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Joint ICTP-IAEA School of Nuclear Energy Management

8 - 26 August 2011

Economics of Nuclear Power

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The Economics of Nuclear Power

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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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Economics – Nuclear power

But the general perception persists:

Nuclear is too expensive and always needs subsidies!

Note: Economics are more than costs

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Economics – Nuclear power

- **In reality nuclear can be economic depending on**
  - **Market structures**
  - **Alternatives**
  - **Location**
  - **Boundaries**
- **Nuclear power's economics improve with**
  - **Rising climate change concerns**
  - **High fossil fuel prices and**
  - **Energy security considerations**
- **Ahead of the competition regarding externalities**

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Cost components of electricity generation

- Investment (capital) and interest charged on capital
- Fuel costs
- Fixed operations & maintenance (O&M) costs
- Variable O&M costs (including possible GHG emission charges)
- Externalities

NOTE: For nuclear, fuel costs include spent fuel management/waste disposal.

Decommissioning is an additional investment cost many years in the future.

Full generating costs matter and not subsets of components

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Existing generating plants

- Only carry fuel and variable O&M costs ("marginal generating costs")
- Investment and fixed O&M costs are "sunk" costs
- If electricity rates are higher than the marginal costs the plant will operate (profit margin?)
- Different generating modes compete on the basis of marginal costs only
- Low marginal costs: Comparative advantage of nuclear power

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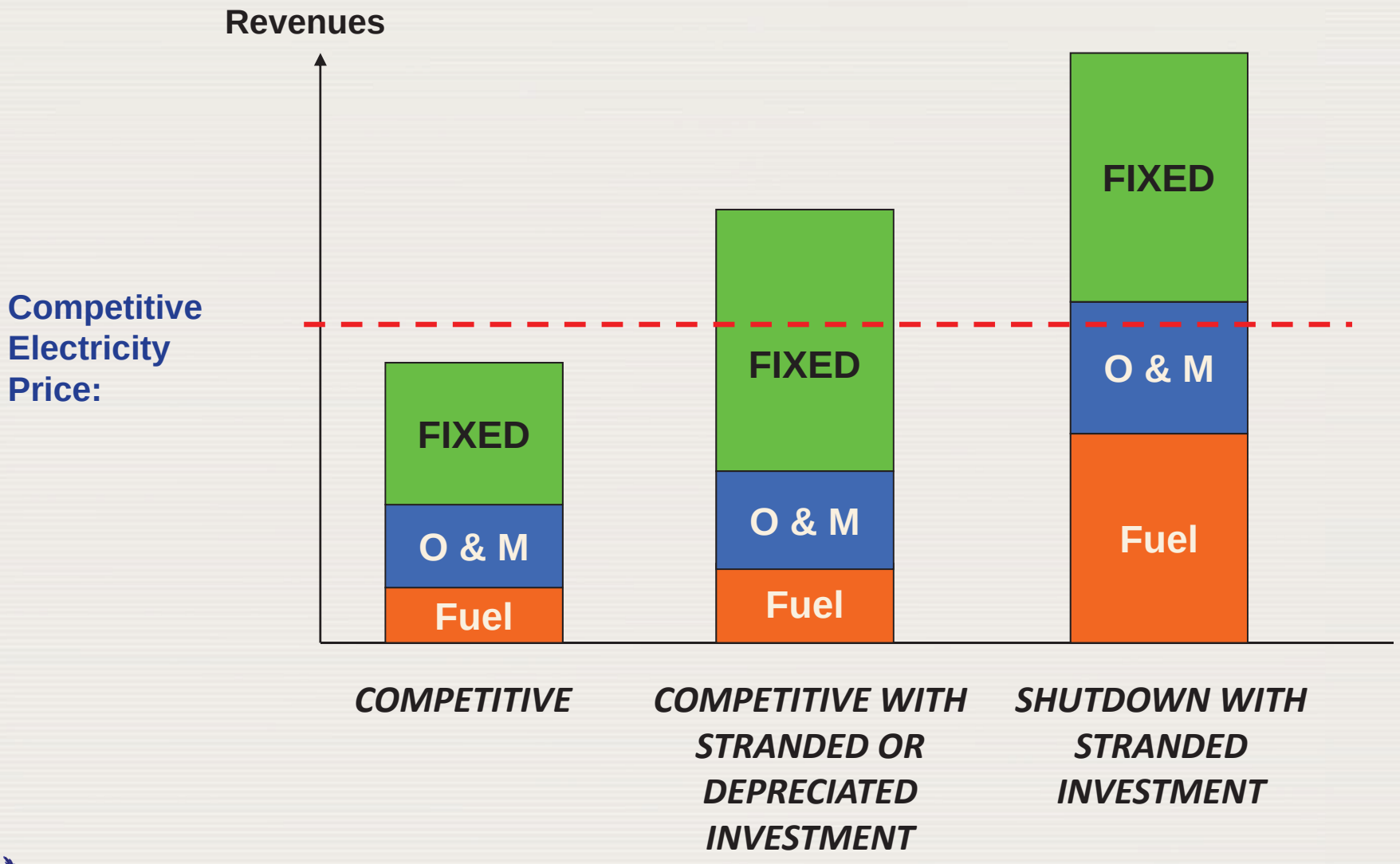
Nuclear Power Plants in a Competitive Market



