The Abdus Salam
International Centre
for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA
International Atomic Energy Agency

2372-22

Joint ICTP-IAEA Workshop on Sustainable Energy Development: Pathways and Strategies after Rio+20

1 - 5 October 2012

Prospects for sustainability of NESs

Elena Poplavskaia

State Scientific Center of the Russian Federation, Obninsk
Russian Federation

Strada Costiera, 11 - 34151 - Trieste - Italy • Tel. +39 0402240111 • Fax. +39 040224163 • sci_info@ictp.it • www.ictp.it
ICTP is governed by UNESCO, IAEA, and Italy, and it is a UNESCO Category 1 Institute

Joint ICTP-IAEA workshop on Sustainable Energy Development: Pathways and Strategies after Rio20

1-5 October, 2012

Prospects for sustainability of NESs

Elena Poplavskaia

SSC RF IPPE

E-mail: epopl@ippe.ru

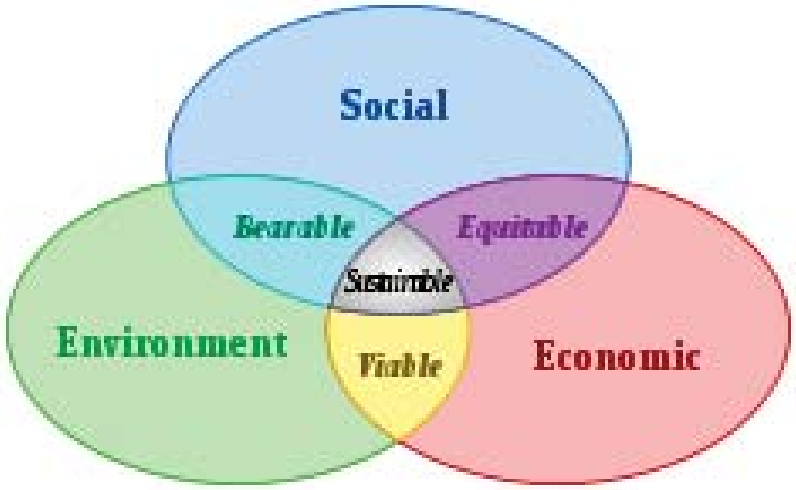
SUSTAINABLE DEVELOPMENT DEFINITION

Sustainable development was defined in 1987 by the Brundtland Commission, known formally as the World Commission on Environment and Development, as

"…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987).

and identified three essential dimensions:

- *economic,*
- *social,*
- *environmental*



NUCLEAR POWER TOWARDS SUSTAINABILITY

How to measure sustainability applied to NP?

FUTURE NP should be based on innovative reactor NFC technologies including the requirements to:

- ❑ **Availability of fuel resources and fuel supply assurance;**
- ❑ **Uranium utilization;**
- ❑ **Fuel cycle flexibility;**
- ❑ **Waste minimization;**
- ❑ **Proliferation resistance;**
- ❑ **Safety;**

and

- ❑ **Cost competiveness.**

INPRO (IAEA)

GOAL: to help ensure that nuclear energy is available to contribute to meeting the energy needs of the 21st century in a sustainable manner.

STATUS OF NUCLEAR POWER

On September 2012:

- **435 nuclear power plants (NPPs) operated in 30 countries worldwide,**
- **Total installed capacity of 370 GWe.**
- **16 % Share of electricity generated in the world**
- **64 NPPs under construction.**

Reactors were connected to grid:

2011: 7 reactors

2012: 2 reactors

2012: Construction starts: 3 reactors

(Rep. Korea, Russia, UAE)

Source: www.iaea.org **/pris**

Post Fukushima

Fukushima accident will slow or delay, but not reverse growth of Nuclear Energy

•Interest to Nuclear Energy among more serious newcomer countries remains high

2011

•UAE and Turkey ordered their first NPPs from Korea and Russia, respectively, and continue their plans

