Nuclear Power and Sustainable Development

Conferência Internacional Água e Energia:
Novas Abordagens Sustentáveis
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Eletrobras Eletronuclear

Sustainability

- **WCED and Brundtland definition:**
  - **World Commission on Environment and Development in its report Our Common Future defined sustainable development as "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (1987)**
- **Three dimensions or pillars**
  - **Environmental**
  - **Economic**
  - **Social/institutional**

Economic dimension

- **Concerns the maintenance, growth and use of different categories of capital:**
  - **man-made**
    - **infrastructures, machines, technology**
  - **natural**
    - **mineral resources, forests, clean air and water, atmosphere**
  - **social/human**
    - **institutions, knowledge, intact societies, tradition**

Economic pillar

- All three types of capital contribute to economic development
- They are inherently substitutable, the extent of which has led to the distinction:
  - strong sustainability
  - weak sustainability

Economics - Strong sustainability

- **Assumes a limited level of substitutability – rather complements than substitutes**
- **Requires each of the capital categories to be maintained separately at some minimum level:**
  - **Exhaustible resources (fossil, uranium, minerals) cannot be consumed really**
  - **Renewable resources must be harvested within the regenerative capacity of the natural capital stock that produces them and its waste must not exceed the of ecosystem's carrying capacity**

Economics - Weak sustainability

- **Refers to the maintenance of the total level of capital passed down through generations without regard to the particular form of capital**
  - **Allows the use of exhaustible resources as long as depletion is compensated by equivalent increases in man-made and social/human capital**
  - **It requires the efficient use of non-renewable resources that reflect full social costs and the timely development of inexhaustible energy systems**

Environmental dimension

- Preservation of natural resources, biodiversity and protecting ecosystems and habitats
  - Minimize environmental pollution, the exploitation of exhaustible resources as well as the so-called 'use of the environment' (ecological footprint)
    - Reduce production and use of harmful substances to a minimum
  - Equitable access by different social/spatial entities (countries, regions, etc.) to common goods (e.g. atmosphere)
  - Observation of carry capacities of ecosystems

Social/institutional dimension

- Deals with the ‘needs’ of the Brundtland definition
  - Not limited to the materialistic needs of
    - food, water, energy, shelter, health and protection in case of old age and social hardship
  - But also includes
    - education, recreation, leisure, social relations, political activities, security, social justice both intra- and intergenerational, good governance and competent institutions, moral concepts, culture and religion
  - Sustainability in satisfying intra- and intergenerational needs is directed at the relationships between society and nature

3Rs – Reduce, reuse, recycle

- **Reducing waste production, recycling of wastes and reusing materials form the basis for sustainable waste management**
  - **Preventing waste generation in the first place through lower input of natural resources, smarter designs and more efficient manufacturing**
  - **Reusing, recycling and proper treatment of materials that would otherwise enter the waste stream**
  - **Replacing products with harmful wastes by environmentally friendly alternative materials**

Trade-offs

- Three pillars of sustainable development (SD) present **conflicting objectives**
- Environment protection x development:
  - S-d (North) versus D-s (South)
- **Trade-offs are necessary**
  - "Poverty is the biggest polluter" (I. Gandhi, 1972)
- Current environmental problems have been previous solutions
  - Technology – culprit or savior?

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

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**

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

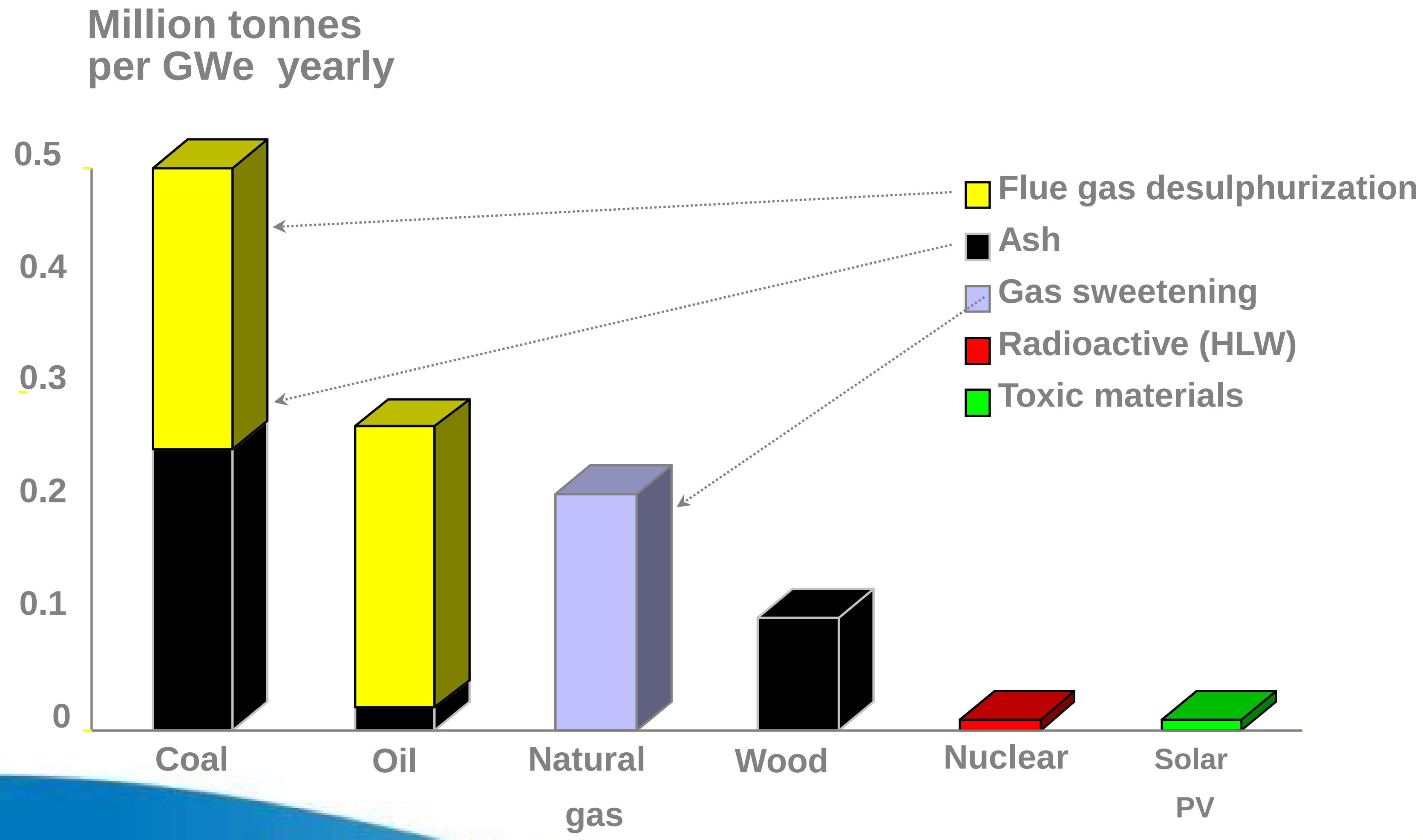
Nuclear energy inherently consistent with “weak sustainability”

- **Consumption of finite resources results in an accumulation of man-made and social & institutional capital available to future generations**
  - **Infrastructures, technologies, institutions and know-how**
- **Despite an enormous resource base (U in seawater), potential decoupling from nuclear fuel resource constraints**
  - **3R - Reprocessing and fast breeder technology**
    - **closed fuel cycles**

Nuclear energy inherently consistent with "weak sustainability"

- **Uranium mining progressively subjected to monitoring and controls (also post mine closures)**
- **Spent fuel volumes managed and small per unit of energy delivered**
- **Final HLW disposal solutions at an advanced stage of technological development, but often lack will & public acceptance for their implementation**
- **HLW even smaller with closed fuel cycles or partitioning and transmutation**

Wastes in fuel preparation and plant operation



Source: IAEA, 1997

Nuclear energy inherently consistent with “weak sustainability”

- **Reduces the rate of degradation of some categories of natural capital**
  - **Atmospheric concentration of greenhouse gases**
  - **Air pollution and regional acidification**
- **Assists in meeting “needs”**
  - **Access**
  - **Affordability**
  - **Supply security**
  - **Skilled labour**
  - **Research**

