also expressed the opinion that the new information could also affect the NRC's evaluation of the fitness of new reactor designs for certification. *Id.,* par. 5.

Purpose

6. The purpose of my declaration is to explain why the Task Force Review provides further support for my opinions that the Fukushima accident presents new and significant information regarding the risks to public health and safety and the environment posed by the operation of nuclear reactors and that the integration of this new information into the NRC's licensing process could affect the outcome of safety and environmental analyses for reactor licensing and relicensing decisions and the NRC's evaluation of the fitness of new reactor designs for certification.

Agreement With Task Force Review's Conclusions Regarding Need to Expand Design Basis

7. In my opinion, the Task Force reasonably concludes that substantial revisions to the very framework of NRC regulations are needed to adequately protect public health and the environment. I also agree that a major overarching step that needs to be taken is to integrate into the design basis for NRC safety requirements an expanded list of severe accidents and events, based on current scientific understanding and evaluations. This would ensure that potential mitigation measures are evaluated on the basis of whether they are needed for safety and not whether they are merely desirable. Should the NRC fail to incorporate an expanded list of severe accident requirements in the design basis of reactors, then a conclusion that the design provides for adequate protection to the public against severe accident risks could not be justified. The necessity for an expanded list of design basis requirements should be viewed in light of the Fukushima experience and the nuclear accident experience which preceded Fukushima, including Three Mile Island and Chernobyl accidents. Specifically, adequate protection of the public is incompatible with the NRC's continued reliance on voluntary evaluation of severe external and internal events, voluntary adoption of mitigation measures, or the use of cost-benefit analysis to evaluate their desirability.

8. I believe my opinion is consistent with the Task Force's statement that:

> Adequate protection has been, and should continue to be, an evolving safety standard supported by new scientific information, technologies, methods, and operating experience. This was the case when new information about the security environment was revealed through the events of September 11, 2001. Licensing or operating a nuclear power plant with no emergency core cooling system or without robust security protections, while done in the past, would not occur under the current regulations. As new information and new analytical techniques are developed, safety standards need to be *reviewed, evaluated, and changed, as necessary, to insure that they continue to address the NRC's requirements to provide reasonable assurance of adequate protection of public health and safety. The Task Force believes, based on its review of the information currently available from Japan and the current regulations, that the time has come for such change.* [p. 18, italics added]

9. I am concerned that over the past three decades or more, the NRC has not conducted the type of review of the adequacy of its safety regulations that is necessary to update its requirements so as to ensure that NRC safety requirements will provide the minimum level of protection required by the Atomic Energy Act. For instance, the Task Force Review points out that, over 30 years ago, the Rogovin Commission recommended that the scope of the design basis should be expanded to include a greater range of severe accidents. The Rogovin Commission explicitly stated that "[m]odification is definitely needed in the current philosophy that there are some accidents ("Class Nine accidents") [2] so unlikely that reactor designs need not

[2] Class Nine accidents are now called "severe accidents." (Task Force Review p. 16)

provide for mitigating their consequences."[3]. This recommendation was effectively disregarded by the NRC. Instead of imposing and enforcing mandatory requirements for prevention and mitigation of severe accidents, the NRC accepted voluntary measures and the use of cost-benefit assessments by licensees to exclude requirements for a range of preventive or mitigative measures. As a result the Task Force Review concluded that despite including some requirements for beyond-design-basis accidents, "the NRC *has not made fundamental changes to the regulatory approach for beyond-design-basis events and severe accidents* for operating reactors." (p. 17, italics added). Even the installation of hardened vents on Mark I and Mark II BWRs was left to the voluntary discretion of the licensees. Given the NRC's failure to make the needed changes in its basic regulatory requirements for safety since the Rogovin Commission report was issued over thirty years ago, and in light of the disastrous consequences of the Fukushima accident, which continues nearly five months after it started, I consider the current inadequacies in the NRC's program for regulation of basic reactor safety to be extraordinarily grave problems.

