Peaceful use of nuclear energy

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Introduction

■**Since Chernobyl accident in 1986, nuclear power was <u>not</u> regarded as a viable option in many countries.**
■**However, in the last two decades, there are two key trends;**

1) There was 40% increase of nuclear electricity between 1990-2005, in spite of limited capacity addition. This is because best practices prevailed through information sharing, learning from others, while at the same time, safety indicators improved.

2) Rising expectation to the role of nuclear power since 2005.
More than 60 countries are considering launching nuclear power programme; 1/3 in Africa, 1/3 in Asia (Slide)

- To meet growing energy demand for better living standard
- Considering as a viable option, given concern over energy supply security, fossil price volatility, and environment

30 countries are operating nuclear power
More than 60 countries are considering launching nuclear power programme

✓ **More than 60 Member States have interest in the introduction of nuclear power**;

- Meeting growing energy demand for better living standard
- Considering as an option, given concern over energy supply security, fossil price volatility, and environment

✓**2010 IAEA Projection (RDS-1)**

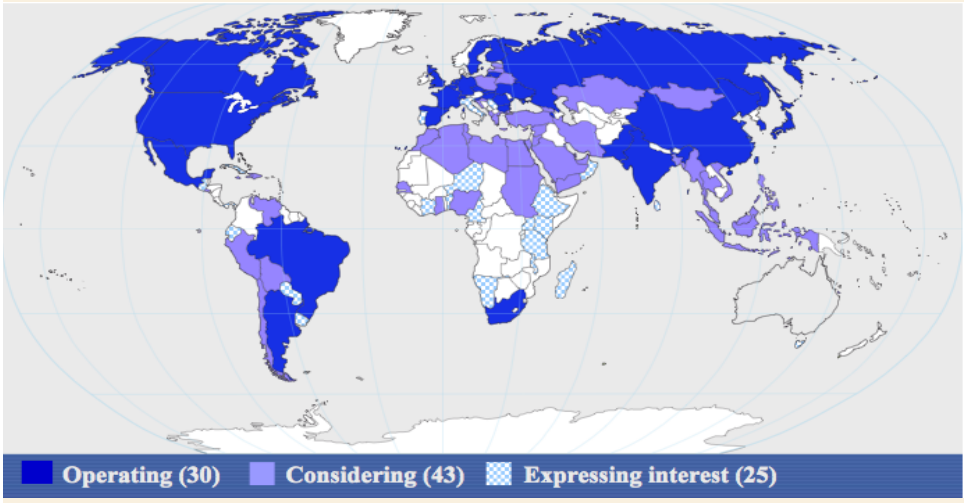
by 2030

- 803 GWe in operation in Hi-projection (2.16 x current 372 GWe)
- 546 GWe in operation in Lo-projection (1.47 x current 372 Gwe)

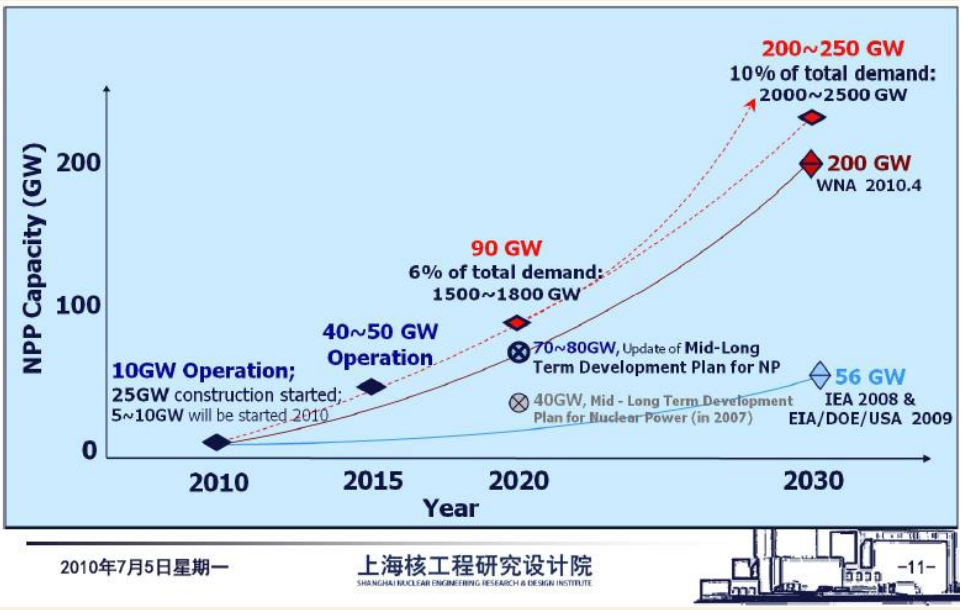
by 2050

- 1415 GWe in operation in Hi-projection (3.8 x current 372 GWe)
- 590GWe in operation in Lo-projection (1.59 x current 372 Gwe