Relevant SD goals for nuclear power

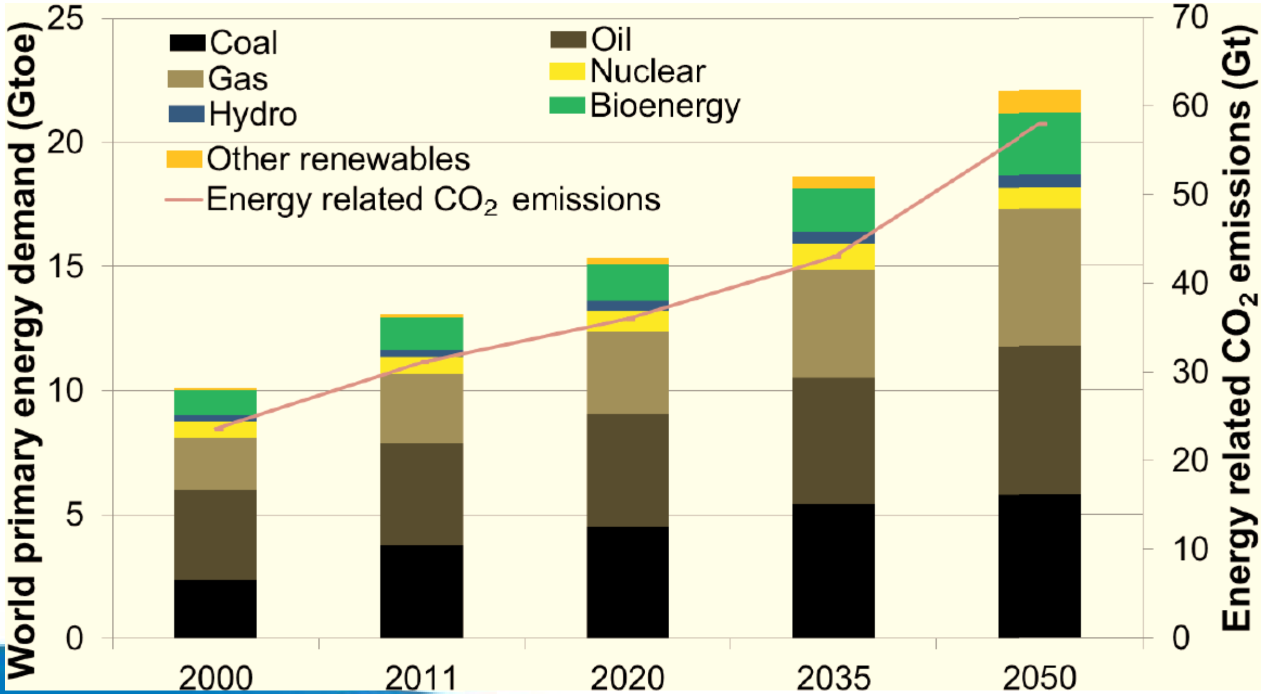
- **Economics**
  - **Enhancement of man-made and human/social capital ("weak sustainability")**
  - **Life-cycle cost advantage over alternative energy supply options**
  - **Financial risks comparable to other energy projects**
- **Environment**
  - **Nuclear fuel cycle minimizes resource use and nuclear waste generation (3R)**
  - **Nuclear fuel cycle reduces the long-term stewardship burden (intergenerational equity)**
  - **Nuclear installations excel in safety and reliability (core damage frequency, off-site impacts/emergency responses)**

Relevant SD goals for nuclear power

- **Social/Institutional**
  - **Public health (highest safety standards)**
  - **Enhanced safeguards regimes**
  - **International cooperation such as**
    - **Internationalization of the fuel cycle**
    - **Safety standards & regulation**
    - **Combating terrorism**
  - **Efficient regulatory systems**
  - **Proliferation resistant fuel cycles**
  - **Physical protection against malicious attacks**

The Energy Challenges are scaling up

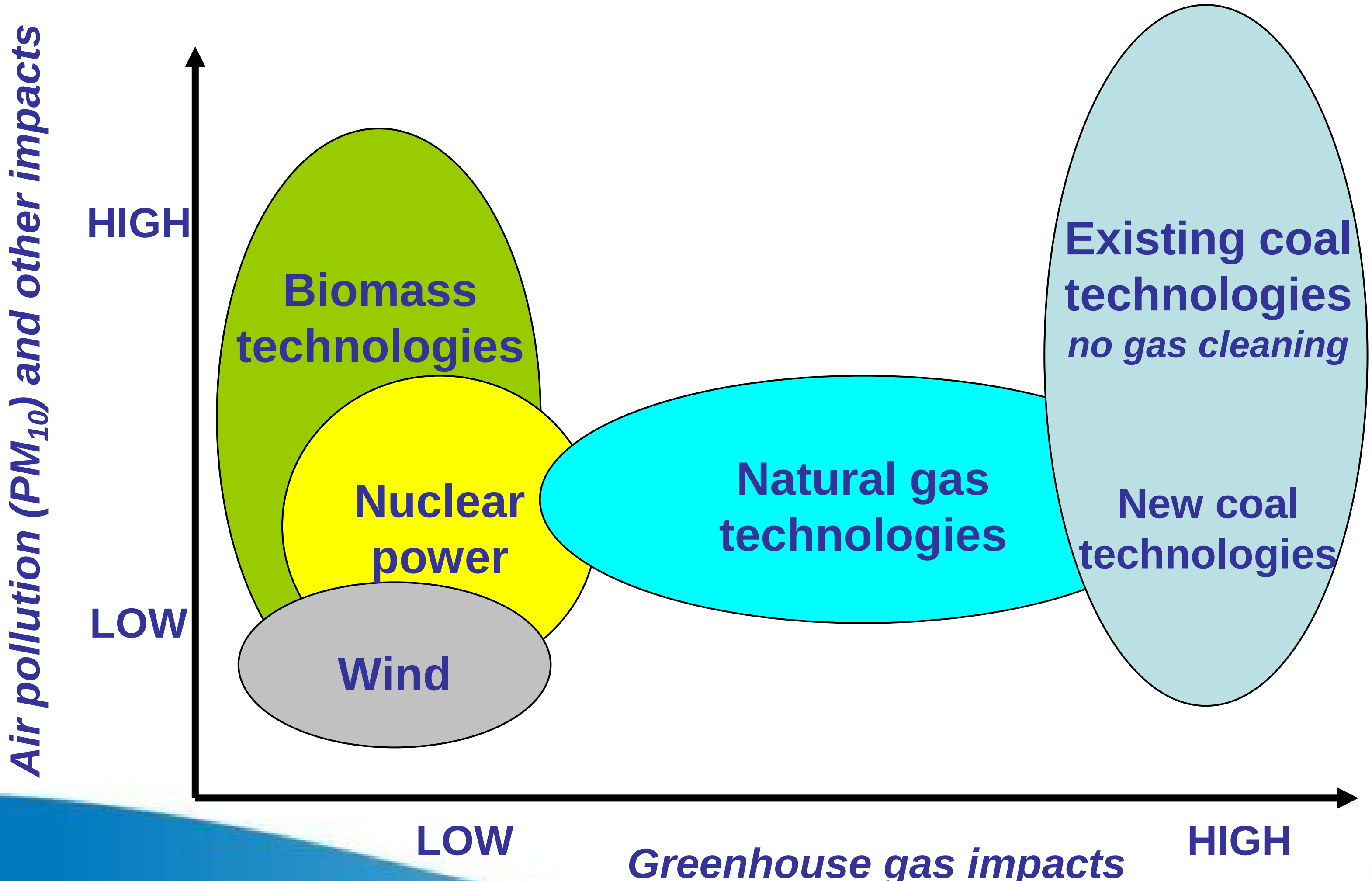
- Population grows: 7.2 B in 2014 to 9.6 B in 2050.
- Urbanisation increases by more than 40% between 2011 and 2050.
- Economies grow at an average rate of 3.2%/yr from 2011-2050 (real GDP).
- In Business-as-Usual scenario, world primary energy demand increases by 70% between 2011-2050.



- **Pressure on resources, health, environment**
- **Sustainability calls for energy system transformation**

Source: IAEA, CCNP (2014)

Externalities of different electricity generating options

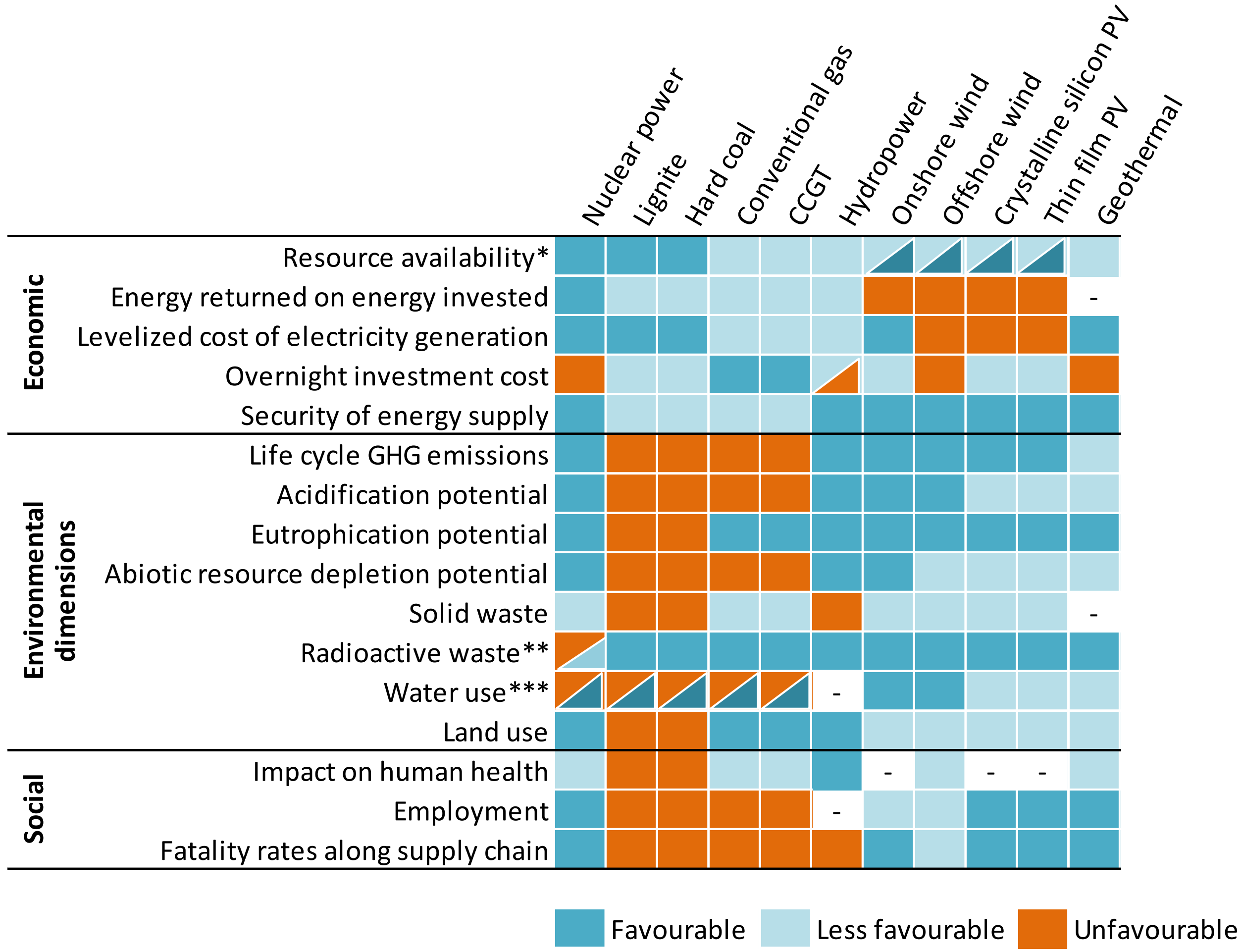


Source: EU-EUR 20198, 2003

So, which energy technology is best?