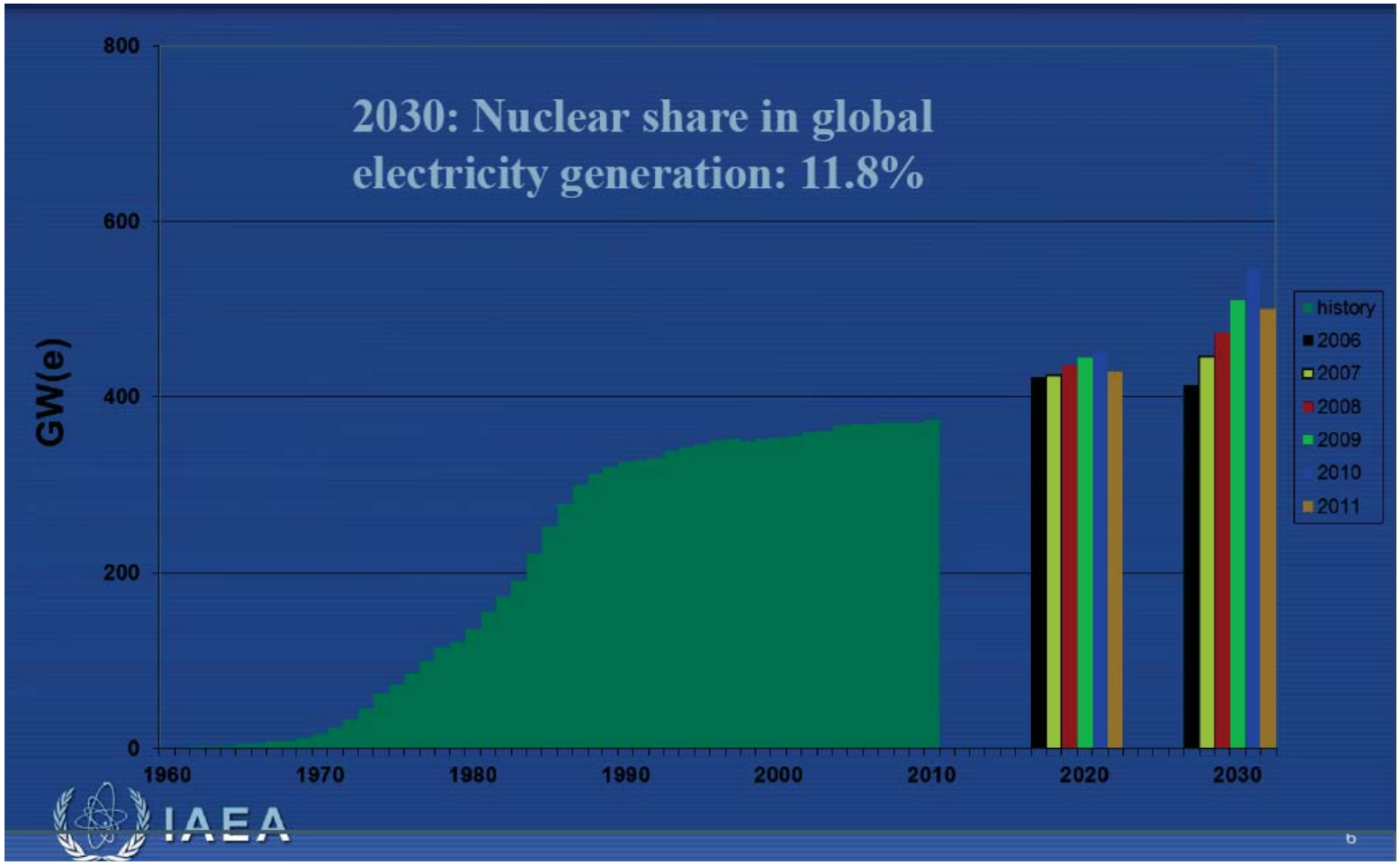
•Belarus signed an Intergovernmental Agreement for its first NPP

•Bangladesh signed an Intergovernmental Agreement with intention to build first NPP

