

Benefits and Challenges of Nuclear Development Programs

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 - CO₂ emissions
 - Security of supply
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85% of the world's installed nuclear capacity

The NEA mission:

Assist its Member countries in maintaining and further developing, through **international co-operation**, the scientific, technological and legal bases, required for the safe, environmentally friendly and economical use of nuclear energy for peaceful purposes.

OECD/NEA works closely with the IAEA, OECD/IEA, other organizations



The NEA works as:

- A **forum** for sharing information and experience and promoting international co-operation
- A **centre of excellence** which helps Member countries to pool and maintain their technical expertise
- A **vehicle for facilitating policy analyses** and developing consensus based on its technical work

NEA areas of work:

- **Nuclear safety and regulation**
- **Nuclear energy development**
- **Radioactive waste management**
- **Radiological protection and public health**
- **Nuclear law and liability**
- **Nuclear science**

- **The Data Bank**
- **Information and communication**

Presentation of OECD Nuclear Energy Agency



NEA strengths:

- The NEA brings together developed countries in a **small, non-political forum** with a precise, technical focus.
- NEA membership represents much of the **world's best nuclear expertise**.
- Homogeneity of NEA membership: **like-minded approach to problems**, a climate of mutual trust and collaboration, the full exchange of experience, and a frank assessment of issues.
- The NEA is relatively **unfettered by political and bureaucratic constraints**, and is able to focus effectively on the specific needs of its Members.
- The NEA publishes **consensus positions on key issues**, providing Member countries with credible references.
- The NEA operates with a **small staff** (65/90), relying on Member country experts, and provides significant added value.
- The NEA's system of **standing technical committees and its system of work** enables the Agency to be flexible and responsive.
- The NEA, as part of a larger multi-disciplinary organisation, is uniquely placed to address **nuclear energy in the context of broader cross-cutting issues** such as sustainable development.

Renewed interest in nuclear energy

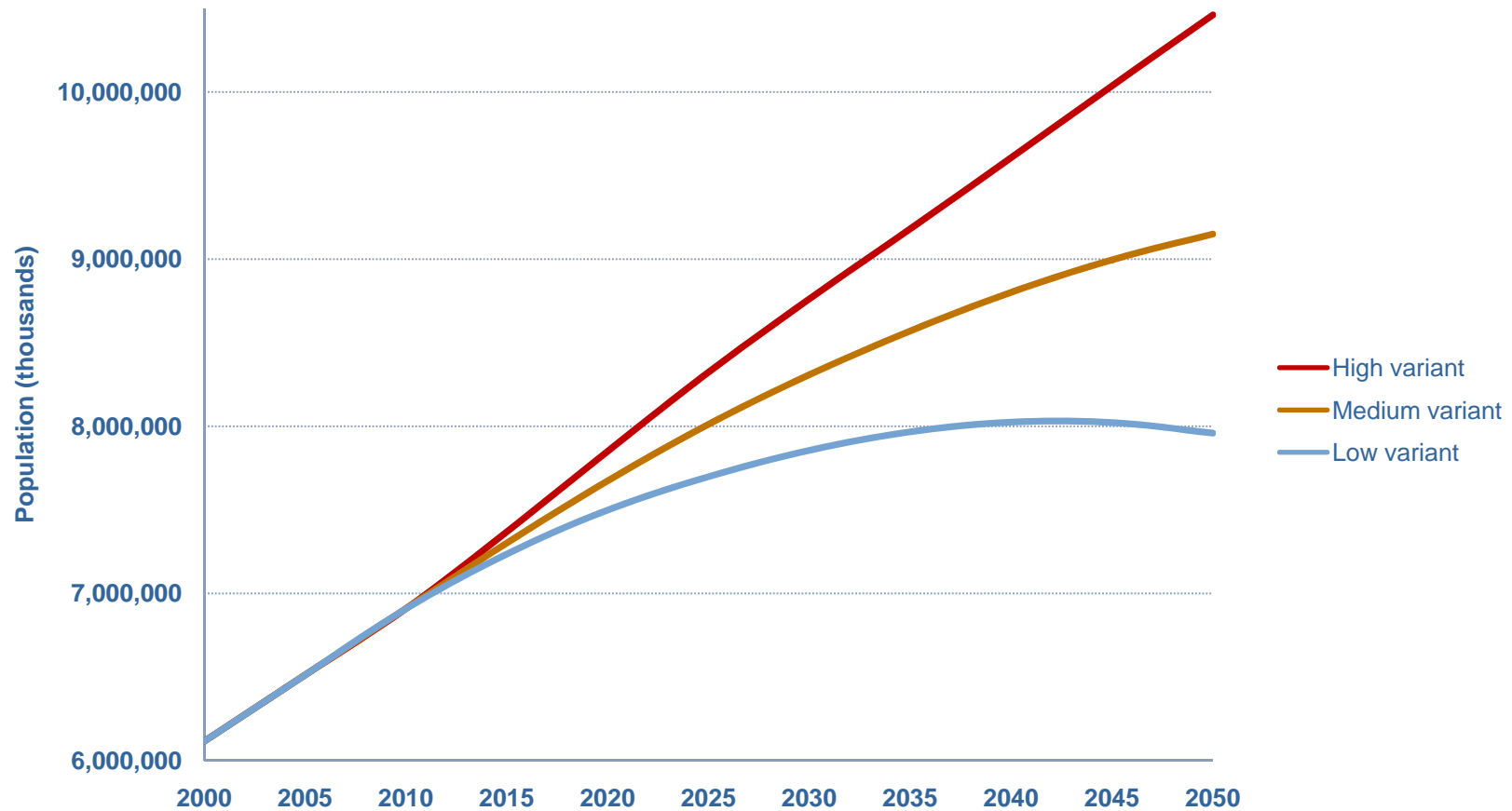
- Growing world population and electricity demand
- CO₂ emissions
- Security of supply

Renewed interest in nuclear energy

Motivation



UN projection of the world population



Source: UN, World Population Prospects: The 2008 Revision

Renewed interest in nuclear energy

Motivation



Figure 6.1 • Electricity demand growth rates by region in the Reference Scenario

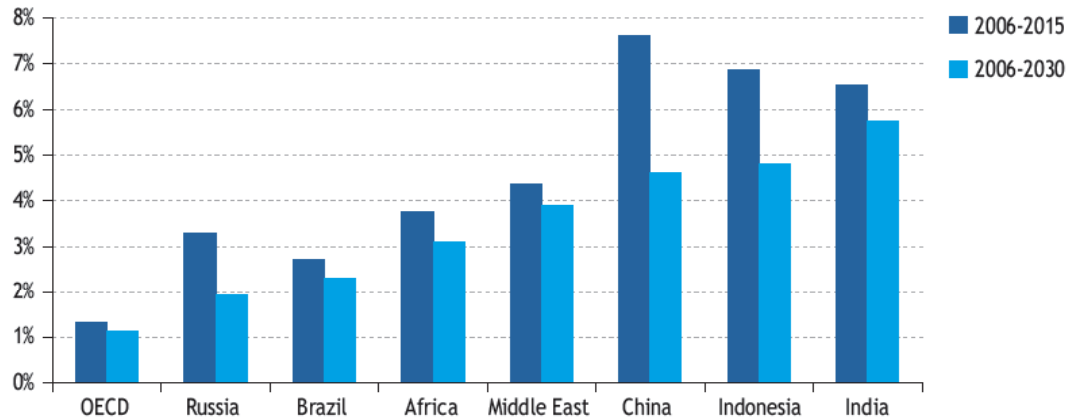
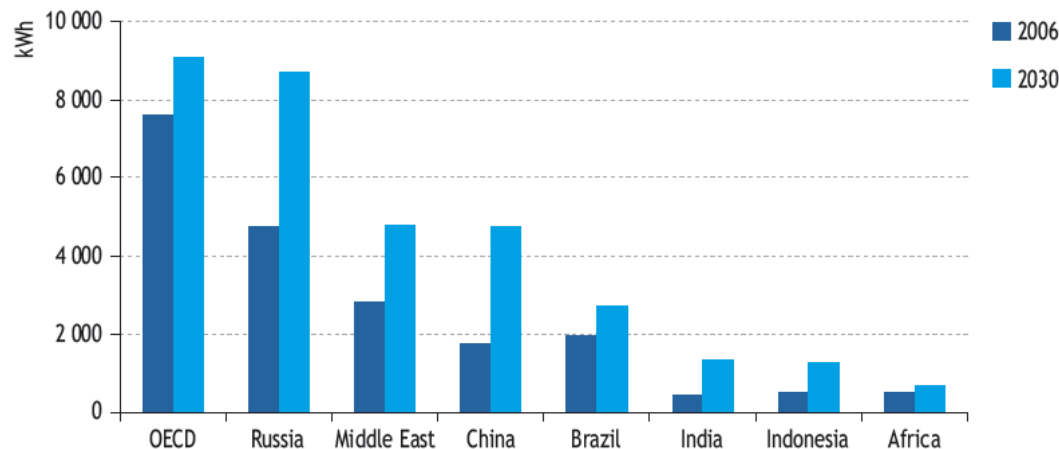


Figure 6.2 • Per-capita electricity demand by selected region in the Reference Scenario



Source: OECD/IEA World Energy Outlook 2008

In 2050:

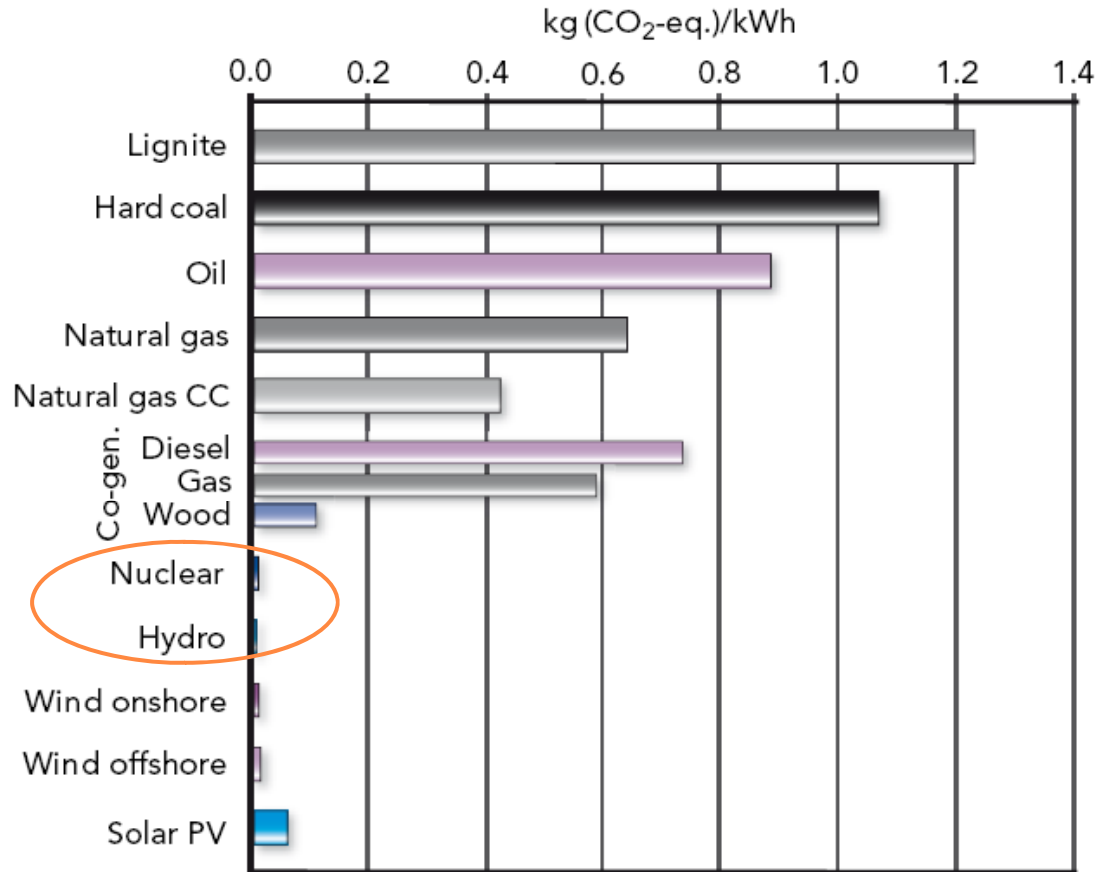
- Population increased by 30-50%
- Electricity demand increased by 150% (~2.5% of annual growth)
- CO₂ emissions must be reduced
- **Role of Nuclear ?**

Renewed interest in nuclear energy

Motivation



Greenhouse gas emissions of selected energy chains



Nuclear Energy:

- Low carbon
- High energetic density
- Predictable operating costs

Source: NEA Nuclear Energy Outlook 2008

Renewed interest in nuclear energy

Scenarios



NEA Low Scenario	NEA High Scenario
Carbon capture and storage at coal-fired plants proves to be successful	Carbon capture and storage proves not to be very successful
Energy from renewable sources is at the high end of expectations	Energy from renewable sources is at the lower end of expectations
Experience with construction of new nuclear power plants is poor	There is early good experience with construction of new nuclear plants
	Public and political concern about climate change and security of supply continues to increase
	Carbon trading schemes are widely introduced and prove to be successful in establishing a value for avoided emissions
Public and political acceptance of nuclear power is low.	There is an increased level of public and political acceptance of nuclear power.

