Nuclear Power and Sustainable Development

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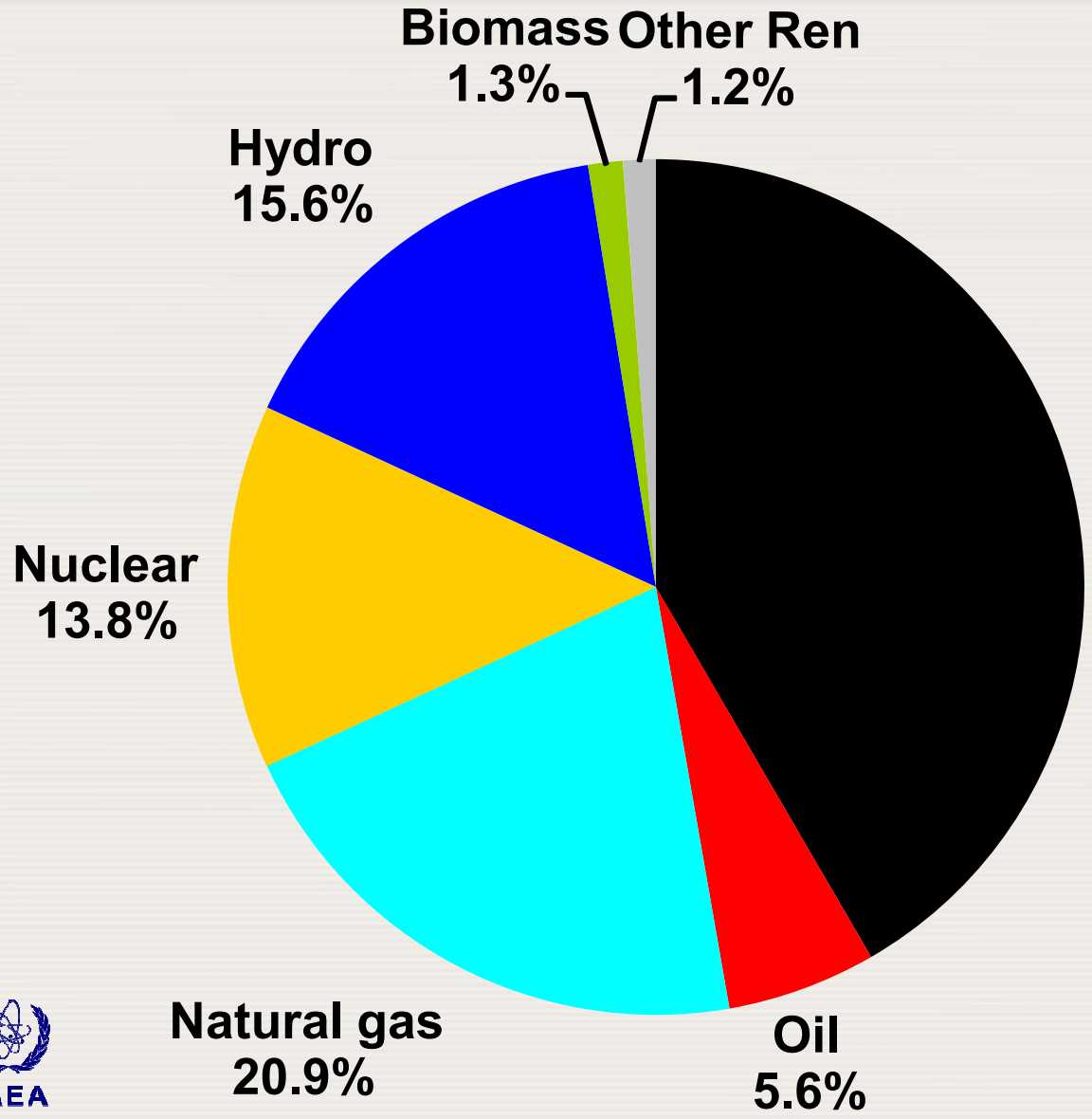
International Atomic Energy Agency

Structure of global electricity supply



Global electricity generation in 2007: 19,770TWh

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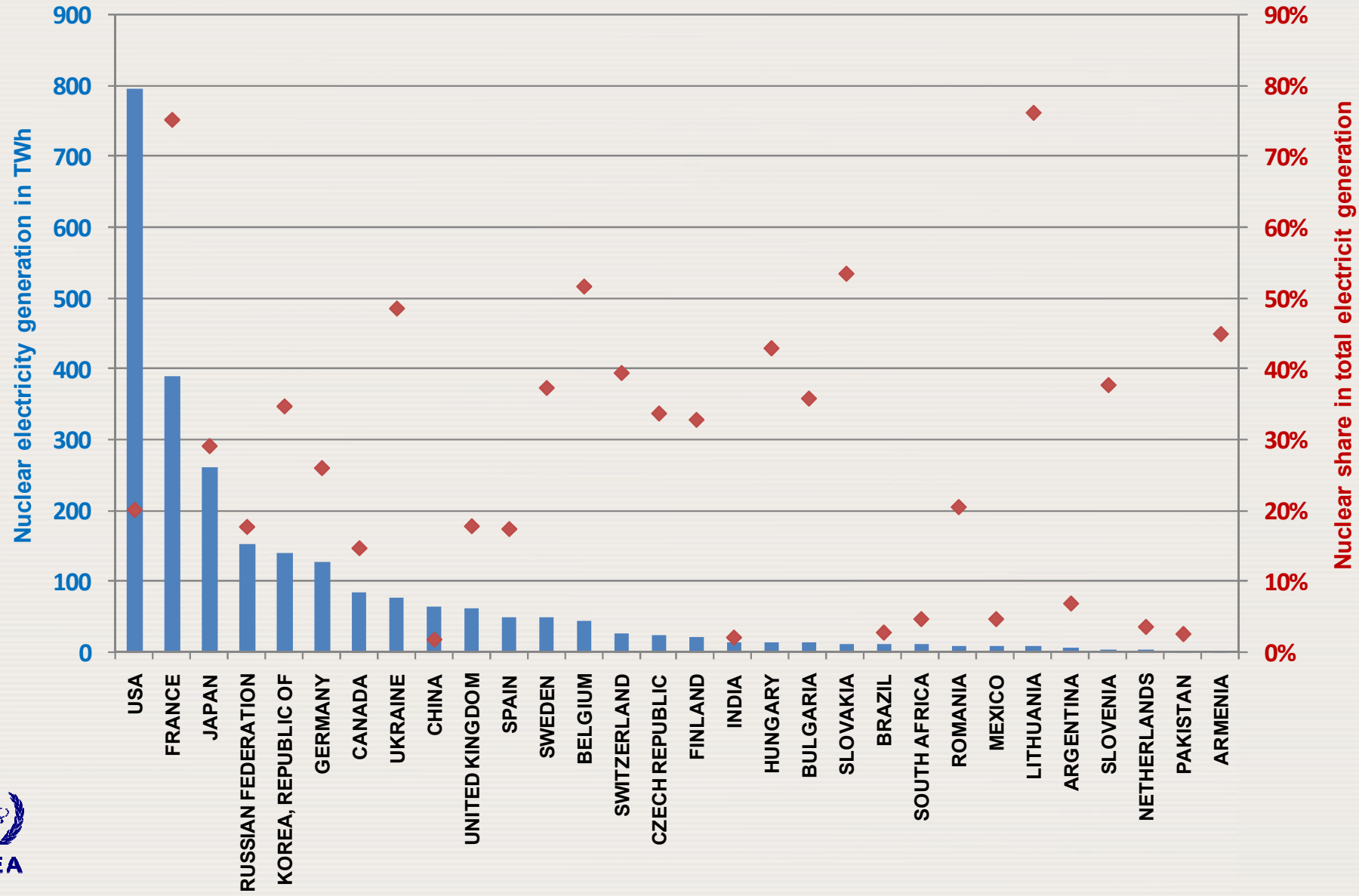
Nuclear share of electricity (2009)



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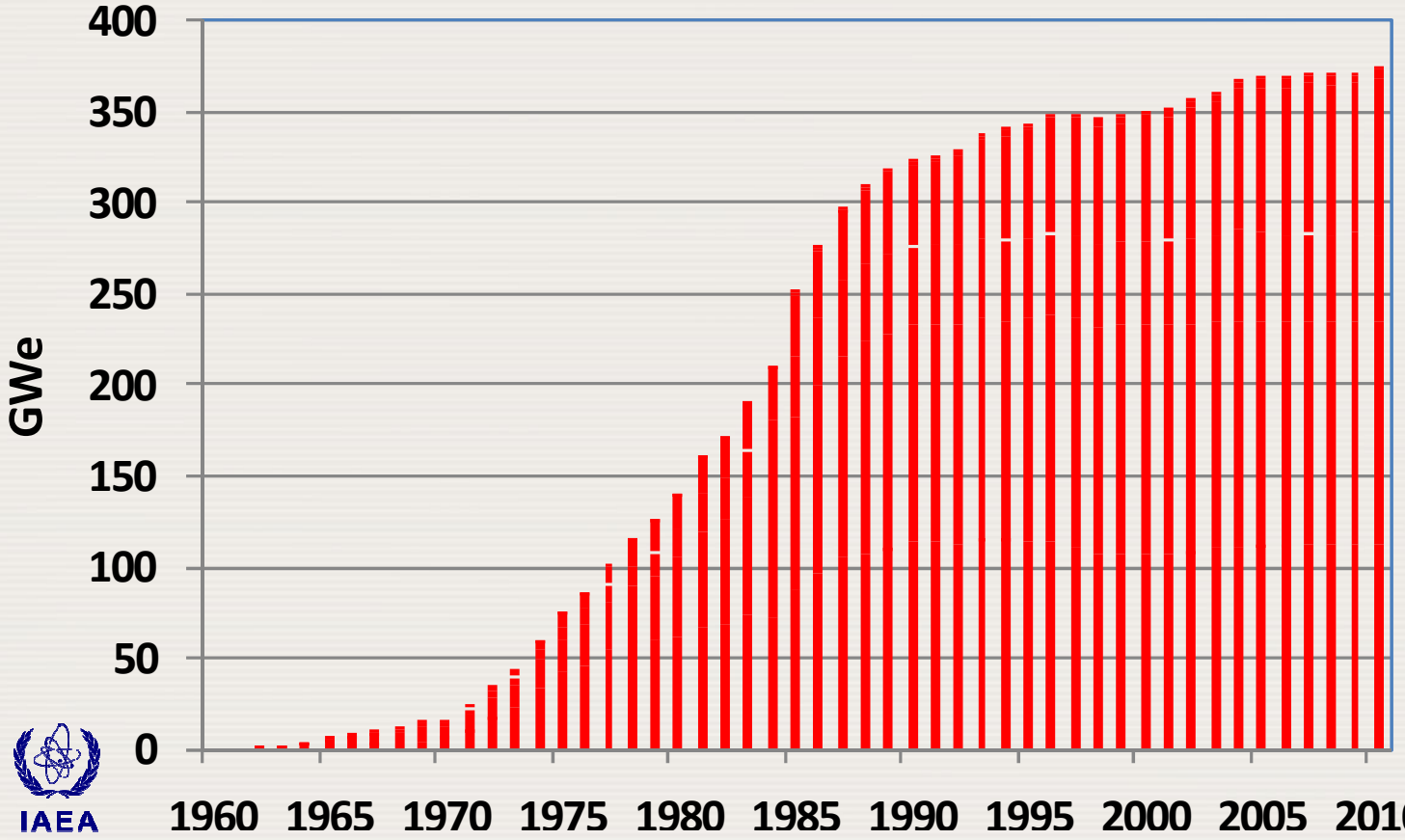
Nuclear power today

On 18 August 2010, 441 nuclear power plants (NPPs) operated in 29 countries worldwide, with a total installed capacity of 374 600 MWe.



"Where does nuclear power go from here?"

60 plants with 58.9 GWe generating capacity

Reasons for the mid 1980s stagnation:

- Energy efficiency improvements
- Economic restructuring
- Significant drop in electricity demand
- Excess generating capacity
- Oil (traded fossil energy) price collapse
- Advent of the high-efficient cheap gas turbine technology (GTCC)
- Electricity market liberalization & privatization

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Reasons for the mid 1980s stagnation:

- Little regard for supply security
- Regulatory interventions after Three Mile Island
- High interest rates
- Chernobyl
- Break up of the Soviet Union

All the above together: New nuclear build out of favour (poor economics and lack of demand)

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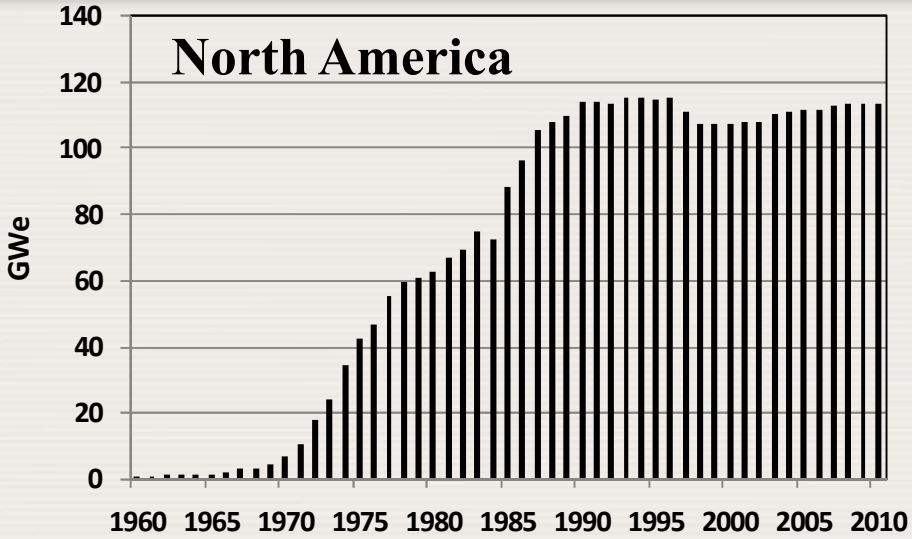
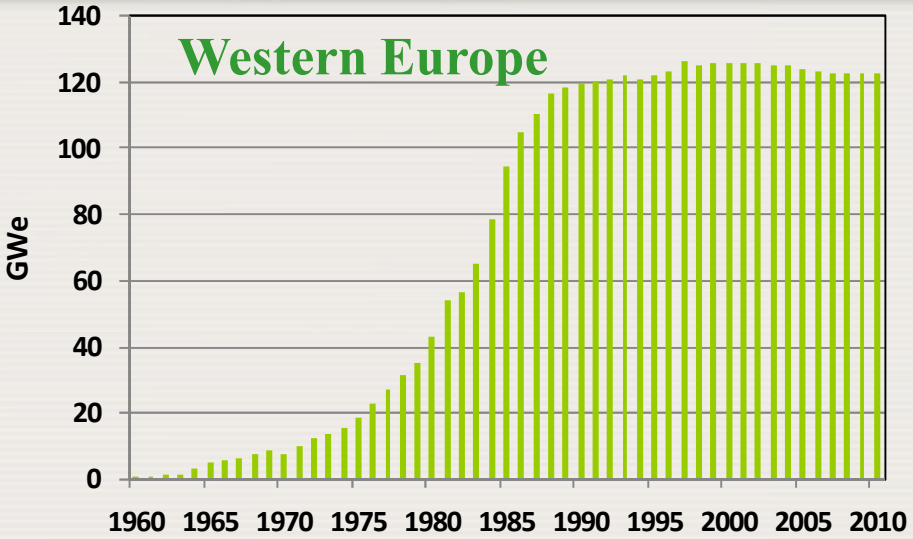
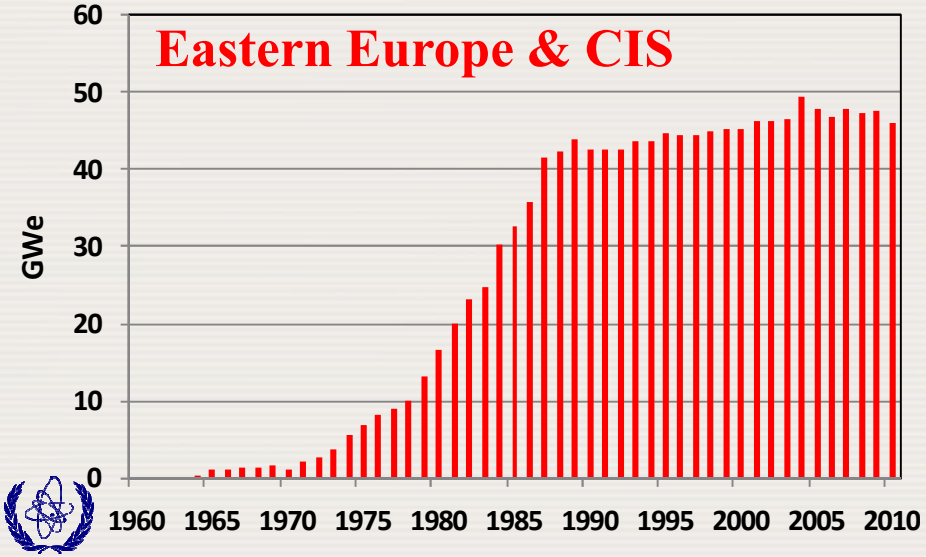
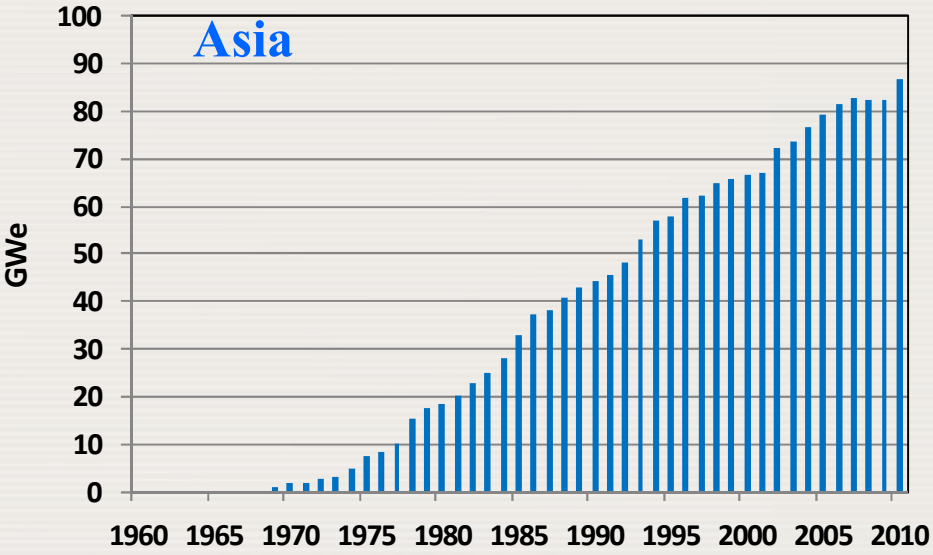
Development of regional nuclear generating capacities









