Institutional and technological innovation to maximize the benefit from the use of NE for Sustainable Development

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OUTLINE

1. Introduction: NE in the context of Sustainable Development

2 . Technological innovation

3. Institutional innovation

4. Collaboration

5. Conclusions

Why innovation is necessary?

- To meet the new demand
- To stay competitive with other options
- (In the area of Nuclear Energy, ultimately)
  To maximize the benefit from the use of Nuclear Energy for Sustainable Development of humankind

Innovation=<u>exploiting</u> new ideas leading to the creation of a new product, process or service to generate new value and to bring about significant <u>changes in society</u>

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)

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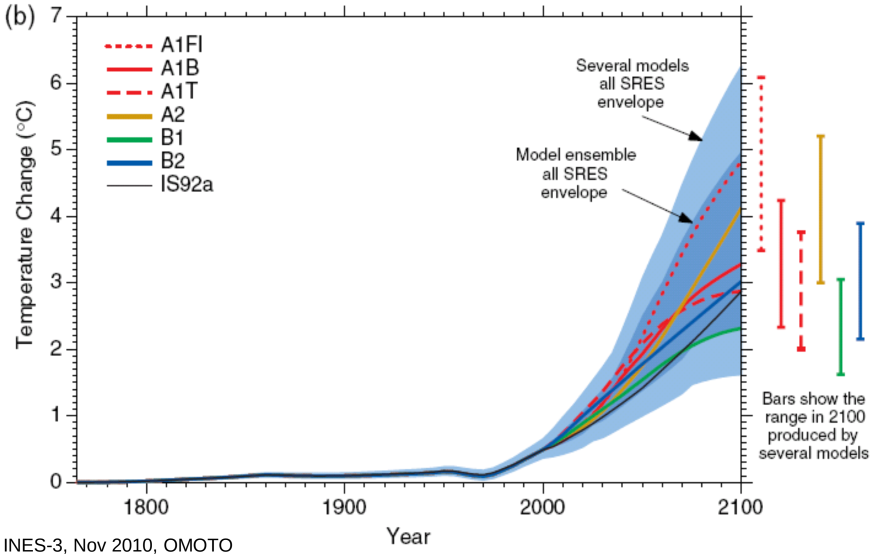
Inequity across generations

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



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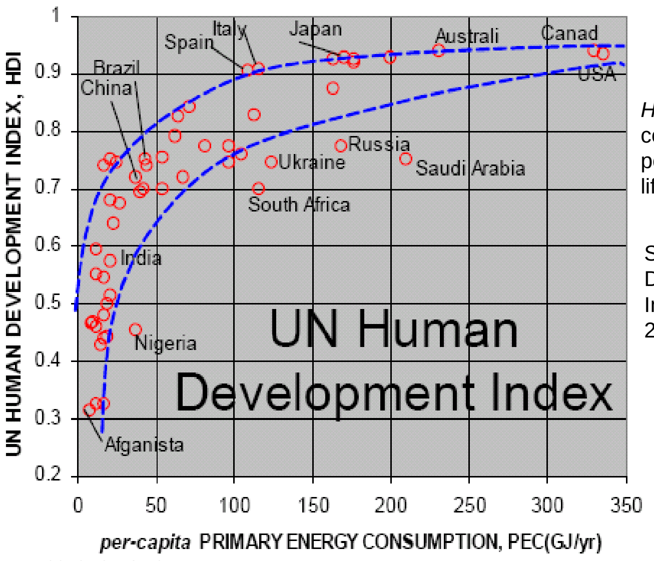
Inequity across countries

HDI and primary energy consumption

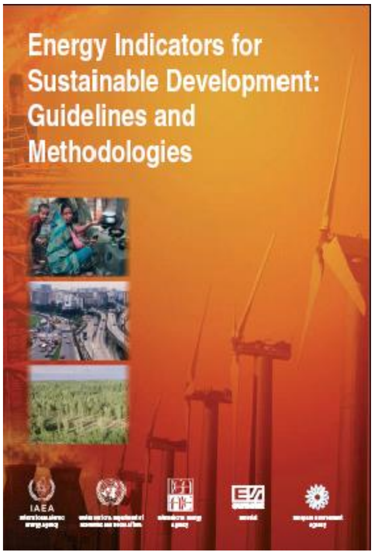


HDI
comparative measure of poverty, literacy, education, life expectancy & others

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 on;
  - 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