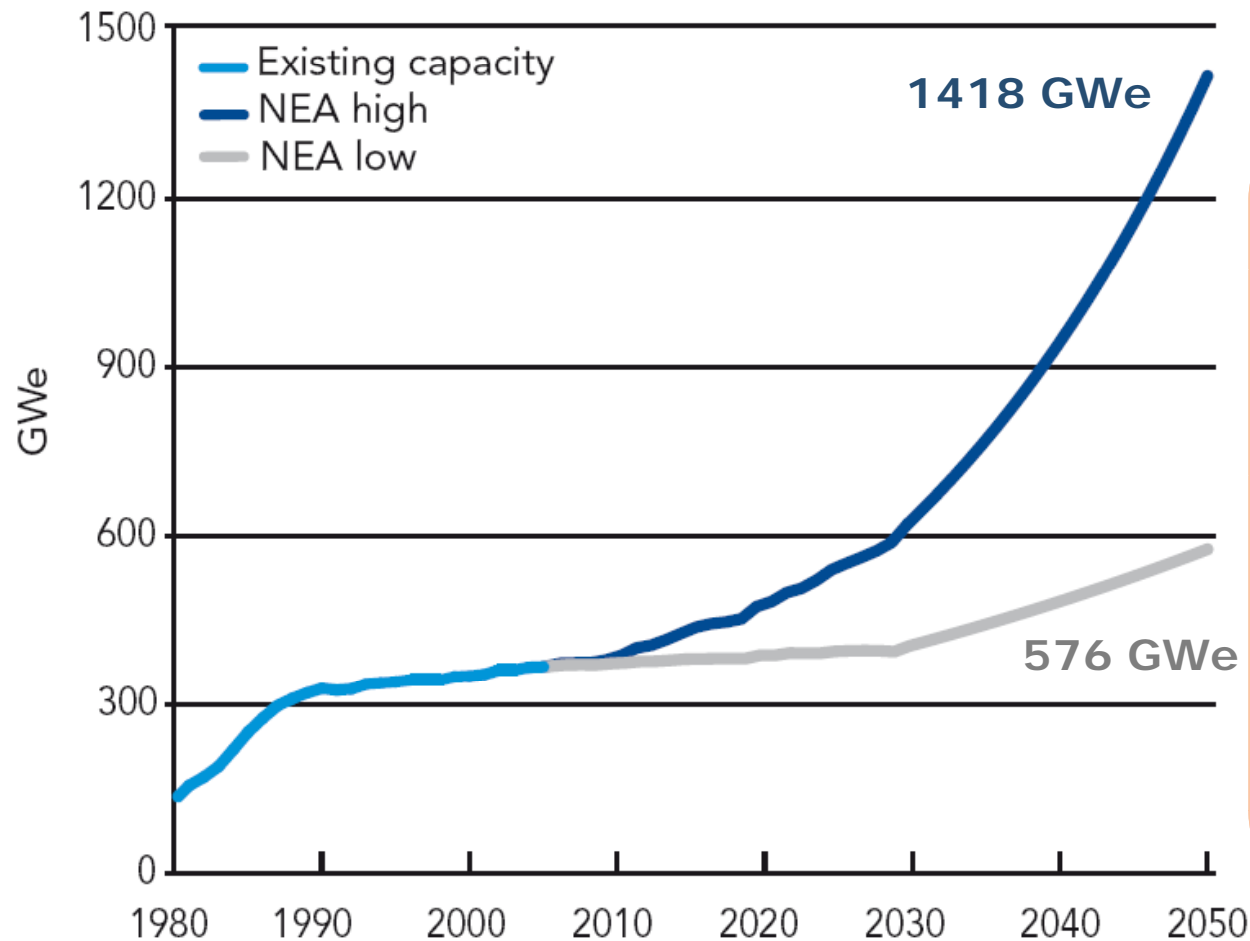
Source: NEA Nuclear Energy Outlook 2008

Renewed interest in nuclear energy

Scenarios



Global nuclear capacity in the NEA high and low scenarios



Source: NEA Nuclear Energy Outlook 2008

In 2050:

- o Nuclear capacity increased by 40%(low) to 200%(high) in 2050, mainly with LWRs

- o The share of nuclear in the worlds power supply in 2050 is 9%(low) to 22%(high)

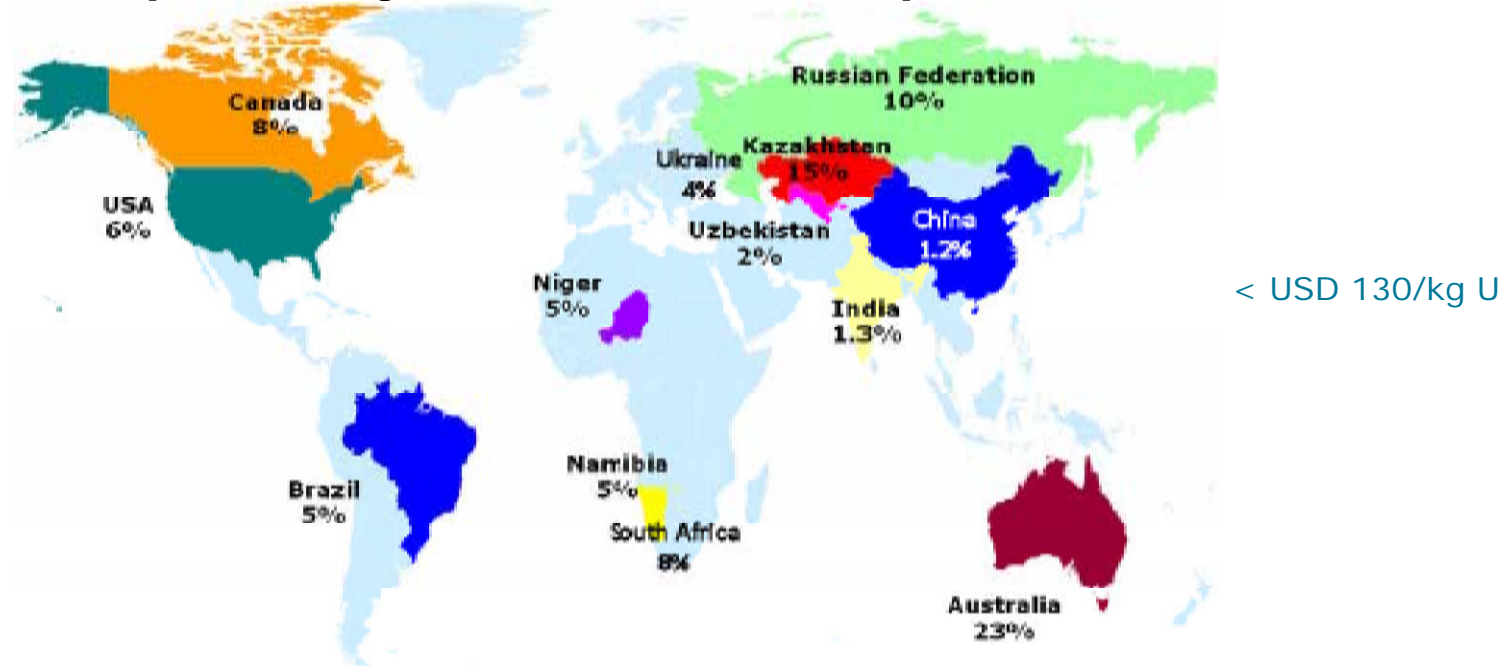
(16% today)

Renewed interest in nuclear energy

Security of Supply



Diverse, politically stable sources of plentiful uranium



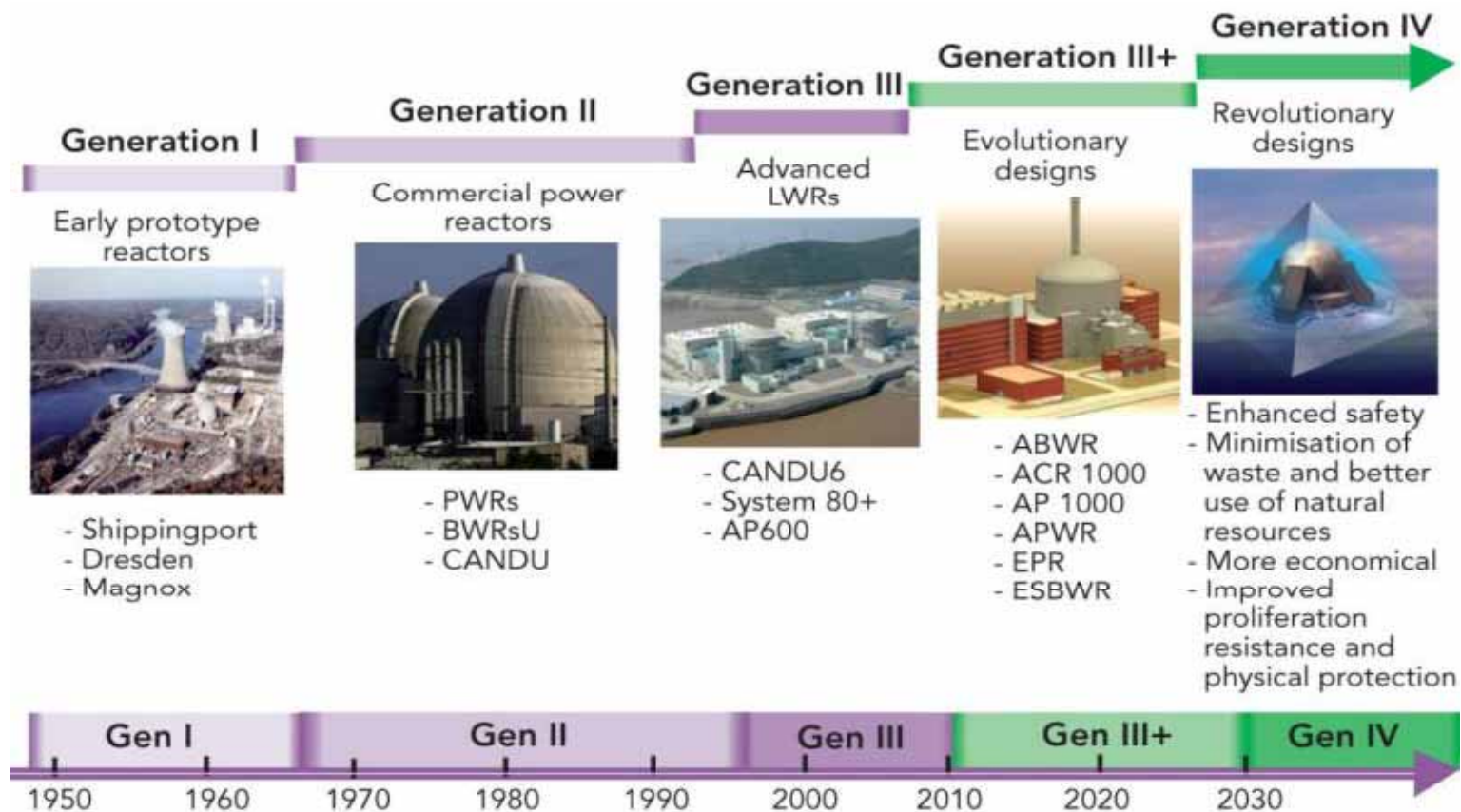
- Currently **identified uranium resources** are sufficient to fuel **all** NPPs in the NEA high scenario to 2030.
- Identified resource base can be expected to increase in size, potentially extending **uranium supply to more than 100 years** (NPP fleet 3 times larger than today), using a once-through fuel cycle.
- If global nuclear renaissance (i.e. NEA high scenario): **increased production needed** and the successful **deployment of advanced reactor and fuel cycle** technologies around 2050.