- All technologies are associated with some risk, waste or interaction with environment.
- None of the low-C technologies should be left aside when assessing the contribution to Climate Change and Sustainable Development.
- Suitability of nuclear power cannot be judged in isolation, but only in comparison with the best available alternatives.
- The use of nuclear is ultimately a country’s sovereign decision.

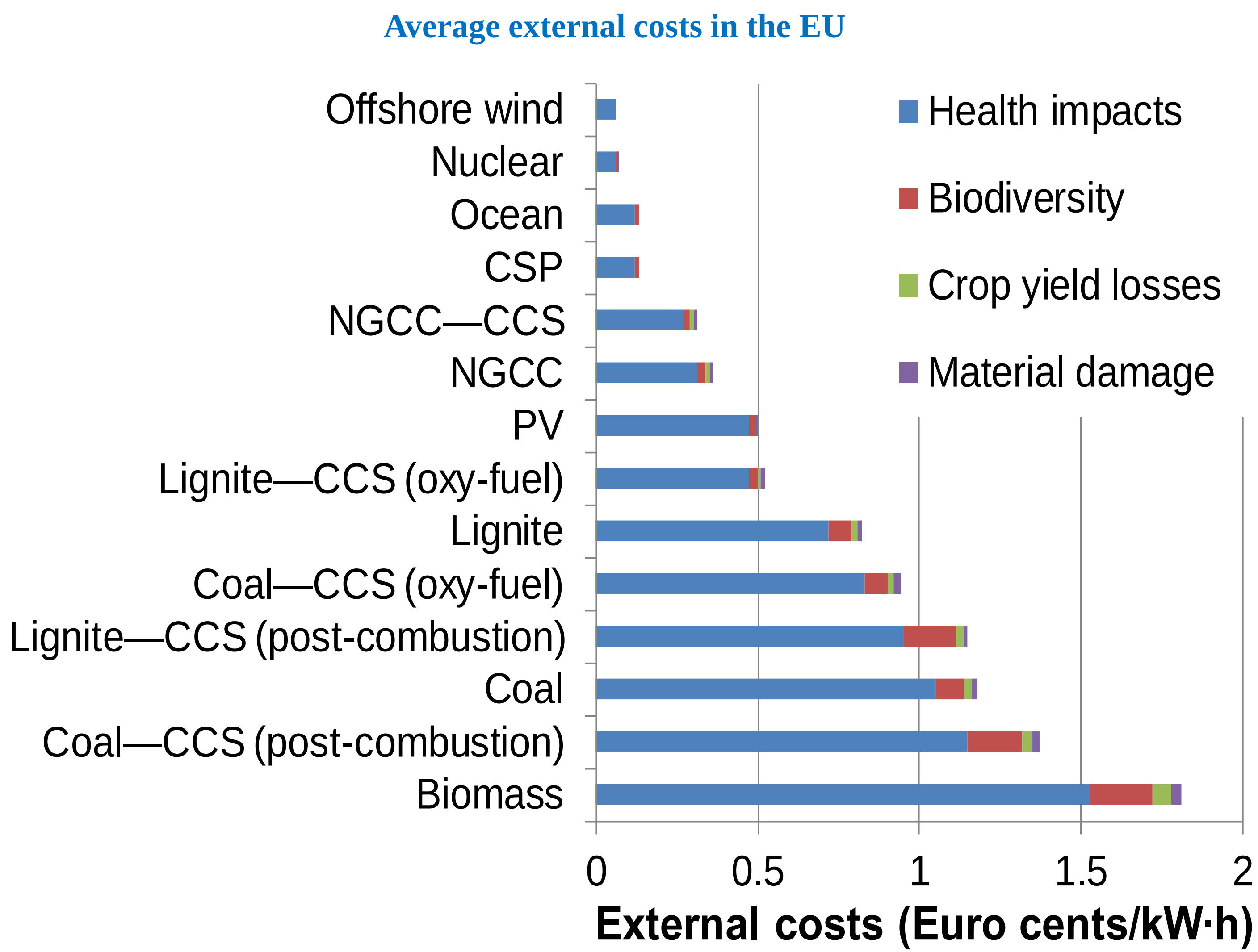
Nuclear compares favourably across many sustainability indicators



* Sensitive to geographical location for solar, wind and hydro technologies
** Closed fuel cycle in fast reactors reduce the volume of HLW and radiotoxicity per unit of electricity generated
*** Dry cooling system eliminates water needs for cooling in thermo-electric power plants

Source: Derived from IAEA

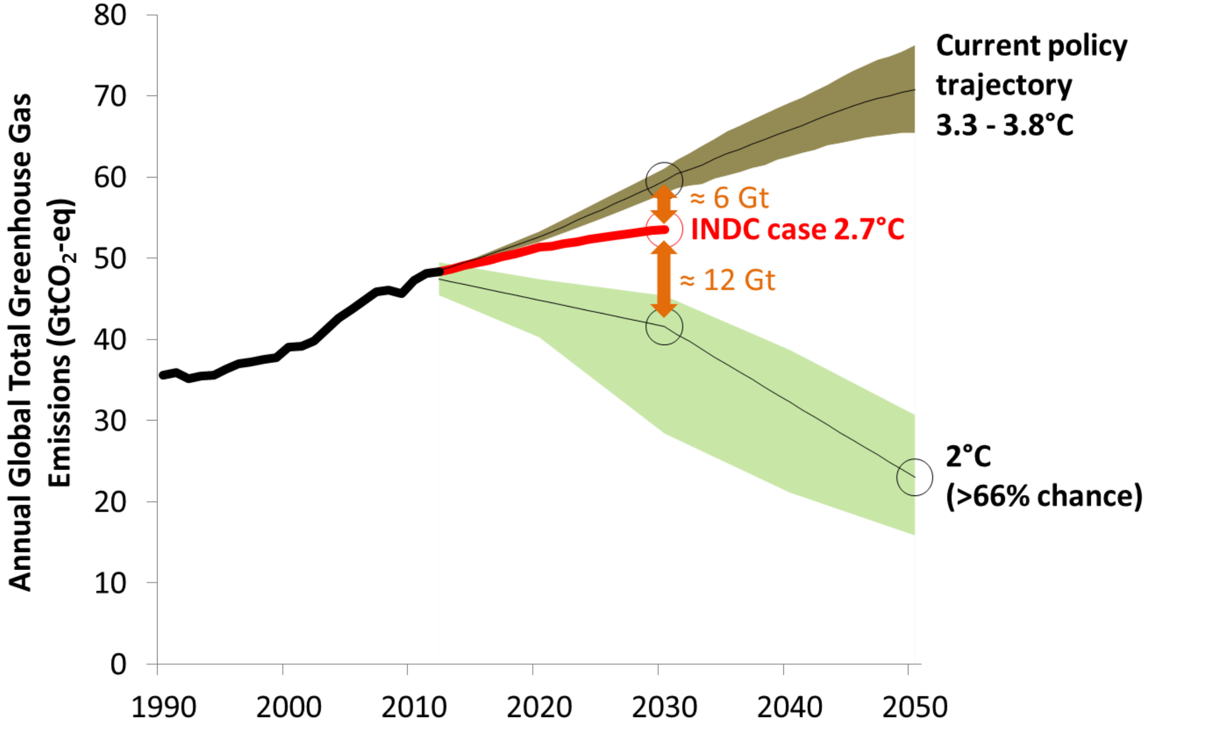
Nuclear power deployment brings about large co-benefits



Source: Derived from NEDS

Global GHG mitigation must be increased Paris Agreement (2015)

- **INDCs curb GHG emissions ... but still fall short of 2°C objective**
- **Climate ambition must be increased progressively**



Source: Derived from Climate Action Tracker, UNEP and IEA

- **Nuclear is not excluded from the Paris Agreement**

Action now at the national level !

