Vladimir KNAPP*, Ivo ŠLAUS**

# NUCLEAR ENERGY – GLOBAL AND EU TRENDS

Climate change is large and imminent threat to humankind and together with pollution → weather of mass destruction
*Copenhagen UNFCCC 2009 limit 2°C increase*
*BAU would bring to 1000 ppm $CO_2$*

**Options, Cost and Dangers**

CCS

Nuclear fusion - ITER - not likely before 2070

Renewable: solar, wind, geothermal – Desertec, area??

Nuclear fission (mature low C tech) - now 6% world total energy production could be increased by 2065 by 3 (1.3%) - 10 (5%) times postponing reprocessing and without breeders.(First breeder in 1951; 1970 US, Japan, China, UK, Germany- Coastal area India???)

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The paper is given in terms of PowerPoint presentation.

* Professor emeritus, FER, University of Zagreb
** Dean, University College of International Relations and Diplomacy, Zagreb

**We Develop Technology -Technology Influences Us - It Improves Our Lives and It Is a Threat**

- Fire
- Agriculture (green revol. - GM food), irrigation
- Tools: knives → weapons
- Transportation (vehicles)
- Money → virtual money
- Electricity, power plants
- Automobiles
- Nuclear Energy → nucl bomb, accidents, waste
- DNA /molecular bio → synthetic biology

Development measured by Human Development Index (HDI) is related to energy consumption:

If energy consumption ≤ 3 tons of oil equivalent/c.y → HDI increases rapidly with energy consumption. Above that level → no correlation between HDI and energy consumption.

If all countries reach 3 toe/capita.year → by 2030 the energy consumption would be doubled if our population remains constant.

If increased to 8.1 billion → 2.6 times larger.

Now enormous energy demand can be met only by fossil fuels, solar energy, fission and fusion.

Fossil fuel →◙ global warming, above and beyond Milankovic's variation!! **anthropogenic** !!

Positive feed-back loops, e.g.

◙ **T** ↑ → sea level ↑ → **ocean capacity of $CO_2$ absorption**↓

◙ **glaciers melting** → ↓ ocean salinity → ↓**sunlight reflection**

**LESSON: Search for alternative inputs much earlier than we reach a maximum.**

C. Llewellyn Smith calls time between 1985 and 2005 lost years.

Importance of ITER.

## Challenges to Sustainable Development

"Under what conditions may nuclear energy qualify as a viable option to fulfill the need for energy services of present and future generations in a sustainable manner ?"

**Basic objectives :**

**♣ assessing to what extent nuclear energy is compatible with the goals of sustainable development and**

**♣ how it can best contribute to them; and**

**♣ identifying areas where, and means whereby, nuclear energy must overcome challenges in order to contribute more effectively to sustainable development.**

## External costs and benifits

***Costs that are born by the society as a whole rather than by consumers represent negative externalities, i.e.***

***"Detrimental to global economic, social and environmental optimisation"***

- **Health and environmental impacts of release of waste - $CO_2$, radioactive waste**
- **Routine operation**
- **Decommissioning & dismantling *(included)***
- **Insurance (severe accidents)**
- **Policy factors not reflected in market prices**
- **Security of supply**
- **Social acceptance**

Nuclear industry is product of the US government R&D. Price-Anderson Indemnity Act (1957) limites industry's liability. As of 1998 system capped insurance coverage for any accident to $9.4G, while NRC estimated worst-case cost $ 300G.

**Not only in nuclear industry - e.g. agriculture.**

***? Jobs ? Free Markets? Private property ?***

**Risk: individual (driving while drunk) - collective**

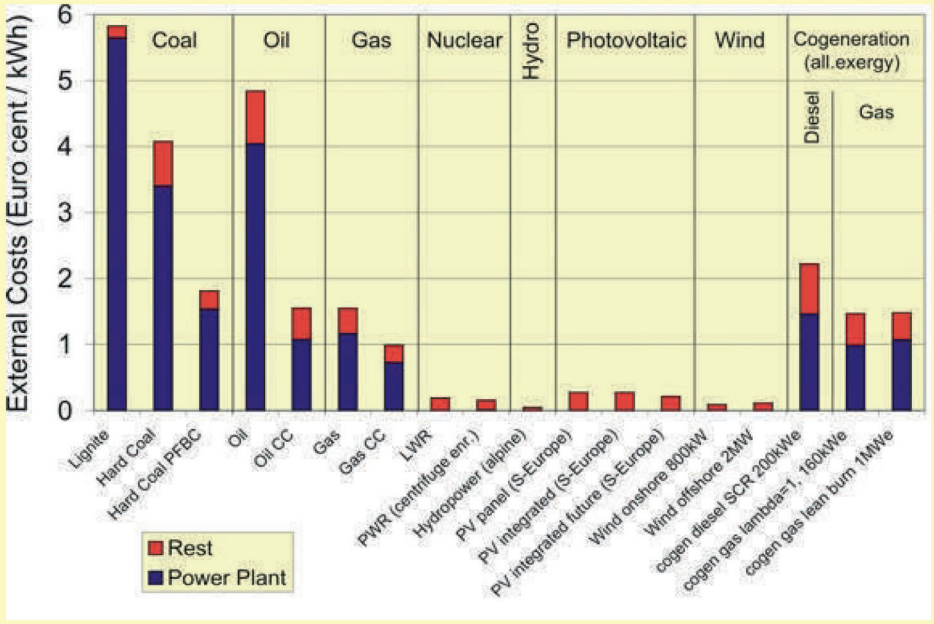
Insurance companies can cover risks only if the risk class can collect adequate resources against probable losses – beyond that people pay.