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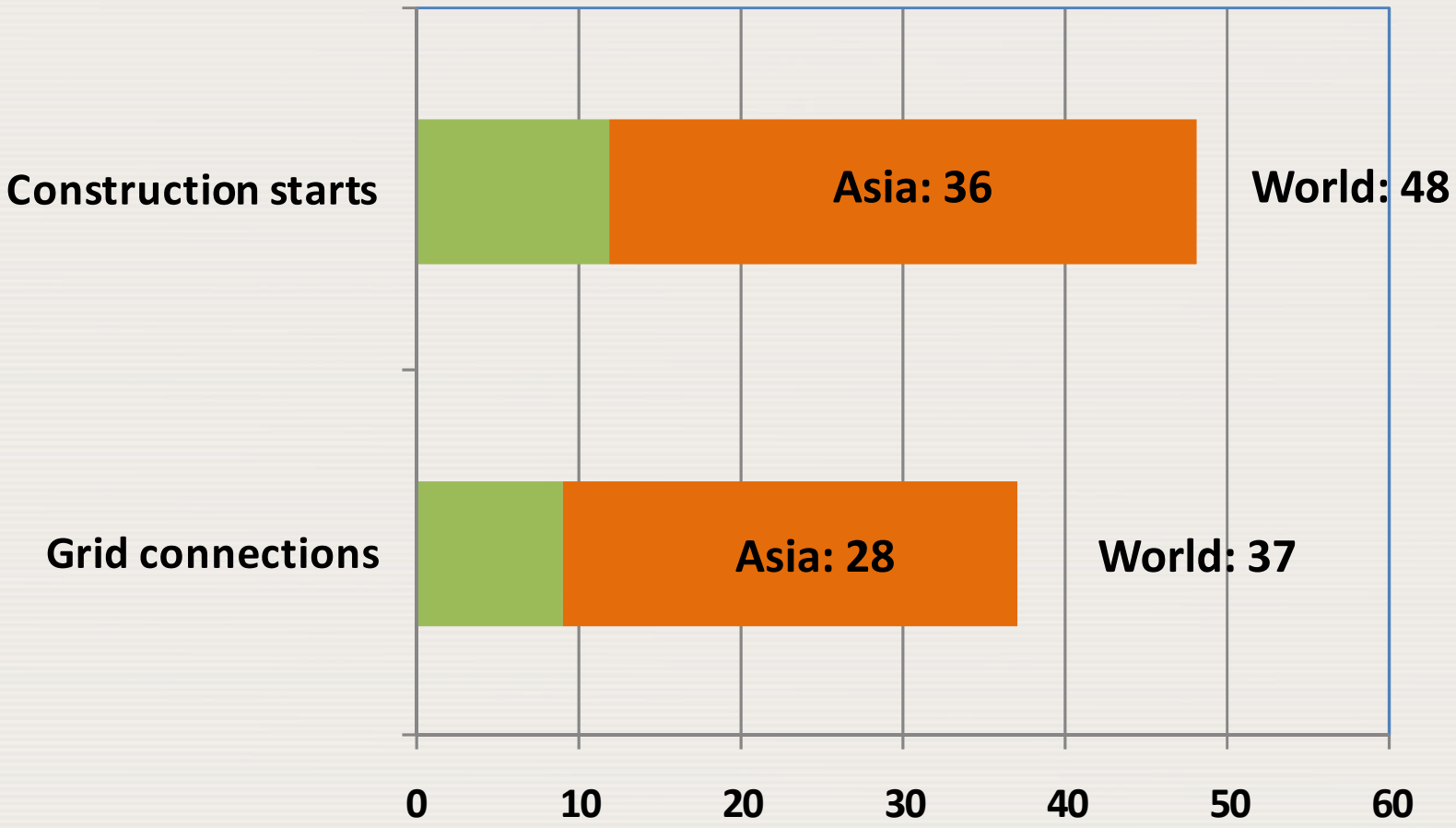
Construction starts and grid connections after 1. January 2000



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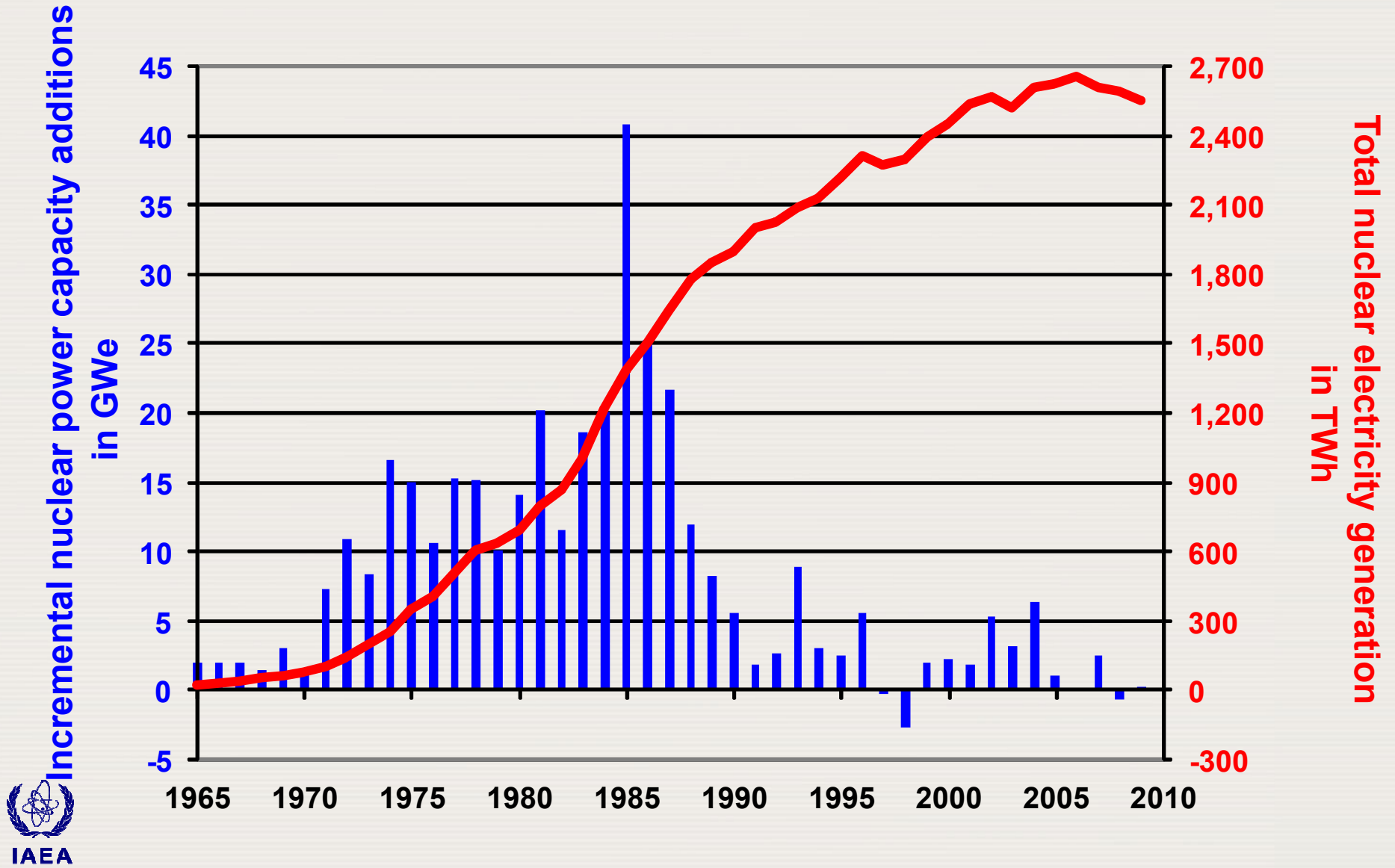
As per 18 August 2010
Source: IAEA - PRIS

Annual Incremental Nuclear Capacity Additions and Total Nuclear Electricity Generation



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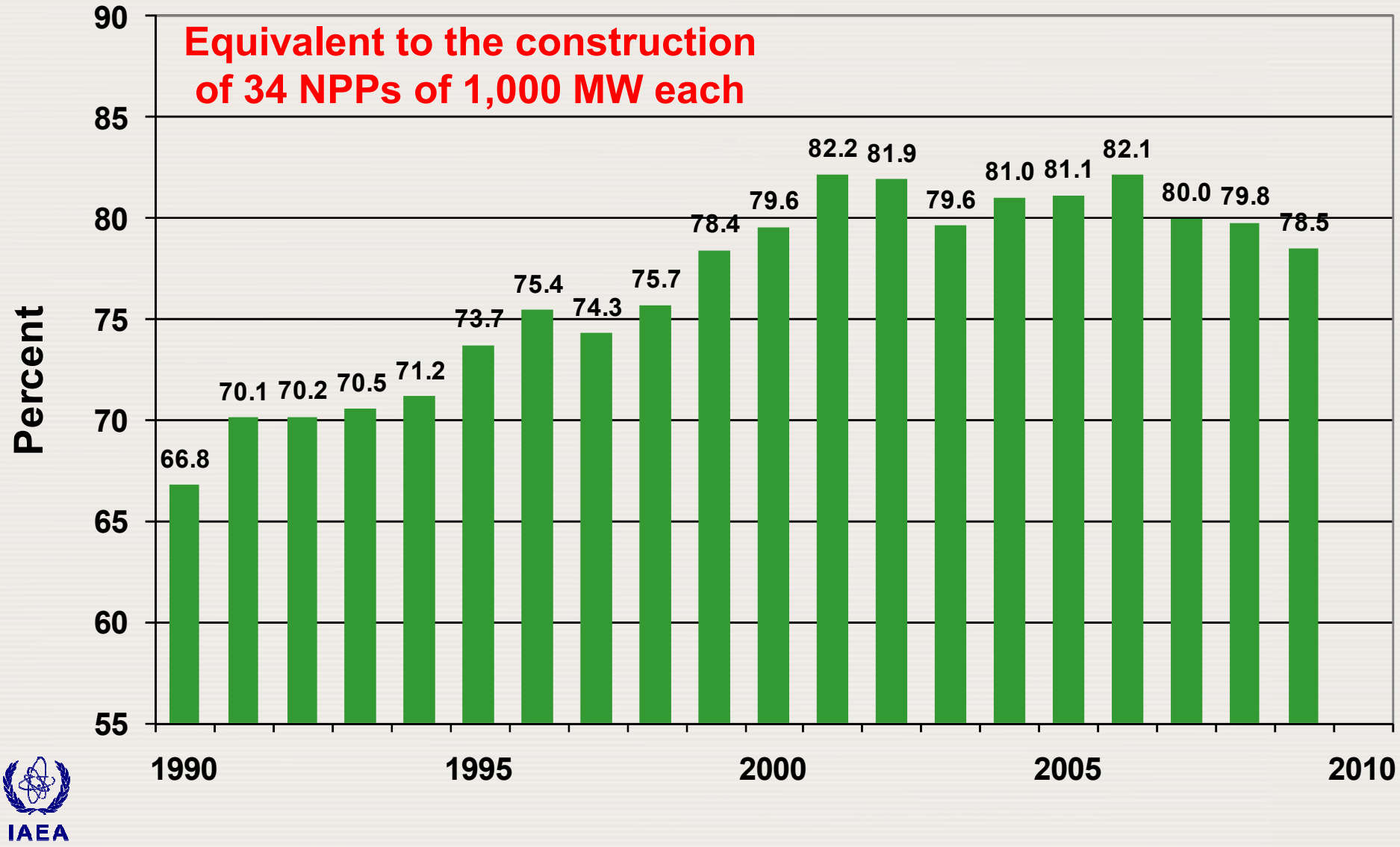
Global energy availability factor of nuclear power plants



Summary of nuclear power today

- A proven technology that provides clean electricity at predictable and competitive costs
- Provides 14% of global electricity supply
- More the 13,000 years of accumulated reactor experience
- Operation of nuclear installations have safety as highest priority
- Lessons learned from past mistakes or accidents have been acted on
- Nuclear takes full responsibility its waste

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Technology options towards a sustainable energy future

- **Improved Energy Efficiency throughout the energy system**
- **More Renewable Energy**
- **Advanced Energy Technologies:**
  - clean fossil fuel technologies including carbon capture & storage (CCS)
  - next generation nuclear technologies

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CSD-9: Outcomes (2001) – confirmed by WSSD (2002)

- Exhaustive debate
- Agreement to disagree on nuclear's role in sustainable development
- Unanimous agreement that choice belongs to countries

BUT

- There is no technology without risks and interaction with the environment.
- Do not discuss a particular technology in isolation.
- Compare a particular technology with alternatives on a life cycle (LCA) basis.

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Contra: Nuclear & Sustainability

- No long-term solution to waste
- Nuclear weapons proliferation & security

WIPP

- Safety: nuclear risks are excessive
- Transboundary consequences, decommissioning & transport
- Too expensive

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Pro: Nuclear & Sustainability

- Brundtland[1)] about keeping options open
- Expands electricity supplies ("connecting the unconnected")
- Reduces harmful emissions
- Puts uranium to productive use
- Increases human & technological capital
- Ahead in internalising externalities

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[1)] development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Economics – Nuclear power

Advantages

- Nuclear power plants are cheap to operate
- Stable & predictable generating costs
- Long life time
- Supply security (insurance premium)
- Low external costs (so far no credit applied)

But…

- High upfront capital costs can be difficult to finance
- Sensitive to interest rates
- Long lead times (planning, construction, etc)
- Long payback periods
- Regulatory/policy risks
- Market risks

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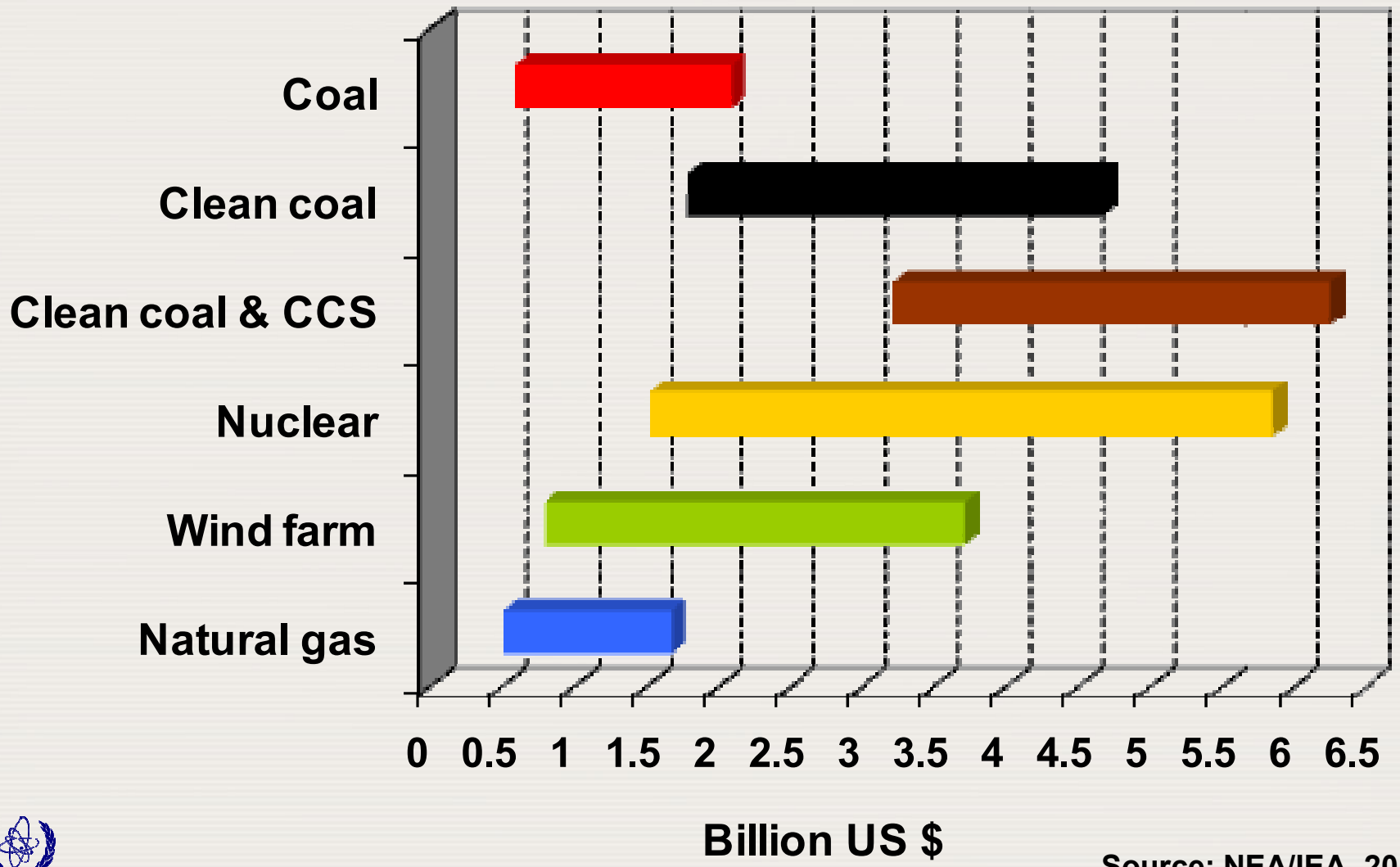
Investment costs for 1,000 MWe