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

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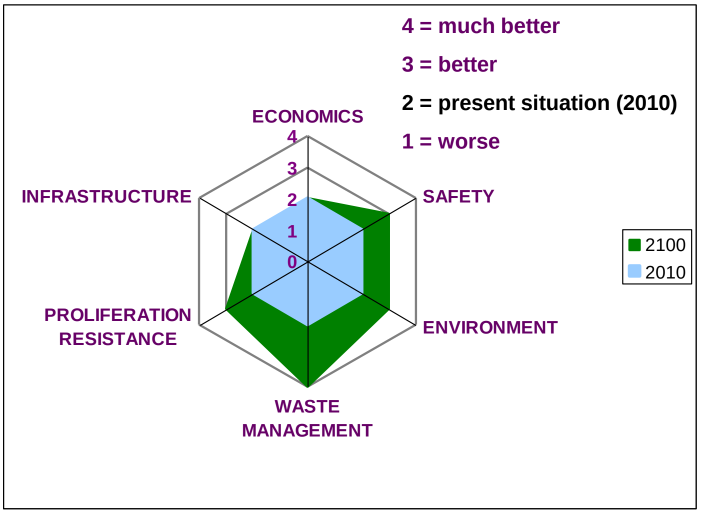
Where we need innovation?

Evaluation of each innovative nuclear energy system using indicators in INPRO methodology would help to see if "Satisfaction at an elevated level" is there



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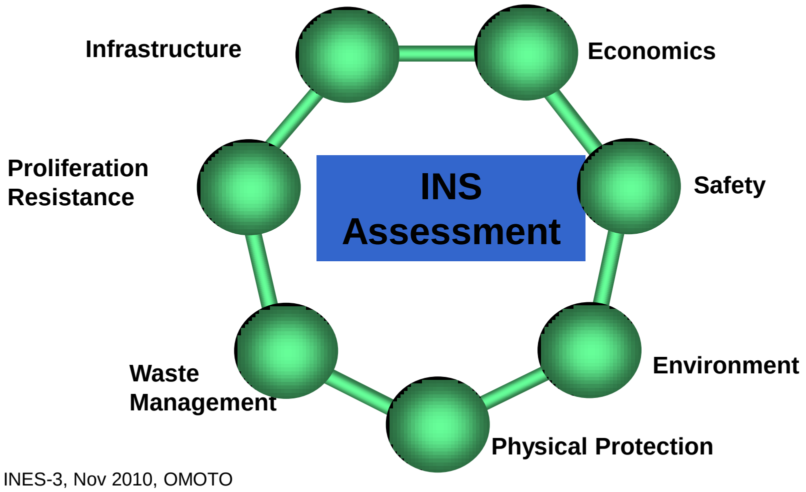
Assessment of Innovative Nuclear System (INS)

IAEA-INPRO had established methodology for evaluation of INS
- **To meet the expectation in seven key areas at an elevated level**
- **Expectation to maximize the benefit of NE use for sustainable development**



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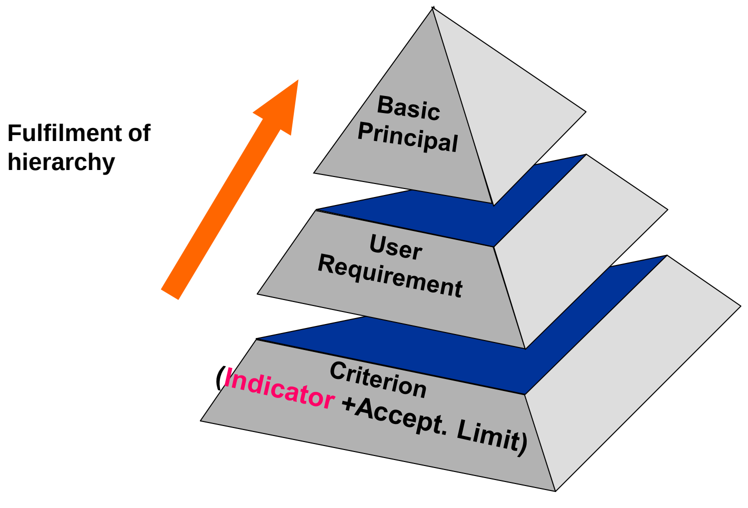
Hierarchy of demands on innovative designs In INPRO methodology



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To stay competitive against alternatives (or against pesticide)

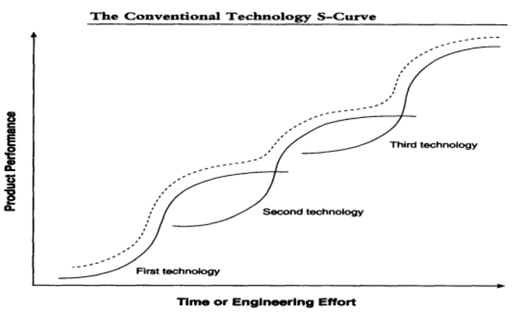
Very often referred quote by Red Queen from Lewis Carrol's "Through the Looking-Glass"

It takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that.