Probability of core meltdown: 1 in 20,000 reactor-year

(Rasmussen 1975), progress since 1975:

Sizewell B, UK, 1995 1,1 in 1 000 000 reactor-years

EPR, Olkiluoto, Finland,2011 0,53 in 1 000 000 reactor-years




Added cost compensating damage health+environment/1kWh

## Radioactive Waste management

***Waste management practices are intended to ensure the confinement and disposal of waste materials in a way that minimizes harmful impacts on humans and the environment at any time***

***3 categories : low, intermediate and high level (depending on its intrinsic rate of decay)***

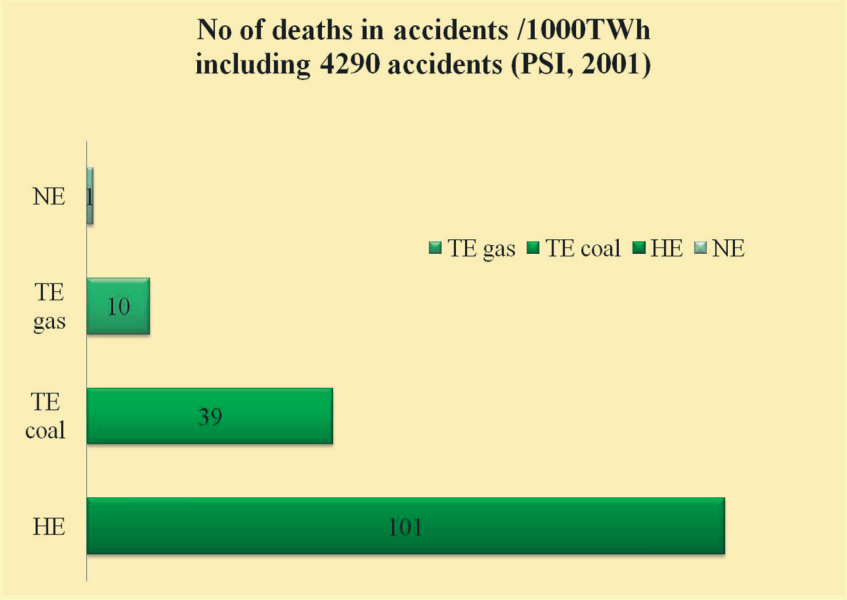
**♠ Disposal of LLW and most ILW, mature practice**
**♠ HLW : ~ 1% of total volume, ~ 99% of total radioactivity**
**Deep geological disposal considered as *viable, reliable and safe solution* by the scientific and technical community**
**Little societal consensus**
**Actual risk vs. perceived risk**
**Ethical considerations**
***Greater involvement of stakeholders and better communication needed***

## ◆ Social aspects of Nuclear Energy

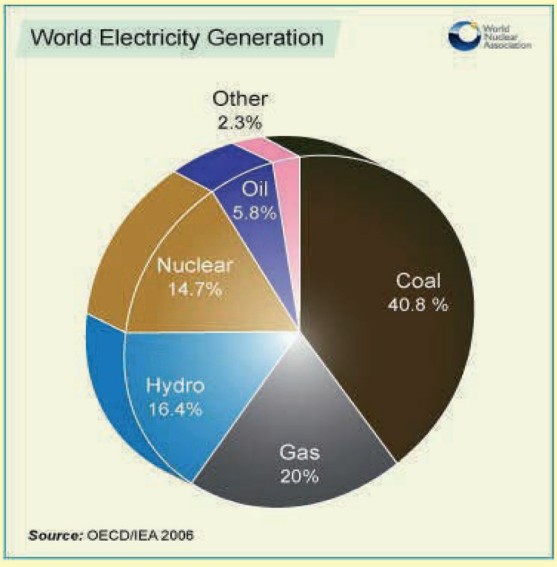
**Nuclear energy is characterized by a net contribution to human and social capital and a challenge in terms of public acceptability and widely varying perceptions of the risks and benefits**