Source: NEA/IEA, 2010

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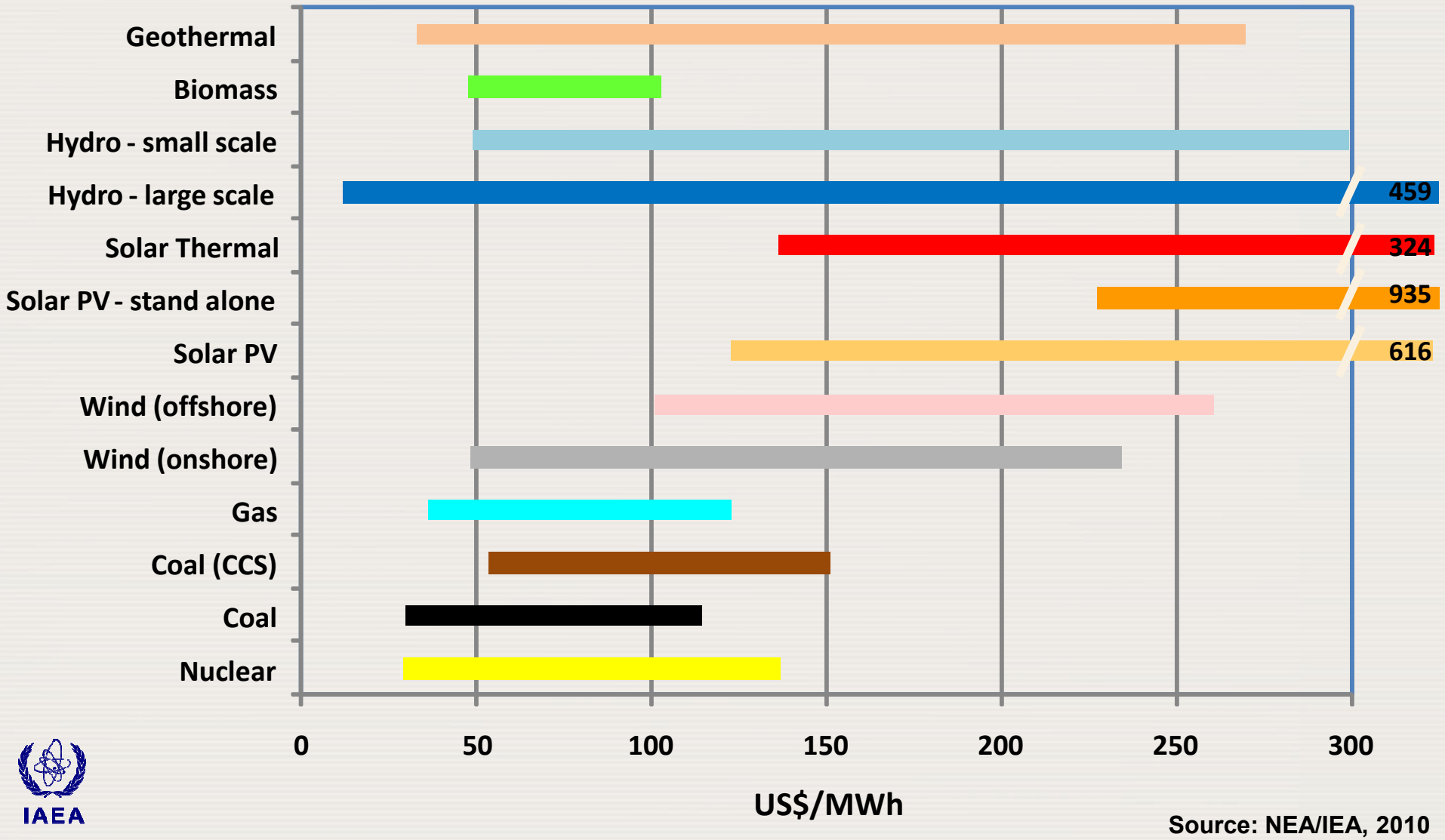
Range of levelized generating costs of new electricity generating capacities



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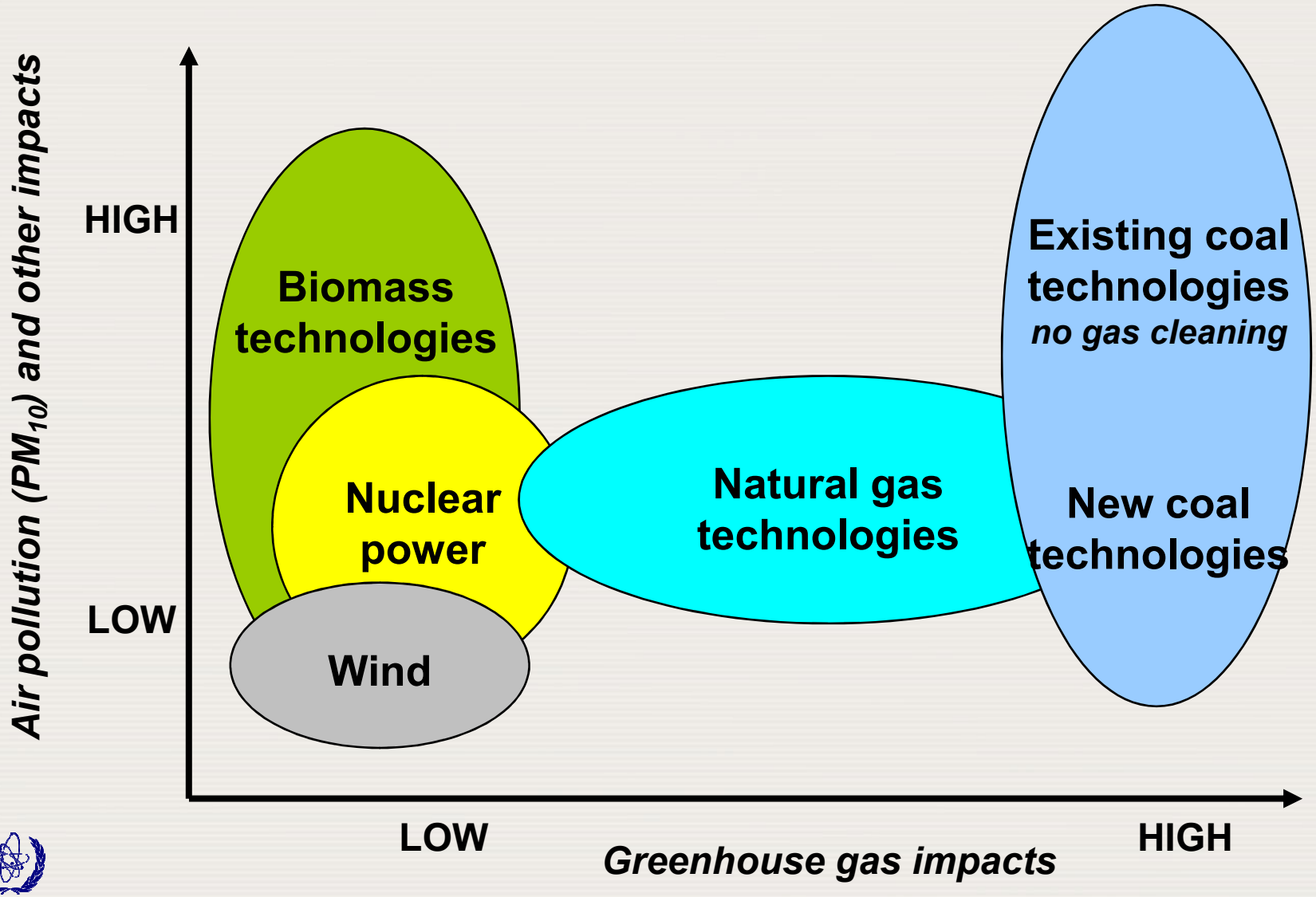
Source: NEA/IEA, 2010

Externalities of different electricity generating options



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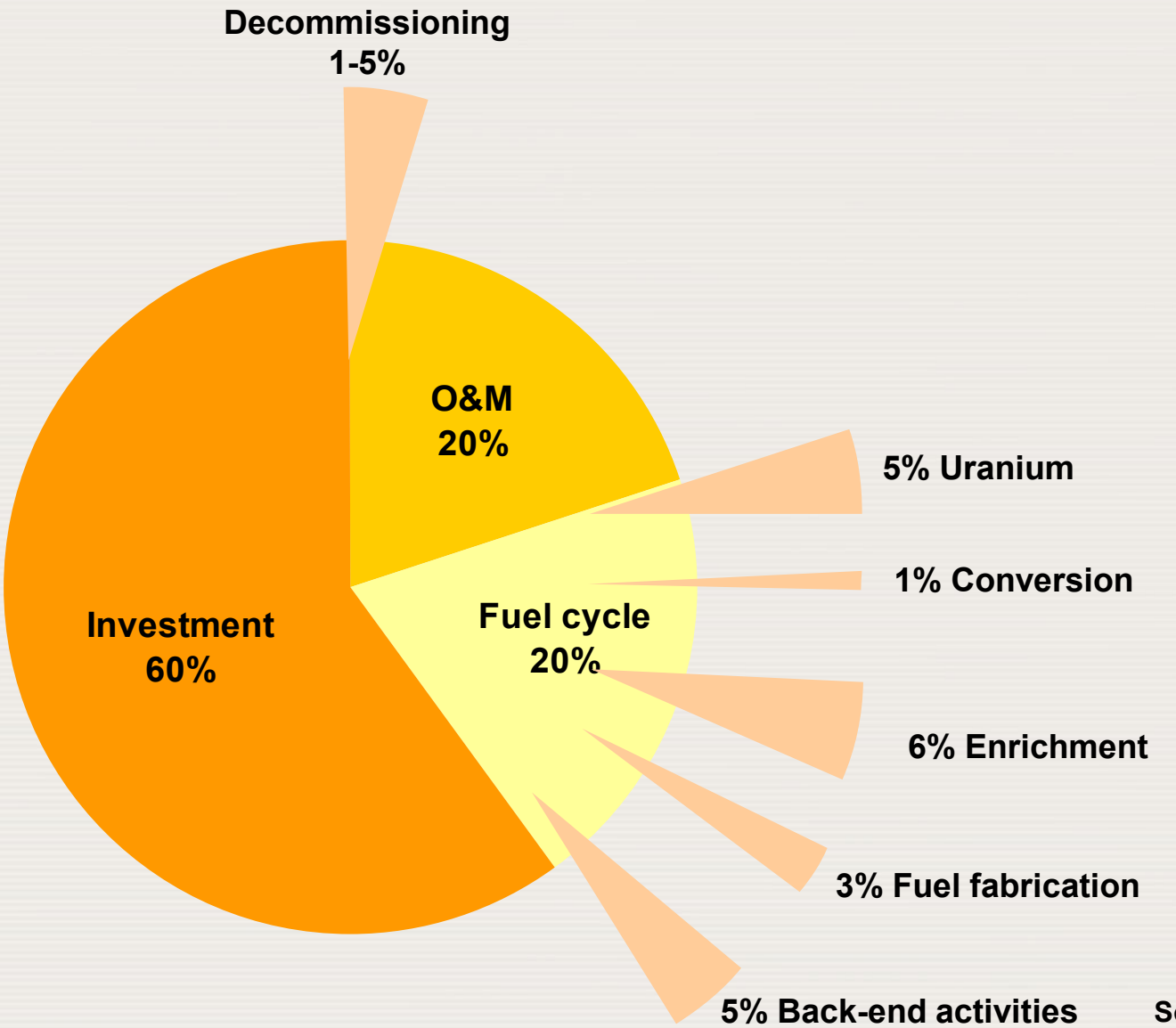
Source: EU-EUR 20198, 2003

Typical nuclear electricity generation cost breakdown



Source: NEA

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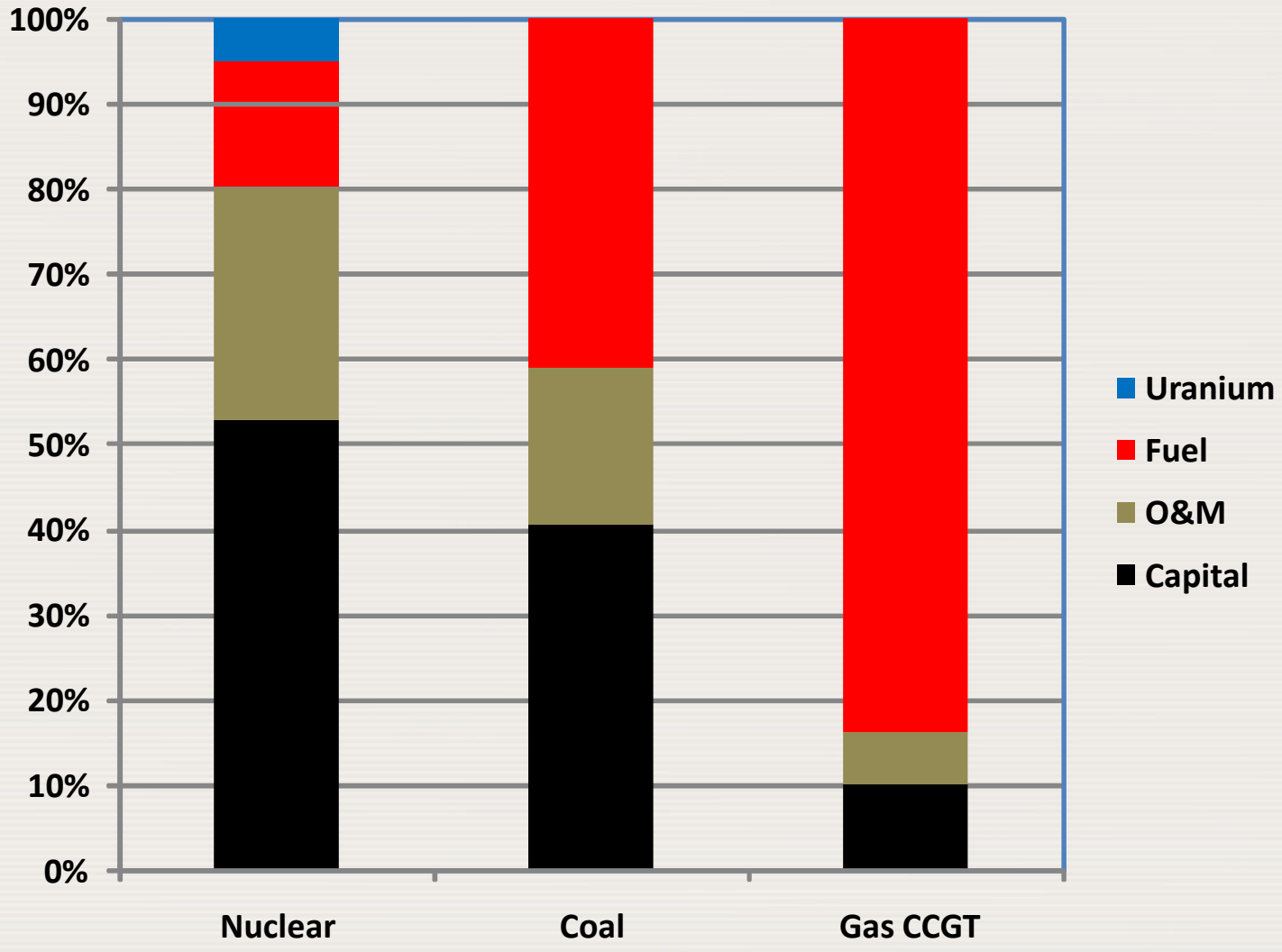
Cost structures of different generating options



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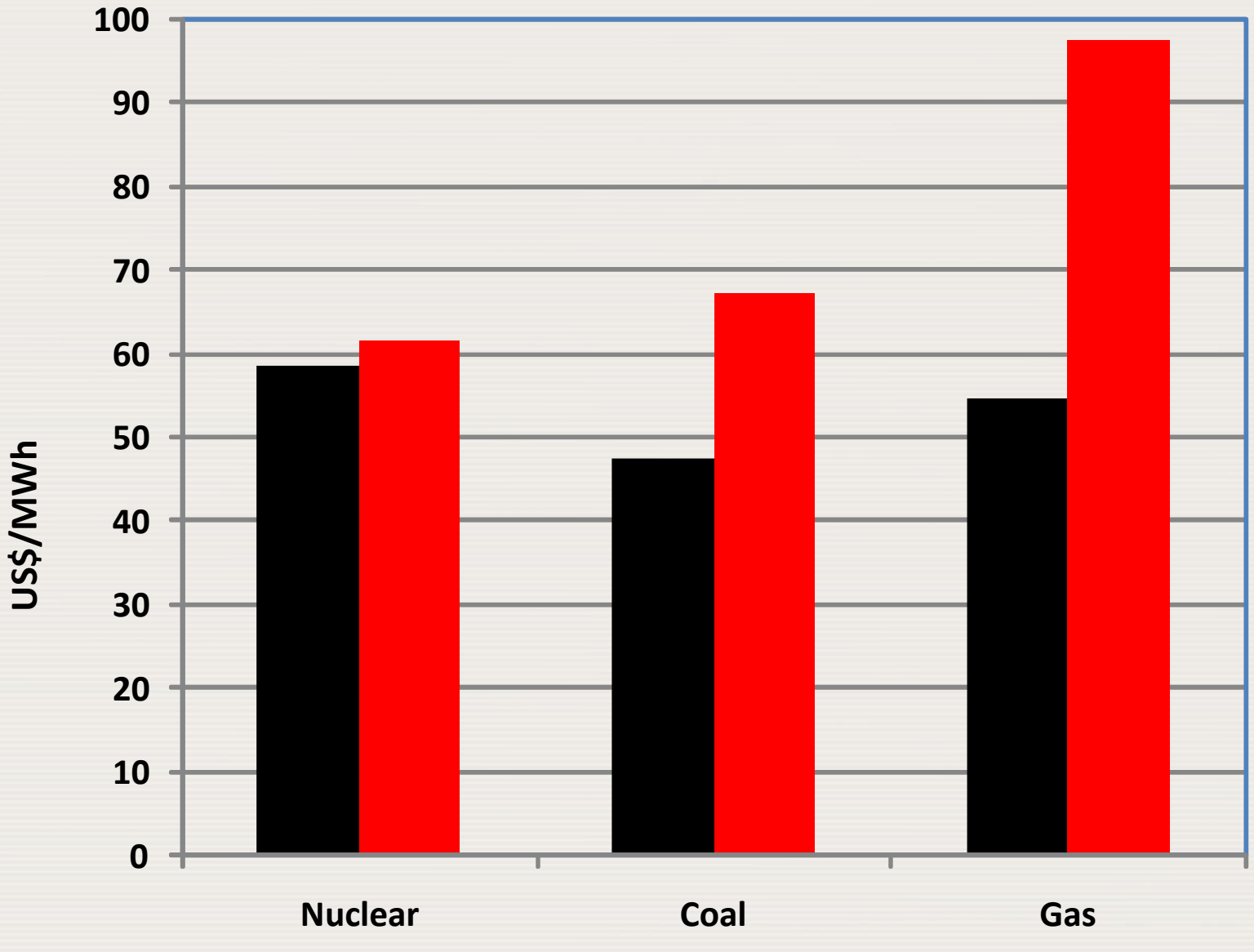
Impact of a doubling of resource prices on generating costs



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Environment – Nuclear power

Advantages

- Low pollution emissions
- Small land requirements
- Small fuel & waste volumes
- Wastes are managed
- Proven intermediary storage

But…

- No final waste repository in operation
- High toxicity
- Needs to be isolated for long time periods
- Potential burden to future generations