Roadmap for nuclear energy

- Generation IV International Forum
- Waste management
- Essential element: Manpower

Generations of Nuclear Technology

Nuclear expansion will mainly rely on current technology



Goals for Generation IV Nuclear Energy Systems

Sustainability

- Environmental objectives, long-term availability of systems, effective fuel utilization
- Minimize and manage nuclear waste, notably reduce the long-term stewardship burden

Economics

- Clear life-cycle cost advantage over other energy sources.
- Level of financial risk comparable to other energy projects.

Safety and Reliability

- Operations will excel in safety and reliability.
- Will have a very low likelihood and degree of reactor core damage.
- No need for offsite emergency response.

Proliferation Resistance and Physical Protection

- Unattractive and the least desirable route for diversion or theft of weapons-usable materials, increased physical protection against acts of terrorism.

The content of typical irradiated nuclear fuel



Valuable materials (96%)

Uranium
(94 to 96 %)

Plutonium
(1 %)



Reprocessing & Recycling

Wastes (4%)

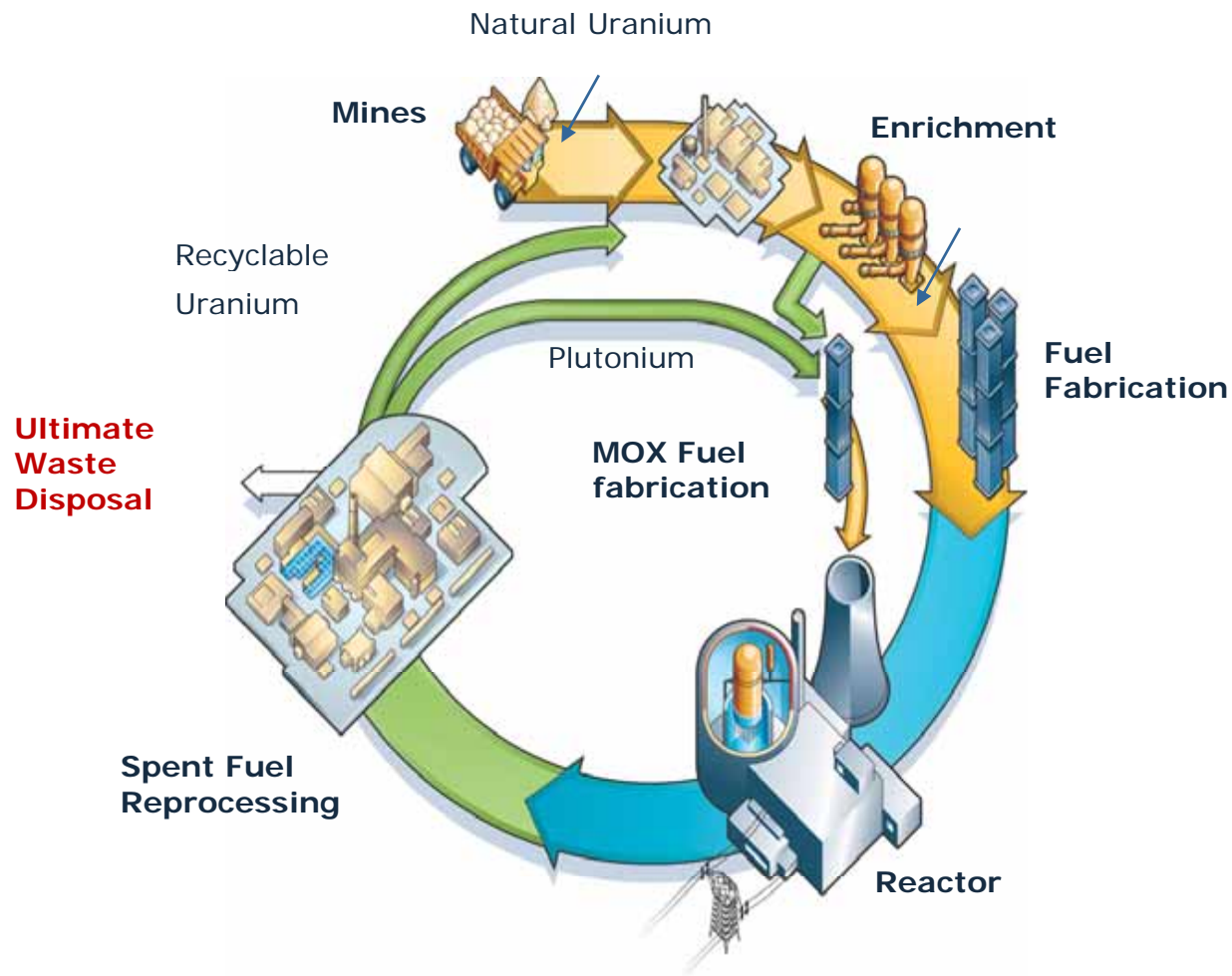
Fission Products
(3 to 5 %)

Minor Actinides
(0,1 %)

Roadmap for nuclear energy

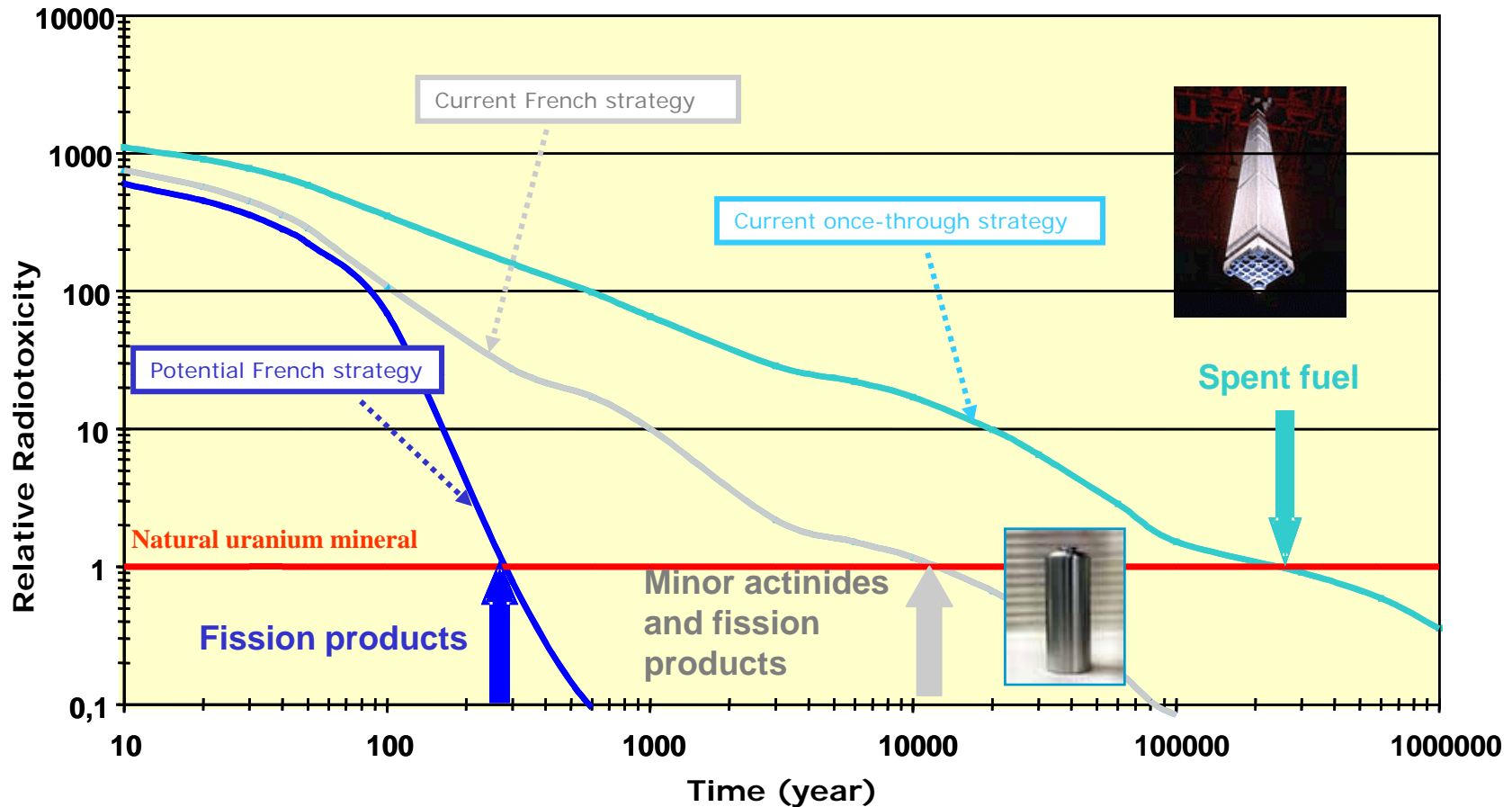
Evolution of Nuclear Power: Closing the fuel cycle

Uranium and plutonium recycling



Roadmap for nuclear energy

Evolution of Nuclear Power: Closing the fuel cycle



Minimizing and managing the nuclear waste:

If fully recycled, the radio-toxicity of the ultimate waste decreases down to natural uranium radio-toxicity in 300 years

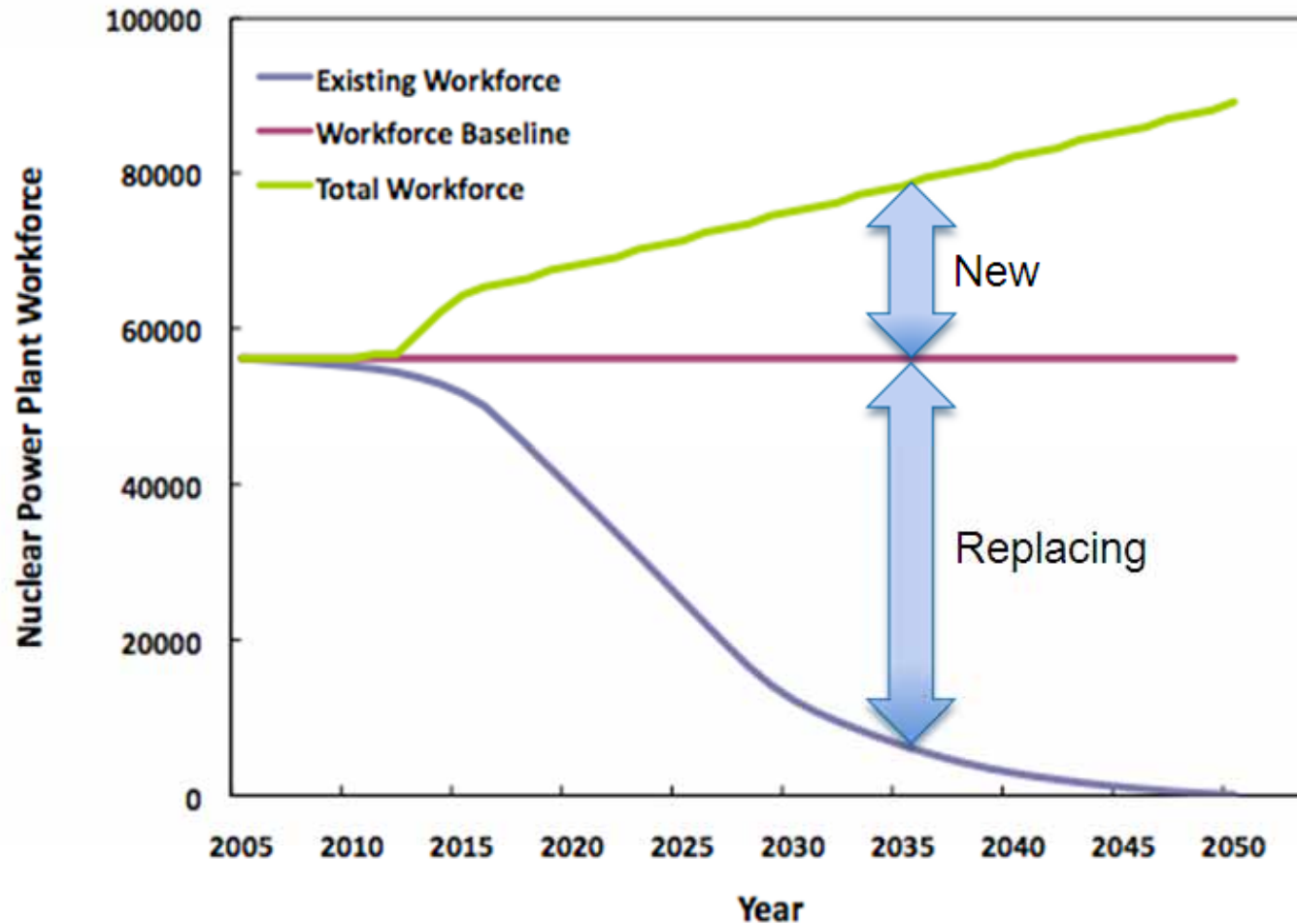
Roadmap for nuclear energy

Essential element: Manpower



Example: US demand for operating personnel

Operating personnel needed for retaining market share in nuclear power



Source: Ning Li et. al, ICAPP-2009

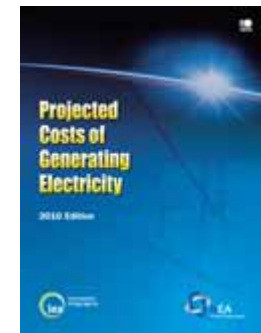
Economical challenges of current and future nuclear development

- Competitiveness of nuclear power generation
- Financing nuclear power plants

Projected Costs of Generating Electricity: 2010 Edition

published on 25 March 2010 is the 7th Edition in the series of Joint IEA/NEA studies (since 1983)

- Presents **base load power generation costs** for 190 power plants with different technologies in 21 countries (date of commissioning 2015).
- The study assumes, for the first time, a **CO₂ price of 30 USD/tonne** and long-term fossil fuel prices based on **WEO 2009**.
- The cost of electricity will depend on a number of **key parameters**, in particular the **cost of raising finance** and the **price of carbon**.