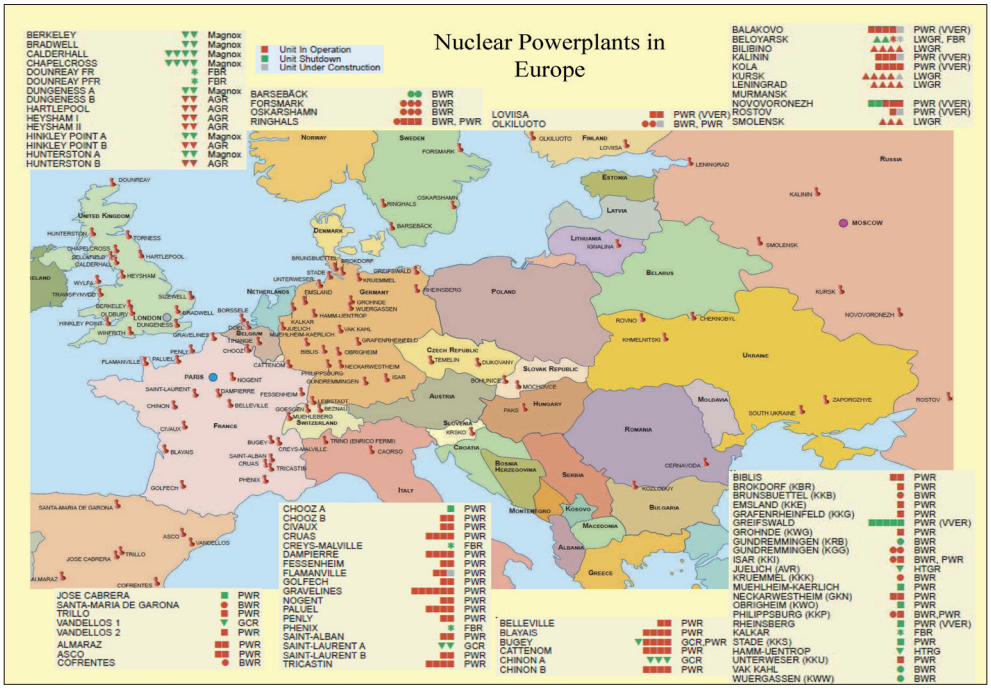
- **human capital in the form of knowledge - education and employment opportunities,**
- **human welfare,**
- **equity and participation,**
- **social capital in the form of effective institutions and voluntary associations,**
- **the rule of law and social cohesion.**

***From a sustainable development perspective, nuclear energy has a major role to play in the 21st century - Dealing adequately with the societal concerns and role of governments is a key issue!***

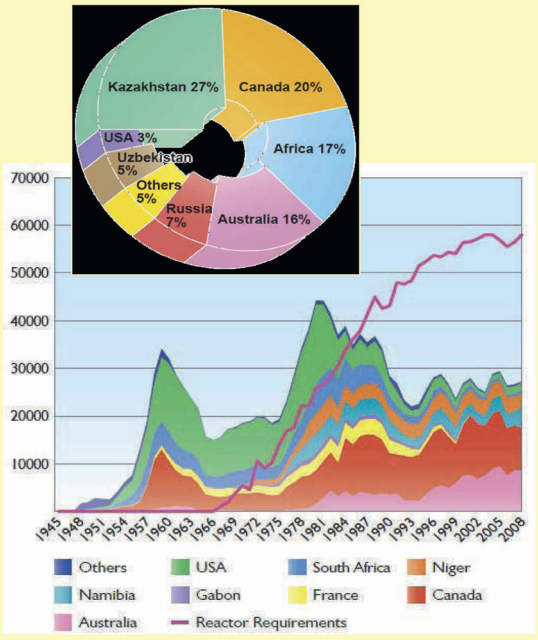


| | Nuclear electricity generation, 2009 (billion kWh) | Share of total electricity production, 2009 (%) | Number of reactors in operation* | Nuclear generating capacity* (MWe) |
|---|---|---|---|---|
| Argentina | 7.6 | 7.0 | 2 | 935 |
| Armenia | 2.3 | 45.0 | 1 | 376 |
| Belgium | 45.0 | 51.7 | 7 | 5943 |
| Brazil | 12.2 | 3.0 | 2 | 1901 |
| Bulgaria | 14.2 | 35.9 | 2 | 1906 |
| Canada | 85.3 | 14.8 | 18 | 12,679 |
| China | 65.7 | 1.9 | 11 | 8587 |
| Czech Rep | 25.7 | 33.8 | 6 | 3686 |
| Finland | 22.6 | 32.9 | 4 | 2696 |
| France | 391.7 | 75.2 | 58 | 63,236 |
| Germany | 127.7 | 26.1 | 17 | 20,339 |
| Hungary | 14.3 | 43.0 | 4 | 1880 |
| India | 14.8 | 2.2 | 19 | 4183 |
| Japan | 263.1 | 28.9 | 55 | 47,348 |
| Lithuania | 10.0 | 76.2 | 0 | 0 |
| Mexico | 10.1 | 4.8 | 2 | 1310 |
| Netherlands | 4.0 | 3.7 | 1 | 485 |
| Pakistan | 2.6 | 2.7 | 2 | 400 |
| Romania | 10.8 | 20.6 | 2 | 1310 |
| Russia | 152.8 | 17.8 | 32 | 22,811 |
| Slovakia | 13.1 | 53.5 | 4 | 1760 |
| Slovenia | 5.5 | 37.9 | 1 | 696 |
| South Africa | 11.6 | 4.8 | 2 | 1842 |
| South Korea | 141.1 | 34.8 | 20 | 17,716 |
| Spain | 50.6 | 17.5 | 8 | 7448 |
| Sweden | 50.0 | 34.7 | 10 | 9399 |
| Switzerland | 26.3 | 39.5 | 5 | 3252 |
| Ukraine | 77.9 | 48.6 | 15 | 13,168 |
| UK | 62.9 | 17.9 | 19 | 11,035 |
| USA | 796.9 | 20.2 | 104 | 101,119 |
| **Total**** | **2558** | **14** | **439** | **374,690** |