Continuous trend of increase in the number in recent several years



Rhodes Forum Oct 2010 Omoto



SOURCE: Zheng Mingguang, SNERDI, icapp2010

Brundtland Report [Our Common Future, 1987]

- Intended to build a bridge to address possible strains
  - Economic development
  - Environmental protection
- Defined sustainable development

  "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"
- Recognized that achieving global *equity* and *sustainable growth* would require *technological and social changes*

Key concept of sustainable development

- Three dimensions
  - Social
  - Economic
  - Environmental

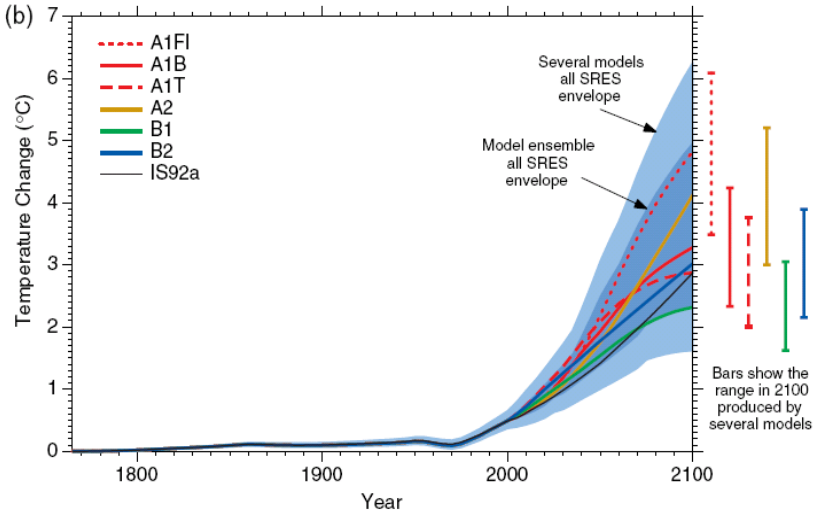
  (further) institutional aspect

- Equity

  Within and across countries (space) as well as across generations (time)

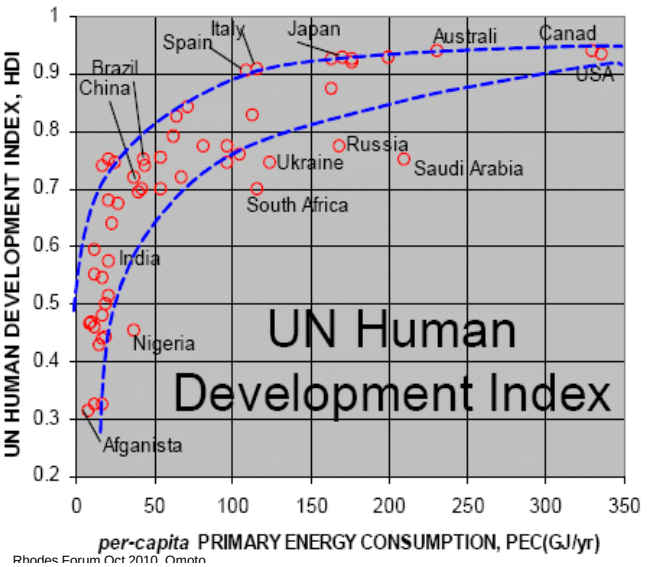
Inequity across generations

Projected range of atmospheric temperature change (SRES scenario, IPCC 2001)