Projected Costs of Generating Electricity: 2010 Edition

- Data from 17 OECD and 4 non-OECD countries (Brazil, China, Russia, South Africa), including a wide range of technologies:
 - **Nuclear:** 20 light water reactors
 - **Gas:** 25 plants of which 22 CCGT (Combined cycle gas turbine)
 - **Coal:** 34 plants of which 22 SC/USC (Supercritical/Ultra-supercritical)
 - **Carbon capture:** 14 coal-fired and 2 gas-fired plants with CC(S) - carbon capture (and storage)
 - **Renewables:** 72 plants: 18 onshore wind, 8 offshore wind, 17 solar PV, 3 solar thermal, 14 hydro, 3 geothermal, 3 biogas, 3 biomass, 1 tidal and 2 wave
 - **CHP:** 20 plants, of which 13 gas, 3 coal, 3 biomass, 1 biogas and municipal waste
- Extensive range of **sensitivity analyses** to changes in key cost parameters (interest rate, fossil fuel and CO₂ prices, construction costs, lead times, lifetimes, load factors) based on “Median Case”

Challenges of nuclear development

Competitiveness



Each technology has strengths and weaknesses

Nuclear delivers significant amounts of low-carbon electricity at stable costs – but has to manage high amounts of capital at risk and is faced with perception issues regarding decommissioning, waste management and proliferation

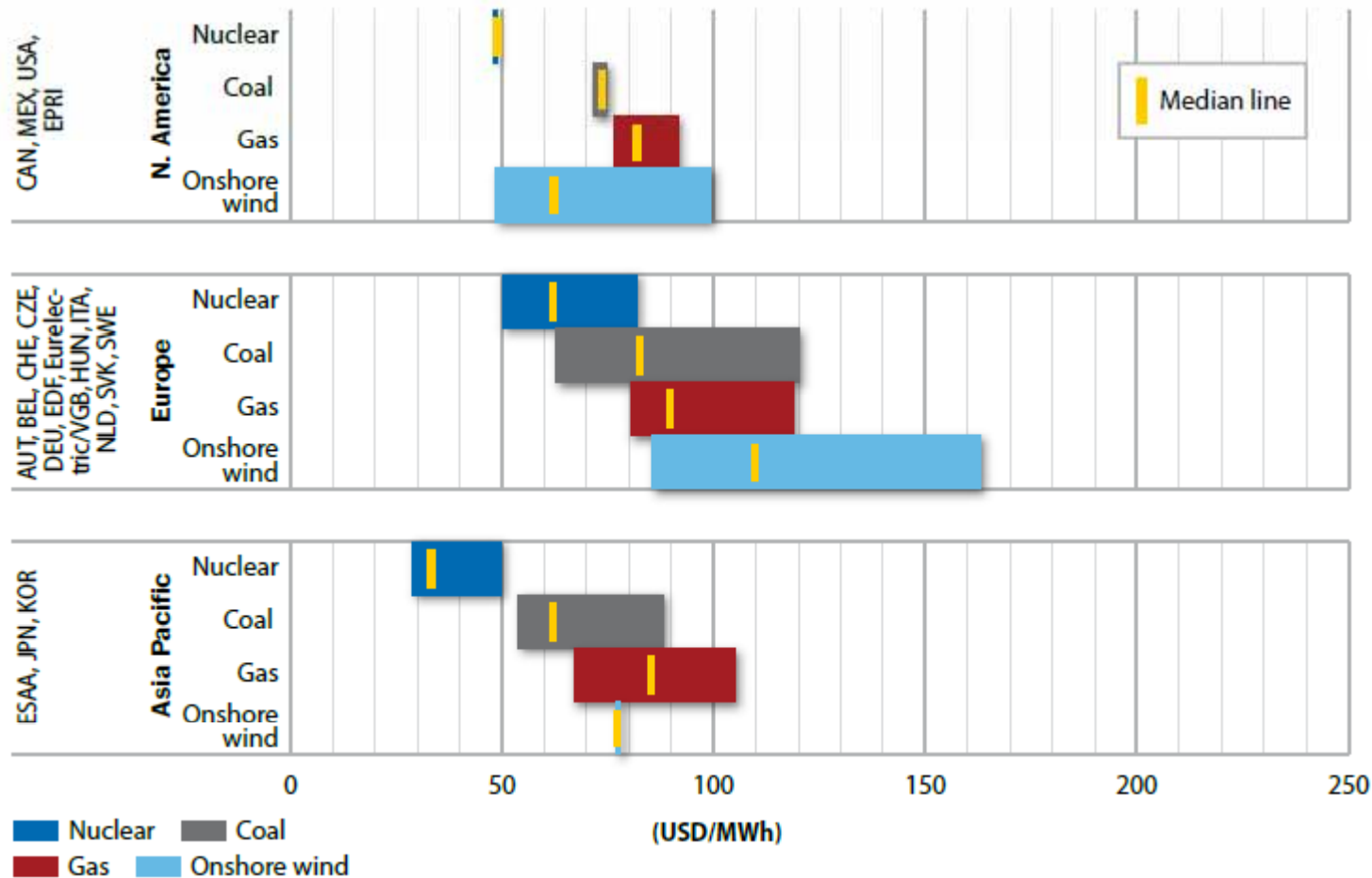
Coal is competitive in the absence of a sufficiently high carbon price – but this advantage is quickly reduced as CO₂ cost rises

Carbon Capture may be a competitive low-carbon generation option – but has not yet been demonstrated at commercial scale for power plants

Gas key advantages are its low capital cost, low CO₂ profile and high operational flexibility, which make it a low risk option – but costs highly depend on gas price levels which may make it not profitable as base load power

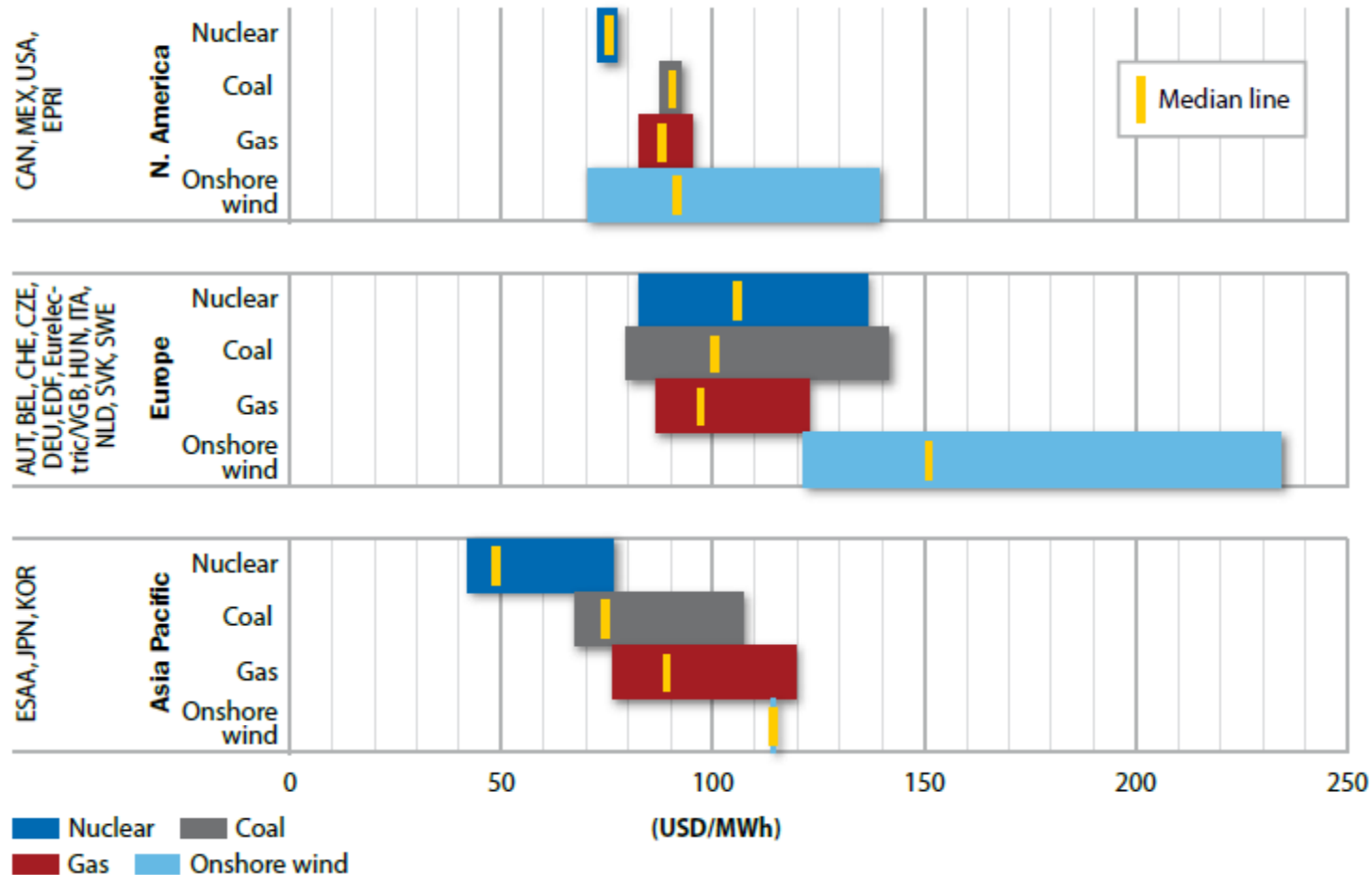
Hydro and, for the first time **onshore wind**, are shown to be competitive in cases where local conditions are favourable. But if not dispatchable, renewables cannot be used for base load.

Regional ranges of LCOE for nuclear, coal, gas and onshore wind plants at 5% real interest rate



Median case: With financing costs at 5%, nuclear, followed by CC(S) – both capital-intensive, low-carbon technologies – are the most competitive solutions.