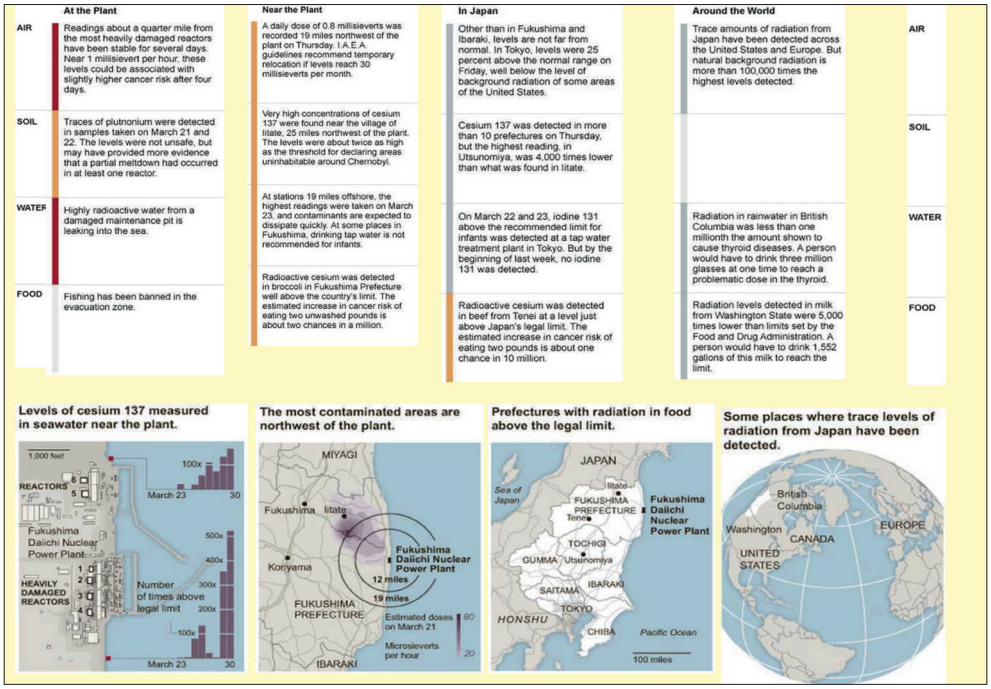


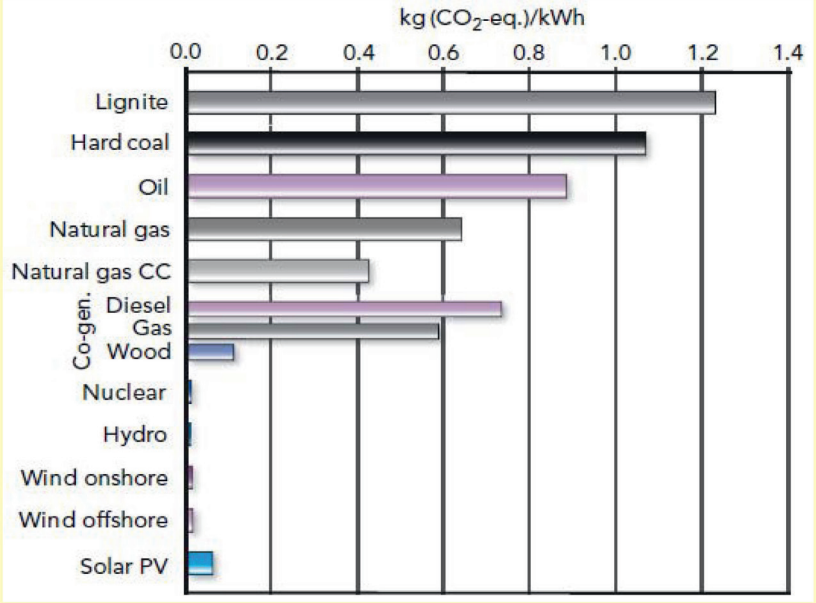

## Uranium Production 2009



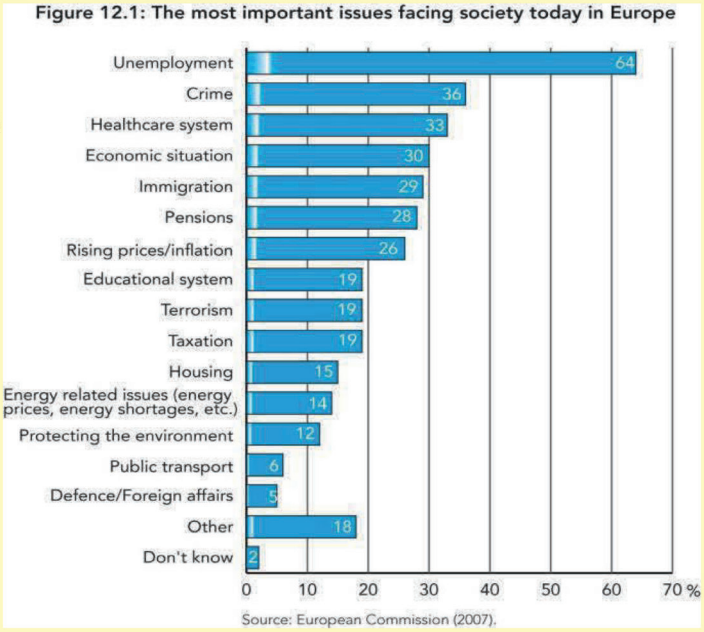

## RESOURCES LIFETIME

| Coal | Gas | Uranium light water | Uranium Breeder |
|---|---|---|---|
| 155 | 65 | 100 | 3,000y |