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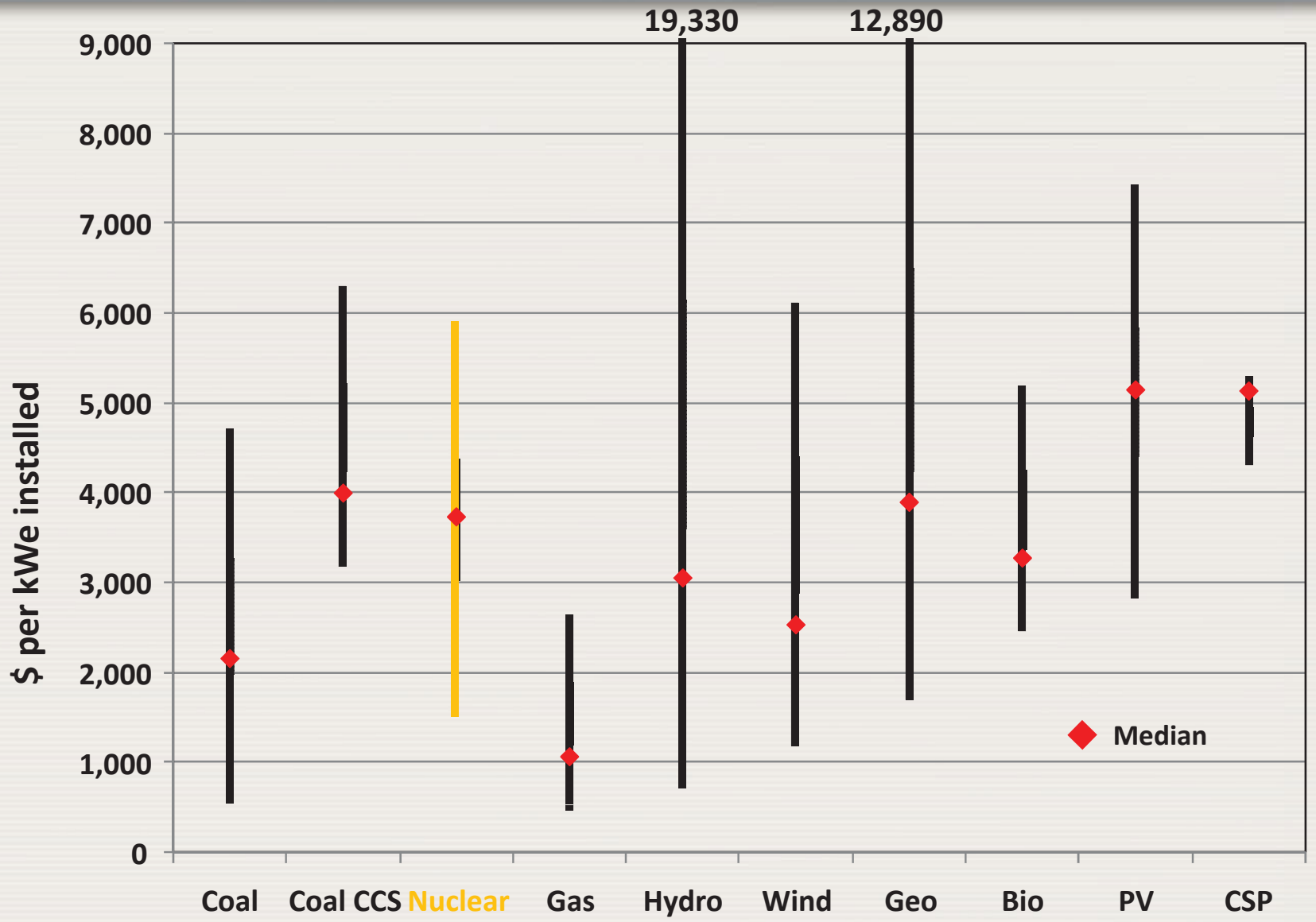
Overnight investment costs (OC) of different electricity generating technologies