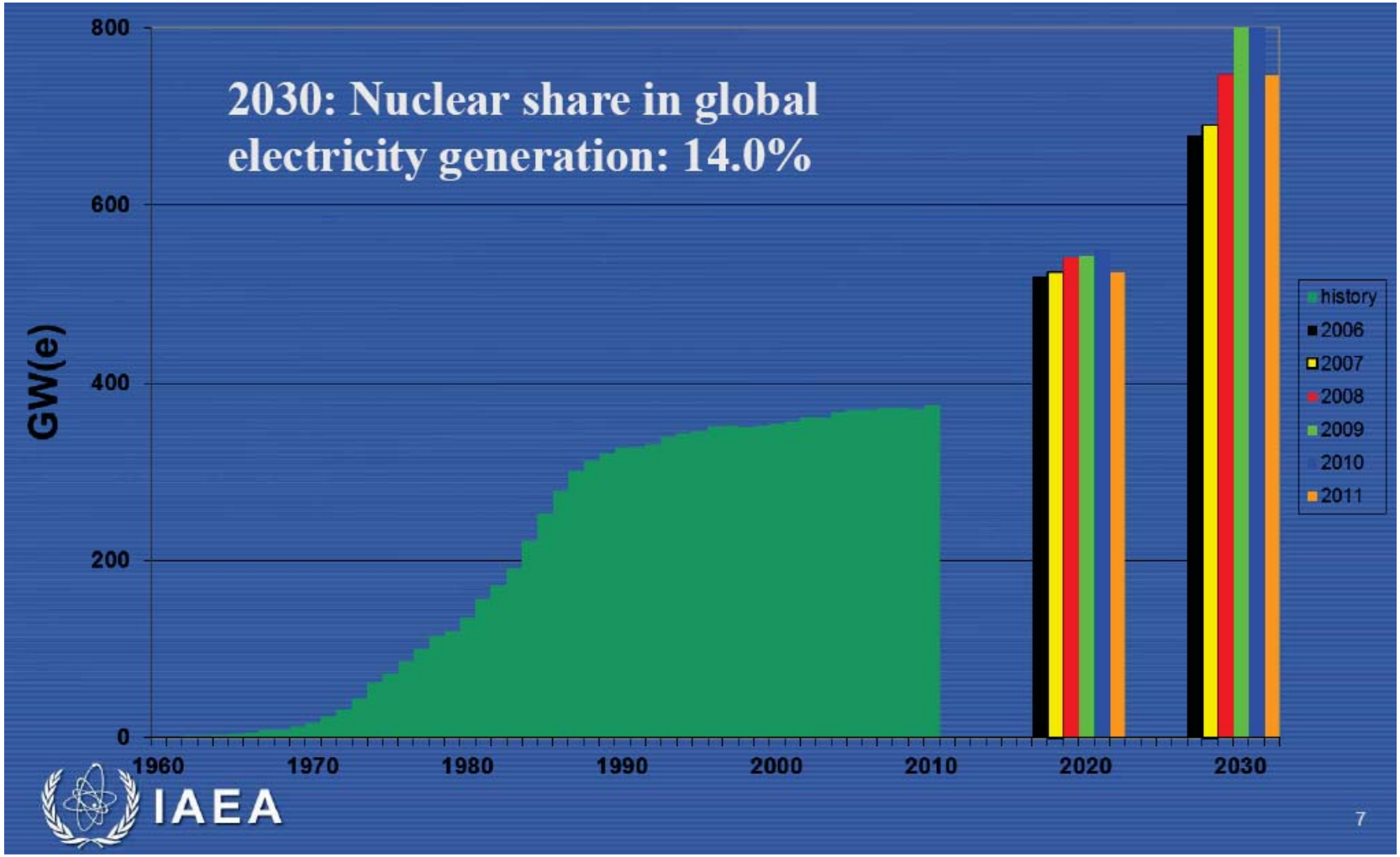
•Vietnam signed a loan agreement i

Source: **Nuclear Power Prospects after the Fukushima Accident**
http://www.iaea.org/OurWork/ST/NE/Main/DDG-corner/Statements/2012/2012_02_21_WNA_India_Sypmosium_NewDelhi_India_PPT.pdf

INTRODUCTION/ NP projections 2011 – low



INTRODUCTION/ NP projections 2011 – high



Source: **Nuclear Power Prospects after the Fukushima Accident**
http://www.iaea.org/OurWork/ST/NE/Main/DDG-corner/Statements/2012/2012_02_21_WNA_India_Sypmosium_NewDelhi_India_PPT.pdf