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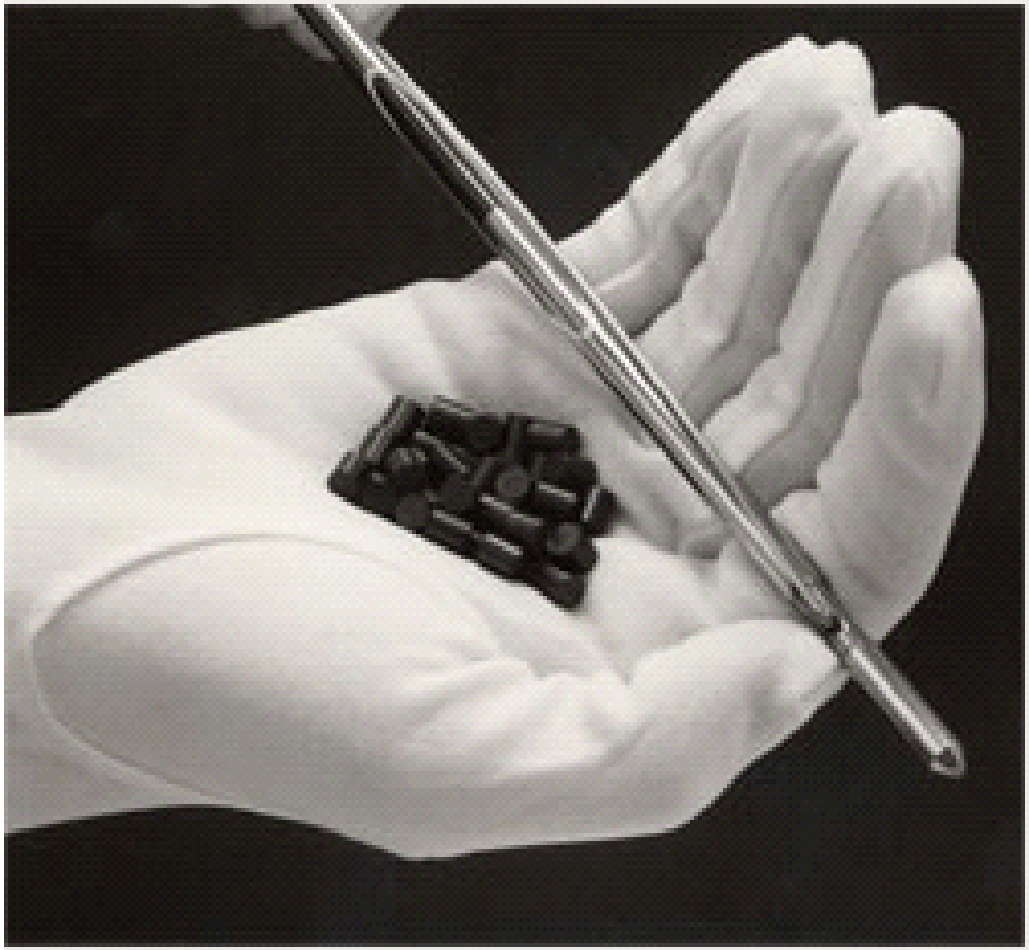
Nuclear Fuel:
Small volumes, high energy contents



- 1 pellet produces the energy of 1.5 tonnes of coal
- Each pellet produces 5000 kWh

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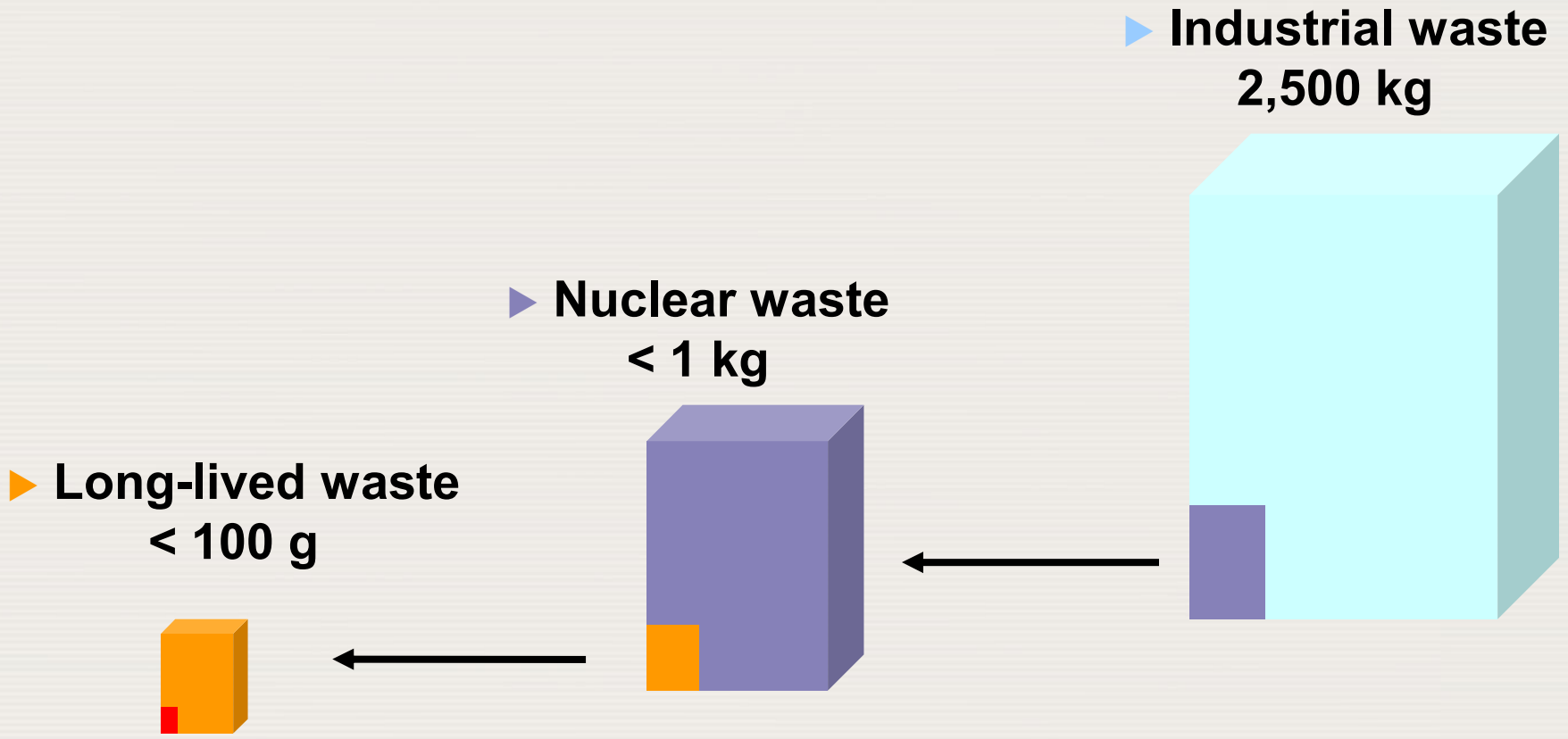
BNFL

Industrial waste per year per capita in France



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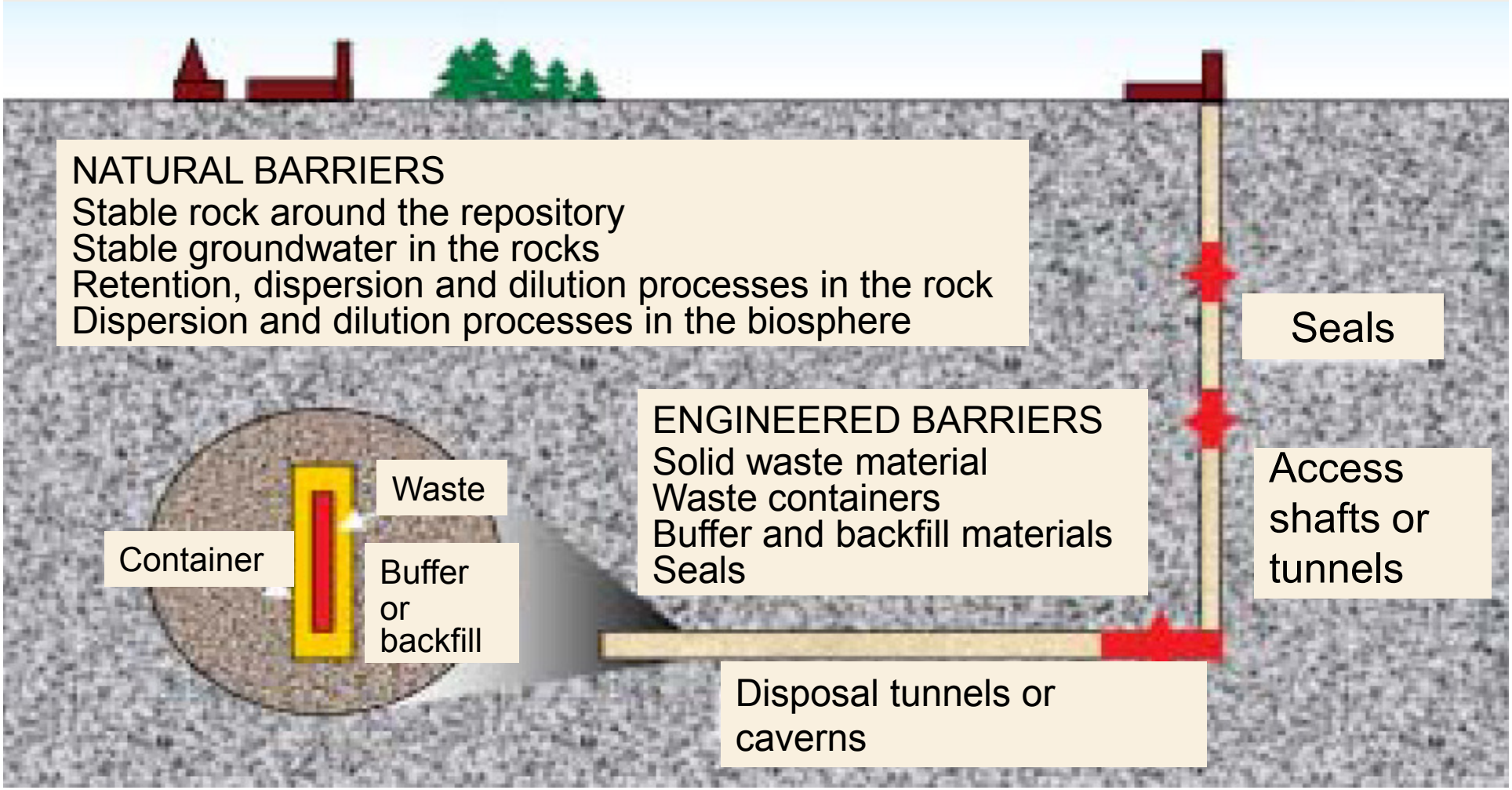
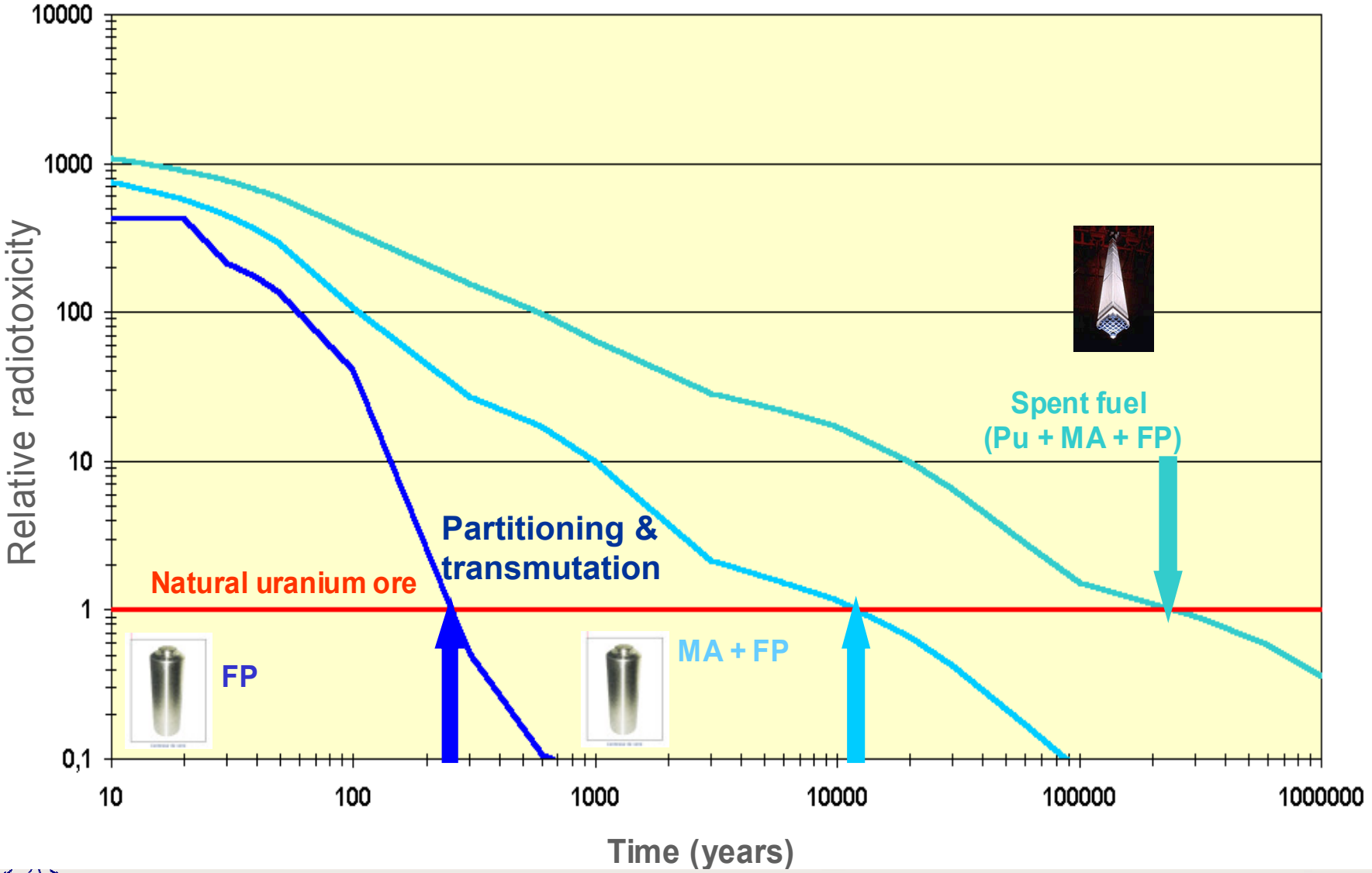
Source: Areva

Geological nuclear waste disposal



Radio-toxicity of spent nuclear fuel



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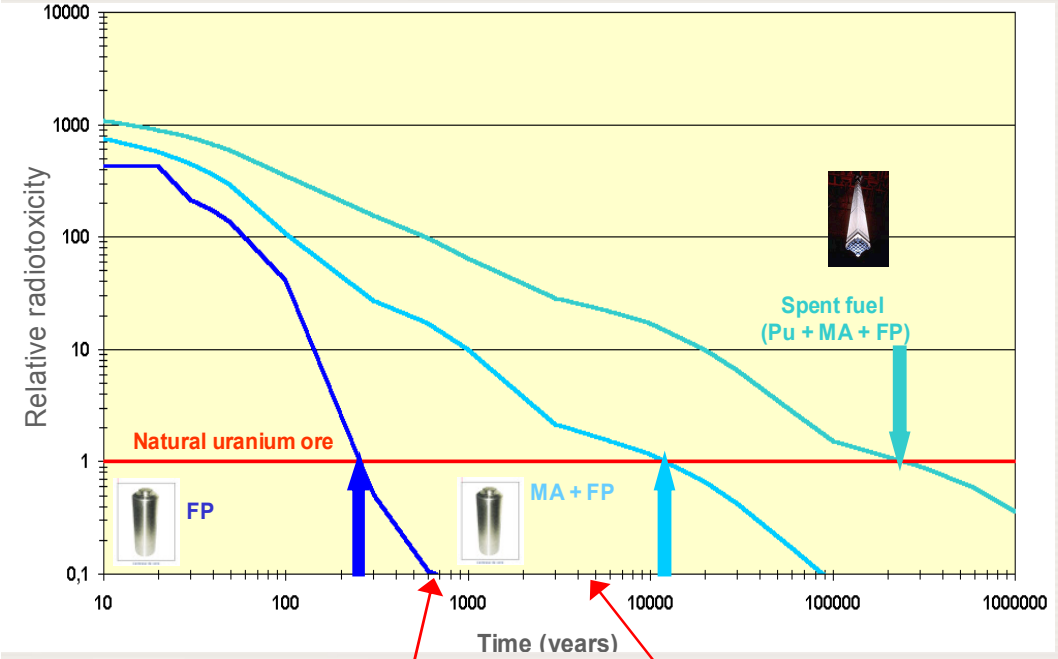
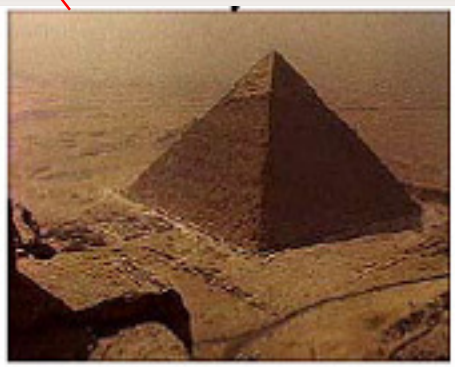
Time lines.....