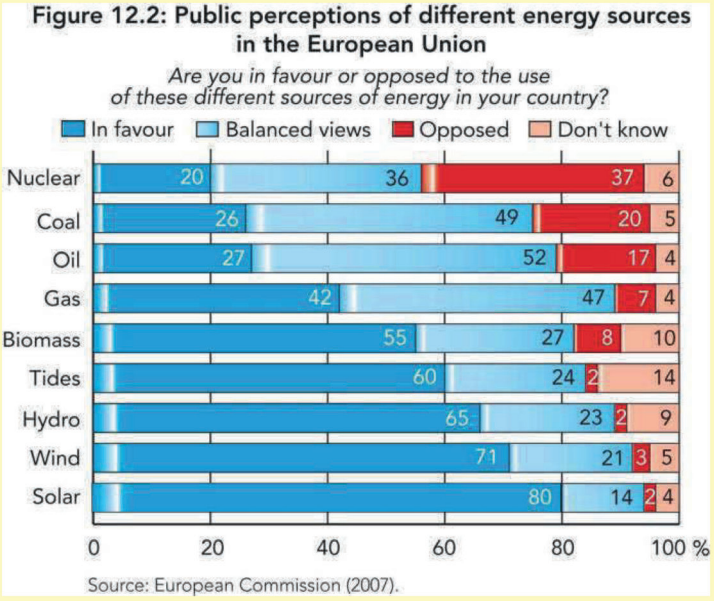

At the Plant
Near the Plant
In Japan
Around the World
AIR
Readings about a quarter mile from the most heavily damaged reactors have been stable for several days. Near 1 millisievert per hour, these levels could be associated with slightly higher cancer risk after four days.
A daily dose of 0.8 millisieverts was recorded 19 miles northwest of the plant on Thursday. I.A.E.A. guidelines recommend temporary relocation if levels reach 30 millisieverts per month.
Other than in Fukushima and Ibaraki, levels are not far from normal. In Tokyo, levels were 25 percent above the normal range on Friday, well below the level of background radiation of some areas of the United States.
Trace amounts of radiation from Japan have been detected across the United States and Europe. But natural background radiation is more than 100,000 times the highest levels detected.
AIR
SOIL
Traces of plutonium were detected in samples taken on March 21 and 22. The levels were not unsafe, but may have provided more evidence that a partial meltdown had occurred in at least one reactor.
Very high concentrations of cesium 137 were found near the village of Iitate, 25 miles northwest of the plant. The levels were about twice as high as the threshold for declaring areas uninhabitable around Chernobyl.
Cesium 137 was detected in more than 10 prefectures on Thursday, but the highest reading, in Utsunomiya, was 4,000 times lower than what was found in Iitate.
SOIL
WATER
Highly radioactive water from a damaged maintenance pit is leaking into the sea.
At stations 19 miles offshore, the highest readings were taken on March 23, and contaminants are expected to dissipate quickly. At some places in Fukushima, drinking tap water is not recommended for infants.
On March 22 and 23, iodine 131 above the recommended limit for infants was detected at a tap water treatment plant in Tokyo. But by the beginning of last week, no iodine 131 was detected.
Radiation in rainwater in British Columbia was less than one millionth the amount shown to cause thyroid diseases. A person would have to drink three million glasses at one time to reach a problematic dose in the thyroid.
WATER
FOOD
Fishing has been banned in the evacuation zone.