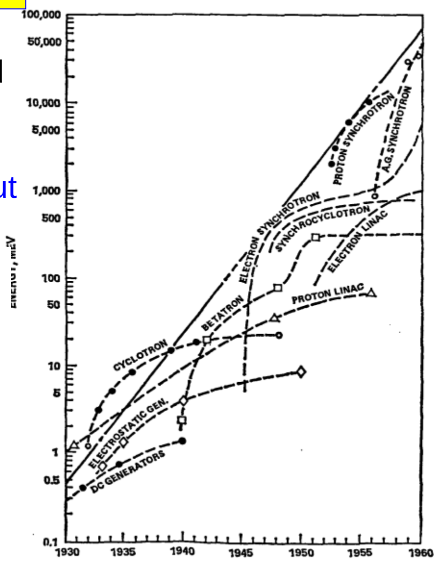
Technological growth

For certain specific technology field

- Integration of sigmoid curves
- Growth by starting a new sigmoid curves before existing one peters out



Christensen, “The Innovator’s dilemma”, 1997



Starr et al, “Parameters of Technological Growth”, Science 182 (October, 1973)

Technological growth theory

- Well know theory of growth utilizing Sigmoid curve

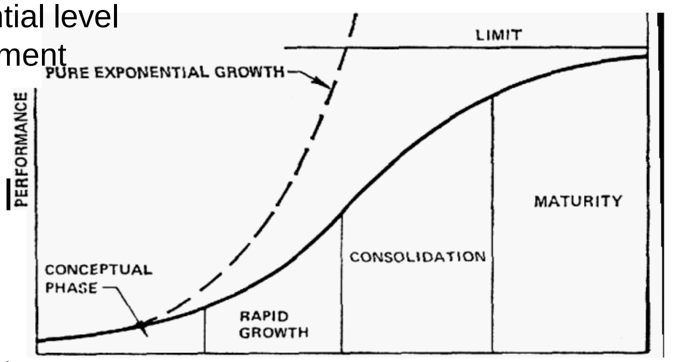
$$\frac{LIMIT}{1-be^{-at}}$$

- Societal expectations characterized by [Starr et al]

$$\beta\frac{Tr-Tp}{Tp}$$

β : relative priority assigned by society
Tr : perceived potential level
Tp : current achievement

For individual device or system



Starr et al, “Parameters of Technological Growth”, Science 182 (October, 1973)

Case of nuclear power technologies

●**Such simplistic characterization may NOT apply to nuclear technology, because**

1) Market is considerably different from ordinary commodity

2) Complex dimensions such as ;

Non-proliferation, Size of necessary technological infrastructure for innovation, Risk and Conservatism...

●**In considering β [Tr-Tp] / Tp for NE**

(1) Tr is high enough, whereas maybe Tp is too low with current technologies

(2) Material : one of the key constraints

(3) β (relative priority assigned by society) : No high enough. Also many societal constraints in the development/implementation process. → *issue of institutional innovation*

1. **Introduction: NE in the context of Sustainable Development**

2 . **Technological innovation**

3. **Institutional innovation**

4. **Collaboration**

5. **Conclusions**

Societal constraints in the development/implementation process

- "Sea of ideas/Findings/Research Results" need "exploitation" to have social value (entitled as "innovation")
- In reality, social & institutional conditions very often bar "exploitation" of new technologies to satisfy Sustainability goal at an elevated level

Examples where we need institutional innovation or adaptive change to maximize the benefits from the use of NE

1. Non-proliferation, disarmament and MNA

2. Stakeholder involvement in informed decision-making

3. Level playing field considering non-market values

4. Sovereign rights of licensing and international safety concern

5. Gaps among individual country's practices

Why different regulatory safety standards apply when one crosses the national border?