Inequity across countries

HDI and primary energy consumption

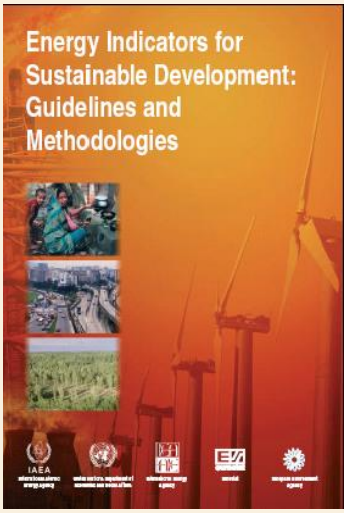


HDI
comparative measure of poverty, literary, education, life expectancy & others

Source: UN Human Development Index report, UNDP, 2000

Energy Indicators for Sustainable Development (EISD)

- Information of
  - Interest: energy
  - Value: sustainability
  - Aspiration: development
- In order to
  - Analyze: past trends and current situation
  - Diagnose: measure distance to target
  - Formulate strategy: explore options
- Energy Indicators using;
  - Equity: Affordability, Accessibility ….
  - Safety: Health effect
  - Economy: Reserve/Production, Security of Supply……
  - Environment: Climate change, air quality, land use…..

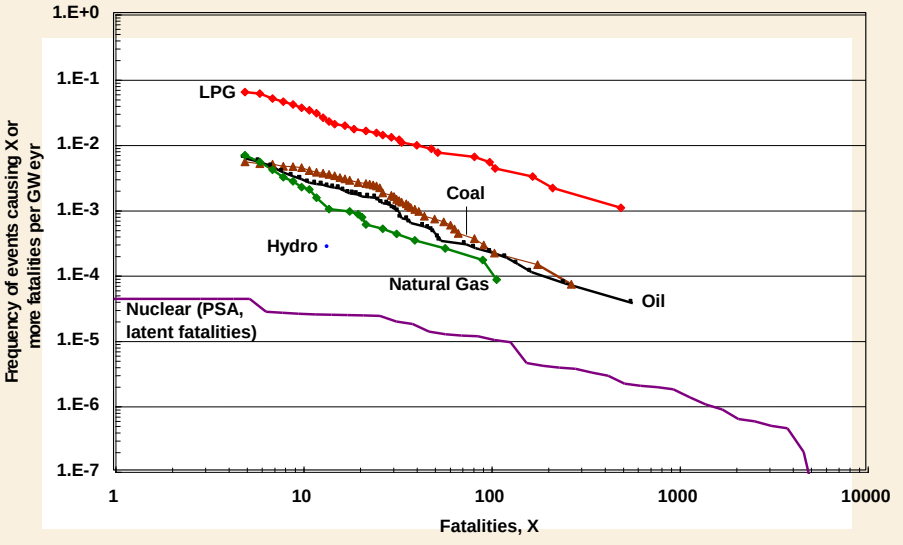


EISD in "Society" dimension

Theme	Sub-theme	Energy Indicator	
Equity	Accessibility	SOC1	Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy
	Affordability	SOC2	Share of household income spent on fuel and electricity
	Disparities	SOC3	Household energy use for each income group and corresponding fuel mix
Health	Safety	SOC4	Accident fatalities per energy produced by fuel chain

Comparative assessment of power generation sources

Frequency-Consequence Curves for Severe Accidents in Various Energy Chains, OECD countries, 1969-2000 (NE→ latent only, Others→ acute fatality)



SOURCE: Burgherr & Hirschberg, 2004

Chernobyl health effect

- Initiated by the IAEA in 2003.
- 8 UN organizations + Belarus, Russia and Ukraine.
- More than 80 experts from 12 countries and 6 international organisations, such as UNSCEAR, WHO
- The results considered by 60th UN General Assembly, November 2005.

Cancer mortality – predictions [Chernobyl Forum report]

- The WHO predicts that among the 600,000 persons receiving significant exposures (liquidators working in 1986–1987, evacuees, and residents of the most 'contaminated' areas), the possible increase in cancer mortality due to this radiation exposure might be up to a few per cent
- This might eventually represent up to four thousand fatal cancers in addition to the approximately 100,000 fatal cancers expected to be due to all other causes in this population
- Among the 5 million persons residing in other 'contaminated' areas, the doses are much lower and any projected increases are more speculative, but are expected to make a difference of much less than one per cent in cancer mortality

Cancer mortality – predictions [Chernobyl Forum report]