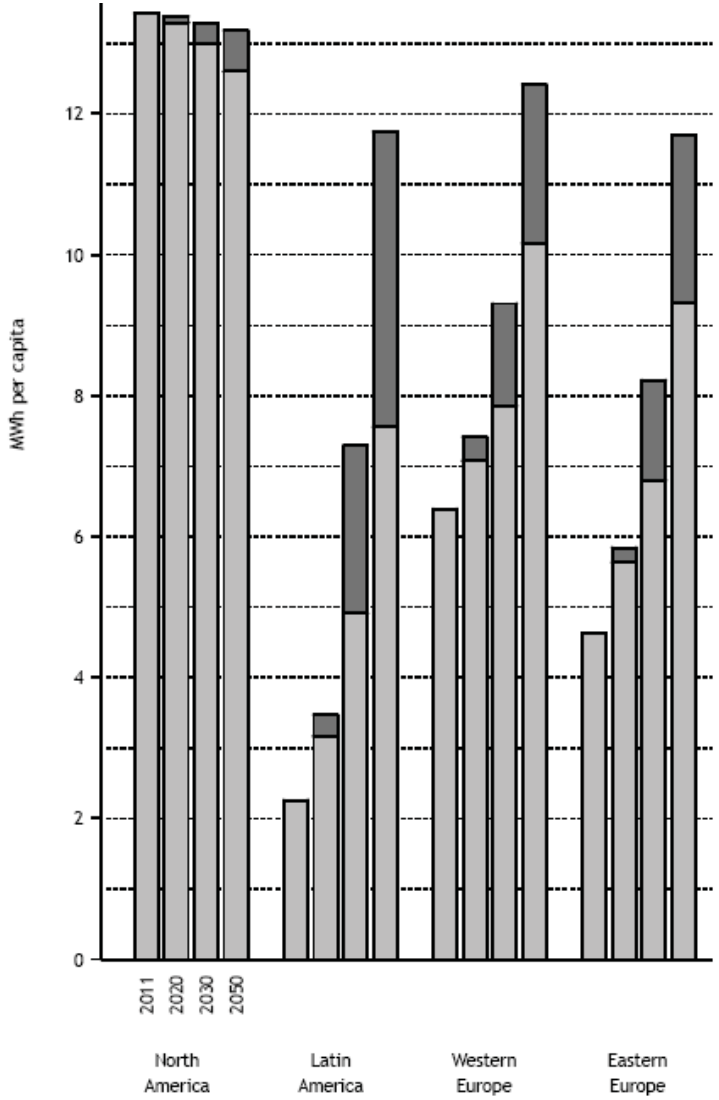
Why is nuclear power?

➢**Global energy demand is set to grow :**	*NP expands supply options*
➢ **Environmental pressures are rising :**	*NP has low GHG emissions*
➢ **Energy supply security back on the political agenda:**	*NP contributes to energy security*
➢ **Reliable base load electricity at predictable and affordable costs for meeting Sustainable development goals:**	*Nuclear power offers stable and predictable generation costs based on low resource costs*

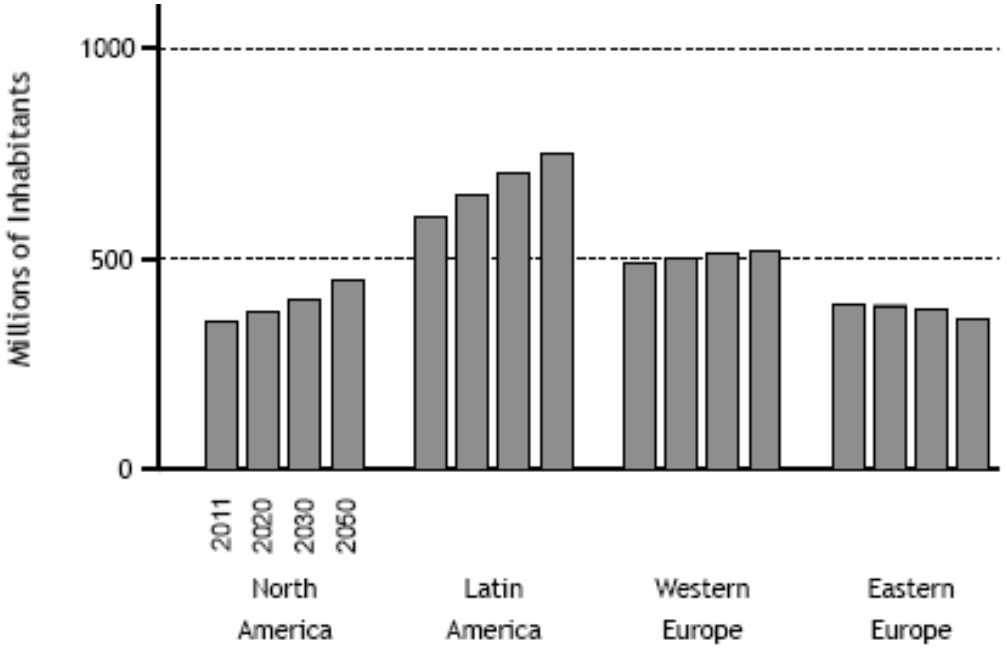
Source: **Nuclear Power Prospects after the Fukushima Accident**
http://www.iaea.org/OurWork/ST/NE/Main/DDG-corner/Statements/2012/2012_02_21_WNA_India_Sypmosium_NewDelhi_India_PPT.pdf