6. Political tenure is too short for Nuclear R&D

Nuclear R&D requires long-term commitment & stable budget
Long-term framework for R&D budget

1.

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 and strengthen security system that does not rely on nuclear weapons.

■ **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.

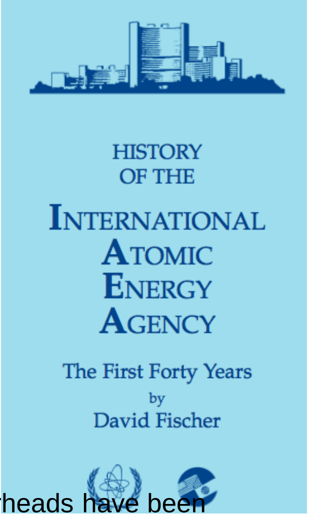
3) Final Document, 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons

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.

1.

Original intention of the address



■ 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.

1.

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 BoG by the then Director General, March 2004

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1.

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

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2.

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 versus individual
  - NIMBY/NOPE/BANANA/ CAVE (”Project No Project”)

- Key issue to materialize HLW repository
  - In many parts of the world, public seems to accept expansion of NP, provided that HLW issue is resolved.

- Knowledge and outreach
  - Our radiant world
  - Event scale…..failure, incident, accident and their severity

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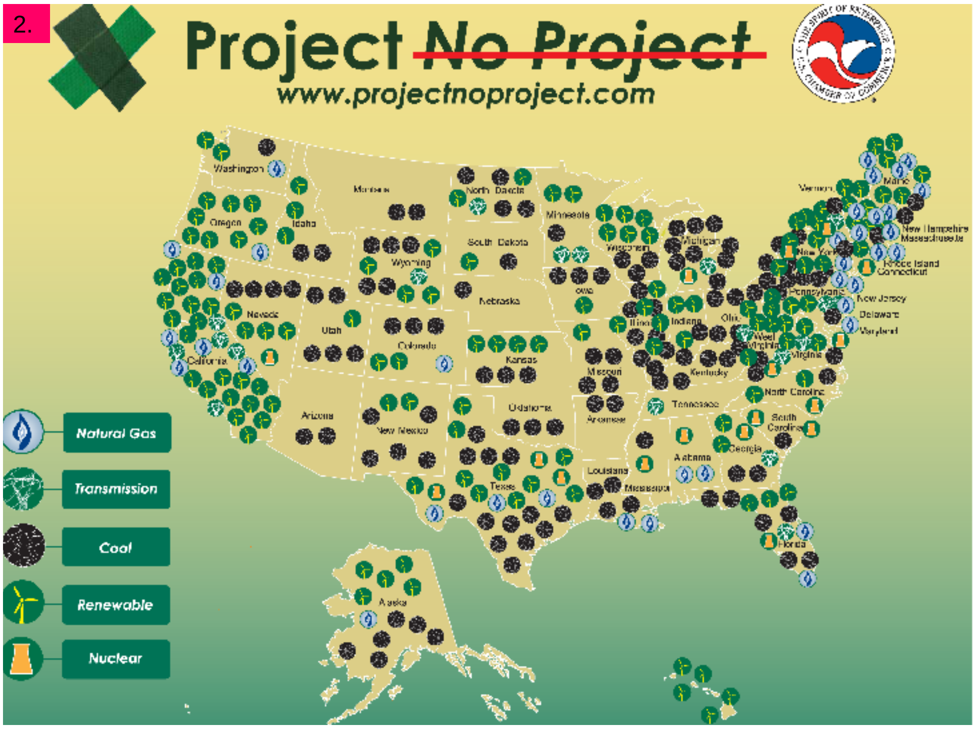

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3.

Economic competitiveness of Nuclear Power

- **Economics of capital-intensive new build**
  - Before amortization, not necessarily a preferred option
  - Used to be least cost option by levelized cost (25-40 years) in Europe
  - Capital cost increase due to tight commodity market until 2008→ start descend after cool-down of global economy, but not in “supplier-market” NP
  - Need for attracting financing scheme
- **Achieve level playing field considering “external cost”**
  - External cost: internalized in nuclear, whereas not necessarily in others
  - Environmental cost of GHG emission
  - Security credit
- **Lifting nuclear exclusion from CDM/JI or bilateral arrangement**
- **Speed to the market** (BOO, BOOT)

3.