- Such increases would be very difficult to detect with available epidemiological tools, given the normal variation in cancer mortality rates
- So far, epidemiological studies of residents of contaminated areas in Belarus, Russia and Ukraine have not provided clear and convincing evidence for a radiation-induced increase in general population mortality
- However, among the more than 4000 thyroid cancer cases diagnosed in 1992-2002 in persons who were children or adolescents at the time of the accident, fifteen deaths related to the progression of the disease had been documented by 2002

Chernobyl : Lessons Learned & Actions

- ❑ Chernobyl accident was the result of a deficient safety culture, as well as specific design features of the reactor. [INSAG]

- ❑ The IAEA
  - stressed the need for the industry to share information
  - encouraged operators to learn from the experience of others, set clear safety standards,
  - assisted in upgrading safety and the reviewing operational performance.

- ❑ Conventions on Nuclear Safety and Early Notification

- ❑ WANO to share operational experiences and lessons learned; to cultivate a safety culture; to improve operational procedures and to pursue continuous improvement by setting safety performance goals.

EISD in "Economy" dimension

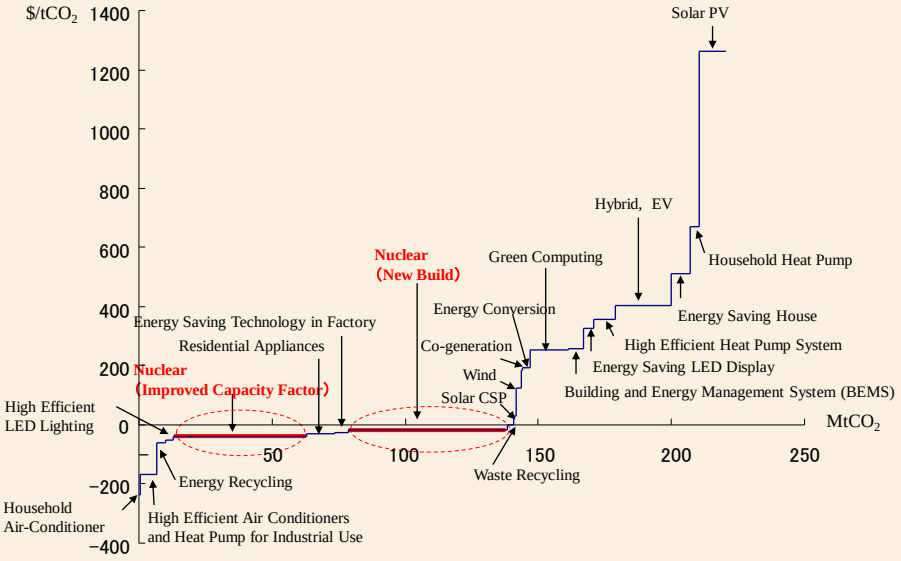
Theme	Sub-theme	Energy Indicator	
Use and production patterns	Overall Use	ECO1	Energy use per capita
	Overall Productivity	ECO2	Energy use per unit of GDP
	Supply efficiency	ECO3	Efficiency of energy conversion & distribution
	Production	ECO4	Reserves to production ratio
		ECO5	Resources to production ratio
	End-use productivity	ECO6	Industrial energy intensities
		ECO7	Agricultural energy intensities
		ECO8	Service / Commercial energy intensities
		ECO9	Household energy intensities
		ECO10	Transport energy intensities
	Fuel Mix	ECO11	Fuel Shares in energy and electricity
		ECO12	Renewable energy share in energy and electricity
	Prices	ECO13	End use energy Prices by fuel and by sector
Security	Imports	ECO14	Net energy import dependency
	Stocks	ECO15	Stocks of critical fuels per corresponding fuel consumption

EISD in "Environment" dimension

Theme	Sub-theme	Energy Indicator	
Atmosphere	Climate Change	ENV1	GHG emissions from energy production and use per capita and per GDP
	Air quality	ENV2	Ambient concentrations of air pollutants in urban areas
		ENV3	Air pollutant emissions from energy systems
Water	Water quality	ENV4	Contaminant discharges in liquid effluents from energy systems including oil discharges
Land	Soil quality	ENV5	Soil area where acidification exceeds critical load
	Forest	ENV6	Rate of deforestation attributed to energy use
	Solid Waste generation & management	ENV7	Ratio of solid waste generation per energy produced
		ENV8	Ratio of solid waste properly disposed to total generated solid waste
		ENV9	Ratio of solid radioactive waste per energy produced
		ENV10	Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste

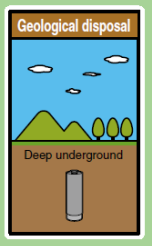
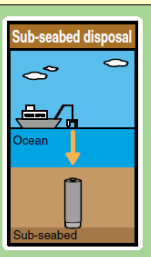
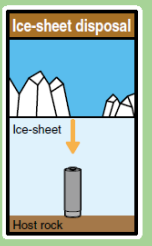
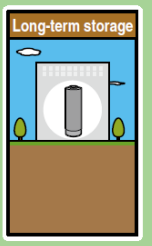
GHG Abatement Cost Curve

(The Institute of Energy Economics, Japan)



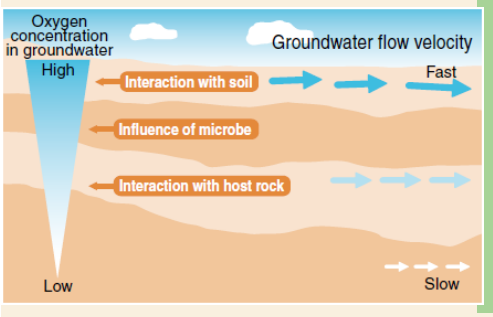
Waste in Fuel Preparation and Plant Operation

Alternative concepts considered

No need of long-term measures				Need of long-term measures
Geological disposal	Space disposal	Sub-seabed disposal	Ice-sheet disposal	Long-term storage
				
Using the favorable containment features provided by the deep underground environment	Problematic with current space technology	Prohibited by international political and legal agreements covering the seabed	Prohibited by international political and legal agreements covering the Antarctic	Imposes undue burdens on future generations

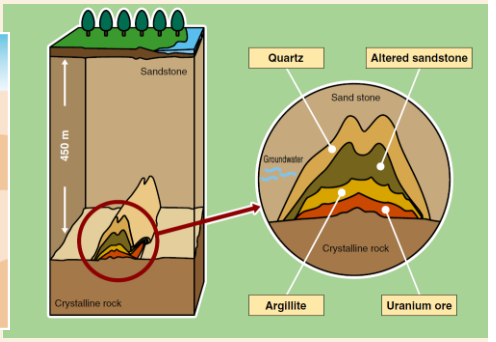
Waste in Fuel Preparation and Plant Operation

Characteristics of confinement in deep underground



Deep meteoric water has a low oxygen content due to interactions with the host rock and consumption by microbial reactions. The deep underground environment is chemically stable and there is virtually no dissolution or corrosion of metals. Dissolved substances also migrate extremely slowly because of the slow groundwater flow rate (e.g. several mm/year).

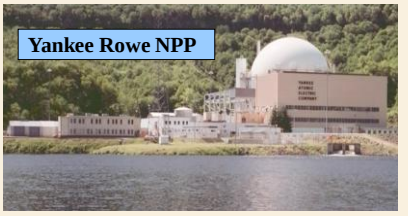
Example of a natural analogue



The uranium ore deposit at Cigar Lake has remained isolated for more than 1300 million years since its formation. Underground conditions led to isolation of the radioactive substances for an extremely long time period.

Decommissioning of nuclear facilities

- **Back to the original state**
- **Preparedness for decommissioning by secured funding**
- **Technology is available but can be optimized further**



Other than power: Use of radiation technique

Medical: Cancer diagnosis & therapy
Health: STI (Sterile Insect tech)
Agriculture:
- Breed improvement
- Bio-organic fertilizer
- Plant growth promoter
- Extension of shelf-life