Potential Effects of Task Force Review on Environmental Analyses for New Reactors, Existing Reactor License Renewal, and Standardized Design Certification

10. If the Task Force's recommendation to incorporate severe accidents into the design basis for NRC safety requirements is considered in environmental analyses for reactor licensing decisions or standardized design certifications, I think it would have very significant effects on the outcome of those analyses, in three key respects. First, the environmental analysis would have to consider the implication of the Task Force Review that compliance with current NRC safety requirements does not adequately protect public health and safety from severe accidents and their environmental effects. Second, for reactors that are unable to comply with new mandatory requirements, it could result in the denial of licenses. Third, the cost of adopting mandatory measures necessary to significantly improve the safety of currently operating reactors and proposed new reactors is likely to be significant.

Change to Estimate of Environmental Risk

11. An analysis of the environmental implications of the Task Force Review would have to consider the ramifications of the Task Force's implicit conclusion that compliance with current NRC safety standards does not adequately protect public health and safety from severe accidents and their environmental effects. For instance, the Task Force Review indicates that seismic and flooding risks as well as risks of seismically-induced fires and floods may be greater than previously understood by the NRC in some cases. Therefore in its environmental analyses, the NRC would have to revise its analysis to reflect the new understanding that the risks and radiological impacts of accidents are greater than previously thought.

Potential Denial of License Applications Based on Environmental Risk Analyses

12. The Task Force Review implicitly raises the potential that some reactors will be unable to

[3] Rogovin Commission report (*Three Mile Island: A Report to the Commissioners and to the Public*, by Mitchell Rogovin and George T. Frampton, et al. NUREG/CR-1250 1980. (Rogovin, Stern & Huge, Washington, DC, January 1980), v. 1, p. 151

comply with new mandatory requirements, thus resulting in the denial of licenses. For instance, this would be the case if a reactor cannot be adequately backfitted to comply with present-day assessment of ground shaking induced by earthquakes. Similarly, multi-unit siting may not be allowed in certain cases due to the impracticality of meeting upgraded emergency management requirements.

Significant Changes to Cost-Benefit Analyses

13. The cost of adopting mandatory measures necessary to significantly improve the safety of currently operating reactors and proposed new reactors is likely to be significant. Adoption of a coherent regulatory framework as recommended by the Task Force, including periodic reassessments of whether the design basis is up to date with scientific assessments of flooding and seismic threats, is likely to result in significantly increased costs for nuclear reactors.

14. The Task Force Review contains numerous recommendations for consideration of new mandatory requirements for increasing the capability of the reactors, equipment, and personnel to handle and to respond to a range of severe accidents. Adoption of such measures could have high costs. This, in turn, will affect the overall cost-benefit analysis for reactors, especially the comparisons of nuclear power with alternative sources of electricity. Examples of potentially significant costs if severe accident mitigation measures are adopted follow in paragraphs 15 through 24 below:

15. If the Task Force recommendations are adopted, all existing reactors will be required to make changes to extend their capacity to handle station blackouts. This design upgrade is likely to have significant costs.

16. Similar considerations apply to new reactor combined construction and operating license applications. For instance, the Task Force recommends adding station blackout requirements to the Advanced Boiling Water Reactor, which would also likely result in increased costs. (p. 72).

17. Even where the Task Force deems some narrow issues to be already resolved by COL (combined license) applications and/or design certification applications, the interplay of other Task Force recommendations may raise environmental issues and cost concerns. For instance, while the Task Force found that the AP1000 and ESBWR designs already have a 72-hour provision for passive emergency core cooling, thereby satisfying the design requirement recommendations for station blackouts (pp. 71-72), other statements in the Task Force Review indicate the existence of environmental concerns that should be addressed in an EIS. For instance, the Task Force recommendations relating to the provision of backup power during the time beyond 72 hours relate mainly to prepositioning equipment offsite (Recommendation 4.1, p. 38) and therefore were regarded as not relevant to AP1000 and ESBWR design certifications but only to the COL process (p. 72). However, in the context of emergency preparedness, the Task Force Review notes that "[i]n the case of large natural disasters such as earthquakes, hurricanes, and floods, the phenomena challenging the plant will also have affected the local community. In these cases, *prearranged resources may not be available because of their inability to reach the plant site....*" (p. 60, italics added). Therefore the designs of the AP1000 and the ESBWR need to be reviewed in the context of their ability to mitigate the environmental impacts of station

blackout lasting more than 72 hours. The potential for destruction of infrastructure that would prevent prestaged offsite equipment from reaching the site would also needs to be taken into account in environmental analyses for COLs and license extension applications.