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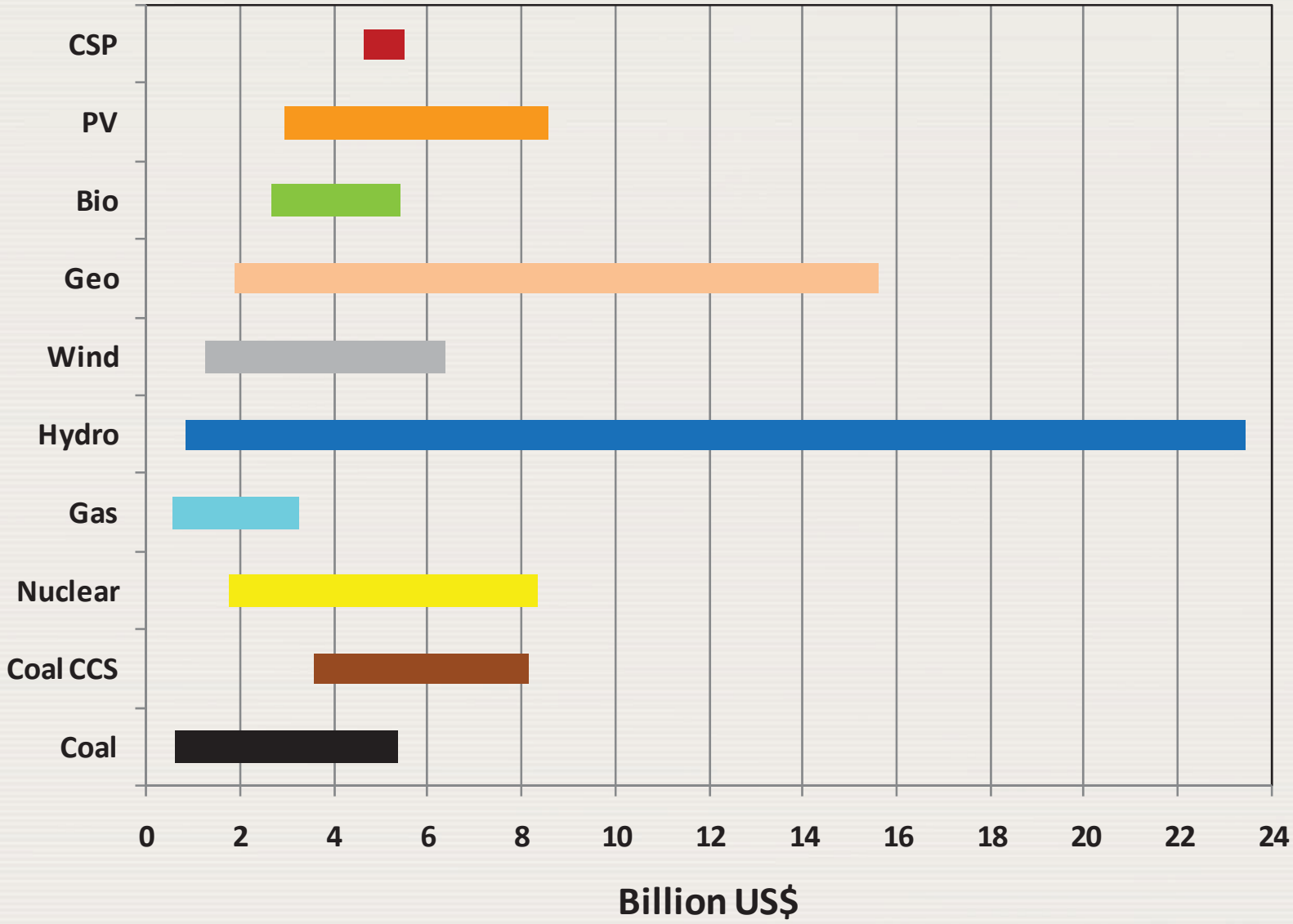
Source: NEA/IEA, 2010