Industry: Semi-conductor, Tire etc
Isotope hydrology

Agriculture

Radiation induced mutation

Post- harvest control utilizing radiation

Non-irradiated Irradiated

Medicine

Diagnosis; PET-CT

Therapy; Ion beam therapy

Industry

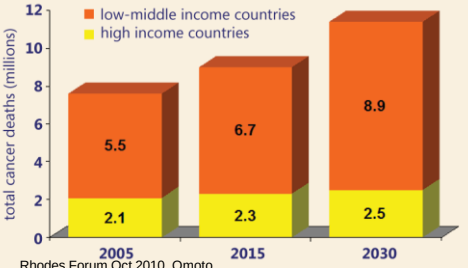
Radiation process;
Radial tires

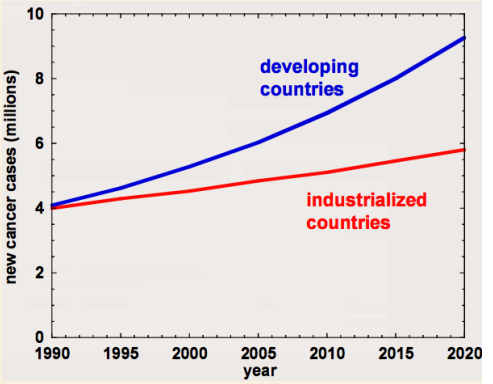
Semiconductors

Non-destructive inspection

Medical use

✓Over the next 20 years there will be 260 million new cancer cases worldwide
✓Approx. 150 million will be in developing countries, and in these, 100 million will be suitable for radiotherapy



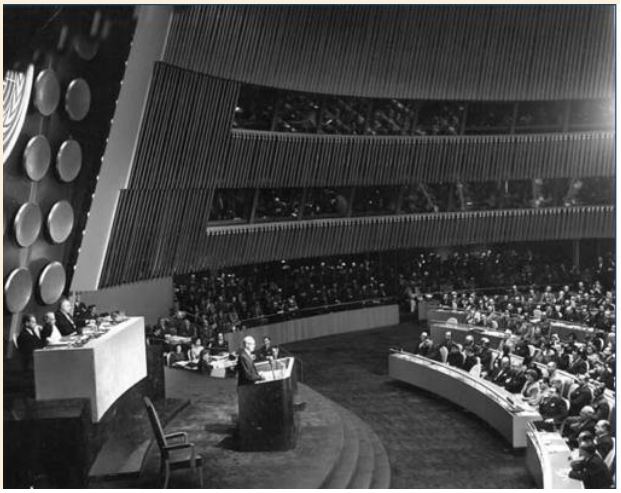


[SOURCE] WHO (2003)

Atoms for Peace" address (1953)

That new language is the language of atomic welfare

…..the knowledge (of nuclear weapons) now possessed by several nations will eventually be shared by others, possibly all others …
….. the probability of civilization destroyed, the annihilation of the irreplaceable heritage of mankind……

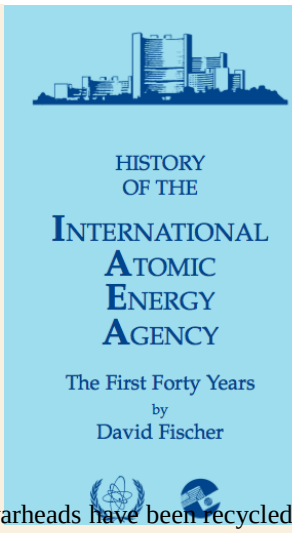


…..The United States would seek more than the mere reduction or elimination of atomic materials for military purposes. …..

…make joint contributions from their stockpiles of uranium and fissionable materials to an international atomic energy agency.

Original intention

- President Eisenhower's aim was nuclear disarmament,
- Spread of the new nuclear technology might be slowed down, it could not be stopped
  → "plug the now leaky holes"
  or
  "control to ensure that it was used for peaceful purposes only"
- The idea of placing military stocks of fissile materials, including material from dismantled nuclear weapons, under the IAEA's surveillance



(IAEA not involved)
The **Megatons to Megawatts™ Program**
Since1995, 375 metric tons of HEU from Russian nuclear warheads have been recycled into low-enriched-uranium fuel for U.S. NPPs (equivalent of 15,000.
Goal of elimination 500 MTs of warhead material to be completed in 2013.
(IAEA involved but not dismantled fissile material)
Fuel bank by the IAEA could remove the "peaceful use" justification for other nations that might be trying to use a civilian nuclear program as cover to make nuclear weapons

On the matter of dual use

- **Technology and material can be used for weapons purpose like other technologies (bio-chemical, transportation, IT….)**

- **Assurance of safety, security and non-proliferation by;**

Intrinsic measures

✓Proliferation-resistance: Pu-denatured, Th cycle, higher burnup ….
✓Safety: Inherent safety, Passive safety, Reliability engineering (redundancy, diversity, QA) and Risk analysis, Defense-in-depth