Notre Dame



Pyramids at Giza

INNOVATION:

Burning of HLW in Fast Reactor in Reducing Radio Toxicity

Plutonium and minor actinides are responsible for most of the long term hazards

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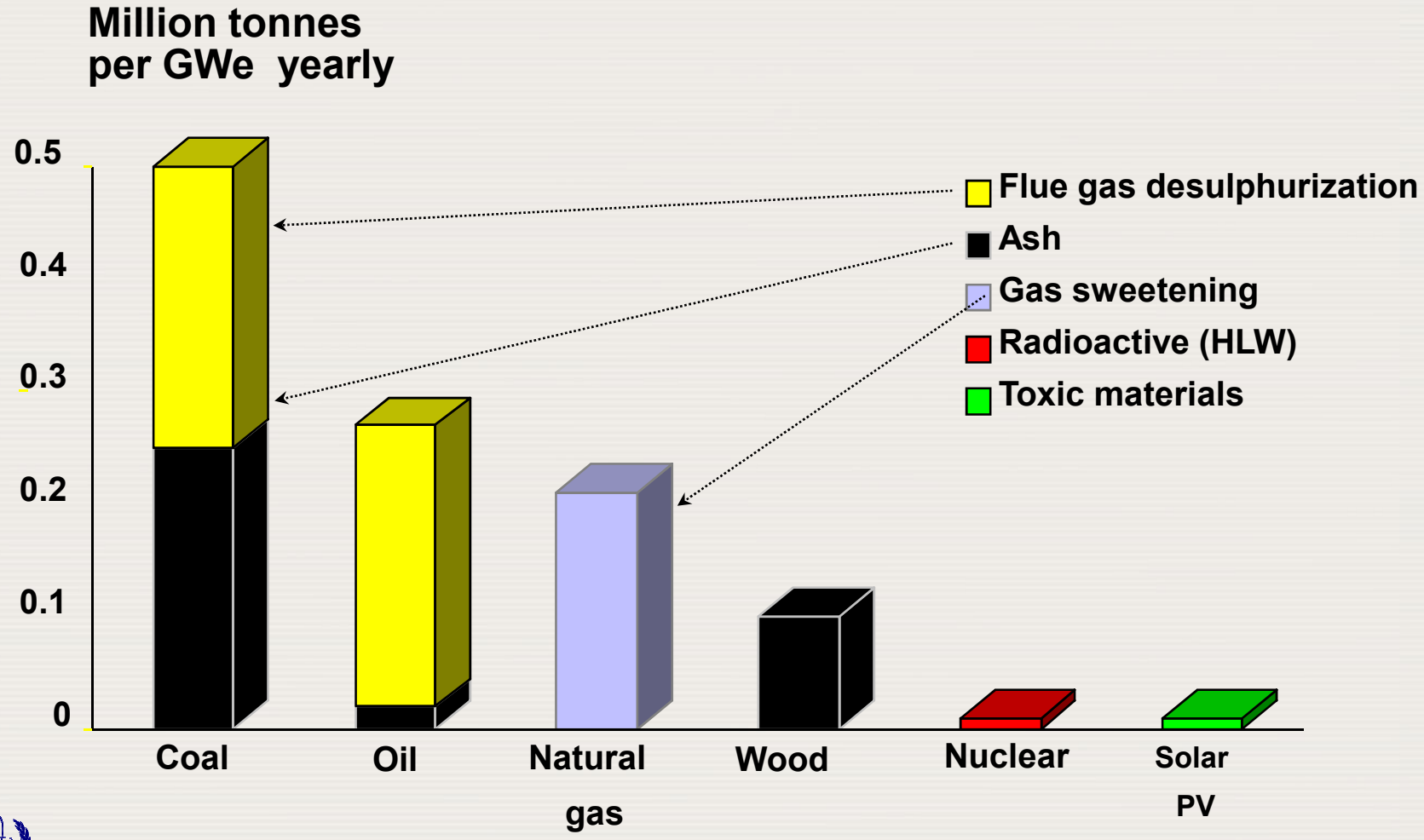
Wastes in fuel preparation and plant operation



Source: IAEA, 1997

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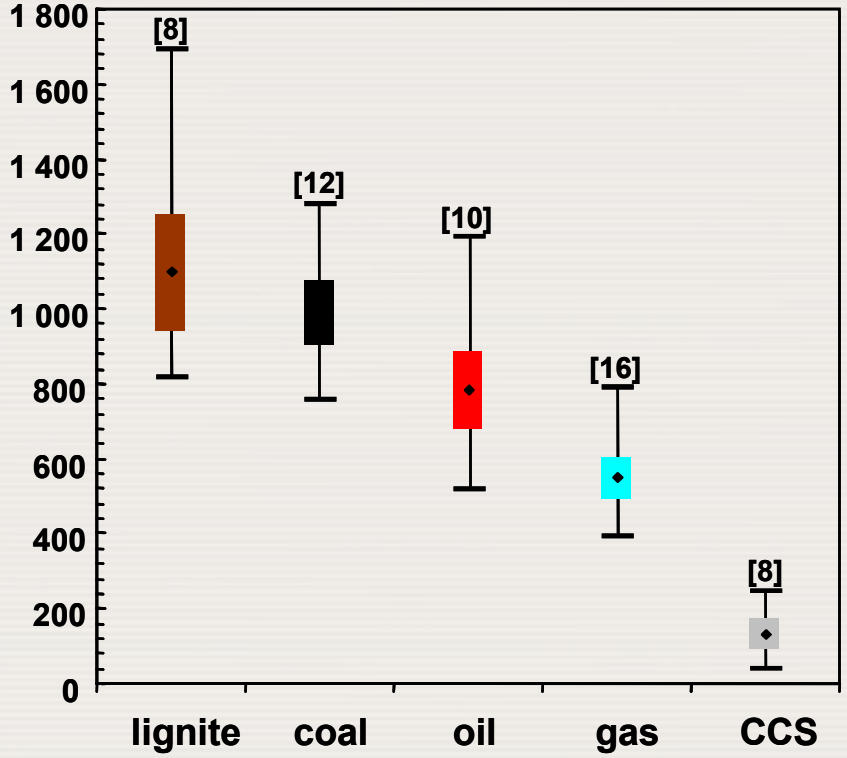
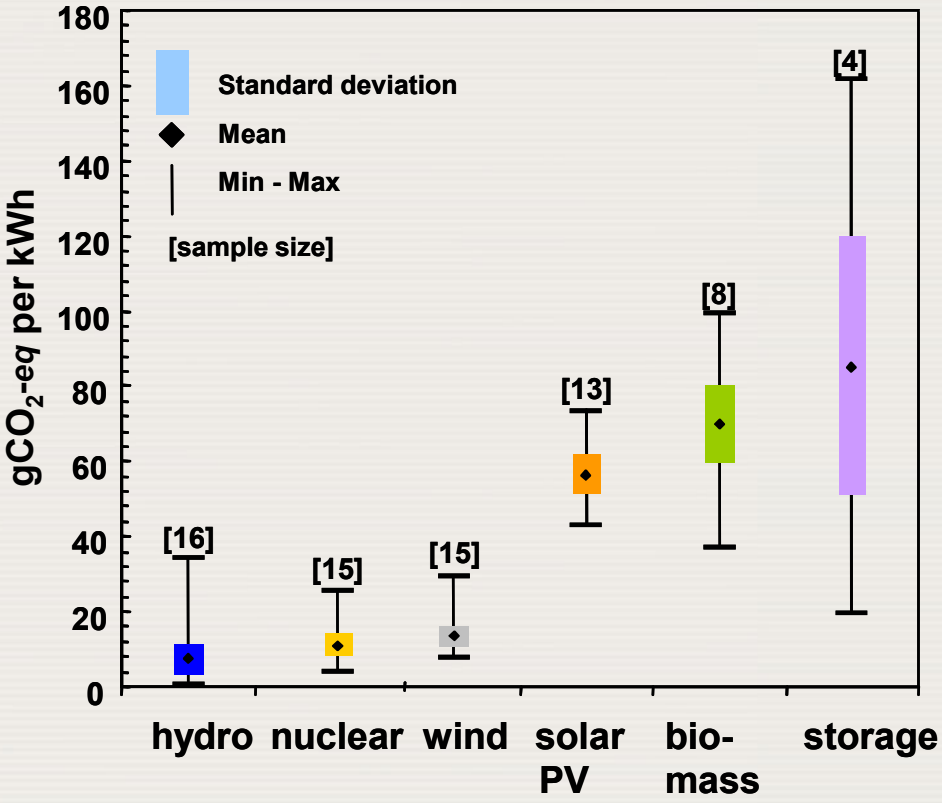
Mitigation – Role of nuclear power

Life cycle GHG emissions of different electricity generating options





Nuclear power: Very low lifetime GHG emissions make the technology a potent climate change mitigation option

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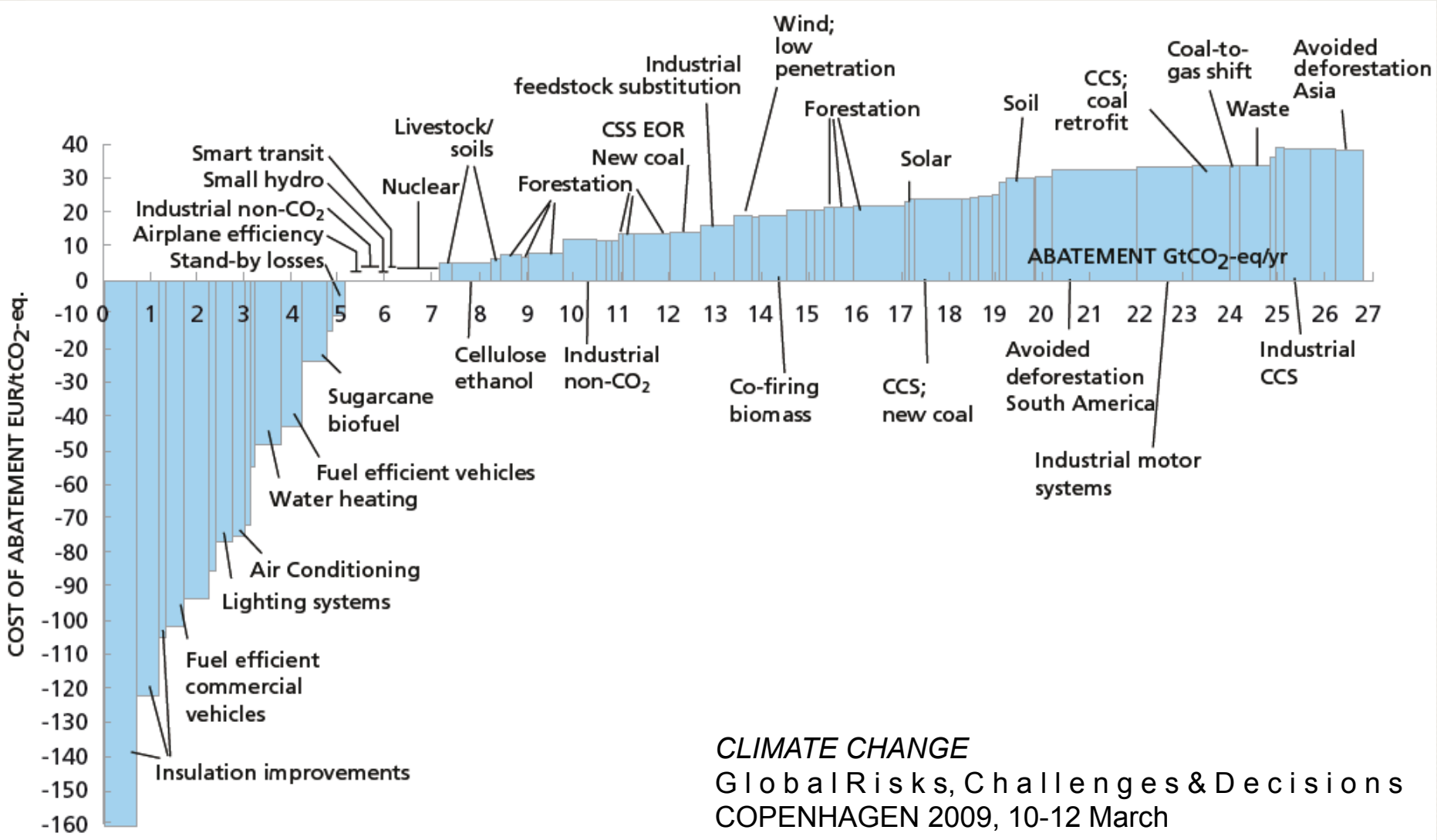
Decarbonising the Economy



CLIMATE CHANGE
Global Risks, Challenges & Decisions
COPENHAGEN 2009, 10-12 March

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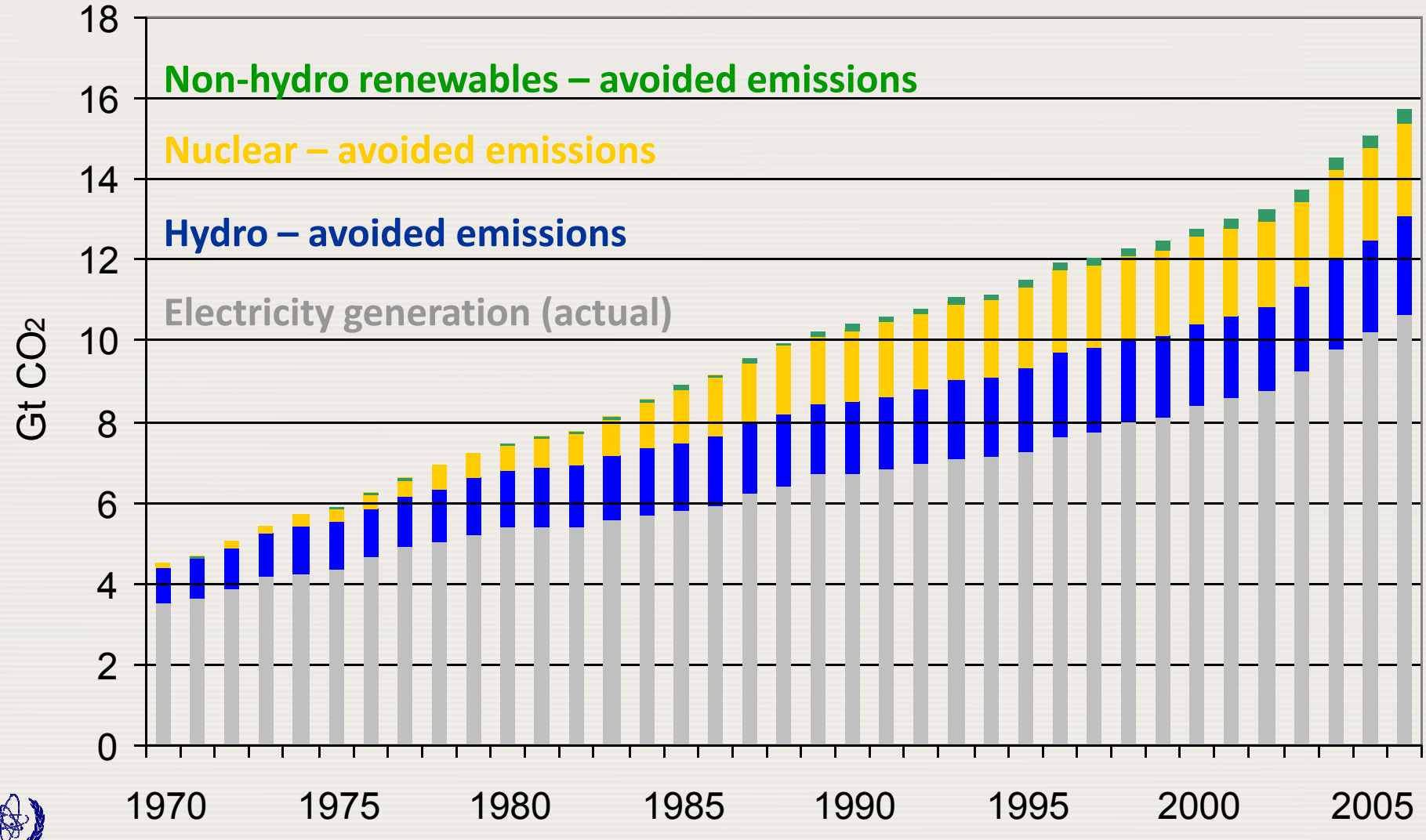
Global CO_2 emissions from electricity generation and emissions avoided by hydro, nuclear & renewables



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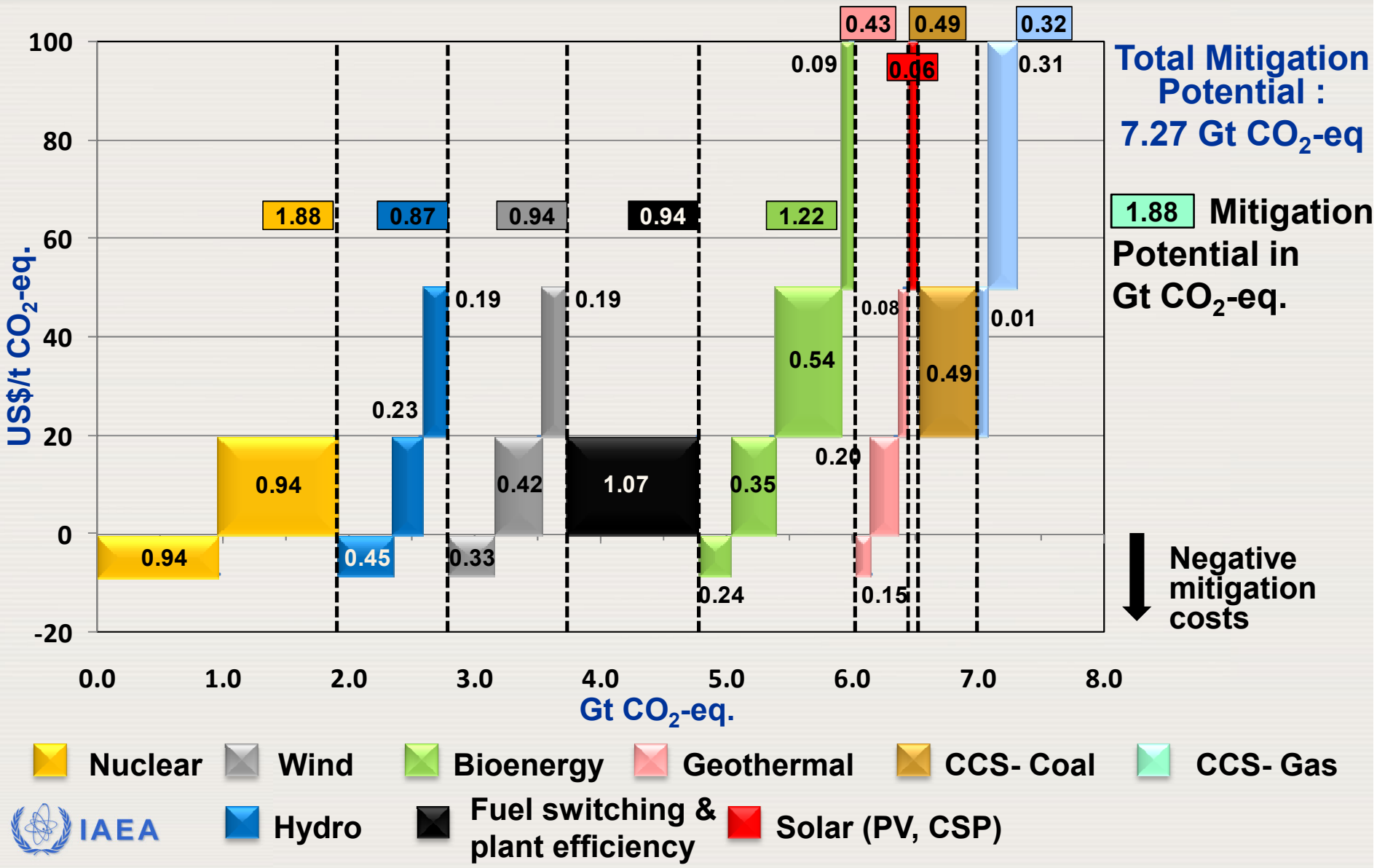
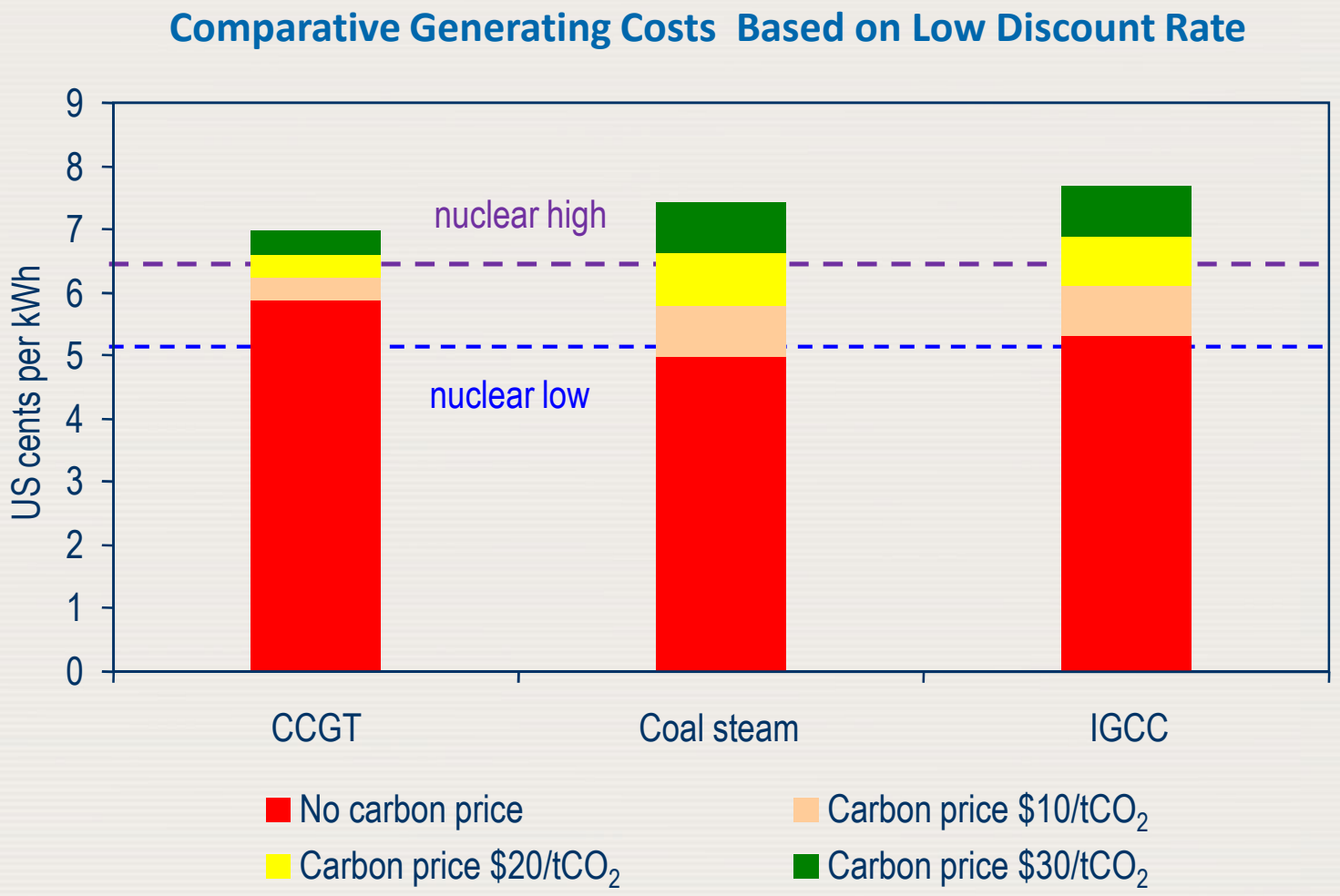
Source: IAEA calculations based on IEA data