18. Similarly, while the Task Force concludes that COL and Early Site Permit (ESP) applications already satisfy Recommendation 2.1 with respect to analysis of seismic and flooding risks (p. 71), it does not appear that all of the seismic and flooding-related implications of the Review have been addressed. Specifically, the flooding and fires that may be induced by earthquakes was closed by the NRC without imposing new requirements; the Task Force Review recommends reopening this issue (p. 32). These are issues that combine site characteristics and reactor design. For instance, the passive cooling features of AP1000s and ESBWRs involve pools of water located above the reactors. In addition, the ESBWR design has a buffer spent fuel pool in roughly the same position relative to the reactor as the Mark I design reactors (i.e., above the reactor vessel). Hence it is important to revisit this issue for these two reactor designs since they may be built at seismically active sites, including in the central and eastern United States (see paragraph 22 below), where there are active COL applications pending.

19. In the context of existing reactors, the Task Force Review recommends incorporating the latest understanding of seismic impacts and flooding (Recommendation 2, p. 30), and reopening the issue seismically induced flooding and fires (Recommendation 3, p. 32). This reassessment may also involve increased costs due to required backfits.

20. Taken as a whole, the Task Force Review's recommendations implicitly call for a review of all new reactor design certifications regarding station blackout (SBO) arrangements, including mitigation measures for SBO events that extend beyond 72 hours and spent fuel pool instrumentation and make up water supply capability. The effects of seismically induced flooding and fires on spent fuel pool arrangements should also be reviewed. All of these reviews could result in the imposition of costly prevention or mitigation measures, affecting comparisons with the alternatives.

21.. In view of the events leading to the hydrogen explosions in Units 1, 3, and 4 at Fukushima, the reliability of the existing hardened vent system in Mark I and Mark II reactors has been thrown into question. The Task Force Review recommends installation of *reliable* hardened vents in all Mark I and Mark II BWRs (Recommendation 5, p. 41). Because such vents have not yet been designed and tested, their costs are unknown. However, they are likely to be substantial. These costs must be determined and evaluated for NEPA purposes for all 23 Mark I reactors and all eight Mark II reactors.

22. The recommended mandatory review of the flooding and seismic design basis of existing reactors to evaluate whether they meet the design basis safety requirements could result in greatly increased costs in some or many cases. The establishment of the Shoreline Fault just offshore the Diablo Canyon Power Plant and the Oceanside thrust in the area of the San Onofre Nuclear Generating Station provides examples of recent developments that could lead to large expenditures for restoring the design basis safety margins for these reactors. As a reflection of the uncertainty, Pacific Gas & Electric (PG&E), which owns Diablo Canyon has itself requested and obtained a delay of 52 months in its license extension application so that the necessary

seismic studies can be completed. Another example relates to seismic hazard assessments in the central and eastern United States. In that case, the NRC has concluded that "[u]pdates to seismic data and models indicate that estimates of the seismic hazard, at some operating nuclear power plant sites in the Central and Eastern United States, have increased."[4] The NRC does not have enough data at present to determine what, if any, backfits may be called for, but intends to use a cost-benefit approach in deciding whether they should be implemented. It specifically states that "[i]n order to progress with the Regulatory Analysis Stage, a comprehensive list of candidate plant backfits must be identified for subsequent value-impact analysis."[5] "Value-impact analysis" is the NRC's terminology for a cost-benefit analysis.[6] However, if backfitting for more severe earthquakes than were incorporated into the original design were *required* for safety rather than left to a cost-benefit analysis, the implications for comparison with the alternatives could be considerable for existing reactors in the Central and Eastern United States.

23. The Task Force noted that the same concern applies to flooding hazards, where "the assumptions and factors that were considered in flood protection at operating plants vary. In some cases, the design basis does not consider the probable maximum flood (PMF)." (p. 29) Again, protection of reactors against updated flood hazards could involve significant costs, depending on the outcome of the updated evaluations.