Population growth, electricity requirements per capita

Total electricity requirements per capita



Population estimates



Sourse: Energy, Electricity and Nuclear Power Estimates for the Period up to 2050 2012 Edition

NUCLEAR POWER ADVANTAGES/Limited Environmental Impacts

Fossile fuel:

- Global climate change
- Air quality degradation (coal, oil)
- Lake acidification and forest damage (coal, oil)
- Toxic waste contamination (coal ash and slag, abatement residues)
- Groundwater contamination
- Marine and coastal pollution (oil)
- Land disturbance
- Large fuel and transport requirements
- Resource depletion

Nuclear (full energy chain)

- Severe reactor accident release
- Waste repository release

Hydroelectric:

- Population displacement
- Land loss and change in use
- Ecosystem changes and health effects
- Loss of biodiversity
- Dam failure
- Decommissioning

Renewables

- Air quality degradation (geothermal, biomass)
- Extensive land use
- Ecosystem changes
- Fabrication impact (solar photovoltaic cells)
- Noise pollution (wind)

Source: Nuclear Power and Sustainable Development IAEA

ENERGY DENSITY CONSUMPTION

1 kg of coal: 3 kW·h

1 kg of oil: 4 kW·h

1 kg of U: 50 000 kW·h

3 500 000 kW·h with reprocessing

1000 MW(e) plant requires the following number of tonnes (t) of fuel annually:

2 600 000 t coal: 2000 train cars(1300 t each)

2 000 000 t oil: 10 supertankers

30 t uranium: reactor core(10 cubic meters)