Mitigation potentials by 2030 of selected electricity generation technologies in different cost ranges



Impact of CO_2 penalty on competitiveness of nuclear power



A relatively modest carbon penalty would significantly improve the ability of nuclear to compete against gas & coal

Source: IEA, 2006

Safety – Nuclear power

Reality

- Safety is an integral part of plant design & operation
- Nuclear power has an excellent safety record
- Lessons learned from past accidents
- Safety culture, peer reviews & best practices
- No room for complacency

Perception

- Nuclear power is dangerous
- It can never be made safe
- Safe is not safe enough
- Nuclear plants are atomic bombs
- No public acceptance

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Nuclear power safety

- Safety is a dynamic concept
- Upgrading of older generation reactors & life time extensions
- Advanced reactor designs with inherent safety features
- The impact of these ongoing efforts are:
  - Improved availability worldwide
  - Lower radiation doses to plant personnel and fewer unplanned stoppages

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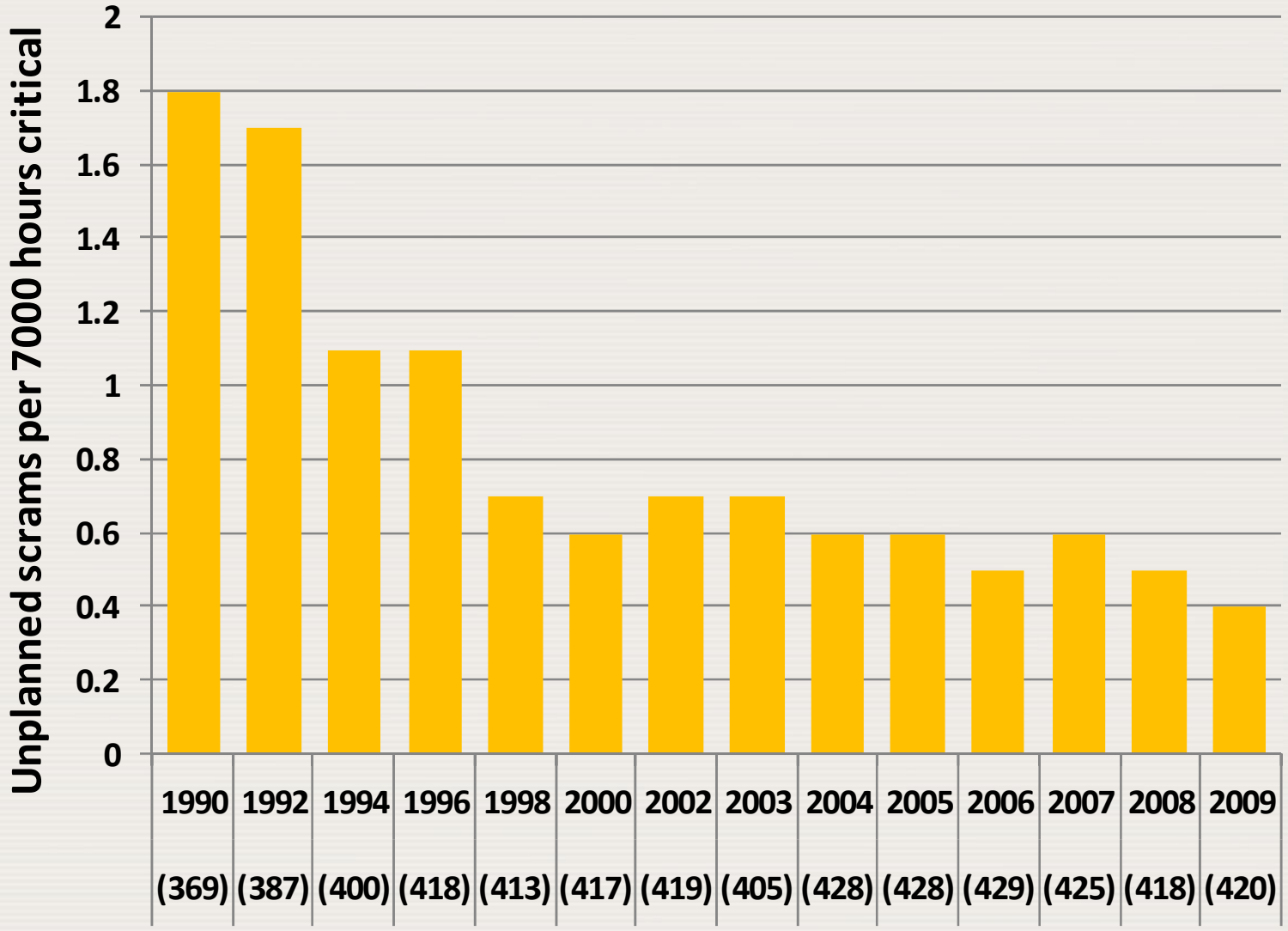
Unplanned scrams per 7000 hours critical



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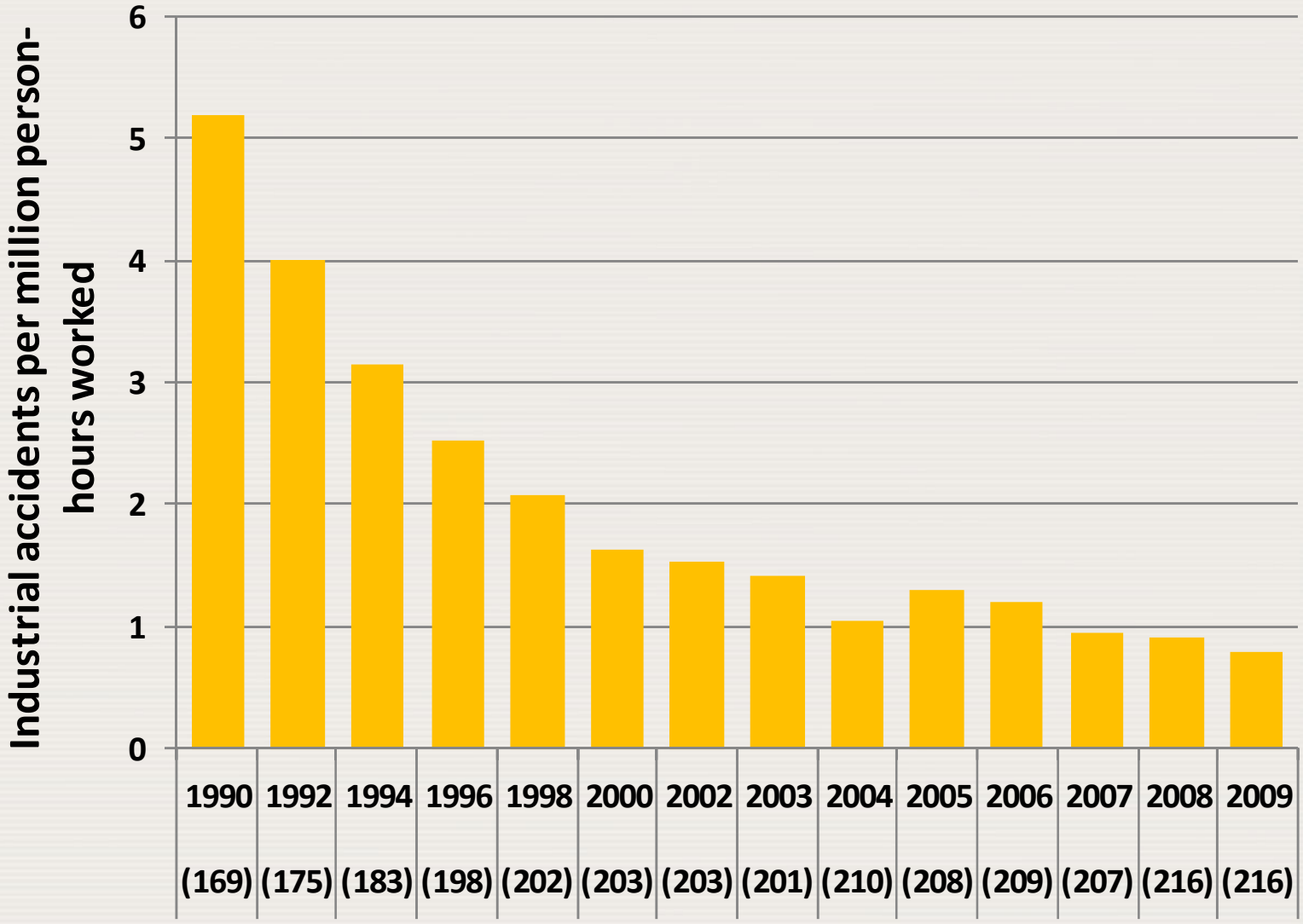
Source: *WANO 2009 Performance Indicators*

Industrial accidents at NPPs per million person-hours worked



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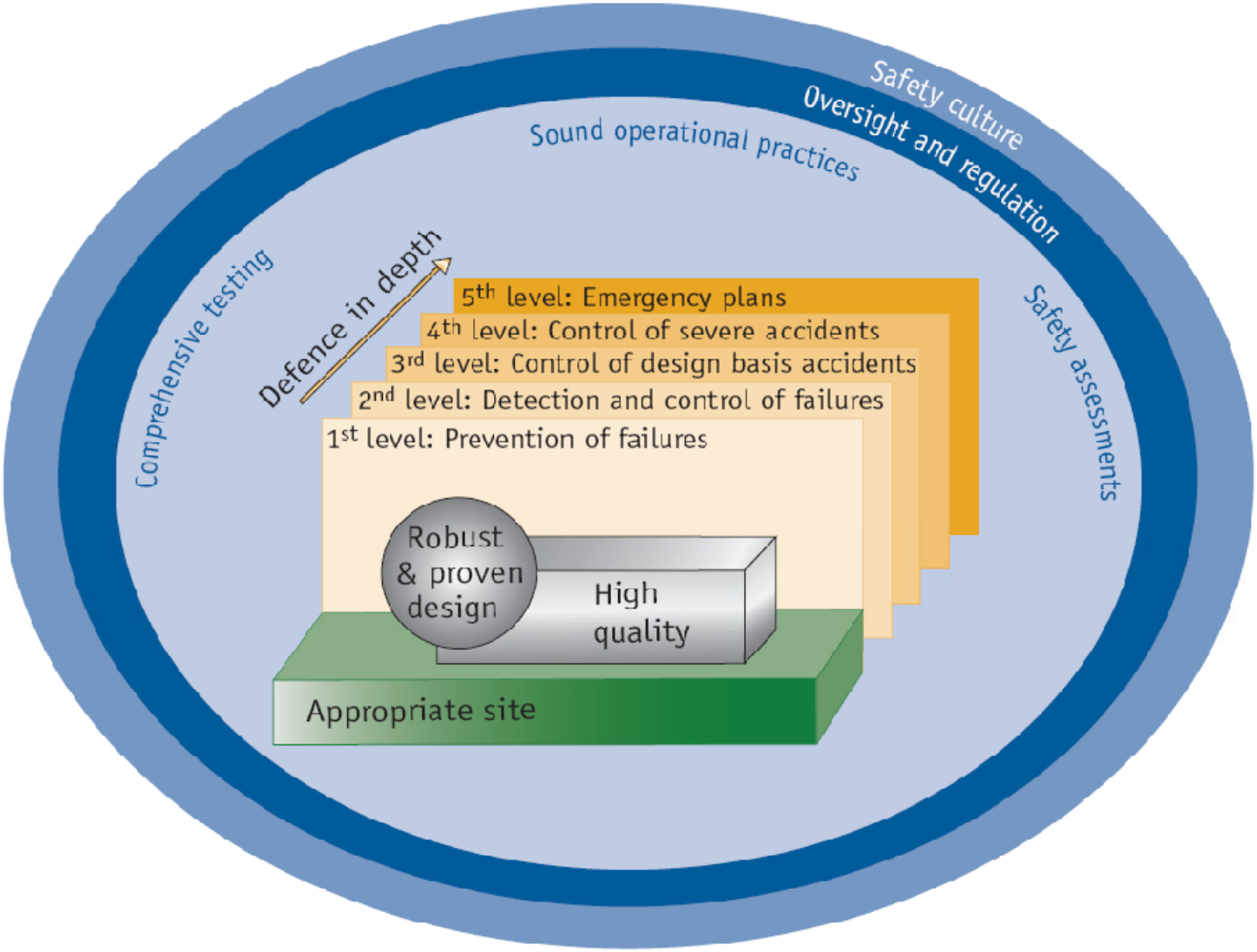
Source: *WANO 2009 Performance Indicators*

Elements of nuclear safety: Defense in Depth



Source: NEA

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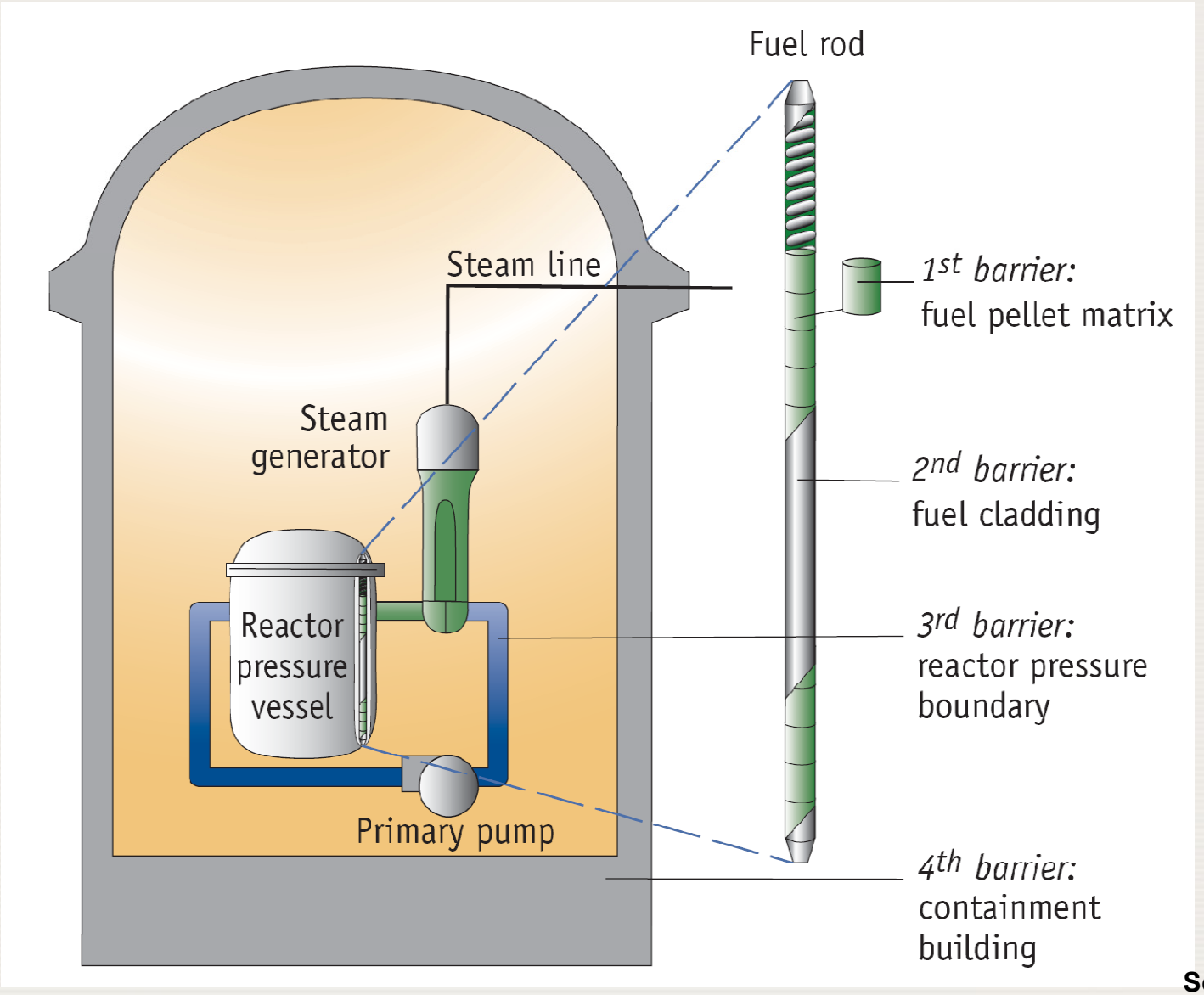
Typical barriers confining radioactive materials