Extrinsic measures

✓Proliferation-resistance: Verification by the IAEA, PSI, Sensitive technology under multi-lateral control
✓Safety: Licensing, Regulatory oversight, Safety Convention (IAEA)…

Room for continuous improvement

"How safe is safe enough" – US Safety Goal

- Individual members of the public should be provided a level of protection from the consequences of nuclear power plant operation such that individuals bear no significant additional risk to life and health
  - → **Translated to 1/1000 of early fatality risks**
  - → **US mortality early mortality data [5 x 10^{-4}] x 1/1000→ goal=5x 10^{-7} / year**
    whereas, Typical PWR: 2 x 10^{-8}
    Typical BWR: 5 x 10^{-11}

- Societal risks to life and health from nuclear power plant operation should be comparable to or less than the risks of generating electricity by viable competing technologies ….
  - → **Translated to 1/1000 of latent cancer fatality risks**
  - →**US cancer mortality data [2x 10^{-3}] x 1/1000→ goal=2x10^{-6} / year**
    whereas, Typical PWR: 2 x 10^{-9}
    Typical BWR: 4 x 10^{-10}

Can atomic "fuel" be dually used in nuclear power plants, and the atomic bomb? (Theme#1 statement)

Fat chance
Do not forget difference in material composition

	WEAPON	Commercial NPPs (LWRs)
Enriched U-235	95%>	> 5%
Plutonium	High in Pu-239 (fissile)	> U-235 5% equivalent, further; 1) 1/3 by higher Pu isotopes (emit spontaneous neutrons and cause fizzle) 2) Heat from Pu-238 melts chemical explosive

Chernobyl Lessons Learned

1. Lack of global peer review to design deficiencies
- Reactor core with positive void coefficient
  (Cases of Swedish and Canadian heavy water reactor to abandon start of operation)
- Partial confinement
- Control rod design

2. Inappropriate man-machine system
- Dependence on rules rather than interlocks
- Over-reliance and allowance to operator's action (6 violations allowed without mechanical interruption)

3. Lack of professionalism
- Test without attendance of reactor physicist
- Tried to finish testing after forced to wait for a long time by power dispatcher (pre-condition for unsafe and unstable condition of Xe buildup and positive void coefficient)
- Violation of rules

4. organizational culture and communication
- No attention to nuclear safety ("another type of самовар")
- Relayed accident information to Moscow just saying "fire" but not "reactor accident"

Engineering practices in safety - its evolution

Inherent safety, Passive safety, Reliability engineering (redundancy, diversity, QA) and Risk analysis, Defense-in-depth

TMI-2, Chernobyl, Safety research, Risk analysis methodology etc.

- **Safety culture**
- **Attention to man-machine interface and organizational factor**
- **Enhanced passive safety (walk-away capability)**
- **Use of safety goal and PSA**
- **Severe Accident Management**
- **External events (Earthquake, Tsunami, Volcano, Aeroplane crash) and other events (fire/flooding)**

Stakeholder involvement

- Public perception on risk:
  - Technological risk judged by “Dread” and “Unkown” (Slovoc)
  - Bias on low-frequency-high-consequence event
- Participation in decision-making process
  - Informed decision-making
  - Case studies in “Site conflicts”
- Public and individual
  - NIMBY/NOPE/BANANA/ CAVE (”Project No Project”)
- Knowledge
  - Our radiant world
  - Event scale…..failure, incident, accident and their severity

Challenges of expansion/introduction

(IAEA status and prospect report on nuclear power, 2008)

1. **Safety and reliability**
2. **Economic competitiveness and financing**
3. **Public acceptance**
4. **Uranium resources**
5. **Fuel and waste management**
6. **Human and industrial resources**
7. **Proliferation risk and security**
8. **Infrastructures, especially in new entrants countries**

Preventing nuclear weapons from spreading

■ **Ultimately by nuclear disarmament**

The division between nuclear weapon "haves" and "have nots" under NPT will not be *not sustainable* as far as nuclear weapon is viable. The only way to prevent nuclear weapons from spreading is to *abolish them*.