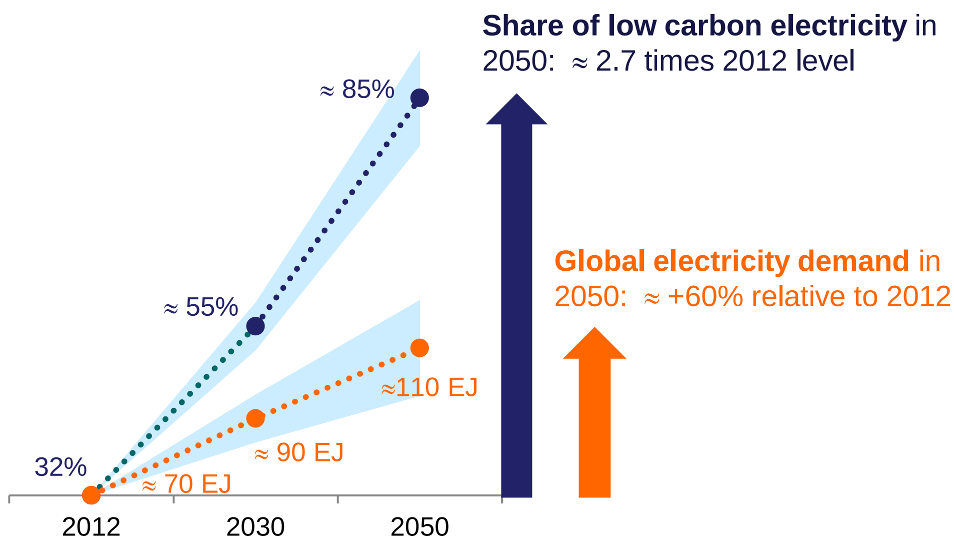
Decarbonising the power sector is key to meet the 2°C target

- Beyond uncertainties of future developments, ***three fundamental actions need to be undertaken simultaneously:***

⇒ Massive deployment of all low carbon source of electricity:
-renewables, nuclear, CCS, switch from coal to gas transitionally

⇒ Improve efficiency of power plants

⇒ Apply stringent EE measures to moderate electricity demand

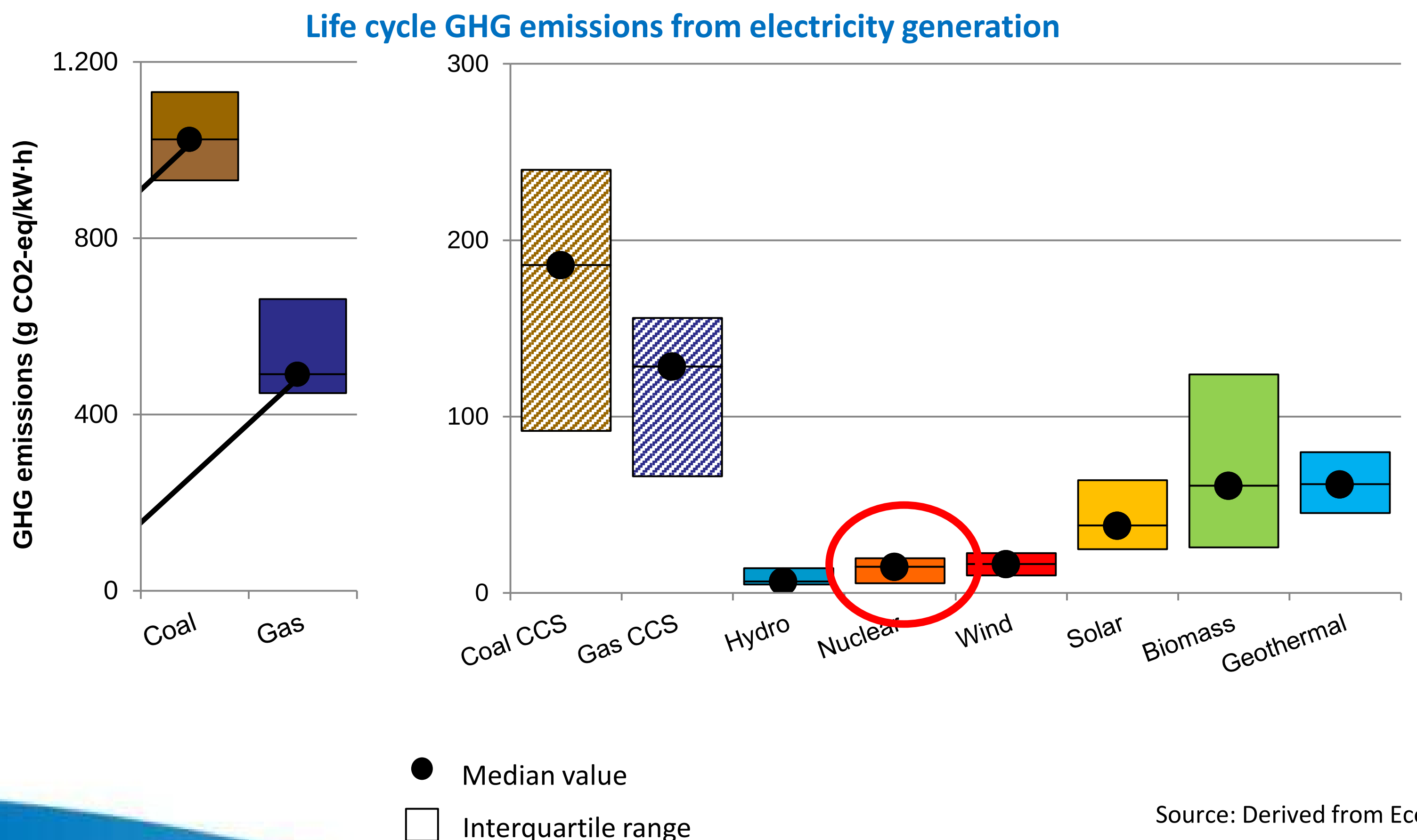


- Only by 2030, the transition in line with the 2°C target requires a threefold increase in clean energy investments (more than $ 1 000 billion on average annually, including $ 81 billion on nuclear)

Source: Derived from IPCC and IEA

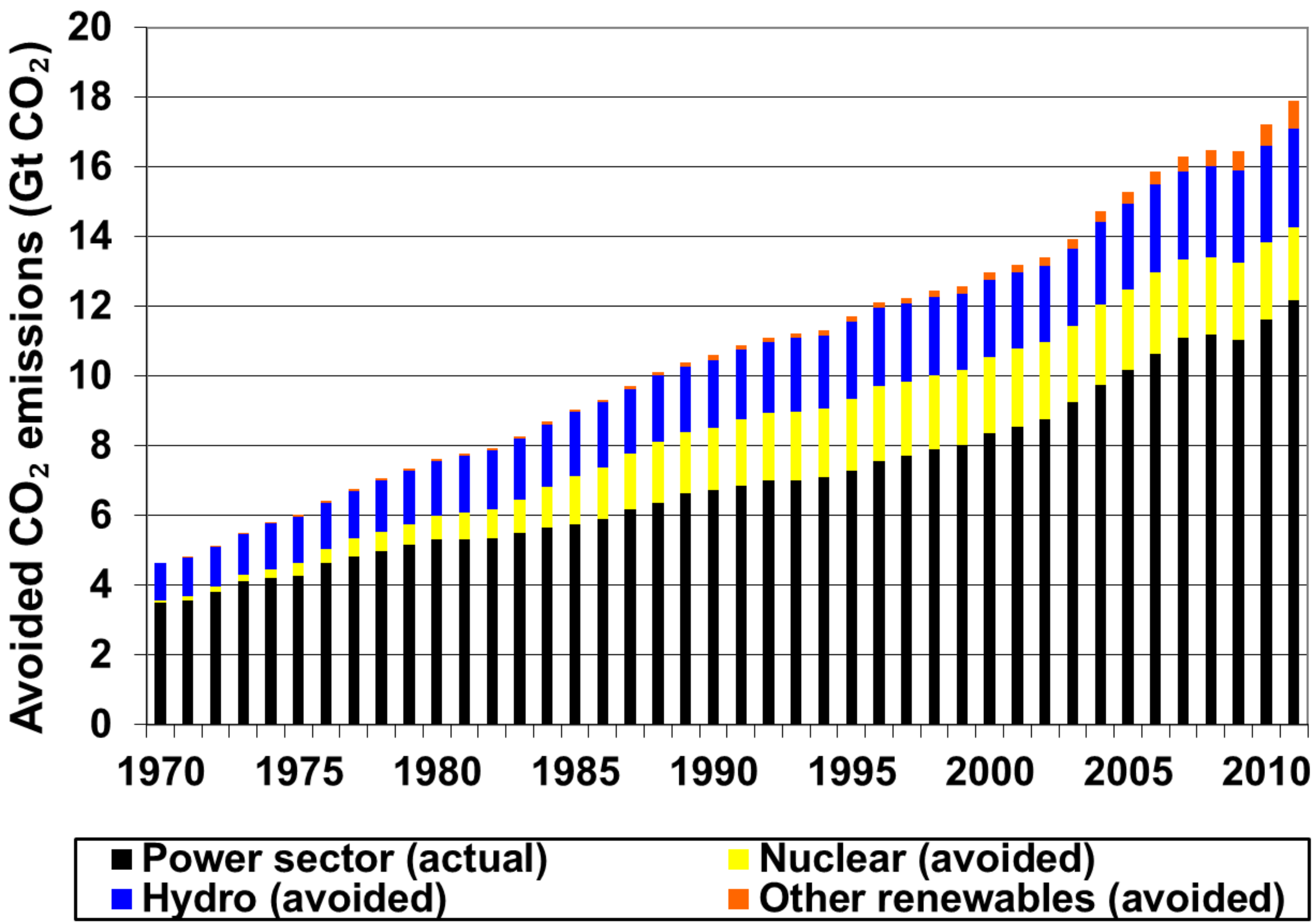
"Many countries expect nuclear power to play an important role in their energy mix in the coming decades. It is one of the lowest emitters of carbon dioxide among energy sources, considering emissions through the entire life cycle."