Source: NEA

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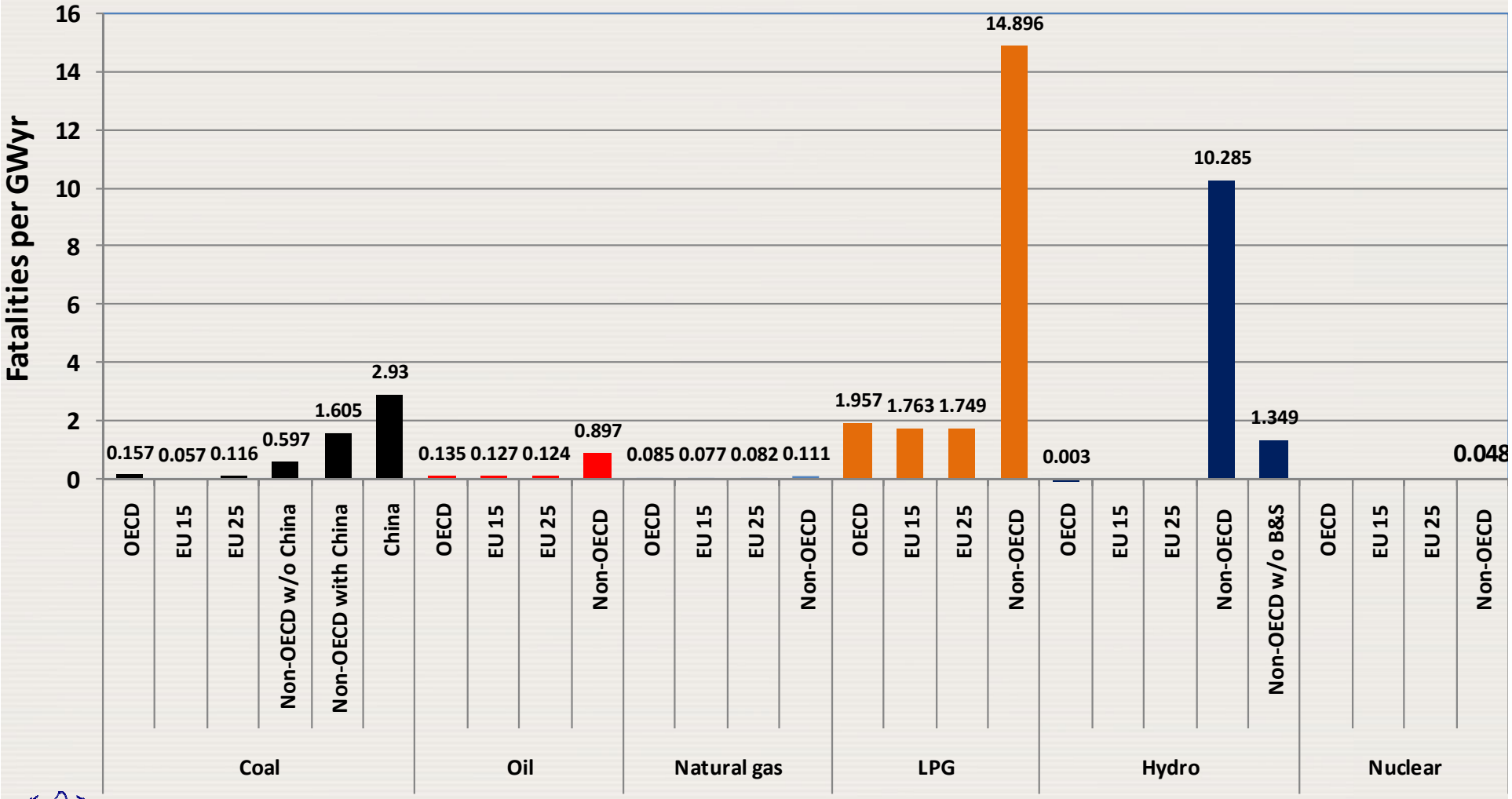
Severe Accident Indicators for OECD and non-OECD Countries



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Source: Burgherr & Hirschberg, 2005

Do not drive into the future by looking in the rear view mirror:

- Yesterday's technology is not tomorrow's
- Innovation ongoing
- With each new investment cycle technology tends to get better

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Innovation: Nuclear power generation

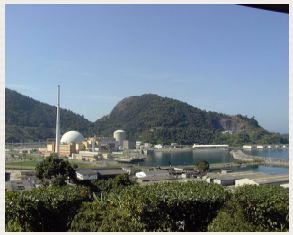
Generation I

Early prototype reactors

- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

Commercial power reactors



- LWR-PWR, BWR
- CANDU
- VVER/RBMK

Generation III

Advanced LWRs & HWRs

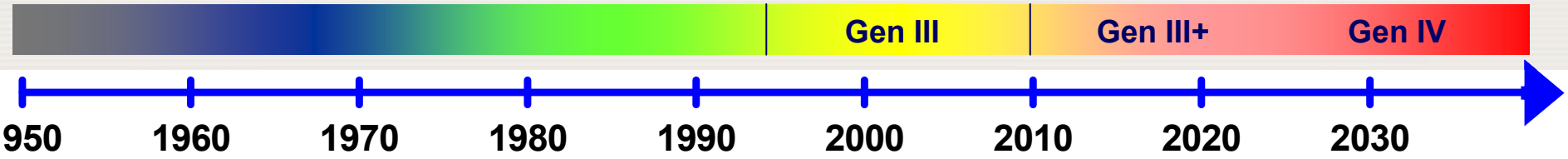
- AP1000, ABWR, System 80+
- ACR
- EPR

Generation III+

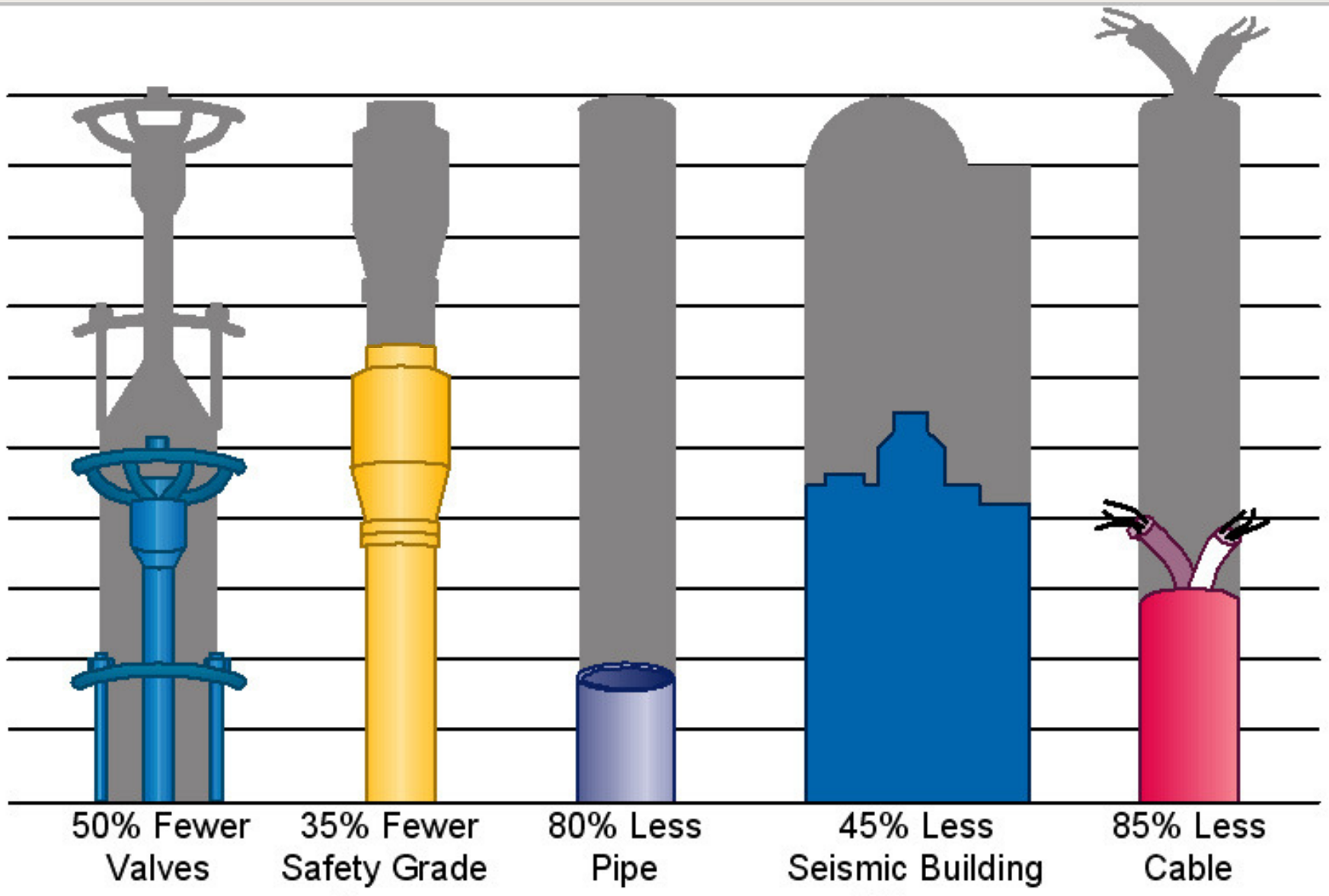
Evolutionary designs with improved economics and safety for near-term deployment

Generation IV

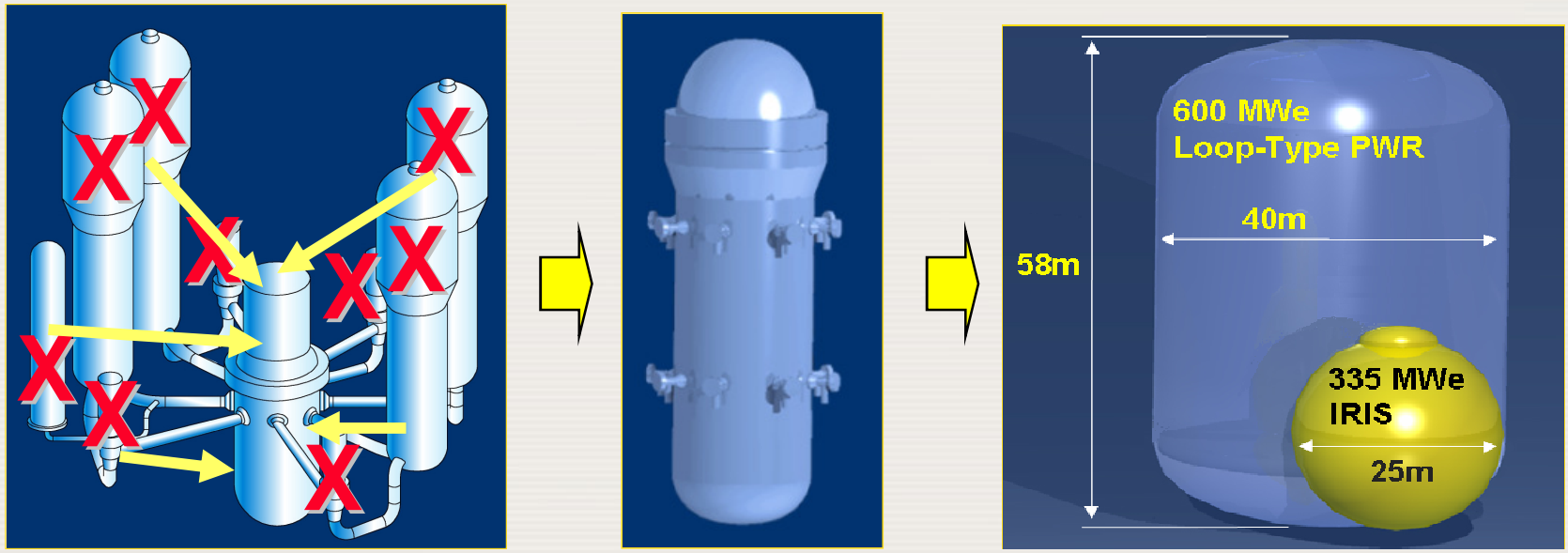
- Highly economical
- Enhanced safety
- Minimal waste
- Proliferation resistant



Innovation: AP 1000



Integral Primary System Reactor (IRIS)



- Simplifies design by eliminating loop piping and external components.
- Enhances safety by eliminating major classes of accidents.
- Compact containment (2 times less power but 9 times less volume, small footprint) enhances economics and security.

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Socio-political compatibility

- **The technology links of the sustainable energy system must be tolerated by the general public.**
- **Satisfying the preceding criteria will prove instrumental in influencing public perceptions and attitudes.**

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Intergenerational compatibility:

- **Energy services must be based on inexhaustible energy sources**
- **Alternatively, the use of finite sources must lead to the creation of sustainable substitutes ("*weak sustainability*")**
- **Wastes from the energy system must not pose a risk to future generations**

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Geopolitical compatibility:

Ideally, energy sources should be evenly distributed geographically, allow for secure supplies and pose no threat to the security of other countries.

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Nuclear weapons proliferation:

- **The genie is out of the bottle**
- **Preventing the misuse of nuclear materials for non-peaceful purposes needs special attention**
- **It is an area where IAEA has a strict mandate**
- **Non-proliferation is a political problem**
- **NPT regimes needs strengthening**

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Demand compatibility:

- **The quality of energy services cannot be inferior to the equivalent services provided by the established system – rather it must have the potential of becoming significantly better.**
- **Supply densities must match demand densities.**

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Global Urbanization and Energy

- Growing populations of South Asia, China and regions of Africa will urbanize at an increasing rate
- Urban residents use several times more energy services provided by different forms of energy what they used in the countryside
- Urbanization increases dependence on electricity

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Connecting the Unconnected

- Large developing countries

- Concentrated demand in megacities

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The future of nuclear power

- The industry is alive and vibrant
- Market liberalization served as a wake-up call
- The industry is heavily engaged in innovation
- The political climate towards the technology has begun to change in many countries
- All credible long-term (>> 2030) demand & supply projections show steep increases in nuclear power

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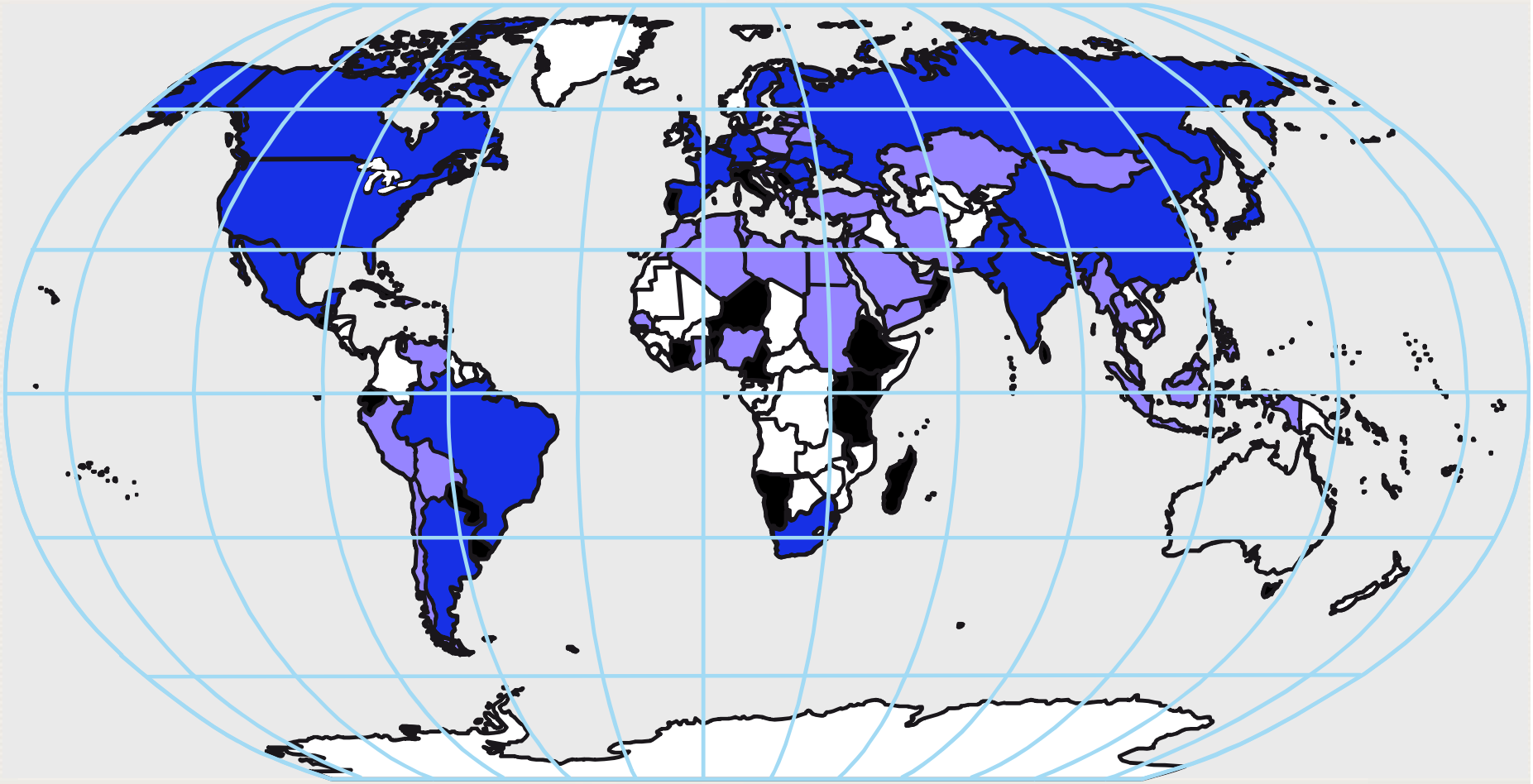
Countries considering nuclear power



Operating (29) Considering (44) Expressing interest (25)