Radioactive cesium was detected in broccoli in Fukushima Prefecture well above the country's limit. The estimated increase in cancer risk of eating two unwashed pounds is about two chances in a million.
Radioactive cesium was detected in beef from Tenei at a level just above Japan's legal limit. The estimated increase in cancer risk of eating two pounds is about one chance in 10 million.
Radiation levels detected in milk from Washington State were 5,000 times lower than limits set by the Food and Drug Administration. A person would have to drink 1,552 gallons of this milk to reach the limit.
FOOD
Levels of cesium 137 measured in seawater near the plant.
1,000 feet
REACTORS
Fukushima Daiichi Nuclear Power Plant
HEAVILY DAMAGED REACTORS
Number of times above legal limit
100x
500x
400x
300x
200x
March 23
30
The most contaminated areas are northwest of the plant.
MIYAGI
Fukushima
Iitate
Koriyama
Fukushima Daiichi Nuclear Power Plant
12 miles
19 miles
FUKUSHIMA PREFECTURE
IBARAKI
Estimated doses on March 21
Microsieverts per hour
80
20
Prefectures with radiation in food above the legal limit.
JAPAN
Sea of Japan
Iitate
FUKUSHIMA PREFECTURE
Tenei
Fukushima Daiichi Nuclear Power Plant
TOCHIGI
GUMMA
Utsunomiya
IBARAKI
SAITAMA
TOKYO
CHIBA
HONSHU
Pacific Ocean
100 miles
Some places where trace levels of radiation from Japan have been detected.
British Columbia
Washington
CANADA
EUROPE
UNITED STATES


kg (CO2-eq.)/kWh
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Lignite
Hard coal
Oil
Natural gas
Natural gas CC
Co-gen.
Diesel
Gas
Wood
Nuclear
Hydro
Wind onshore
Wind offshore
Solar PV

What Concerns Public?

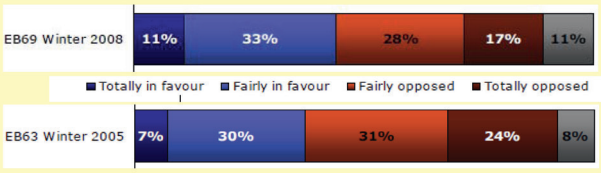



Perception .....



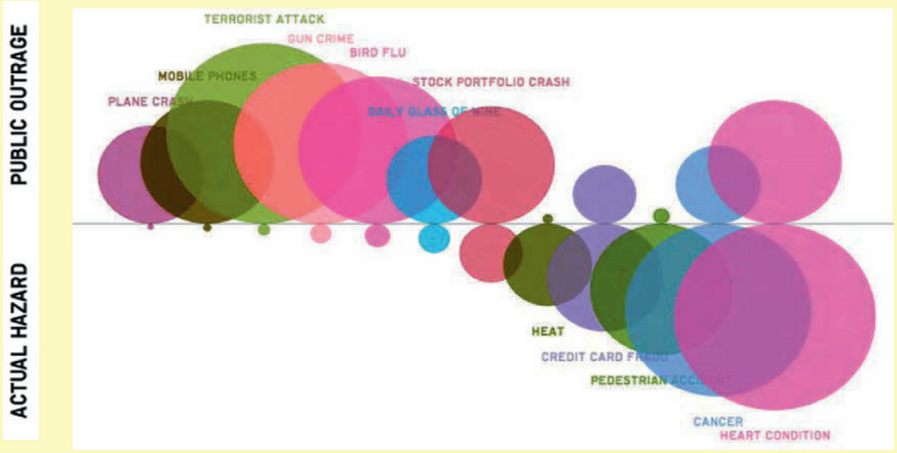
## Radioactivity and Public in EU

**QB2 Are you totally in favor, fairly in favor, fairly opposed or totally opposed to energy production by nuclear power stations?-%EU**






Answers:
Total “in favour”



**Accidents**

| Place | Year | Dead | Cause |
|---|---|---|---|
| Benxihu, China | 1942 | 1549 | Coal explosion |
| Baquiao, China | 1975 | 26000+145000 | typhon |
| Machu II, India | 1979 | 2500 | HE |
| Cubatao, Brazil | 1984 | 508 | oil fire |
| Chernobyl, USSR | 1986 | 56 + thousands | NE |
| Warri, Nigeria | 1998 | › 500 | oil |