Lifting nuclear exclusion from CDM/JI

- **A part of long-standing discussion by FNCA (Forum of Nuclear Cooperation in Asia)**
- **FNCA joint action plan to influence (2010 February)**
  - ✓**UNFCCC SBSTA (Subsidiary Body for Scientific and Technological Advice)**
  - ✓**KP/CMP (The Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol)**
  - ✓**EB (Executive Board of CDM)**
- **Bilateral agreement on carbon credit may be practical rather than convincing the world that eligibility be determined solely depending on GHG emission profile of power generation source**

4.

Sovereign rights of licensing and international safety concern

- **Licensing: individual country's sovereign right**
- **"Accident anywhere in the world is accident everywhere"**
- **Once licensed, constructed & operated, then regarded as "proven" type**
- **RBMK design without international scrutiny**
  Partial containment
  Positive void coefficient at low power
  Positive scram effect
- **The case of Marviken and Gentilly with positive void coefficient?**
- **Invite international expert review against IAEA Safety Standards**
  GRSR (UK)
  Safety Review Mission (IAEA)

5.

Gap in individual country's practices Comparison of NPP Performance (Japan and the USA)

●Un-planned Shutdown in JAPAN

- Relatively low frequency of un-planned shutdown
- Nevertheless, once shutdown, longer time before restart

●Duration of Planned shutdown time in JAPAN

- 3 or 4 times longer
- Extensive preventive maintenance works and inspections
- Earthquake, Less on-line maintenance, etc.

	Cycle Length (Months)	**Shutdown Frequency** (Event/Reactor-year)	**Ave. Shutdown Period (days)**	**Ave. Inspection Period (days)**	**Plant Availability (%) MEDIAN**
Japan	13.0	1.02	78	143. 5	71.6
USA	19.2	1.86	19	42. 3	91.8

SOURCE: IAEA-PRIS, 2007 to 2009

5.

Policy paper by JAEC (25May2010) discusses Contribution by NE to JAPAN's Growth Strategy

1) Contribution of nuclear power to "Green innovation"

- 25% reduction from 1990 level of CO2 emission by 2020, on the condition that all other major emitters agree on ambitious reduction targets
- 1% increase of availability displaces CO2 emission by 3M Tons/Y
- One new unit displaces CO2 emission by 5M Tons/Y

While currently

- Current availability of 54 LWRs: 60-70% due to earthquake and other reasons

2) Contribution of nuclear applications to "Life innovation"

- Improved standard of life (medical use, food irradiation etc)

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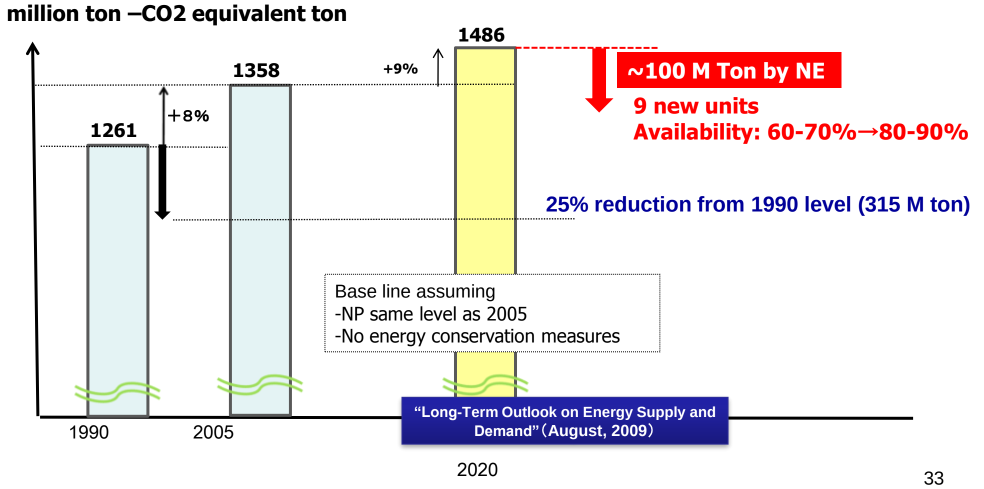
5.