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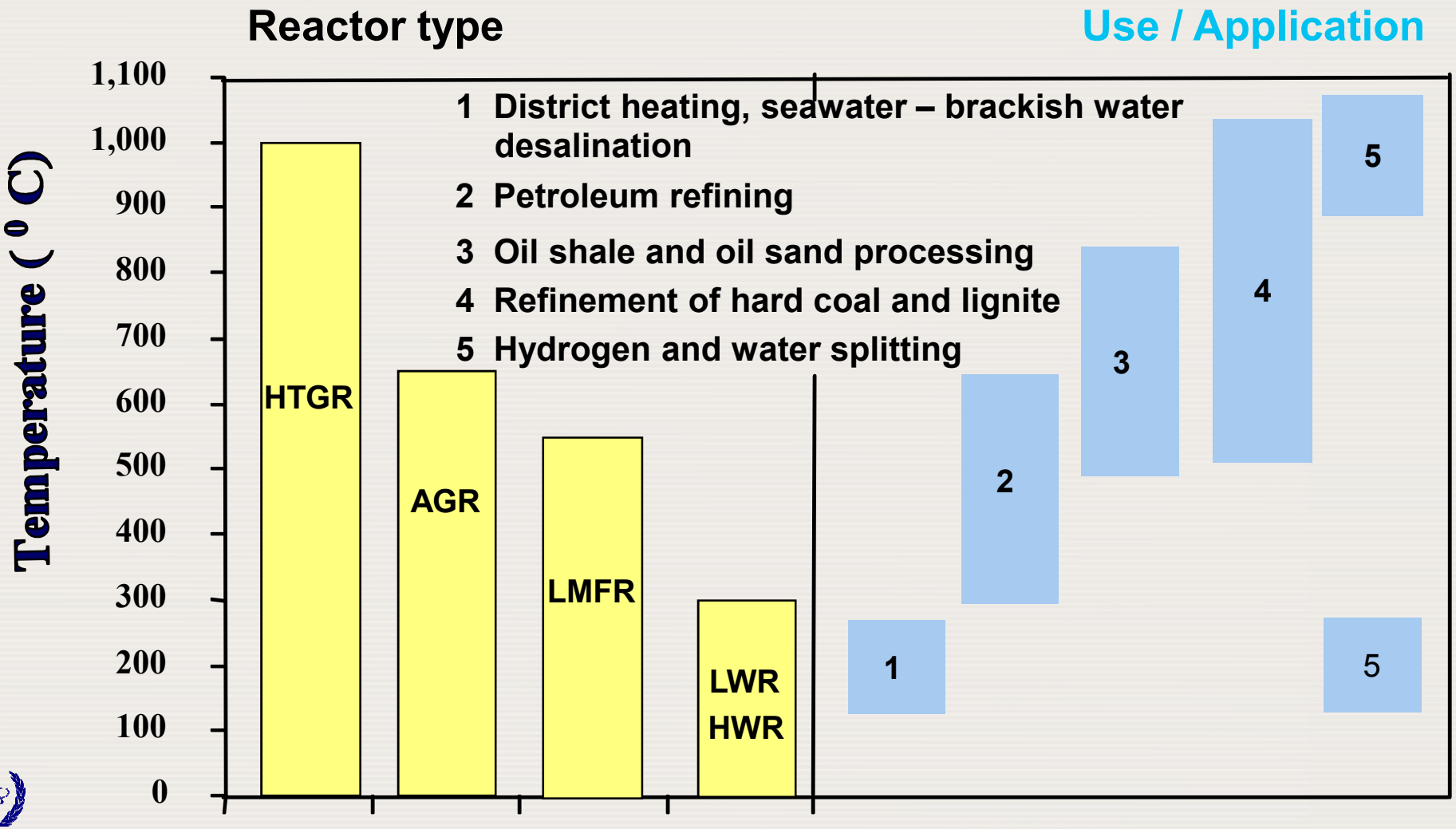
Nuclear energy is more than just electricity generation



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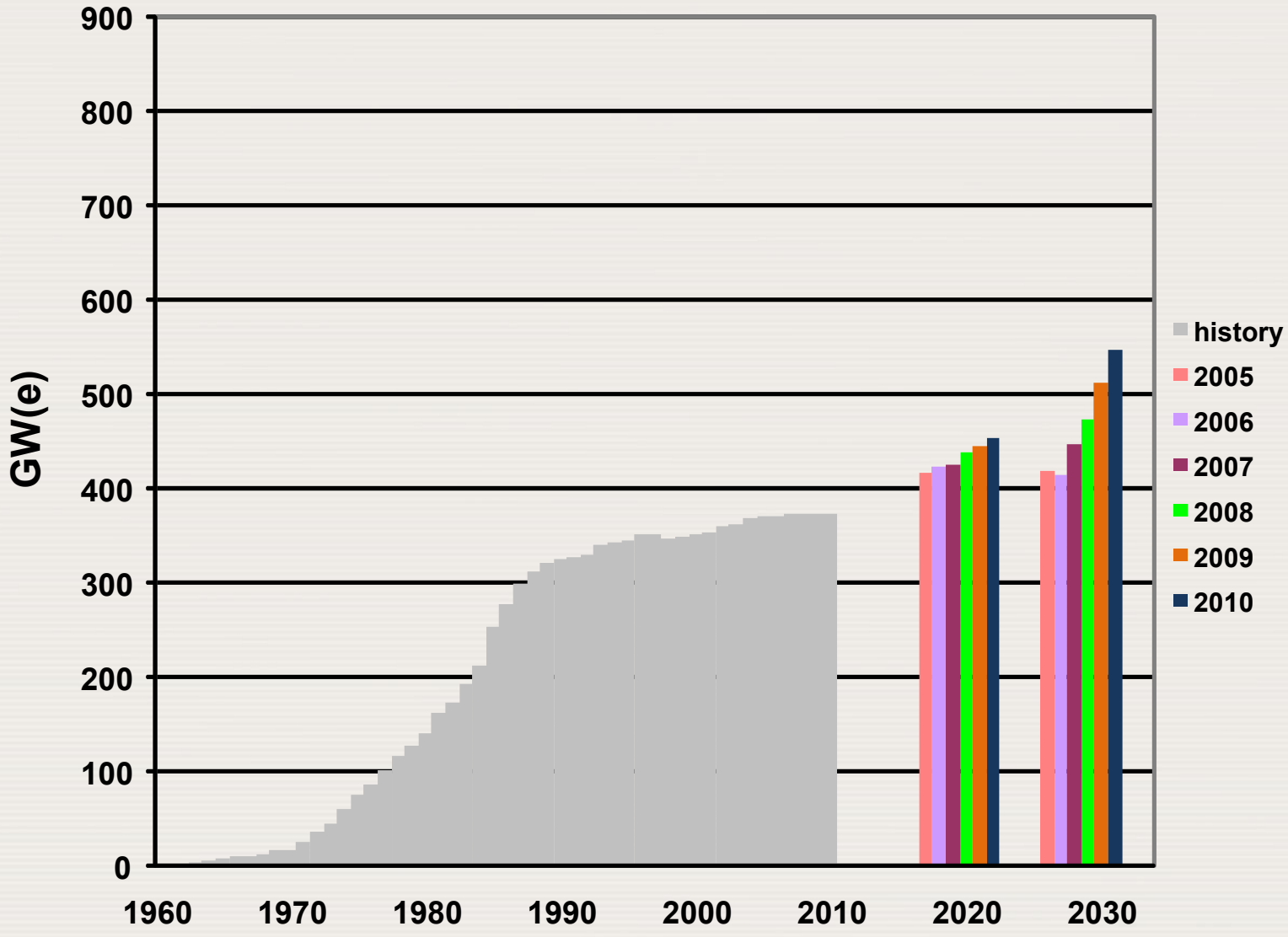
IAEA – LOW Projection



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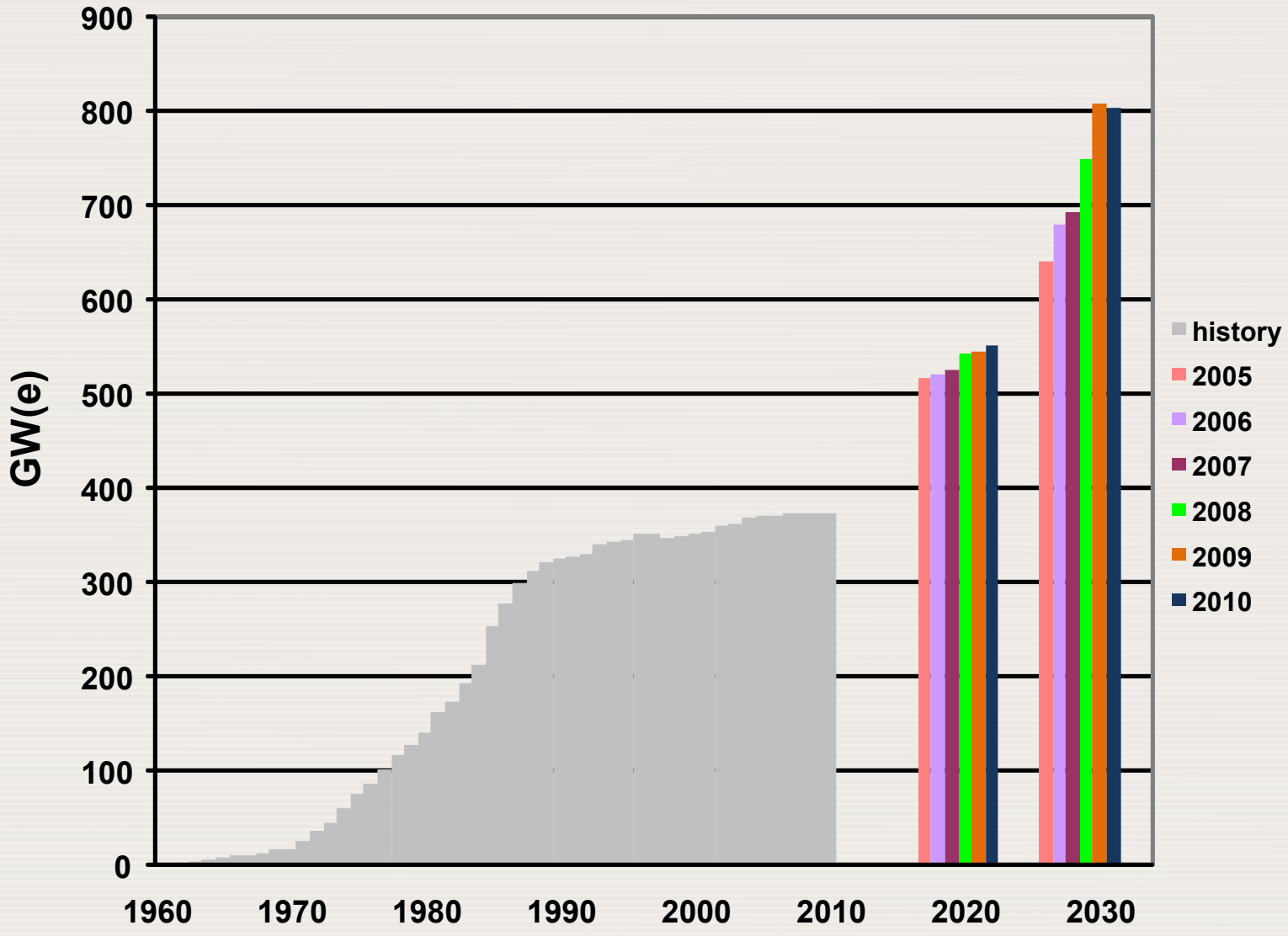
IAEA – HIGH Projection



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Why Nuclear Power?

- Global energy demand is set to grow
- Environmental pressures are rising
- Energy supply security back on the political agenda
- Demand for reliable base load electricity at predictable and affordable costs persists
- Potentially decoupled from natural resource availability
- Innovation improves on yesterday's technology
- Technology spin-offs

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Why Nuclear Power?

- Nuclear base load electricity is economically competitive and provides 14% to global electricity supply
- Nuclear power contributes to supply security and price stability
- Nuclear power virtually avoids air pollution and the emissions of gases threatening climate stability
- Most externalities internalized

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Why Nuclear Power?

- There is no technology without wastes and risks
- Nuclear waste volumes are small and manageable
- On factual balance, nuclear compares well with alternatives
- It is readily available at large scale
- Nuclear power alone is not the “silver bullet” for mitigating climate change and sustainable energy development – but for sure it can be an integral part of any solution

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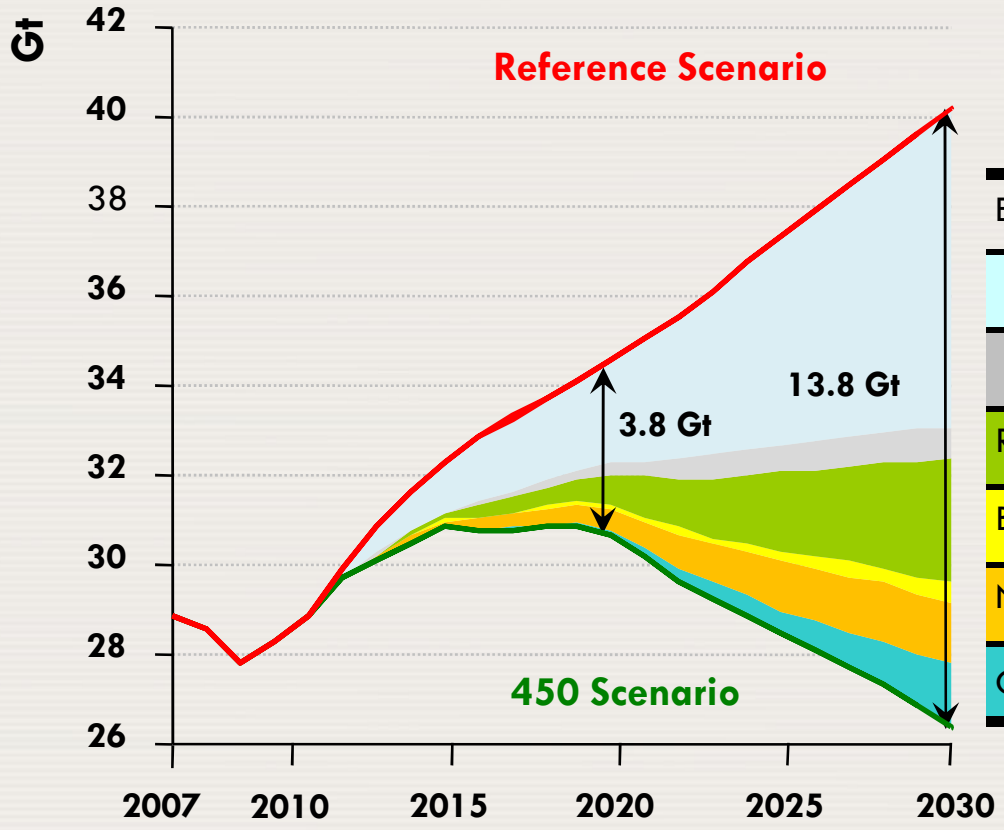
World abatement of energy-related CO_2 emissions in the 450 Scenario



Share of abatement %	2020	2030
Efficiency	65	57
End-use	*59*	*52*
Power plants	*6*	*5*
Renewables	18	20
Biofuels	1	3
Nuclear	13	10
CCS	3	10

Efficiency measures account for two-thirds of the 3.8 Gt of abatement in 2020, with renewables contributing close to one-fifth

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Source: WEO 2009, OECD/IEA, 2009

One size does not fit all

- Countries differ with respect to
  - energy demand growth
  - alternatives
  - financing options
  - weighing/preferences
    - accident risks (nuclear, mining, oil spills, LNG…), cheap electricity, air pollution, jobs, import dependence, climate change
- All countries use a mix. All are different.
- Local conditions determine the optimal supply and technology mix.

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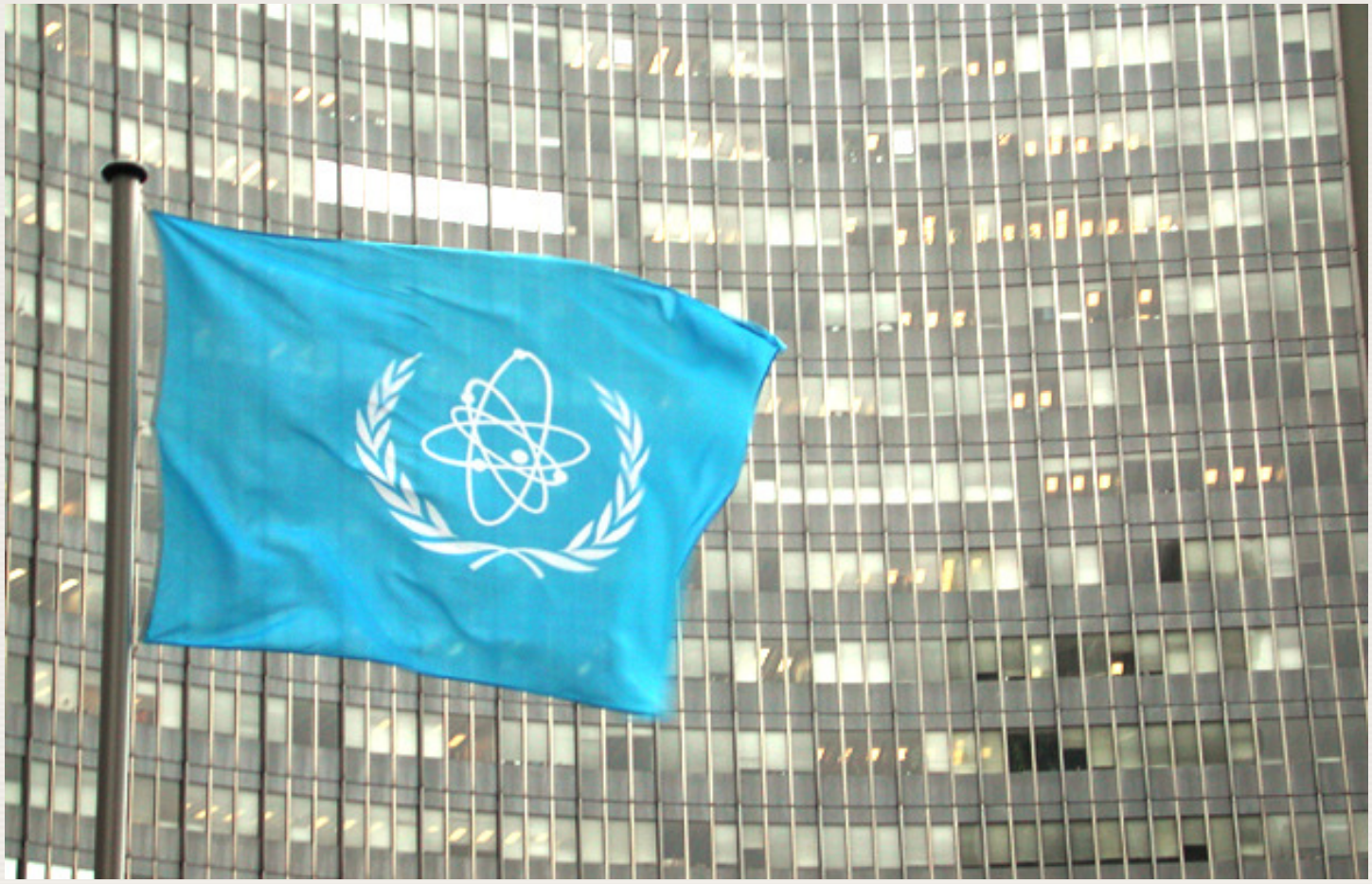

…atoms for peace.

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