**Public perception**

**NIMBY** – not in my back yard

**BANANA** - build absolutely nothing anywhere near anybody

**Sources of radiation**

| | | | |
|---|---|---|---|
| Medicine | 14% | Cosmic | 14% |
| Nucl indus | 1% | Radon | 42% |
| Building/soil | 18% | Food/Water | 11% |

**Radiation doses**

| | | |
|---|---|---|
| Deantal x-rays | 5 μSv | |
| Chest x-ray | 100 μSv | |
| EPA yearly limit public | 1,000 μSv | |
| Everage CT scan | 10 mSv | 1 rem |
| Temporary radiation sick | 1,000 mSv | 100 rem |
| Fatal dose | 10,000 mSv | 1000 rem |

***First reactor in electric grid Calder Hall in 1956 in UK***
**NE Accidents before Fukushima**
Three Mile Island 1979: reactor fully damaged
(PWR) radiation contained
no health+environmetal effects
(though 30% $^{131}I$ leaked from the core, only 0.6% ended in countainment and 0.001% in environment
large economic impact
*Nuclear industry improved its technol + safety*
Chernobyl, 1986: reactor destructed
Graphite moderated RBMK Deaths: 31 immed+25 soon
estimated 4,000
*Irrelevant lesson for nuclear industry*
***Both caused by human error.***
***Fukushima: March 11, 2011***
**April 18 : radiation level at Unit 1 & 3 10-49 mSv/h (robots)**

TEPco 2002 falsifying safety records – forced to shut down 17 of its reactors. Smaller 6.6 eartzhquake in 2007 forced TEPco to shut down all 7 reactors at the world largest nuclear power station on the west coast. 2004 incident killed five workers and 1996 radioactive fallout drifted over Tokyo.

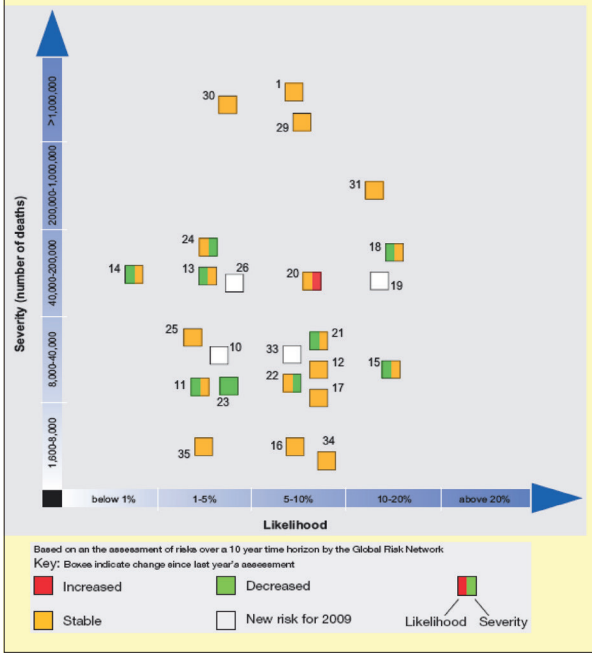
Japan's energy options:

Geoth: could 80,000 MW - even more, now 536 MW
Japan produces 66% of world geoth turbines

Wind: land-based could provide 50% of Japan need

Photovoltaic: now 3,500 MW, in 2030 53,000 MW

R&D for NE = $2.3G, for wind $10M




## Global risks 2009 - dead

**ECONOMIC**
1 Food price volatility
2 Oil and gas price spike
3 Major fall in US$
4 Slowing Chinese economy (6%)
5 Fiscal crises
6 Asset price collapse
7 Retrenchment from globalization (developed)
8 Retrenchment from globalization (emerging)
9 Regulation cost
10 Underinvestment in infrastructure

**GEOPOLITICAL**
11 International terrorism
12 Collapse of NPT
13 US/Iran conflict
14 US/DPRK conflict
15 Afghanistan instability
16 Transnational crime and corruption
17 Israel-Palestine conflict
**18 Violence in Iraq**
**19 Global governance gaps**

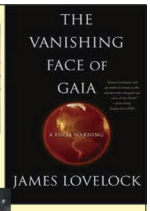
**ENVIRONMENTAL**
20 Extreme climate change related weather
21 Droughts and desertification
22 Loss of freshwater
23 NatCat: Cyclone
24 NatCat: Earthquake
25 NatCat: Inland flooding
26 NatCat: Coastal flooding
27 Air pollution
28 Biodiversity loss

**SOCIETAL**
29 Pandemic
30 Infectious disease
31 Chronic disease
32 Liability regimes
33 Migration

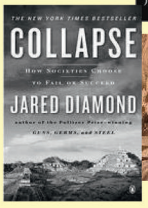
**TECHNOLOGICAL**
34 CII brakdown
35 Emergence of nanotechnology risks
36 Data fraud/loss