24. Finally, the Task Force Review points out the importance of considering mitigation measures associated with multi-unit events. Such events had not been considered before and therefore were assigned zero probability for all intents and purposes. The Task Force review recommends a revision of regulations to cover multi-unit events, for instance, to ensure adequate emergency core and spent fuel cooling for more than one unit at a time:

> As part of the revision to 10 CFR 50.63, the NRC should require that the *equipment* and personnel necessary to implement the minimum and extended coping strategies shall include *sufficient capacity to provide core and spent fuel pool cooling, and reactor cooling system and primary containment integrity for all units at a multiunit facility.* The staff should also make the appropriate revisions to the definitions of "station blackout" and "alternate ac source" in 10 CFR 50.2. [p. 39, italics added]

Because most new applicants for COLs, such as Vogtle 3 and 4, propose to locate the new units at sites that already have reactors, the entire basis of emergency response adequacy, station-blackout related requirements, and emergency core and spent fuel pool cooling needs to be

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[4] *Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants Safety/Risk Assessments*, Generic Issue 199 (GI-199), Nuclear Regulatory Commission, August 2010, at http://pbadupws.nrc.gov/docs/ML1002/ML100270639.pdf, p. 30

[5] GI-199 p. 30

[6] NRC guidelines require "that the value-impact of an alternative be quantified as the "net value" (or "net benefit"). To the extent possible, all attributes, whether values or impacts, are quantified in monetary terms and added together (with the appropriate algebraic signs) to obtain the net value in dollars. The net value calculation is generally favored over other measures, such as a value-impact ratio or internal rate of return (RWG 1996, Section III.A.2)." (*Regulatory Analysis Technical Evaluation Handbook: Final Report*, NUREG/BR-0184, Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, January 1997, p. 5.2. Link at http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=446391.

reconsidered for the total number of units proposed at the site. The design and cost implications could be significant and must be reconsidered and reevaluated.

Conclusions

25. I agree with the conclusions of the Task Force that significant changes to the NRC's regulatory system are needed in order to ensure that the operation of new reactors and re-licensed existing reactors does not pose unacceptable safety and environmental risks to the public. In light of the disastrous and ongoing events at Fukushima since March 11, 2011, it is clear that the issues of public safety raised by the Task Force are exceptionally grave. I also believe that it is highly likely that consideration of the Task Force's conclusions and recommendations in environmental analyses for new reactor licensing, existing reactor re-licensing, and design certification rulemakings, would materially affect the outcome of many and possibly all those studies.

The facts presented above are true and correct to the best of my knowledge, and the opinions expressed therein are based on my best professional judgment.

Arjun Makhijani

Date: 8 August 2011

Dr. Arjun Makhijani

INSTITUTE FOR ENERGY AND ENVIRONMENTAL RESEARCH

6935 Laurel Avenue, Suite 201
Takoma Park, MD 20912

Phone: (301) 270-5500
FAX: (301) 270-3029
e-mail: ieer@ieer.org
http://www.ieer.org

Curriculum Vita of Arjun Makhijani

Address and Phone:
Institute for Energy and Environmental Research
6935 Laurel Ave., Suite 201
Takoma Park, MD 20912
Phone: 301-270-5500
e-mail: arjun@ieer.org
Website: www.ieer.org

A recognized authority on energy issues, Dr. Makhijani is the author and co-author of numerous reports and books on energy and environment related issues, including two published by MIT Press. He was the principal author of the first study of the energy efficiency potential of the US economy published in 1971. He is the author of *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy* (2007).

In 2007, he was elected Fellow of the American Physical Society. He was named a Ploughshares Hero, by the Ploughshares Fund (2006); was awarded the Jane Bagley Lehman Award of the Tides Foundation in 2008 and the Josephine Butler Nuclear Free Future Award in 2001; and in 1989 he received The John Bartlow Martin Award for Public Interest Magazine Journalism of the Medill School of Journalism, Northwestern University, with Robert Alvarez. He has many published articles in journals and magazines as varied as *The Bulletin of the Atomic Scientists, Environment, The Physics of Fluids, The Journal of the American Medical Association*, and *The Progressive*, as well as in newspapers, including the *Washington Post*.