Regional ranges of LCOE for nuclear, coal, gas and onshore wind plants at **10% real interest rate**

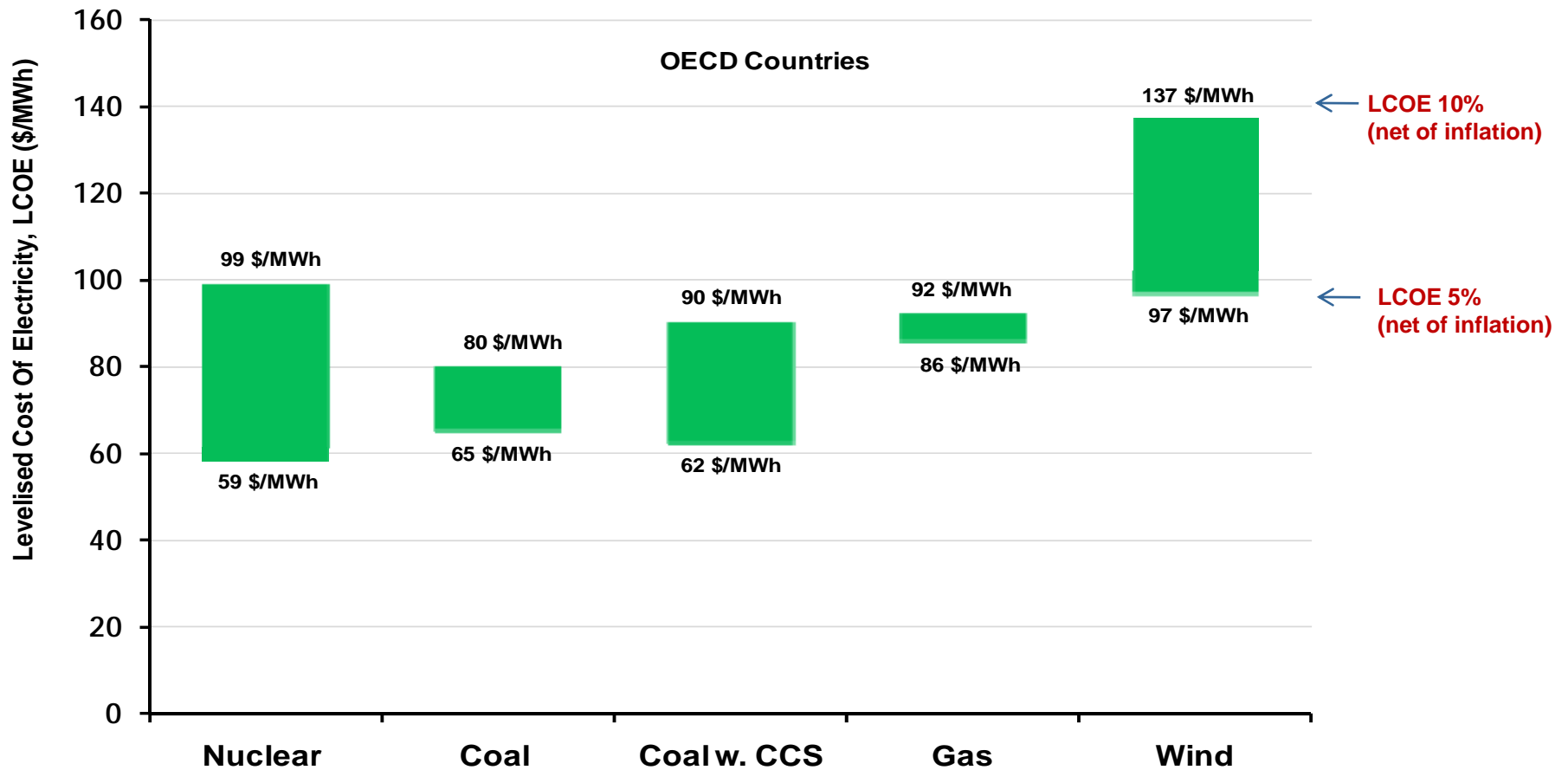


Median case: With financing costs at 10%, coal-fired generation, followed by coal with CC(S), and CCGTs are the cheapest sources of electricity.

Main Conclusions: Median Case - Sensitivity to Cost of Financing



LCOE: Levelized Cost of Electricity, in 2008 USD

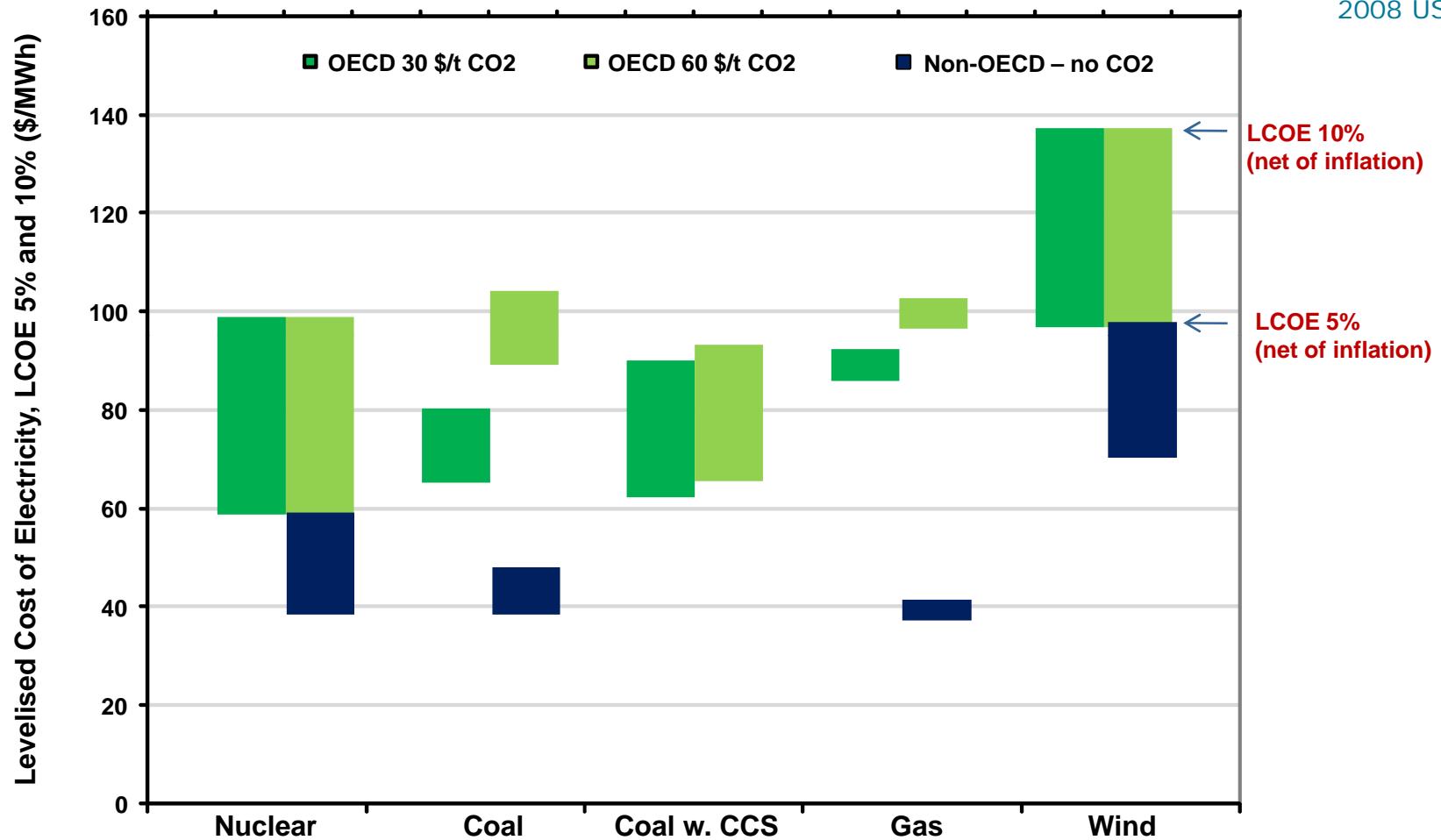


No technology has a clear overall advantage globally or even regionally.