Difficult to achieve the emission goal without NE 25% reduction target from 1990 level of CO2 emission by 2020



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Network by Universities/Research institutes & Industry/Utility and even with consumers

- **To provide new technologies/methodologies for potential use by the Industry leading to destructive innovation**

(The Bayh-Dole ACT OF 1980)

- **Universities are encouraged to collaborate with commercial concerns to promote the utilization of inventions arising from federal funding**
- **Similar law in Japan (1999, amended to another law 2007)**

- **Innovation through conflict resolution (with consumers for instance) or from borders of classical disciplines (Prof. Ikoma, U of Tokyo, National Innovation Eco-system, 2006)**

Pool the resources

- International/Regional approach already in place, though the level of cooperation varies;
  - SNE-TP in Europe
  - GIF/INPRO
  - ITER
- As R&D budget is tightened and the share of ITER and FR project increases;
  - Less budget for basic nuclear technology research
  - Alternative technology might be squeezed
- Alternative technology development
  - CO_2 Brayton cycle for 2ndary circuit of FR
  - Th use
  - FR version SCWR
  - Pyro-processing
  - Chemical enrichment (TIT)
  - Recovery of Uranium from seawater (TIT)
- How to fund for Alternative technology development?

CONCLUSIONS

1. Sustainable Development:
   Quantitative analysis using EISD to explore options
   using INPRO methodology in 7 areas
2. “Sea of ideas/Findings/Research Results” need “exploitation” to be entitled as “innovation”
3. Institutional innovation : high priority

5.

“Basic Energy Plan” (8June2010) and “Action Plan for Nuclear Power” (4June 2010) by METI

1) New build by 2030 : 14 units or more
2) Nuclear electricity by 2030: 50%
3) Low carbon power generation source (renewable and nuclear) by 2030: 70%
4) Practical actions for Nuclear Power include;
   - Availability increase and new build
   - Consensus building
   - Fuel cycle and HLW repository
   - Securing stable supply of Uranium
   - International relations

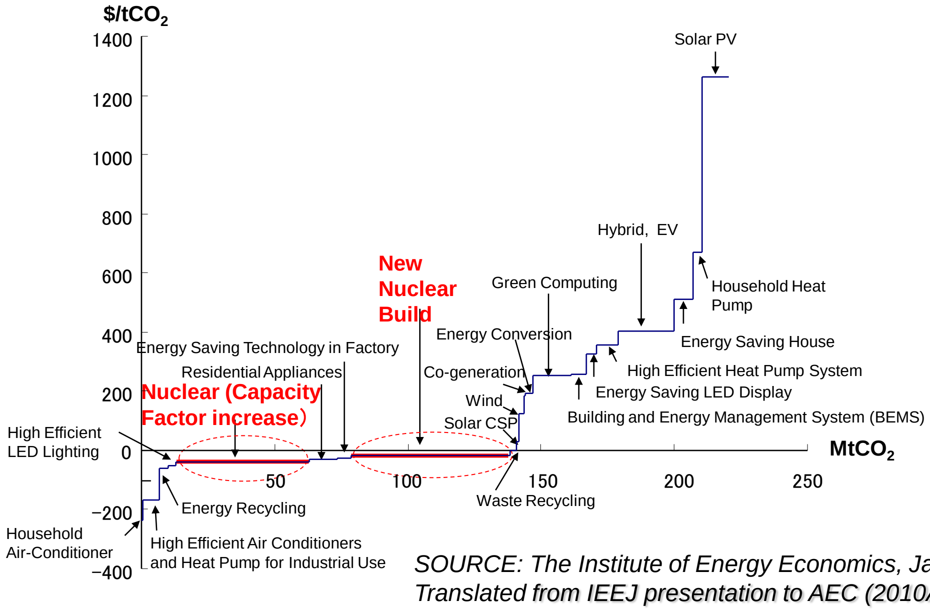
5.

Challenges to achieve the expected role by Nuclear Power

- New build
  - Loan guarantee?, Economic competitiveness of NP?, Licensing?: No
  - Societal issue: yes for some
- Higher availability of NPPs
  - Need to restart of remaining units at Kashiwazaki-Kariwa
  - Need to change: Operational cycle, Power uprating, outage duration, licensing procedures (pre-approval of standard design and fuel) etc
- In general
  - Consensus on the use of NE
  - Need to revisit gaps from global standard practices such as;
    - Use best practices in the world
    - A number of organizations with similar functions
    - Low mobility of experts among nuclear organizations
    - Relationship with local government
    - Scope of the use of irradiation to food

5.

Marginal Abatement Cost Curve in Japan



SOURCE: The Institute of Energy Economics, Japan
Translated from IEEJ presentation to AEC (2010April)