— IAEA Director General Yukiya Amano



Source: Derived from Ecoinvent

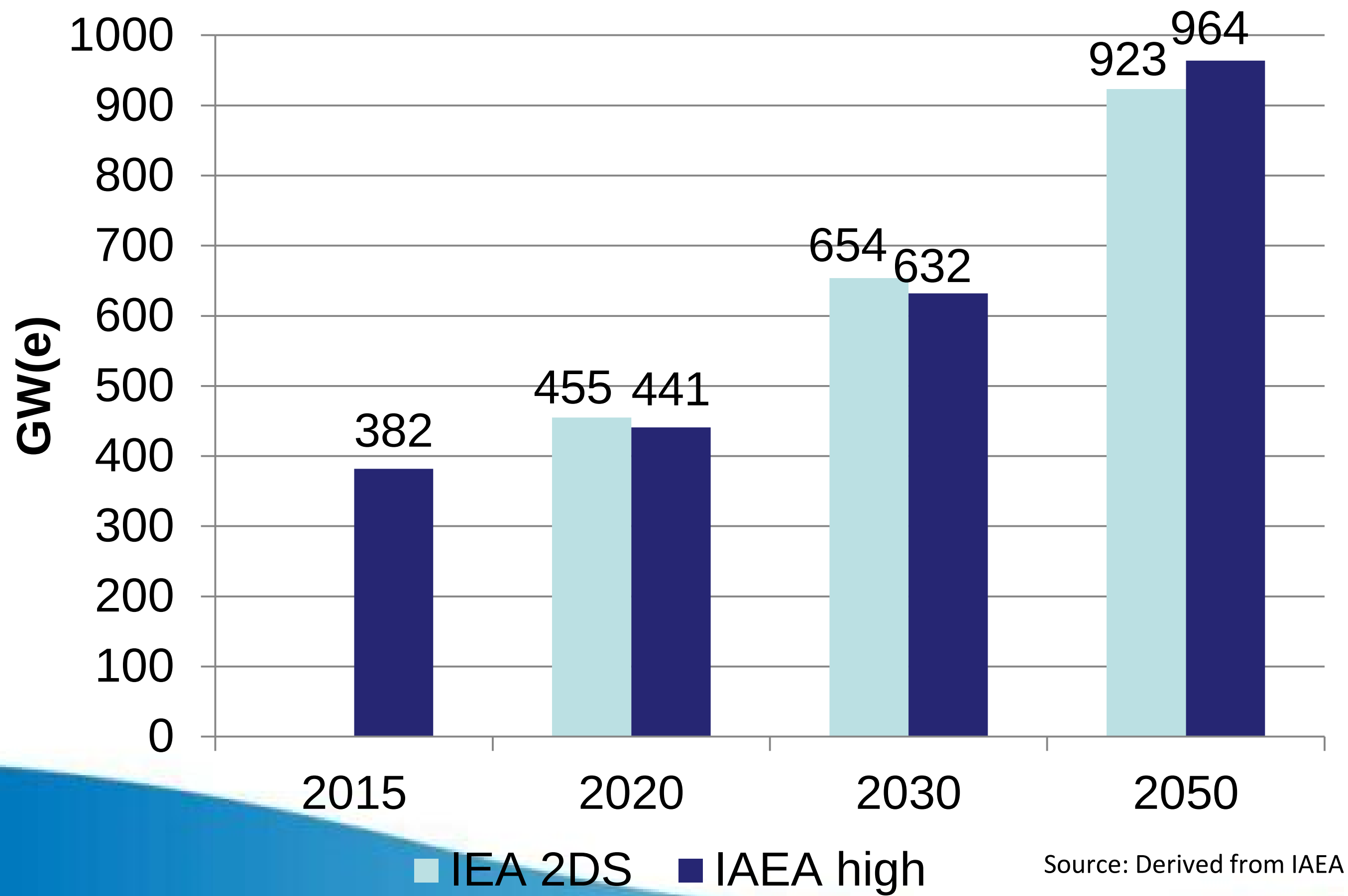
Nuclear energy currently avoids the release of 2 Gt of CO_2 per year



Source: Derived from IEA data

>2x growth needed to support the Paris Agreement 2°C target

According to the International Energy Agency, **more nuclear energy is needed** to achieve decarbonisation and meet the 2 degree goal.

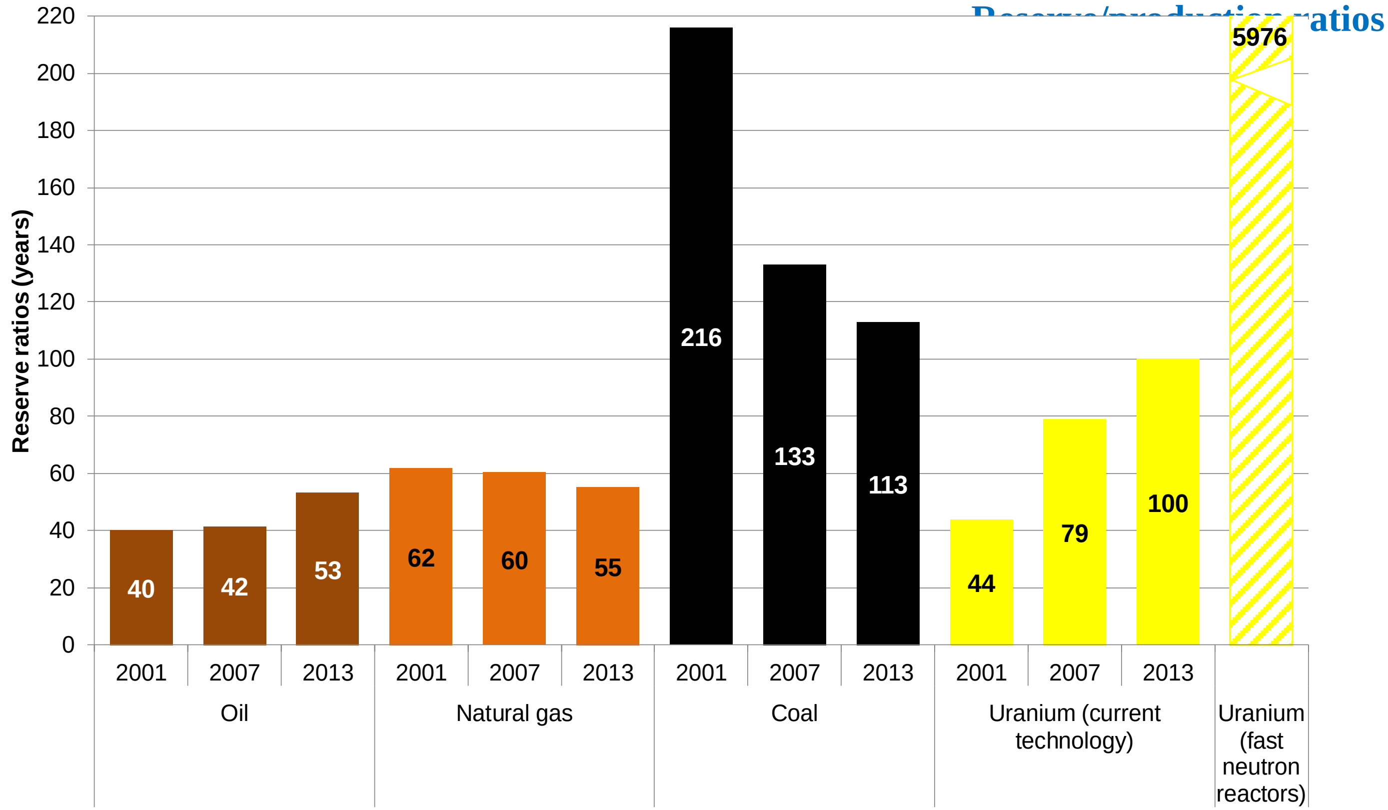


Capacity level needed to support 2°C target

Source: Derived from IAEA and IEA

What about uranium ?

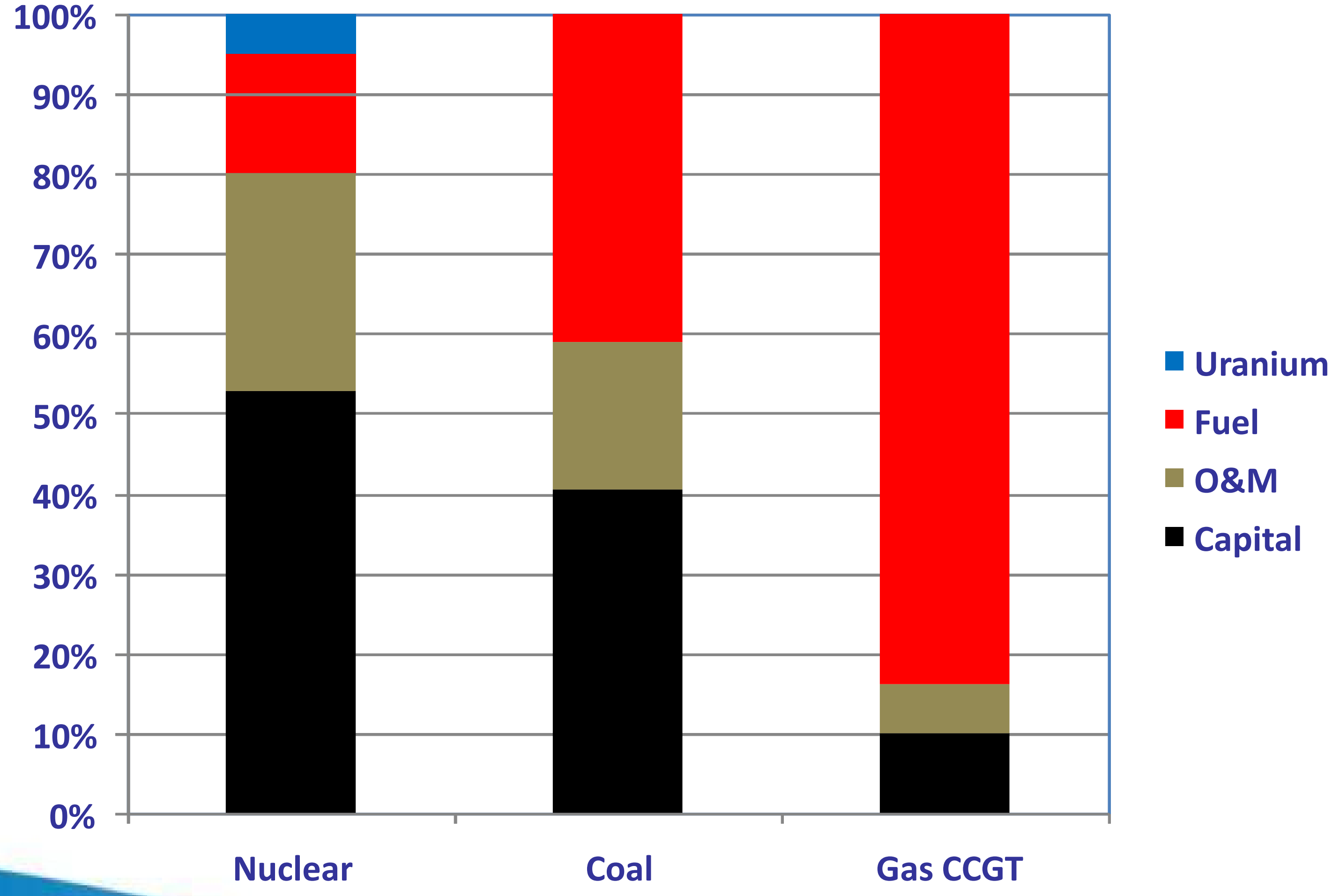
- Supplies are plentiful and resources are well diversified
- Small fuel volumes
- Possibility to accumulate significant stockpiles