Main Conclusions: Median Case - Sensitivity to CO₂ cost

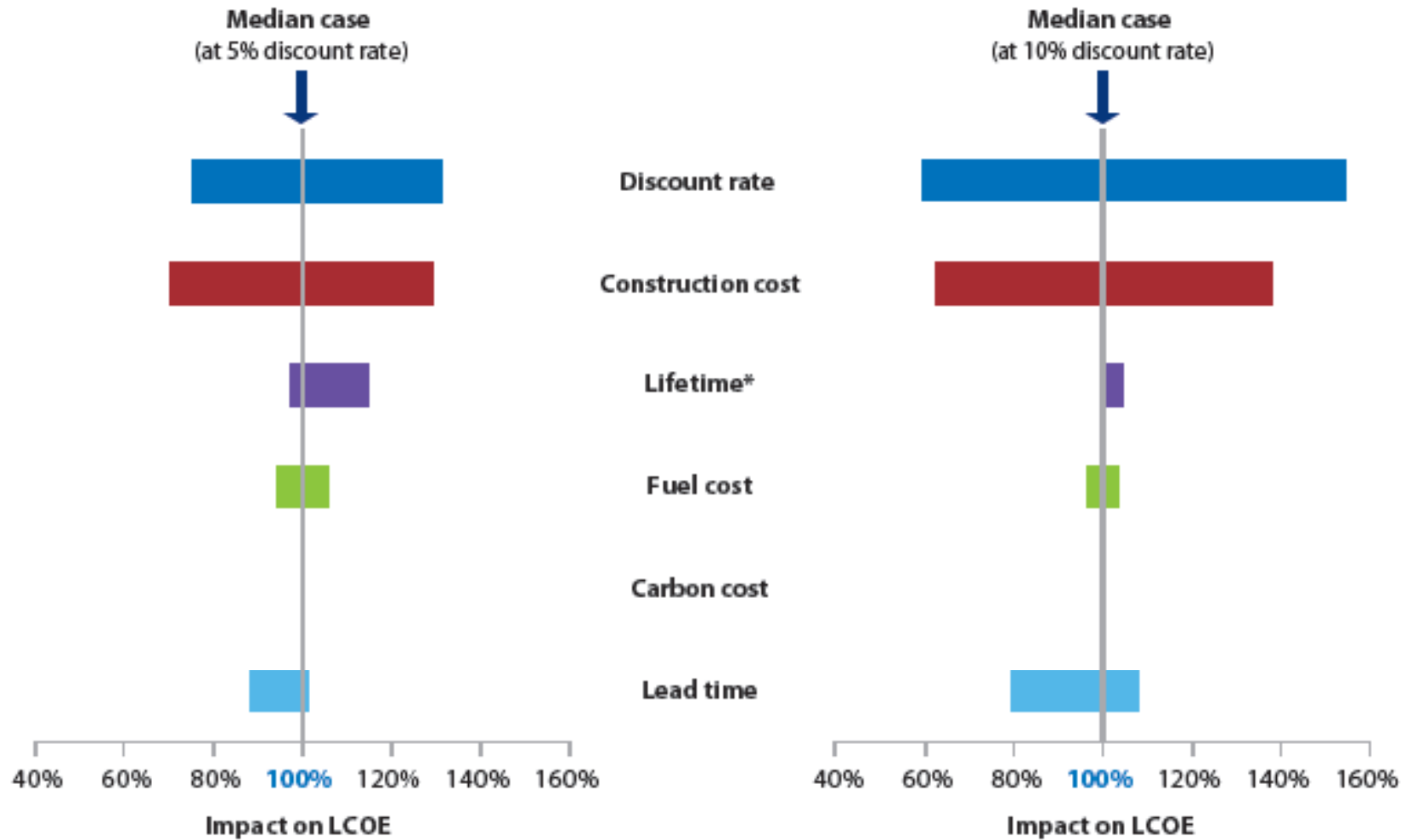


2008 USD



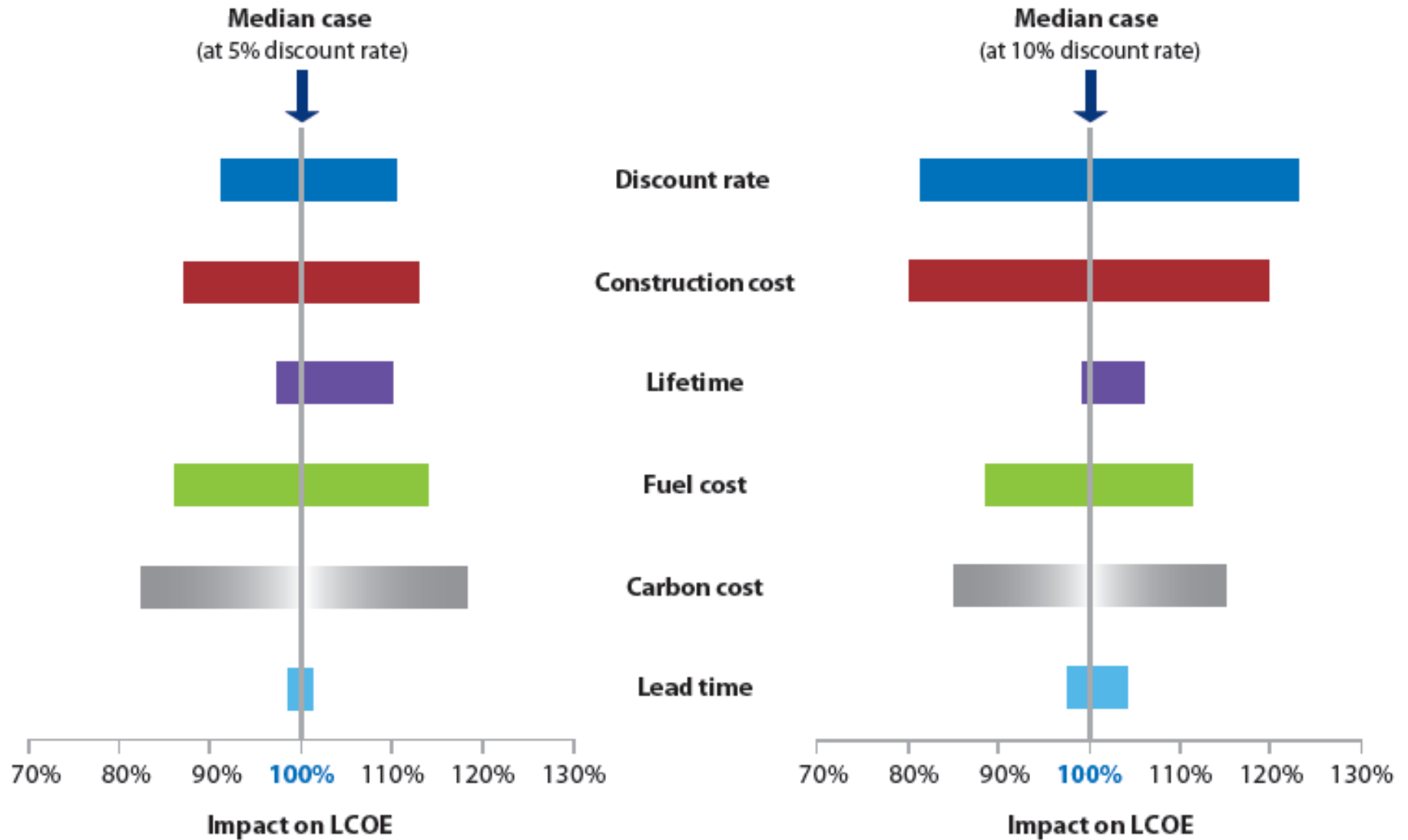
To bolster competitiveness of low-carbon technologies such as nuclear, renewables and CCS decisively, strong government action to lower the cost of financing and a significant CO₂ price signal is needed.

Nuclear: Sensitivity analysis to $\pm 50\%$ variation

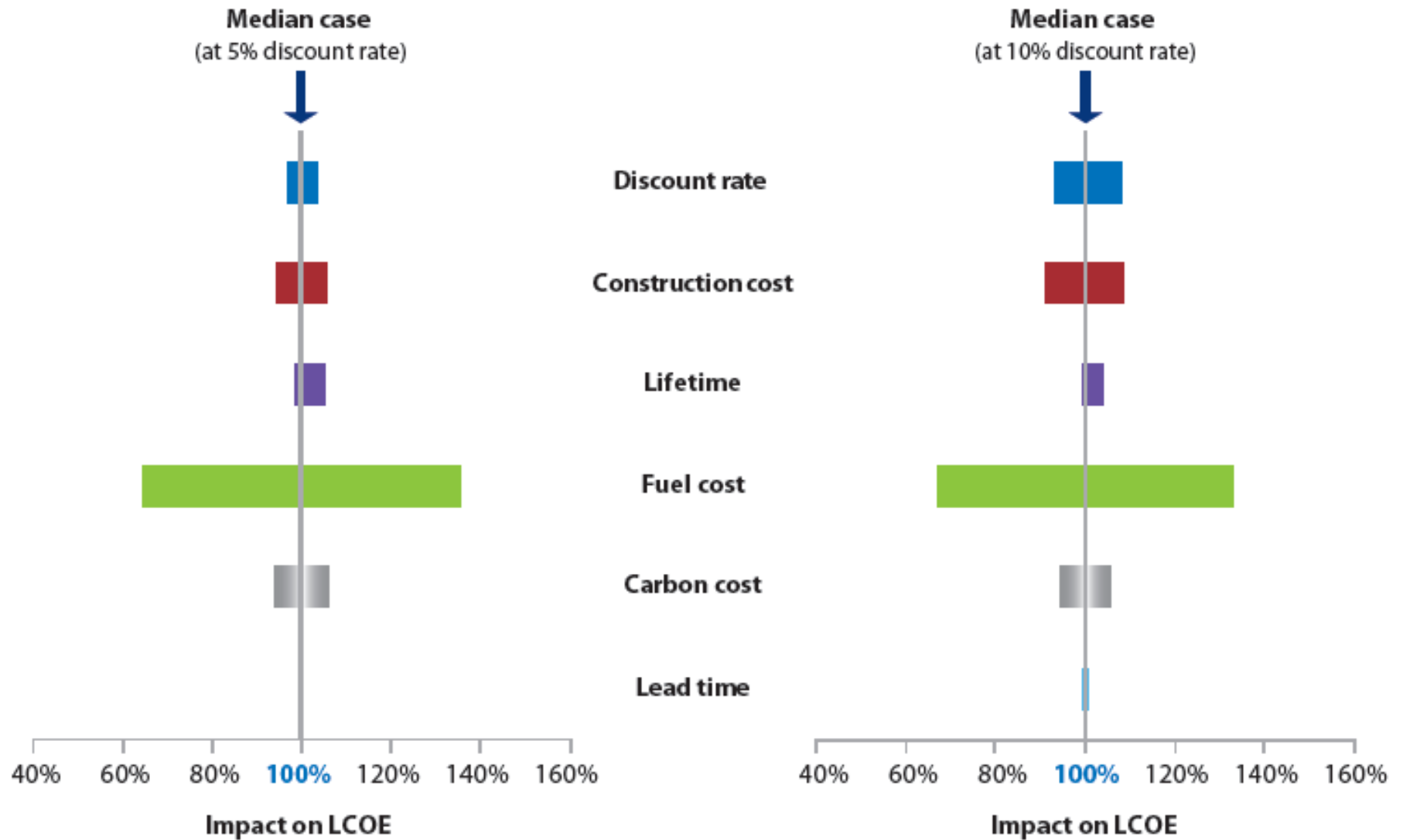


* Lifetime and LCOE are inversely related, as a lifetime extension results in total levelised cost reduction and a lifetime decrease leads to a generation cost increase.

Coal: Sensitivity analysis to $\pm 50\%$ variation



Gas: Sensitivity analysis to $\pm 50\%$ variation



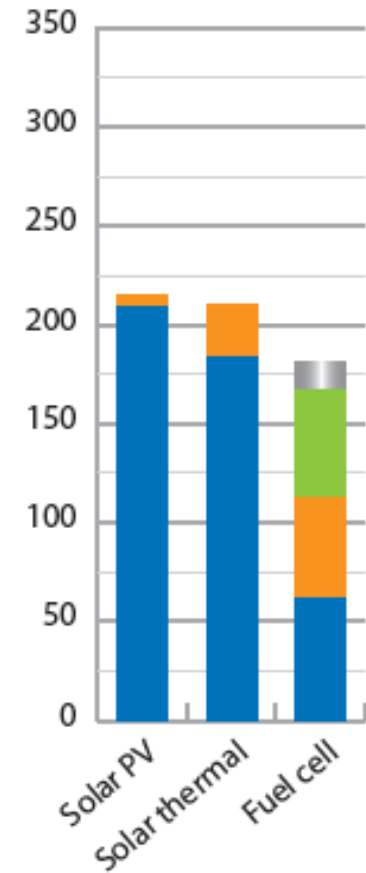
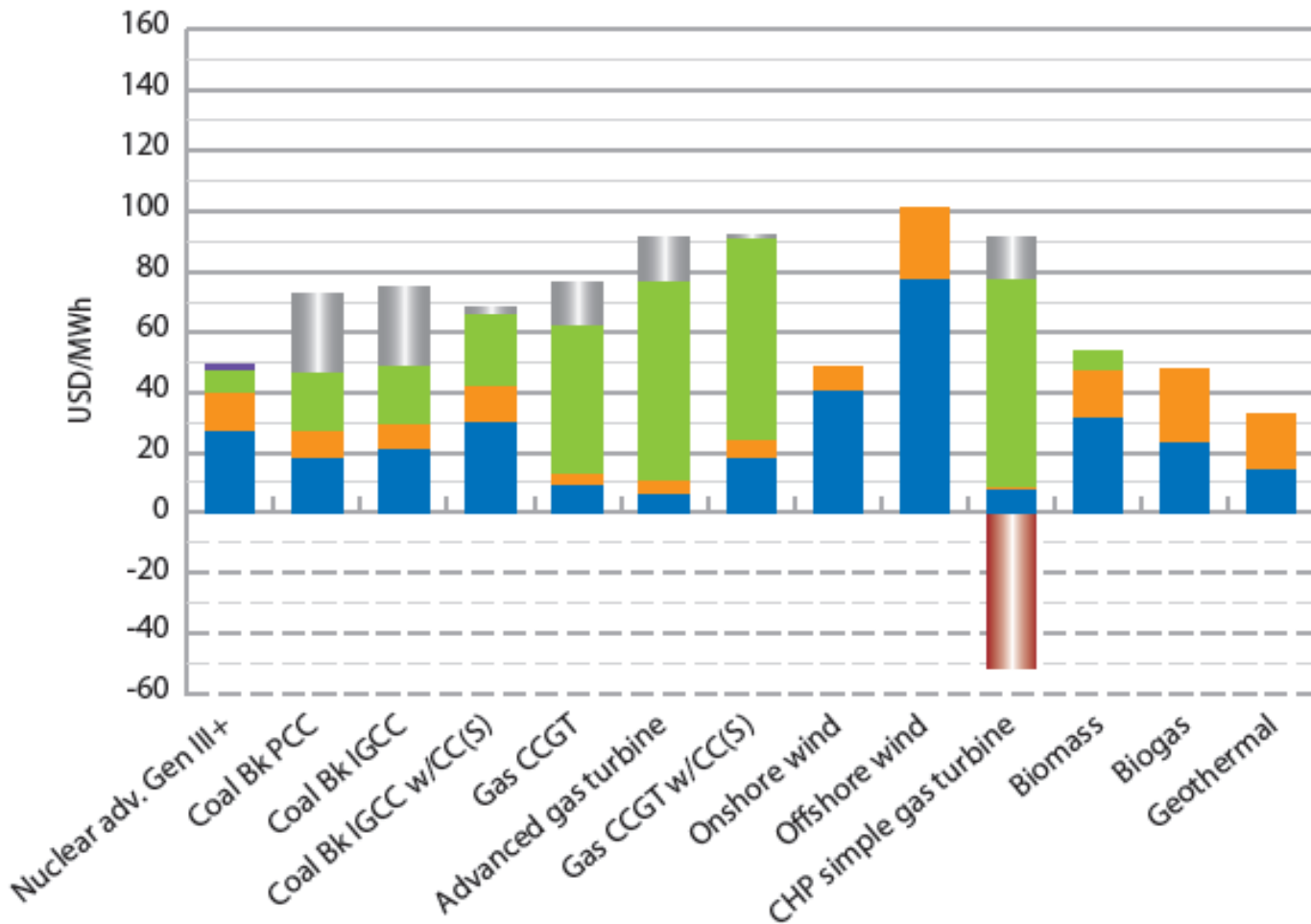
The case of the USA