■ **Some recent news**

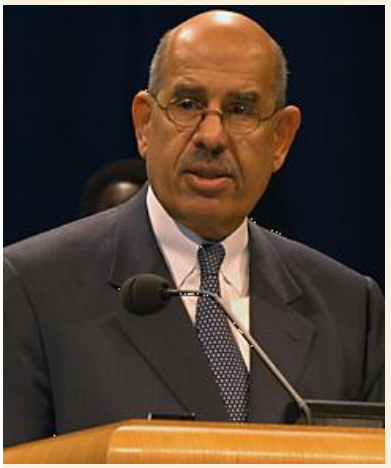
1) Articles proposing "abolition of nuclear weapons" in January 2007 and January 2008 by George P Shultz, William J Perry, Henry A Kissinger and Sam Nunn
2) Obama speech in Prague in 2009.
3) Final Document, 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons

Action 3: The nuclear- weapon States commit to undertake further efforts to reduce and ultimately eliminate all types of nuclear weapons.

Action 5: The nuclear-weapon States are called upon to report the above undertakings to the Preparatory Committee at 2014. The 2015 Review Conference will take stock and consider the next steps for the full implementation of article VI.

Proliferation risk

Multilateral control of sensitive part of fuel cycle



"the wide dissemination of the most proliferation-sensitive parts of the nuclear fuel cycle…could be the 'Achilles' heel' of the nuclear non-proliferation regime. It is important to tighten control over these operations, which could be done by bringing them under some form of multilateral control, in a limited number of regional centers….."

-*Introductory Statement* to the IAEA Board of Governors by the Director General, March 2004

Proliferation risk

Enabling expansion of NP while minimizing risk

New initiatives proposed (2003-2006)

- ✓**Multilateral Approaches to Nuclear Fuel Cycle (M. ElBaradei, IAEA)**
- ✓**Global Nuclear Energy Partnership (GNEP) (USA)**
- ✓**President Putin's initiative to develop a Global Nuclear Power Infrastructure (GNPI) (Russia)**

Proliferation risk

Multilateral approaches / studies

Multilateral approaches – nothing new

- Russian supply and take-back of fuel for Russian type reactors
- Supply and take-back of US or Russian origin research reactor fuel
- Joint financing of UP-3 and THORP reprocessing facilities

Multilateral studies – nothing new

- 1977 Regional Nuclear Fuel Cycle Centres
- 1980 INFCE International Nuclear Fuel Cycle Evaluation
- 1982 International Plutonium Storage

What is new? – Changing nuclear environment

- Rising expectation to the role of nuclear power, including new countries considering embarking on nuclear power programme
- Understanding that open fuel cycle is not viable in the long run (sustainability)
- Renewed concern over proliferation risk

Infrastructure building by newcomers to operate nuclear power

International cooperation

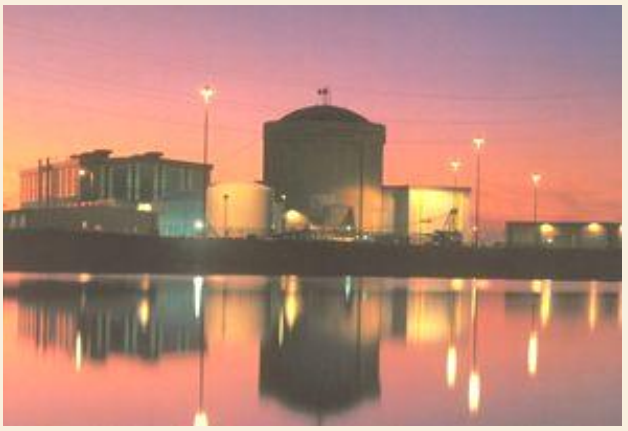
- Key role by the IAEA
- Guidance documents for progressive development and evaluation of "where we stand" by each newcomer, the IAEA mission
- Issue specific support: law, regulation, human resources development...

Regional approach

- Pool resources rather than build by each
- Fuel Cycle in the long-run
- Confidence building with the neighbours

Responsible supply and responsible use

- ***"Every country has the right to introduce nuclear power, as well as the responsibility to do it right "*** (M. Elbaradei, General Conference speech 2008 September)
- Accident anywhere is accident everywhere
- Code of conduct & peer review
- International peer review on compliance of safety design to IAEA standards (by solving the issue of sovereign rights of licensing)



…Thank you for your attention