Source: Nuclear Power and Sustainable Development IAEA

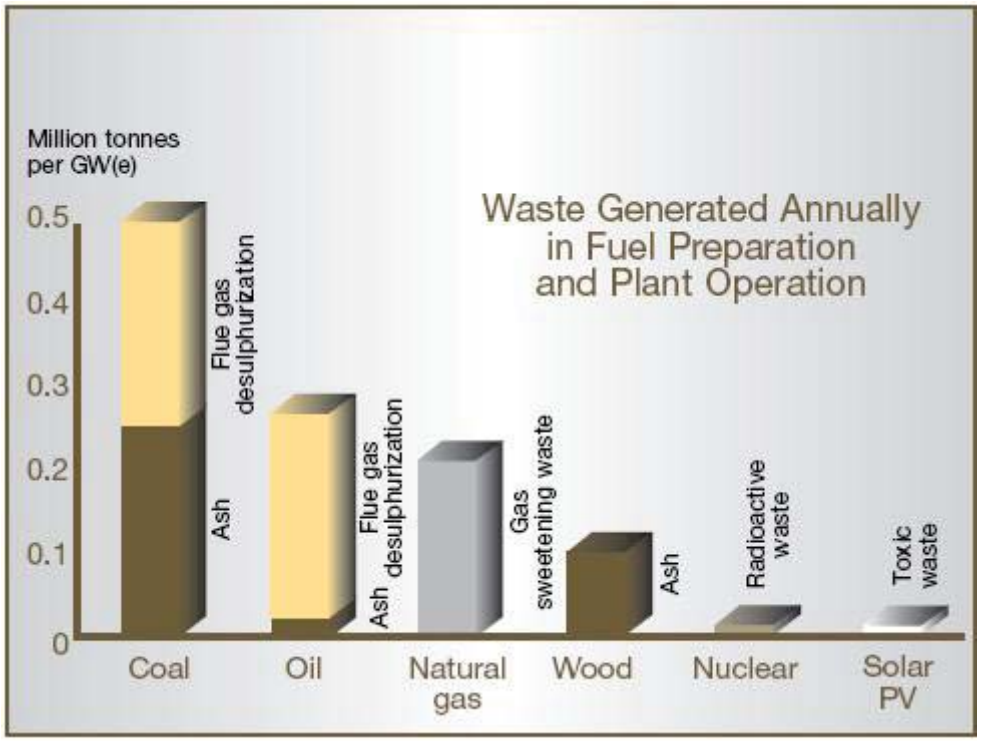
LAND REQUIREMENTS

Fossil and nuclear sites:	**1–4 km²**
Solar thermal or photovoltaic (PV) parks:	**20–50 km² (a small city)**
Wind *fields*:	**50–150 km²**
Biomass *plantations*:	**4000–6000 km² (a province)**

Source: Nuclear Power and Sustainable Development IAEA

WASTE (1)

Waste Generated Annually in Fuel Preparation and Plant Operation



A 1000 MW(e) coal plant produces annually:

~44 000 t of sulphur oxides and
~22 000 t of nitrous oxides

320 000 t of ash containing 400 t of heavy metals:

- **arsenic,**
- **cadmium,**
- **cobalt,**
- **lead,**
- **mercury,**
- **nickel and**
- **vanadium**

Source: Nuclear Power and Sustainable Development IAEA

WASTE (3)

A 1000 MW(e) nuclear power plant does not release noxious gases or other pollutants and produces annually only:

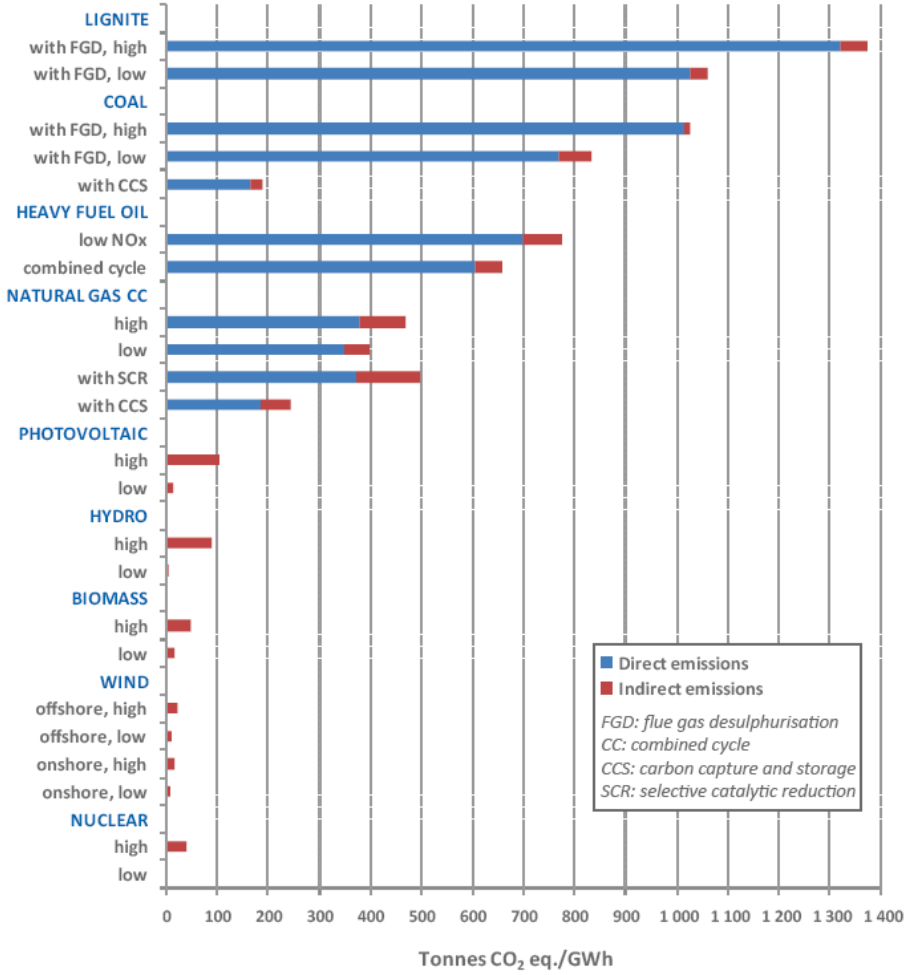
- **some 30 t of discharged HLR SF with**
- **800 t of ILW and LLW.**

In the USA, solid LLW has been reduced ten-fold over the past decade to 30 cubic meters annually of compacted waste per plant.