Levelized Cost of Electricity



At 5% discount rate

2008 USD



Note: The load factor of onshore wind is 41%

Investment costs O&M Fuel costs Waste management CHP heat credit Carbon cost

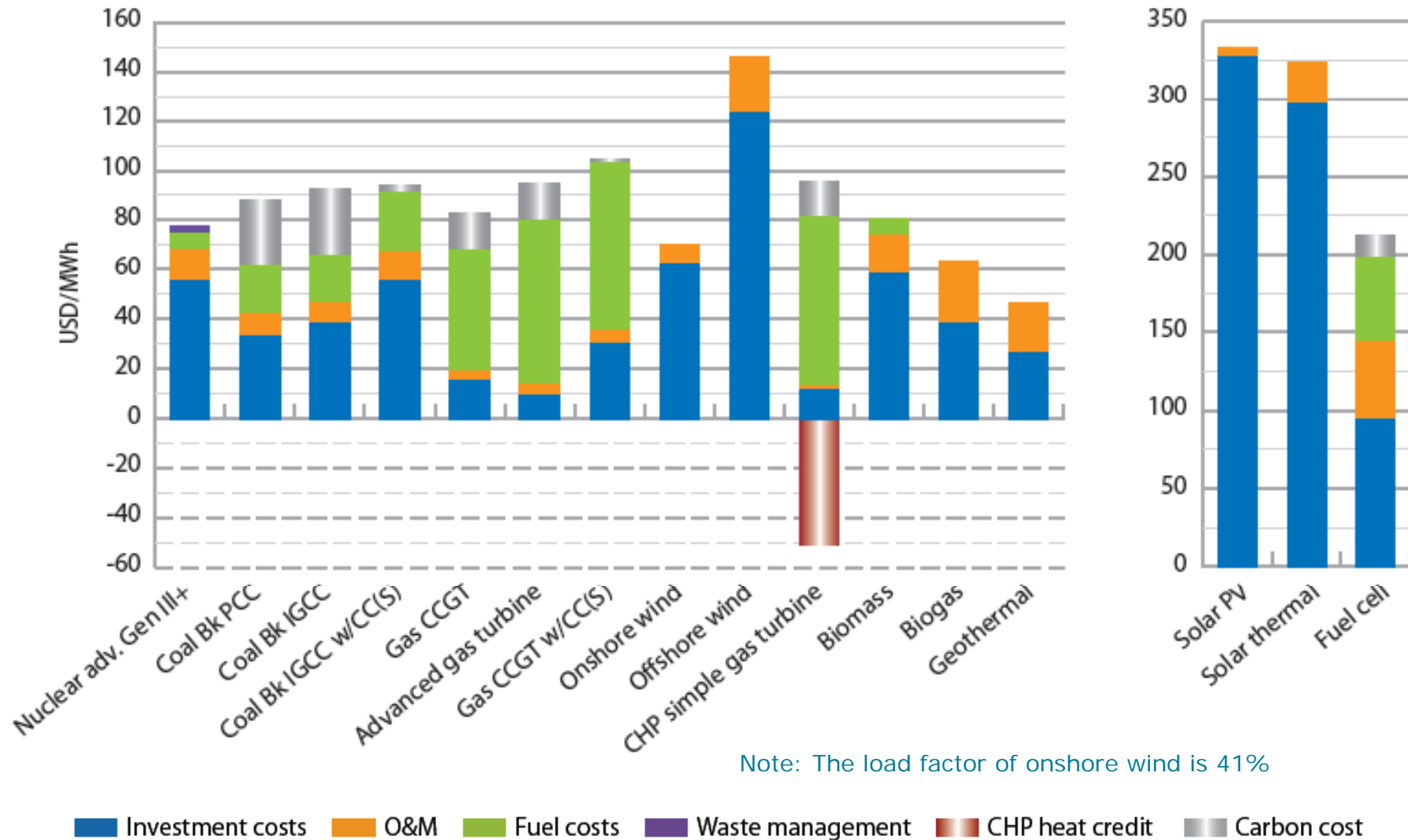
The case of the USA

Levelized Cost of Electricity



At 10% discount rate

2008 USD



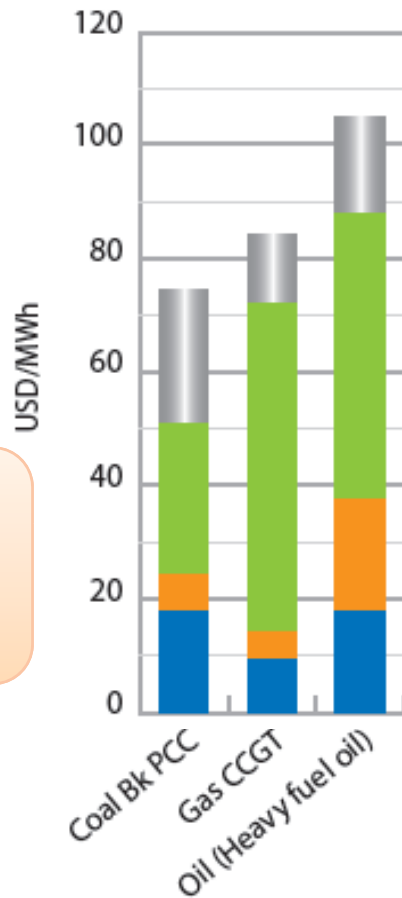
Note: The load factor of onshore wind is 41%

The case of Mexico

Levelized Cost of Electricity



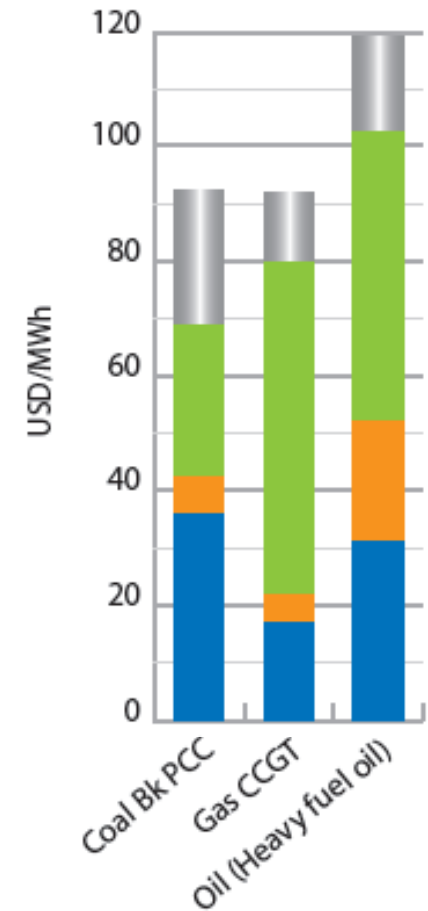
At 5% discount rate



North American average for nuclear at 5% discount rate is **48.7 USD/MWh**

At 10% discount rate

2008 USD



North American average for nuclear at 10% discount rate is **77.4 USD/MWh**

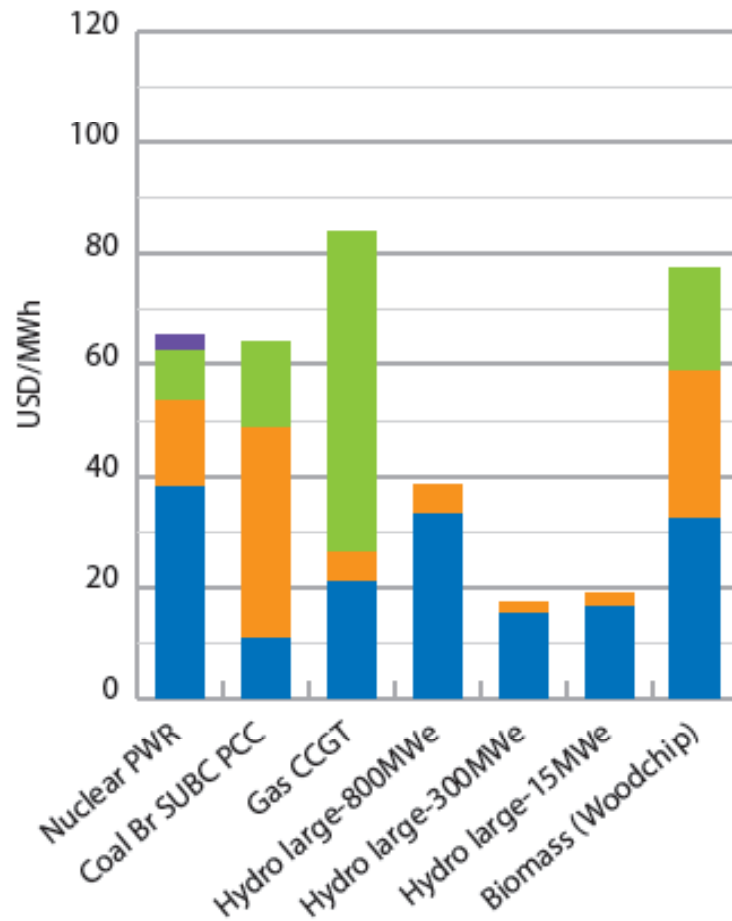
Investment costs O&M Fuel costs Waste management CHP heat credit Carbon cost

The case of Brazil

Levelized Cost of Electricity

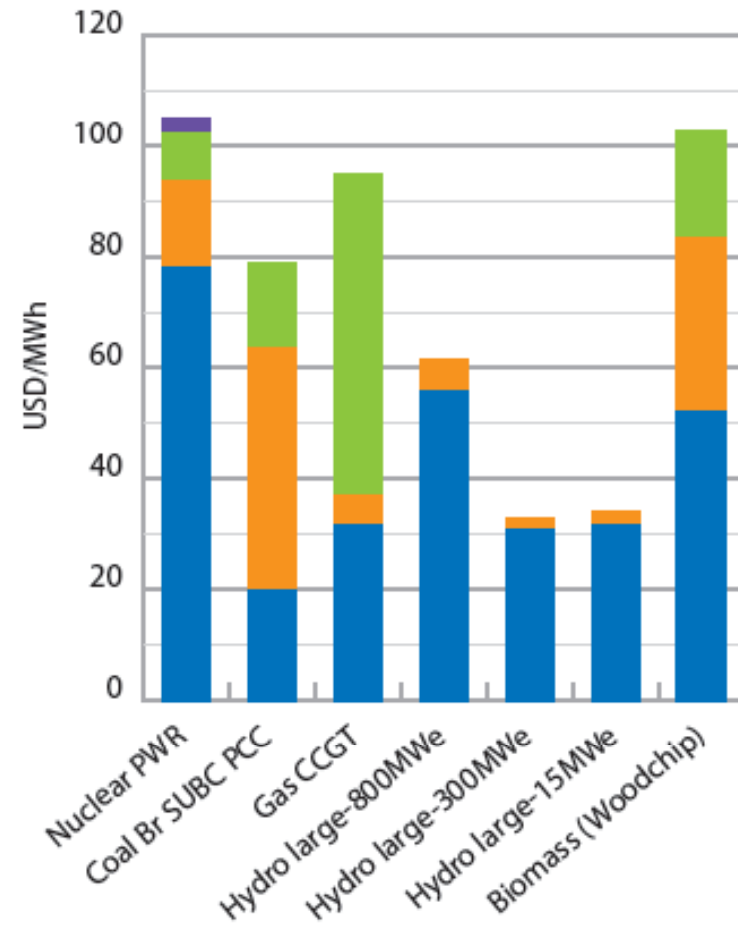


At 5% discount rate



At 10% discount rate

2008 USD



■ Investment costs
 ■ O&M
 ■ Fuel costs
 ■ Waste management
 ■ CHP heat credit
 ■ Carbon cost

Challenges of nuclear development

Competitiveness: Key Messages



- Looking at detailed country numbers, the study shows large differences between countries; **national policies and local circumstances matter**.
- Boundary issues such as **system costs** (which may be substantial especially for intermittent renewables) or specific financing issues must be assessed in a more qualitative manner. The study offers discussions of:
 - Financing issues
 - System Costs of Integrating Variable Renewables
 - Prospects for Carbon Capture and Storage
 - The Working of Electricity Markets
- **At 5%**, nuclear energy is an attractive option for base load power generation in all three OECD regions.
- **At 10%**, nuclear energy remains a competitive option for base load power generation in the United States and OECD Asia.
- A **30 \$/tonne CO₂ price** is not enough to give a decisive advantage to low-carbon technologies in all circumstances – Government action remains key.