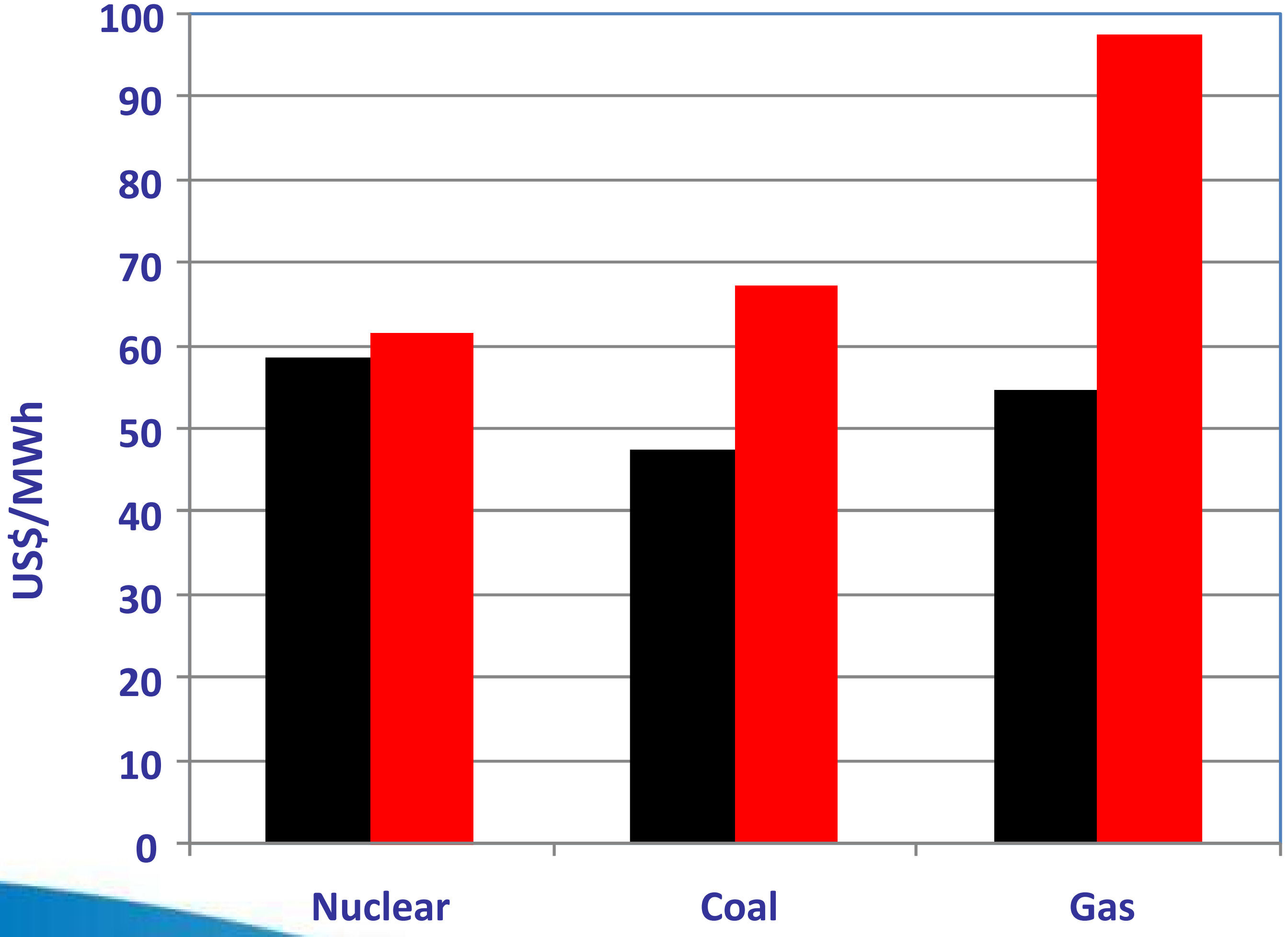
- Nuclear power enhances security of supply

Source: Derived from OECD NEA IAEA

Cost structures of different generating options

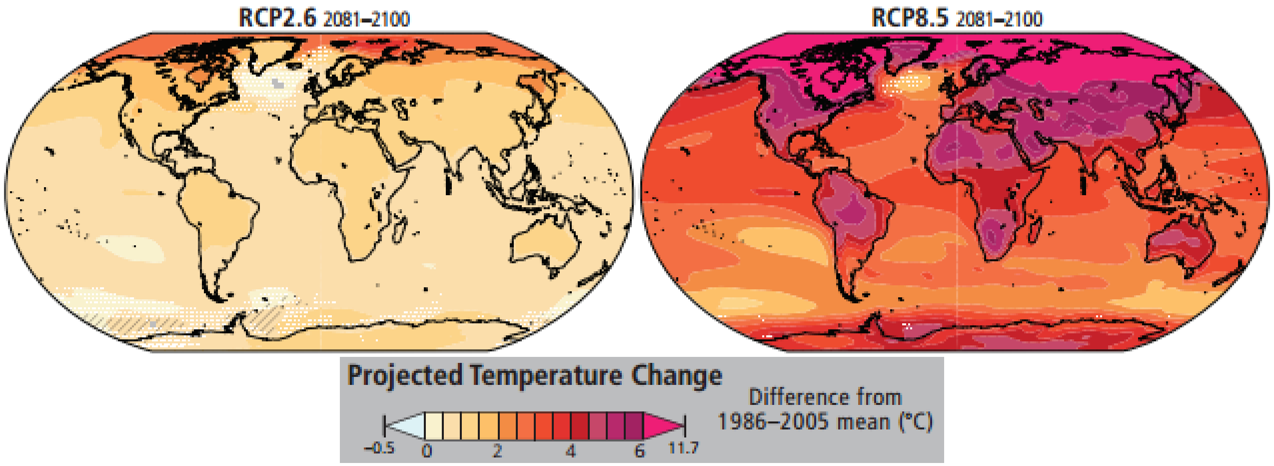


Impact of a doubling of resource prices on generating costs



Climate Change (CC) and Extreme Weather (EW)

- **Gradual change:** *Changes in mean and variability over decades*
  - Temperature
  - Precipitation
  - Wind patterns
  - Insolation
  - Sea level rise



- **Extreme events: Occurrence above or below threshold, near to boundaries of observed values**
  - **Heat waves, heavy precipitation, drought, high winds/storms, etc…**
  - **Increasing frequency and intensity, affecting larger areas, prevailing longer**

Source: Derived from IPCC

Mitigation and adaptation

Much research has been done on how to mitigate climate change (CC) through changes in the energy system

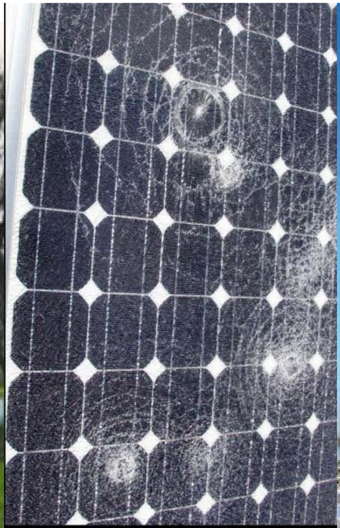
- **Few studies have evaluated the reverse**: the impact of CC and extreme weather (EW) on energy infrastructure
- Expectations are that regardless of action now, there will be a certain level of CC (IPCC AR5 WGI)