Source: Nuclear Power and Sustainable Development IAEA

GHG EMISSION

Direct and indirect GHG emission for energy generation system



Globally, the use of nuclear power and hydroelectric as an alternative to fossil fuels over the past several decades has helped restrain CO_2 emissions.

Today, nuclear power and hydroelectric each avoid annually some 8% of global CO_2 emissions from energy production

Source: Mitigation of Climate Change. Intergovernmental Panel on Climate Change 2007

RESOURCE EXTENSION, SECURITY OF SUPPLY

Ratios of uranium resource to current level of consumption for different categories of resources (period in years)

	Known conventional resources	Total conventional resources	With unconventional resources
With present reactor technology	100	300	700
With recycling using fast neutron reactors	> 3 000	> 9 000	> 21 000

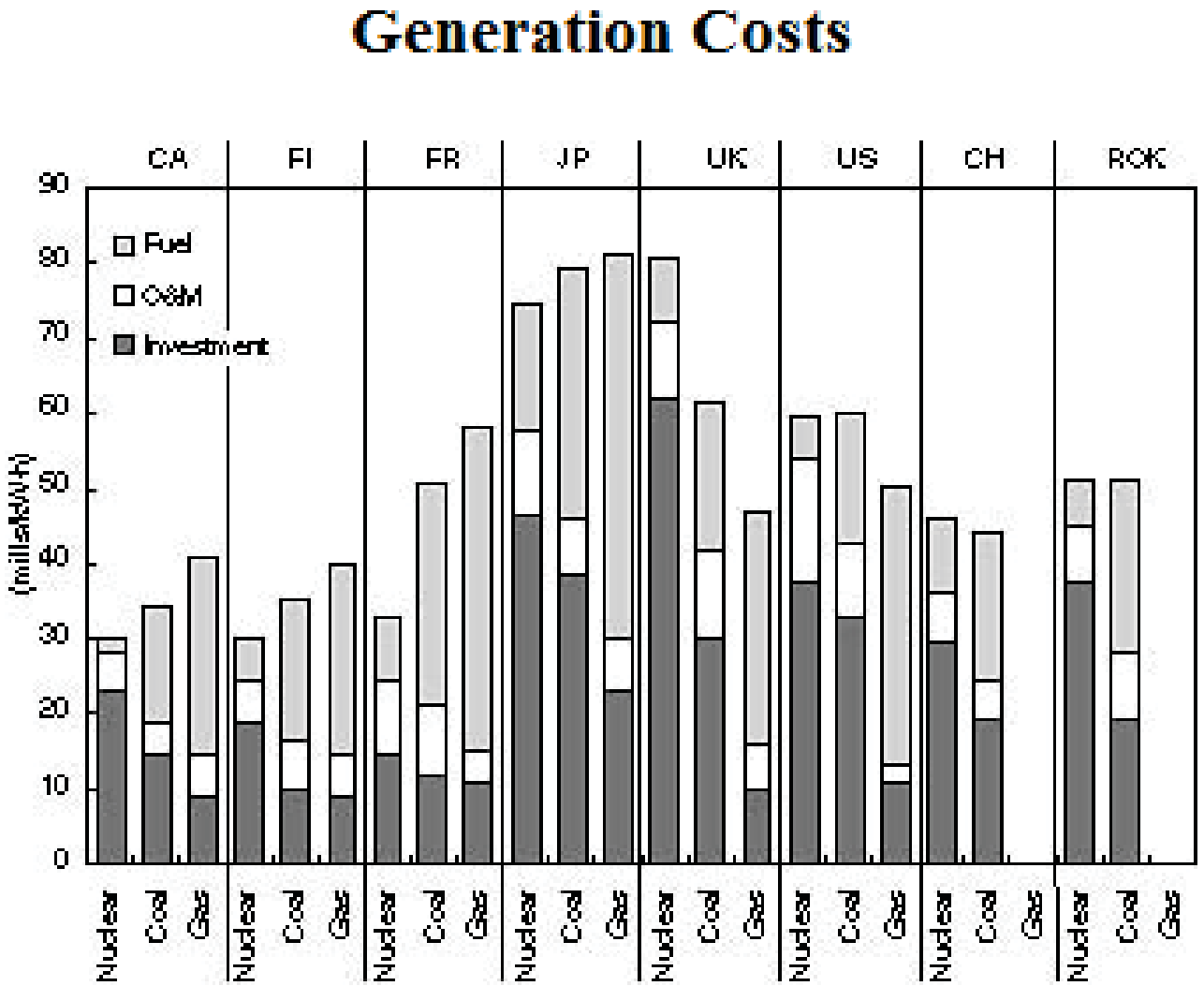
Source: Nuclear Energy Outlook, O ECD Nuclear Energy Agency , 2008