Challenges of nuclear development

Financing of Nuclear Power Plants



Issues with financing of nuclear power plants:

- High capital cost and technical complexity:
 - Construction risks (cost overruns, delays)
 - Operation risks (equipment failures, outages)
- Long period required to recoup investment
 - Risk from electricity market uncertainties
- The often controversial nature of nuclear projects
 - Political and regulatory risks
 - Public acceptance
- Need for clear solutions and financing schemes for radioactive waste management and decommissioning
 - Should be formulated by government
- Need for NPPs to operate at high capacity factors
 - Baseload conditions preferable

Challenges of nuclear development

Financing of Nuclear Power Plants



Possible government actions to support the financing of NPPs

- Provide clear and sustained policy support for nuclear development:
 - Nuclear energy as part of long-term national energy strategy
 - Broad-based political consensus and public acceptance
- Work with electricity utilities, investors and nuclear industry from an early stage to address concerns that may prevent investment
 - Avoid mistakes in establishing parameters for new NPPs
- Establish an efficient and effective regulatory system
 - Adequate public involvement
 - Providing investors with certainty (e.g. by pre-approving standardized designs)
- Put in place arrangements for the management of radioactive waste
 - Roadmap clear and waste fund built up from electricity tariffs
 - Effective framework for nuclear insurance and liabilities
- Ensure that electricity market doesn't disadvantage NPPs
 - Guarantees of CO₂ reduction policy

Conclusions

- Strong renewed interest for nuclear power
 - Growing population and electricity demand
 - Low carbon emissions
 - Predictable electricity prices
 - Security of supply

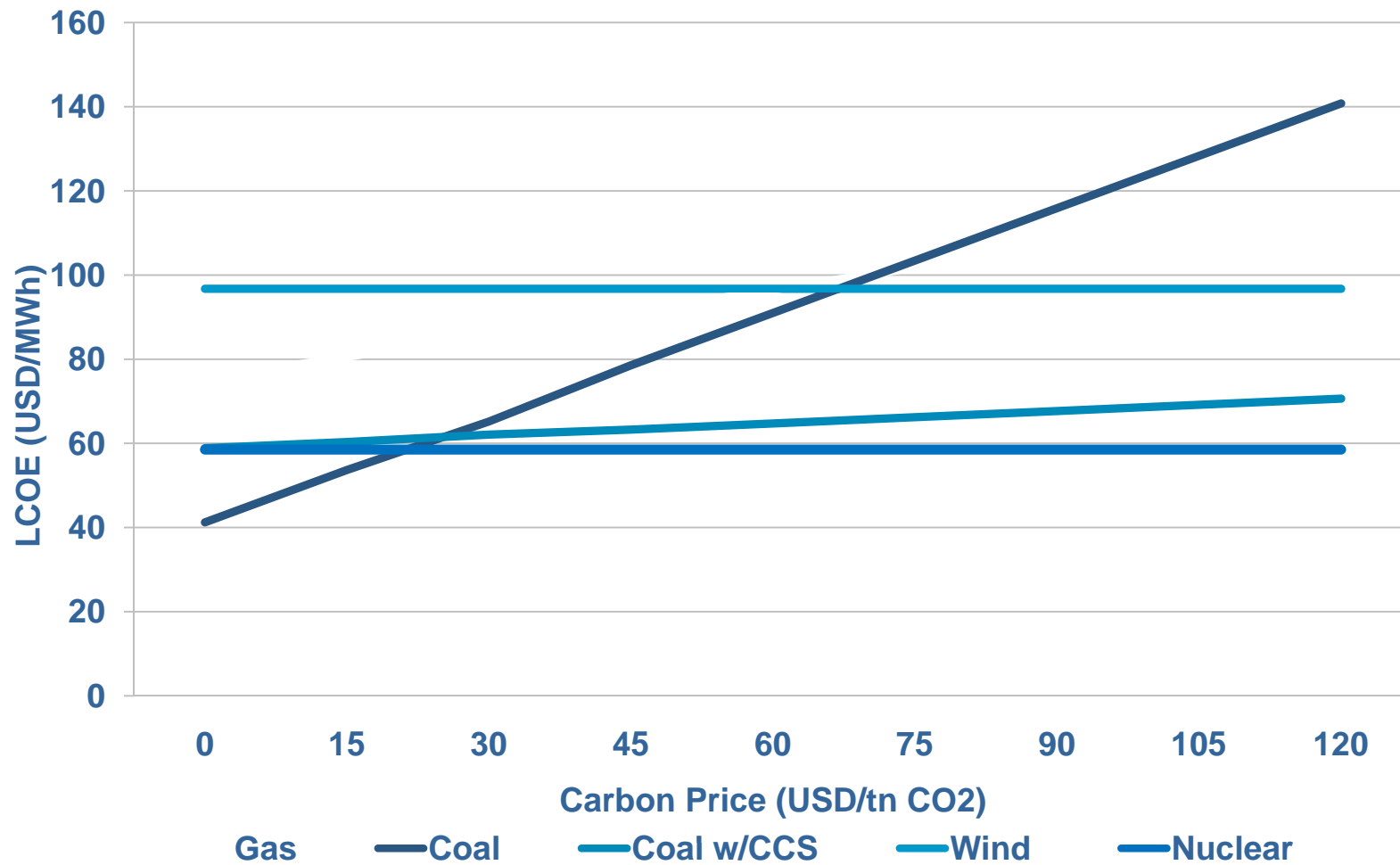
- Considerable expansion of sustainable nuclear power technically possible
 - Enough uranium even for ambitious nuclear programs
 - Generation III+ and Generation IV designs
 - Environmentally friendly waste management achievable

- Nuclear power is economically competitive
 - Government involvement needed to ensure stability
 - Broad-based political consensus on nuclear power
 - Regulatory aspects
 - Guarantees for CO₂ reduction policies

Additional slides

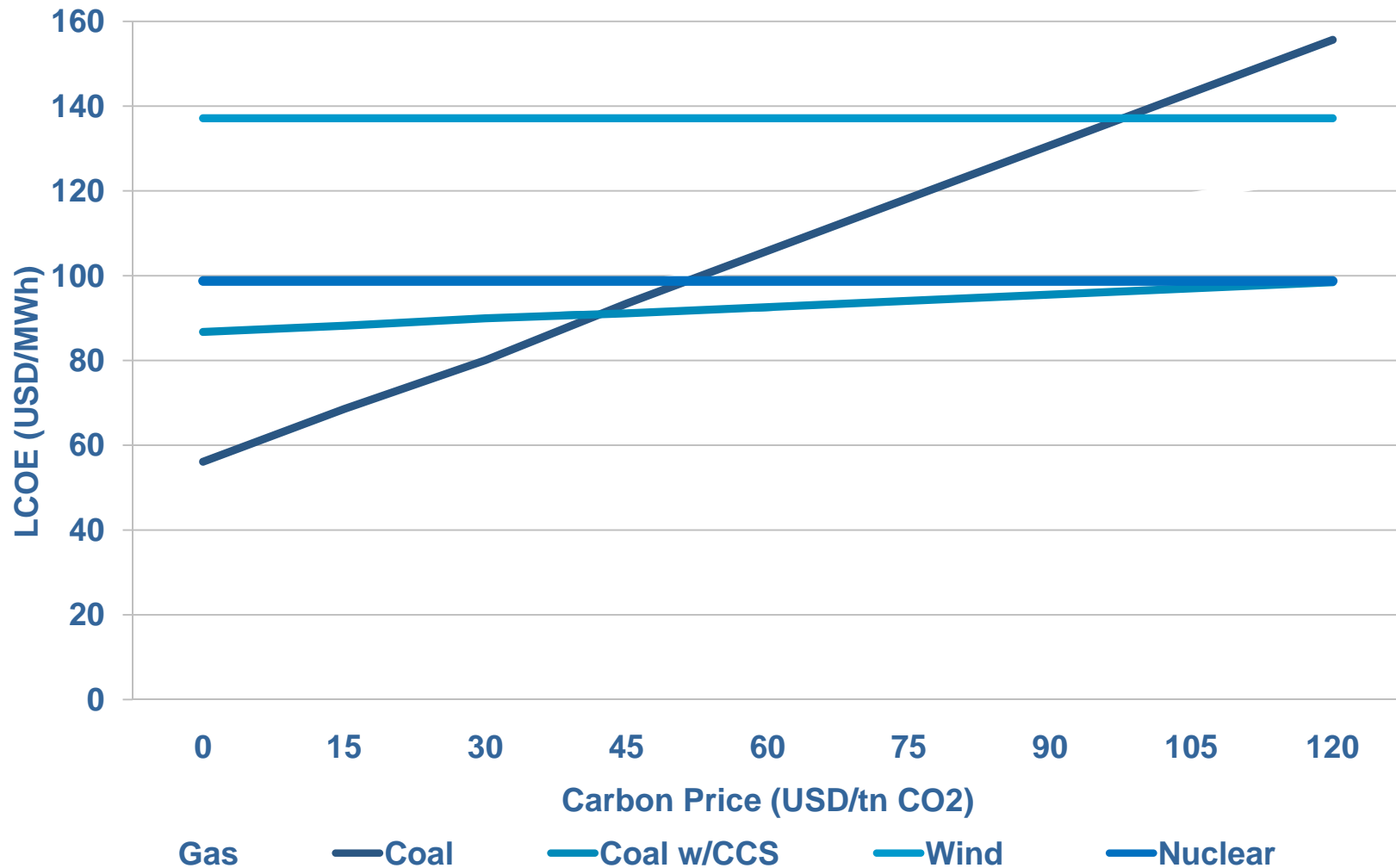
CO₂ Price Sensitivity all OECD

Discount rate **5%**



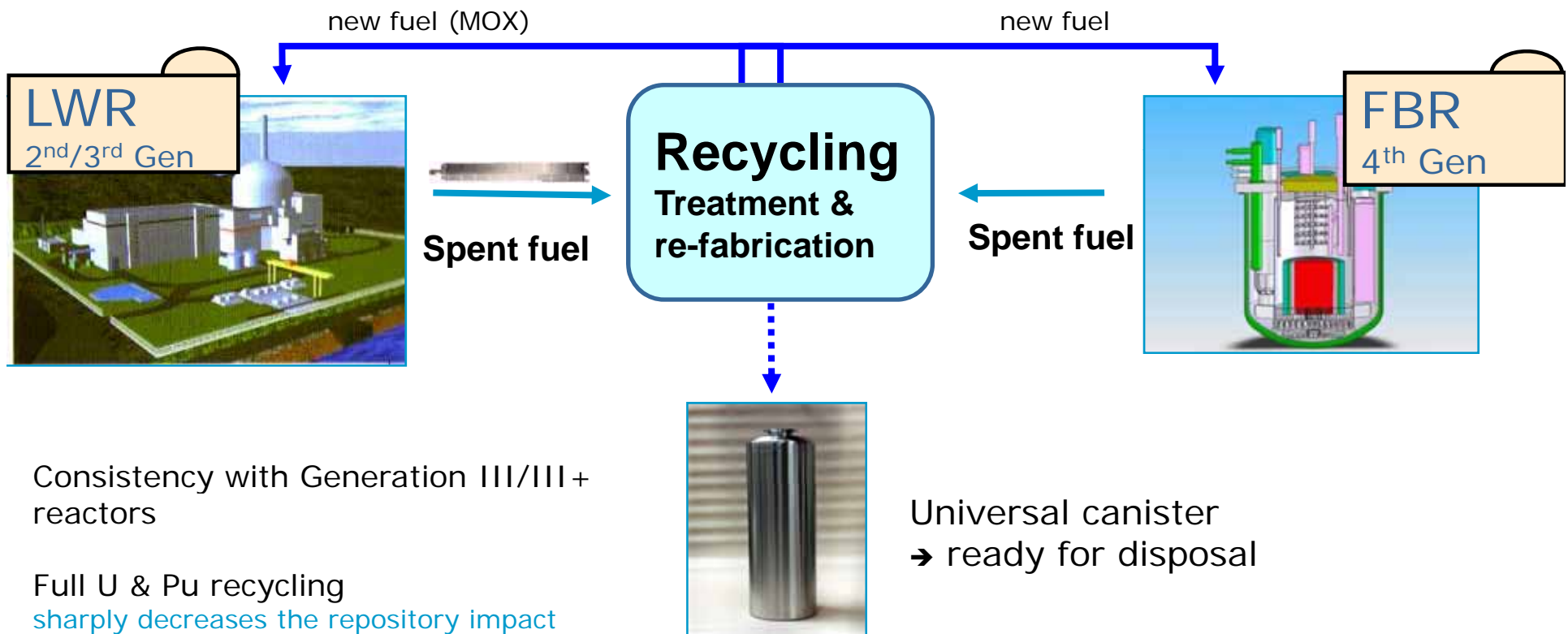
CO₂ Price Sensitivity all OECD

Discount rate **10%**



Resource preservation and waste management

The recycling plant



Consistency with Generation III/III+ reactors

Full U & Pu recycling
sharply decreases the repository impact

Universal canister
→ ready for disposal

Treatment & Recycling competitiveness

Resistance to Proliferation (Integrated Plant, no Pu alone)