Dr. Makhijani has testified before Congress, and has appeared on ABC World News Tonight, the CBS Evening News, CBS 60 Minutes, NPR, CNN, and BBC, among others. He has served as a consultant on energy issues to utilities, including the Tennessee Valley Authority, the Edison Electric Institute, the Lawrence Berkeley Laboratory, and several agencies of the United Nations.

Education:

- Ph.D. University of California, Berkeley, 1972, from the Department of Electrical Engineering. Area of specialization: plasma physics as applied to controlled nuclear fusion. Dissertation topic: multiple mirror confinement of plasmas. Minor fields of doctoral study: statistics and physics.
- M.S. (Electrical Engineering) Washington State University, Pullman, Washington, 1967. Thesis topic: electromagnetic wave propagation in the ionosphere.
- Bachelor of Engineering (Electrical), University of Bombay, Bombay, India, 1965.

Current Employment:

- 1987-present: President and Senior Engineer, Institute for Energy and Environmental Research, Takoma Park, Maryland. (part-time in 1987).
- February 3, 2004-present, Associate, SC&A, Inc., one of the principal investigators in the audit of the reconstruction of worker radiation doses under the Energy Employees Occupational Illness Compensation Program Act under contract to the Centers for Disease Control and Prevention, U.S. Department of Health and Human Services.

Other Long-term Employment

- 1984-88: Associate Professor, Capitol College, Laurel, Maryland (part-time in 1988).
- 1983-84: Assistant Professor, Capitol College, Laurel, Maryland.
- 1977-79: Visiting Professor, National Institute of Bank Management, Bombay, India. Principal responsibility: evaluation of the Institute's extensive pilot rural development program.
- 1975-87: Independent consultant (see page 2 for details)
- 1972-74: Project Specialist, Ford Foundation Energy Policy Project. Responsibilities included research and writing on the technical and economic aspects of energy conservation and supply in the U.S.; analysis of Third World rural energy problems; preparation of requests for proposals; evaluation of proposals; and the management of grants made by the Project to other institutions.
- 1969-70: Assistant Electrical Engineer, Kaiser Engineers, Oakland California. Responsibilities included the design and checking of the electrical aspects of mineral industries such as cement plants, and plants for processing mineral ores such as lead and uranium ores. Pioneered the use of the desk-top computer at Kaiser Engineers for performing electrical design calculations.

Professional Societies:

- Institute of Electrical and Electronics Engineers and its Power Engineering Society
- American Physical Society (Fellow)
- Health Physics Society
- American Association for the Advancement of Science

Awards and Honors:

- The John Bartlow Martin Award for Public Interest Magazine Journalism of the Medill School of Journalism, Northwestern University, 1989, with Robert Alvarez
- The Josephine Butler Nuclear Free Future Award, 2001
- Ploughshares Hero, Ploughshares Fund, 2006
- Elected a Fellow of the American Physical Society, 2007, *"For his tireless efforts to provide the public with accurate and understandable information on energy and environmental issues"*
- Jane Bagley Lehman Award of the Tides Foundation, 2007/2008

Invited Faculty Member, Center for Health and the Global Environment, Harvard Medical School: Annual Congressional Course, *Environmental Change: The Science and Human Health Impacts*, April 18-19, 2006, Lecture Topic: An Update on Nuclear Power - Is it Safe?

Consulting Experience, 1975-1987
Consultant on a wide variety of issues relating to technical and economic analyses of alternative energy sources; electric utility rates and investment planning; energy conservation; analysis of energy use in agriculture; US energy policy; energy policy for the Third World; evaluations of portions of the nuclear fuel cycle.

Partial list of institutions to which I was a consultant in the 1975-87 period:

- Tennessee Valley Authority
- Lower Colorado River Authority
- Federation of Rocky Mountain States
- Environmental Policy Institute
- Lawrence Berkeley Laboratory
- Food and Agriculture Organization of the United Nations
- International Labour Office of the United Nations
- United Nations Environment Programme
- United Nations Center on Transnational Corporations
- The Ford Foundation
- Economic and Social Commission for Asia and the Pacific
- United Nations Development Programme

Languages: English, French, Hindi, Sindhi, and Marathi.

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