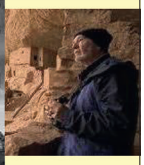
Izvor: World Economic Forum 2009

## Support for NE




**"The important and overriding consideration is time; we have nuclear power now, and new nuclear building should be started immediately."**
**James Lovelock, The Revenge of Gaia: Earth's Climate Crisis and the Fate of Humanity, July 2006**

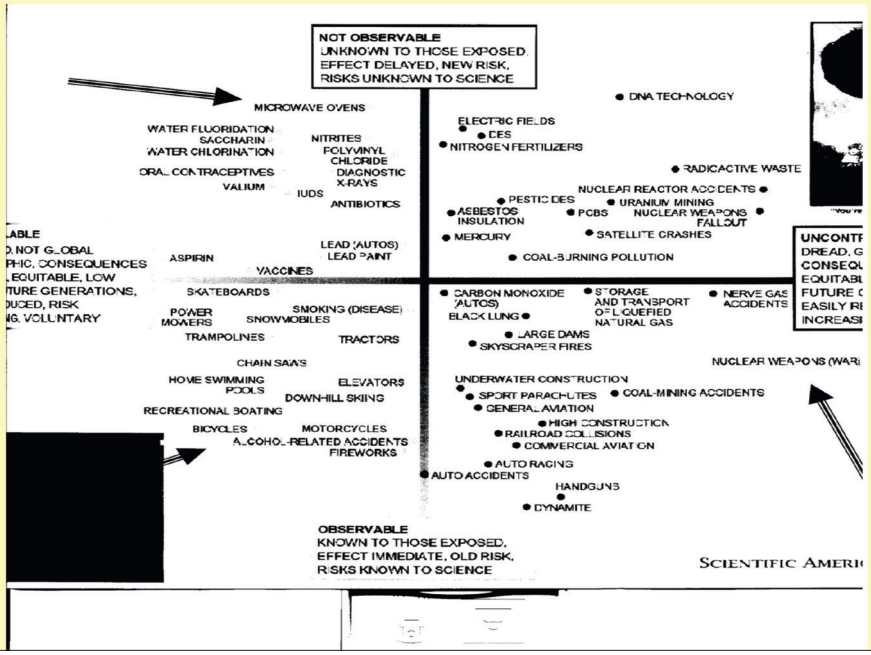


**"To deal with our energy problems we need everything available to us, including nuclear power."**
**Dr. Jared Diamond, Biologist, UCLA professor, July 2005**

**"Nuclear energy is the best option to curb carbon emissions"**
**Dr. R.K. Pachauri, Chairman, Intergovernmental Panel on Climate Change, Aug 2008**

**"I have never seen a credible scenario for reducing emissions that did not include nuclear energy"**
**Yvode Boer-Executive Secretary, UNFCCC , June 2007**


NOT OBSERVABLE
UNKNOWN TO THOSE EXPOSED,
EFFECT DELAYED, NEW RISK,
RISKS UNKNOWN TO SCIENCE
MICROWAVE OVENS
WATER FLUORIDATION
SACCHARIN
WATER CHLORINATION
NITRITES
POLYVINYL CHLORIDE
ORAL CONTRACEPTIVES
DIAGNOSTIC X-RAYS
VALIUM
IUDS
ANTIBIOTICS
DNA TECHNOLOGY
ELECTRIC FIELDS
CFCS
NITROGEN FERTILIZERS
RADIOACTIVE WASTE
NUCLEAR REACTOR ACCIDENTS
PESTICIDES
URANIUM MINING
ASBESTOS INSULATION
PCBS
NUCLEAR WEAPONS FALLOUT
MERCURY
SATELLITE CRASHES
COAL-BURNING POLLUTION
LEAD (AUTOS)
LEAD PAINT
ASPIRIN
VACCINES
SKATEBOARDS
POWER MOWERS
SNOWMOBILES
SMOKING (DISEASE)
TRAMPOLINES
TRACTORS
CHAIN SAWS
HOME SWIMMING POOLS
ELEVATORS
DOWNHILL SKIING
RECREATIONAL BOATING
BICYCLES
MOTORCYCLES
ALCOHOL-RELATED ACCIDENTS
FIREWORKS
CARBON MONOXIDE (AUTOS)
BLACK LUNG
STORAGE AND TRANSPORT OF LIQUEFIED NATURAL GAS
NERVE GAS ACCIDENTS
LARGE DAMS
SKYSCRAPER FIRES
NUCLEAR WEAPONS (WAR)
UNDERWATER CONSTRUCTION
SPORT PARACHUTES
COAL-MINING ACCIDENTS
GENERAL AVIATION
HIGH CONSTRUCTION
RAILROAD COLLISIONS
COMMERCIAL AVIATION
AUTO RACING
AUTO ACCIDENTS
HANDGUNS
DYNAMITE
OBSERVABLE
KNOWN TO THOSE EXPOSED,
EFFECT IMMEDIATE, OLD RISK,
RISKS KNOWN TO SCIENCE
SCIENTIFIC AMERI