> ➢ ***identify the impacts of CC and EW and adapt to lessen those impacts***

Impacts on energy infrastructure



Extraction/Resource → Transport → Conversion → Transmission & Distribution

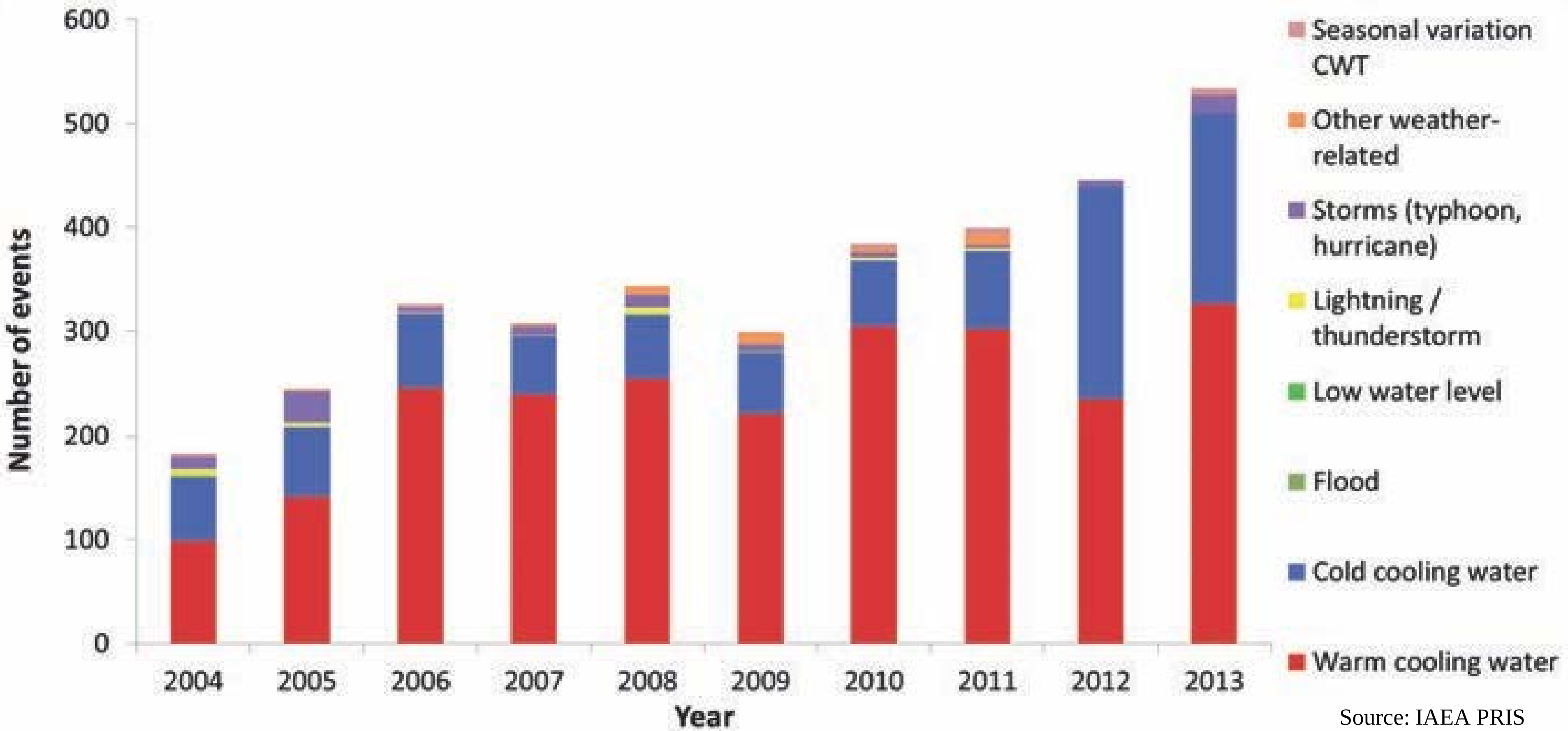
Conversion impacts: nuclear

Gradual CC	EW event	Combinations
T↑ decreasing thermal and cooling efficiency P↓ less and warmer cooling water SL ↑ impact on plants located at low elevation	T^ larger efficiency loss and cooling challenge P˅ even less and warmer cooling water W^ damage cooling towers P^ flooding emergency equipment and spent fuel storage	T^ + P˅ acute cooling problem T^ + P˅ + W^ smoke from forest fire damaging instrumentation, inhibiting access

Outages due to weather related causes

- In last decade: 2/3 of outage events were due to warm cooling water

- From 1980 – 1999, events are balanced between lightning (33%), winds (33%), and freezing (30%)
- In the 2000s, heat related events began to appear



Source: IAEA PRIS

How well equipped is Nuclear to adapt to Climate Change?

Positives

- Reliability of Nuclear Plants operating during severe weather, e.g., 2012 Hurricane Sandy;
- Nuclear is a hardened energy asset;
- New design basis and safety upgrades can increase resilience of nuclear to extreme external events;

Negatives

- Efficiency loss, cooling challenge, etc

Adaptation measures for existing NPPs

- Consideration no 1 – safety
- Consideration no 2 – related cost

Future nuclear reactors can be more adaptive and resilient

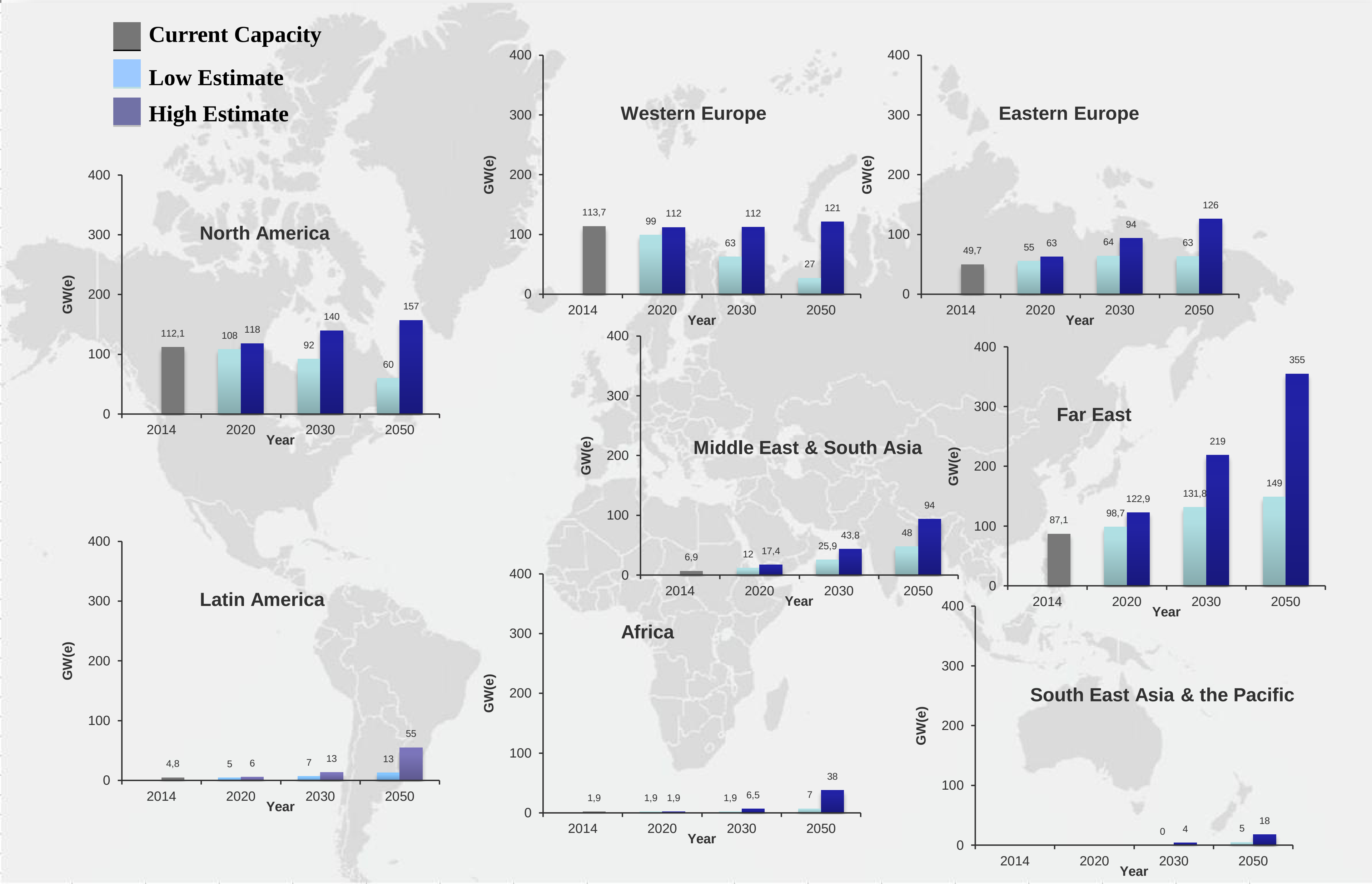
Technology Measures:

- The design bases for future reactors can be changed in response to projected degrees of climate change and shifts in extreme weather events.

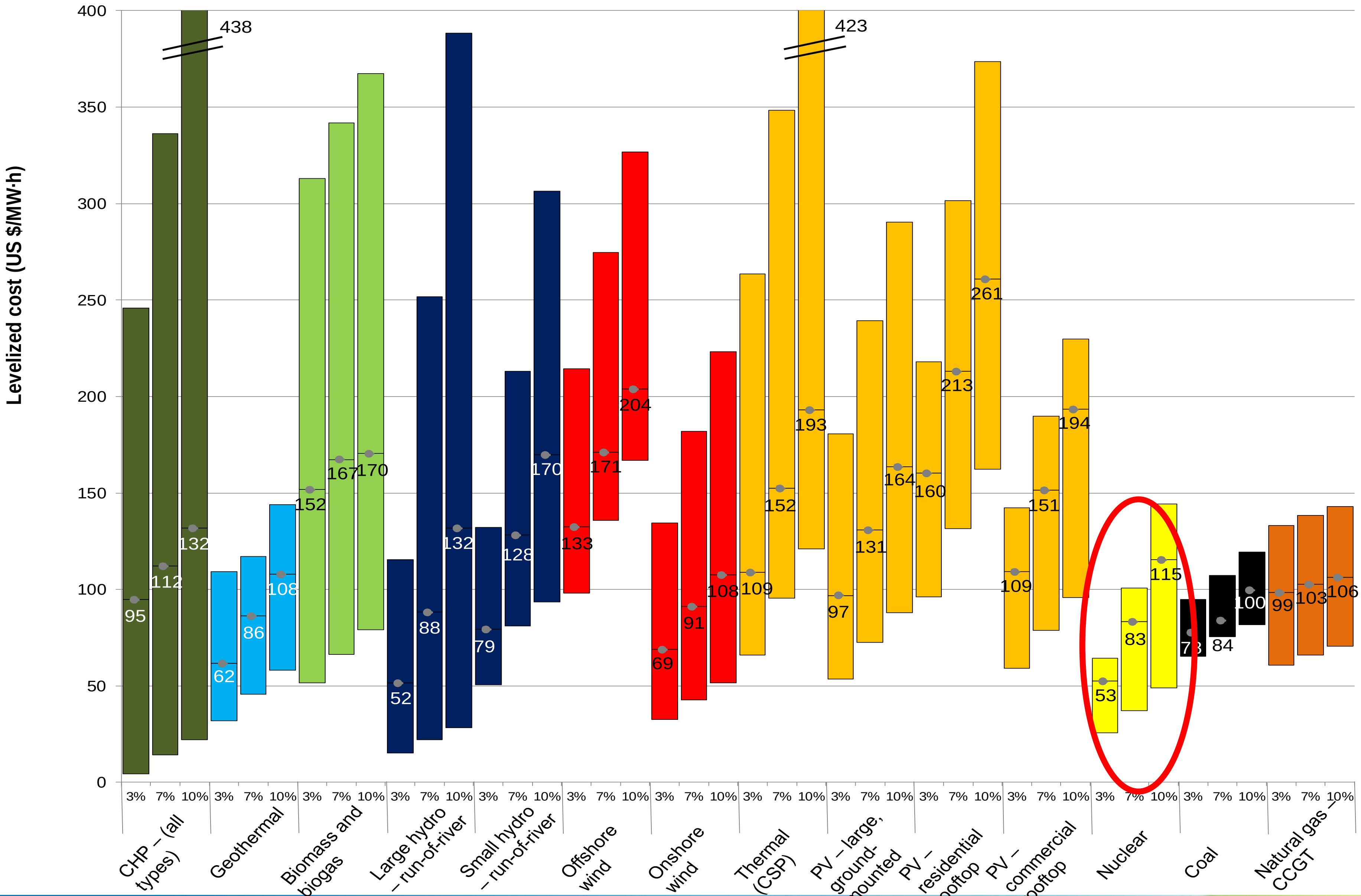
Examples:

- New plants designed to operate at higher thermal efficiencies requiring less cooling water
- Smaller reactors (SMRs) used that need less water resources.
- Dry cooling equipment used where water resources are vulnerable.

Nuclear Power Development in Different Regions

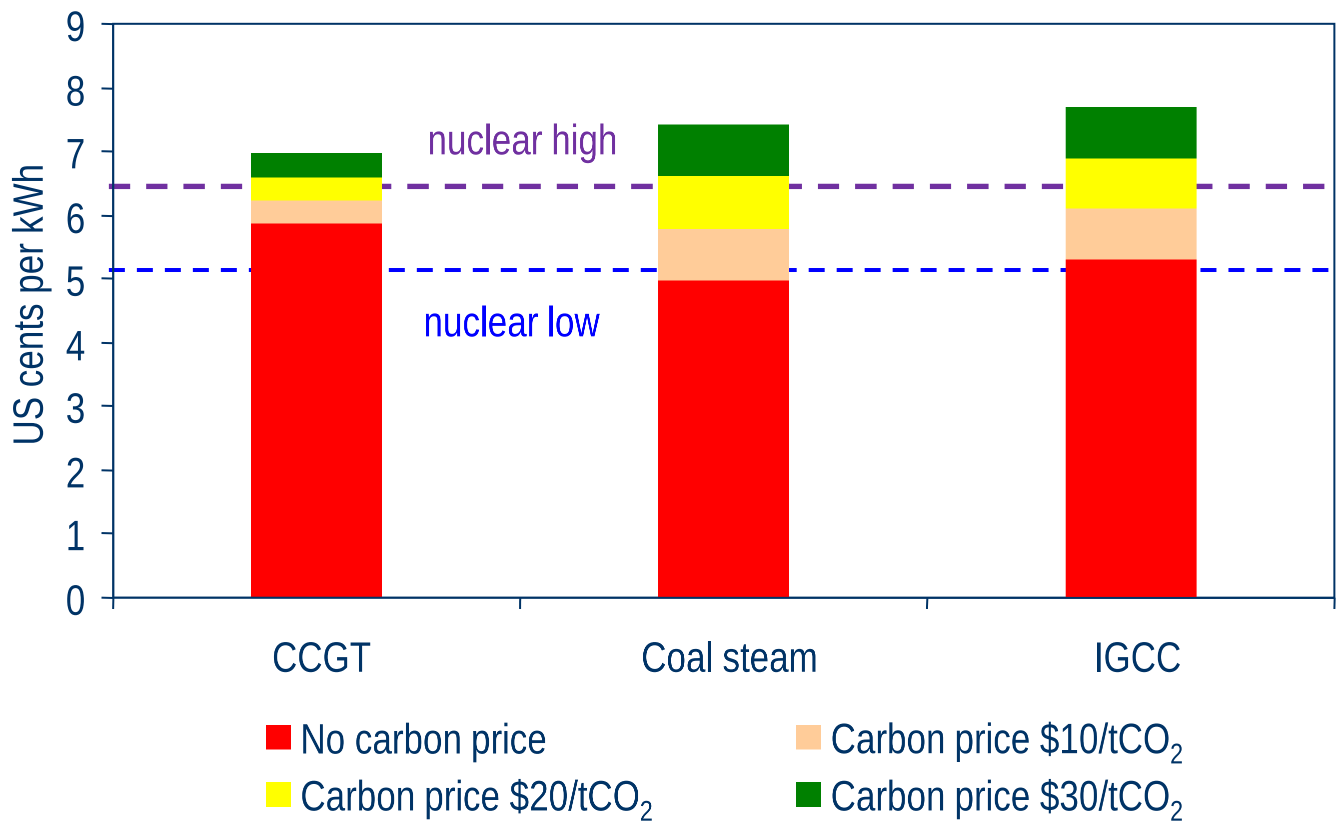


Is nuclear competitive?



Impact of CO_2 penalty on competitiveness of nuclear power

Comparative Generating Costs Based on Low Discount Rate



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

Source: IEA, 2006

Nuclear power, economic growth and new employment

- Nuclear, CSP and small hydro provide comparable number of jobs per MWe of installed capacity

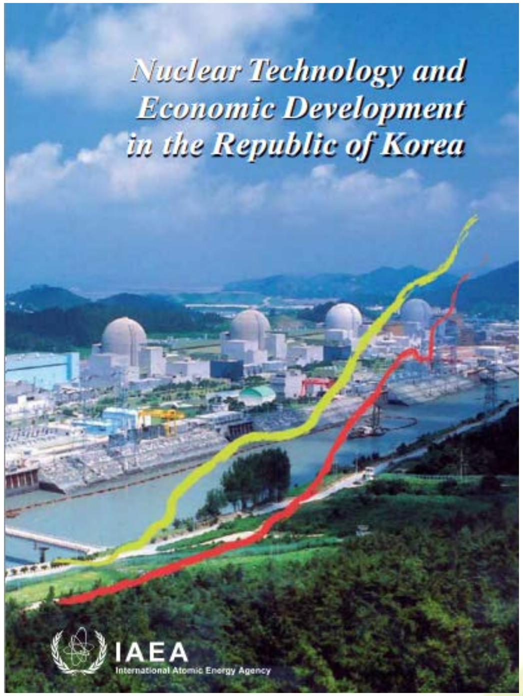
Comparison of permanent direct local jobs per megawatt of installed electric capacity.

Technology	Jobs/MWe
PV	1.06
Nuclear	0.5038
CSP	0.47
Micro Hydro < 20 MW	0.45
Hydro > 20 MW	0.19
Coal	0.1866
Hydro > 500 MW	0.1137
Hydro Pumped Storage	0.0954
Combined Cycle	0.0544
Wind	0.049

Source: Harker and Hirschboeck, 2010

…there are also indirect jobs

⇒ In USA, for every 100 direct jobs in nuclear plant, 726 indirect and induced jobs are created in the rest of economy



- In comparison to its alternatives, more skilled labour is necessary to design and operate nuclear technologies

⇒ High potential to generate economic value

Addressing the issues

- **Innovation is key**
  - **“Even if you’re headed in the right direction, if you stand still, you’ll get run over”**
- **Advanced fuel cycles**
- **Physical protection**
- **Reactor design/technology**
- **Safety**
- **Institutions and capacity building**
- **Knowledge management**

Addressing the issues

- Fuel cycle management to follow 3R principles
  - Reduction of natural resource use
  - Higher burn-up
  - Reprocessing and reuse of U and Pu
  - Minimization of waste generation
- Separation and transmutation (S&T) addresses
  - times lines of radio-toxicity of HLW
  - volumes
  - proliferation issues

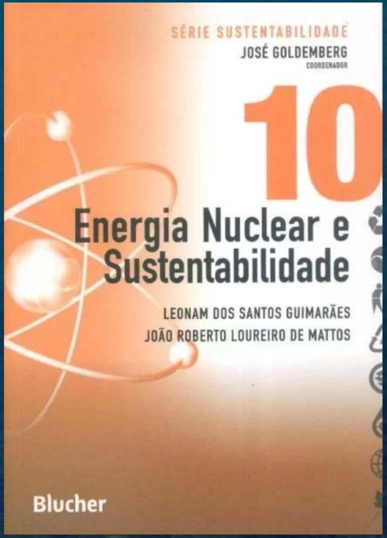
Addressing the issues

- **Proliferation is a political issue calling first of all for political solutions**
  - **Strengthening of the safeguards regime**
  - **Black box**
  - **MNA**
  - **Internationalization of the fuel cycle**
- **Technology solutions**
  - **Development of proliferation-resistant advanced nuclear systems**

Nuclear power and sustainable development

- **Current technology and fuel cycles compare well with non-nuclear alternatives**
- **Nuclear is not perfect – there is ample room for improvement**
- **SD is a moving target**
- **Today's technology is not tomorrow's**
- **Nuclear power to build on its own strength**

MUITO OBRIGADO PELA ATENÇÃO!



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