Economics

Table 11.1a: LCOE for nuclear, pulverised coal, IGCC, gas and biomass (different studies)							
		MIT 2003	CERI 2004	RAE 2004	University of Chicago 2004	IEA/NEA 2005	UK DTI 2006
		[C]	[D]	[E]	[F]	[G]	[H]
Nuclear							
Overnight cost	$/kW	2 208	1 778-252	2 233	1 299-1 948	1 179-2 717	2 644
Fuel cycle cost [A]	$/MWh	6.5	2.8-4.1	7.8	5.8	3-12.7	7.5
Capacity factor		85%	90%	>90%	85%	85%	85%
LCOE	**$/MWh**	**74**	**56-67**	**44**	**51-77**	**33-74**	**71**
Pulverised coal							
Overnight cost	$/kW	1 435	1 212	1 592	1 287	778-2 540	1 657-1 725
Fuel price	$/GJ	1.3	1.4	2.3		0.2-3	2
Capacity factor		85%	90%	>90%		85%	90%
LCOE	**$/MWh**	**47**	**45**	**51**	**36-44**	**28-75**	**51-53**
IGCC							
Overnight cost	$/kW			1 942	1 448	1 479-2 096	1 935-1 725
Fuel price	$/GJ			2.3		1.4-2.8	2
Capacity factor				>90%		85%	90%
LCOE	**$/MWh**			**62**		**41-58**	**53-60**
Gas [B]							
Overnight cost	$/kW	552	539	583	639	3 94-1 115	827
Fuel price	$/GJ	3.7	4.5	4.2	3.5-4.6	3.8-6.1	6.5
Capacity factor		85%	90%	>90%		85%	85%
LCOE	**$/MWh**	**45**	**57**	**43**	**38-49**	**44-69**	**66**
Biomass							
Overnight cost	$/kW			3 573		1 840-2 358	
Fuel price	$/GJ			1.3			
Capacity factor						85%	
LCOE	**$/MWh**			**131**		**54-109**	

Source: Projected Costs of Generating Electricity, OECD NEA 2010

Economics


Generation Costs
CA
FI
FR
JP
UK
US
CH
ROK
Fuel
O&M
Investment
(mills/kWh)
0
10
20
30
40
50
60
70
80
90
Nuclear
Coal
Gas

NON-ELECTRICAL APPLICATION

- District heating,
- Seawater desalination;
- Military vessels and Arctic Sea ice-breakers.

High temperature steam for industrial applications:

- Hydrogen production
- Aluminium production
- Steelmaking
- Chemical industry
- Oil recovery
- Shale oil recovery
- Tar sand oil recovery
- Coal gasification

Conclusions (1)

Nuclear power shows a unique potential as a large-scale sustainable energy source:

- **no GHG emissions;**
- **no air pollution;**
- **It is largely immune to intermittency and unpredictability (solar, wind);**
- **use fuel with high energy density with resource and fabrication plants placed in geopolitical stable countries;**
- **reliable source of energy for countries where demand for electricity is growing rapidly (China, India), contributes to security of supply**
- **Can be economically competitive, if carbon pricing is considering and financing costs are controlled,**

But…

Conclusions (2)

Nuclear power still faces a number of challengers:

- **! Requirements for continuous enhancement of safety (reinforced by the recent accident at Fukushima Daiichi);**
- **Needs to control the spread of technologies and materials that may be used for non-peaceful purposes;**
- **Implement final solutions for radioactive waste disposal and management;**

If NP is to continue to contribute to SD, such challenges require consistent effort.

Thanks for your attention!

Grazie per la vostra attenzione!