Overnight costs (OC) for 1 000 MWe generating capacity



Source: NEA/IEA, 2010

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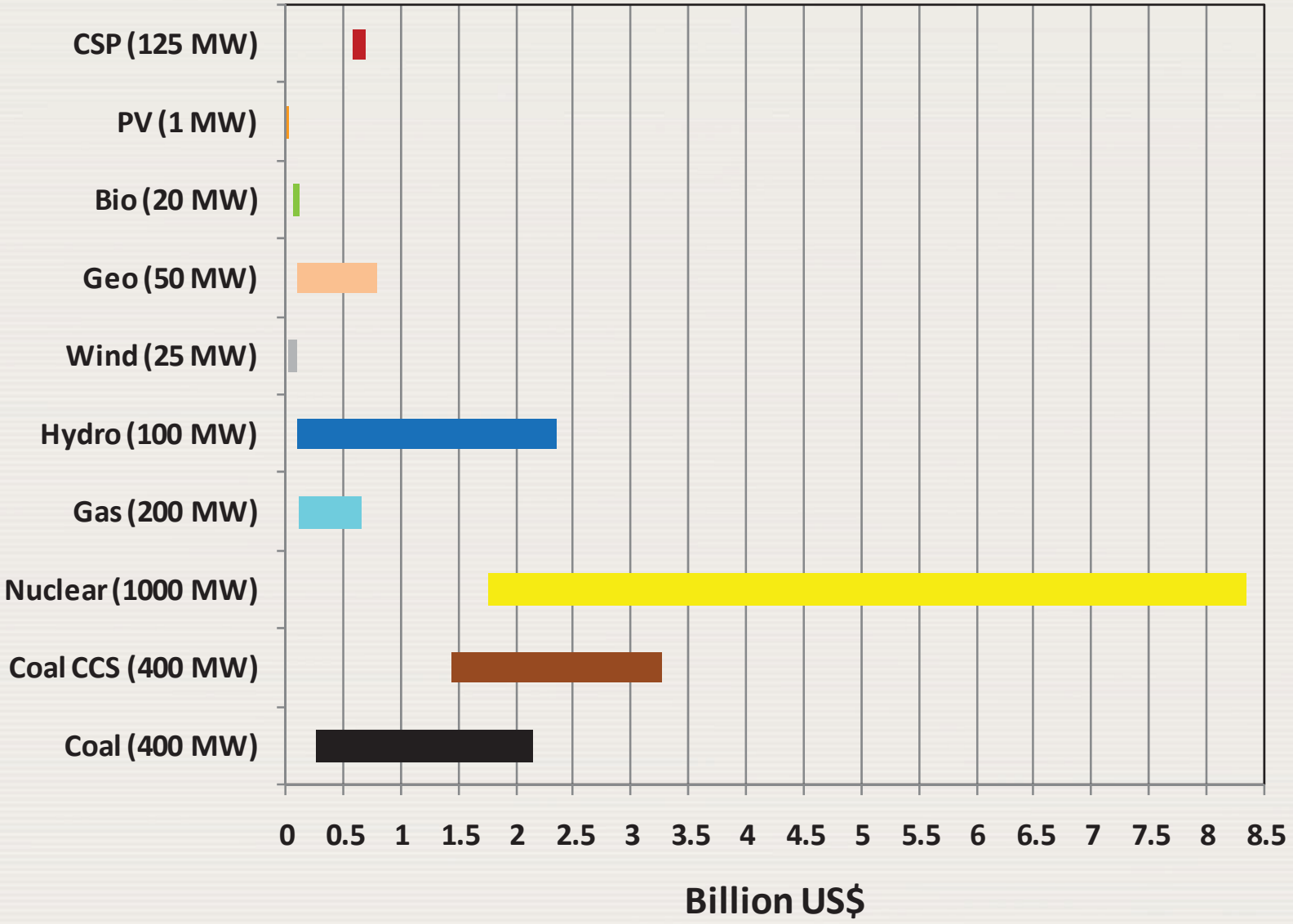
Actual investments per unit (investment decision)



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Source: NEA/IEA, 2010

Investors face more than overnight costs: Key uncertainties

- Boundaries – what is included and what is not
- Which price basis & assumptions on inflation, currency exchange rate, etc
- Location & Infrastructure
- Interest rates and finance structure (IDC, financing costs)
- Completion risks
- Liberalized or regulated market (operating risks)
- Educated nuclear work force
- Component supply situation
- Regulatory/licensing competence & political risks
- Potential subsidies
- Tax implications

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Latest concerns

- Diverging expectations
  - Flamanville: €46/MWh (vs €30/MWh expectation by consumers)
- Material costs up by 50% since 2004
- Construction delays
- Quality concerns
- Knowledge & skilled labour force
- Regulatory & licensing competence

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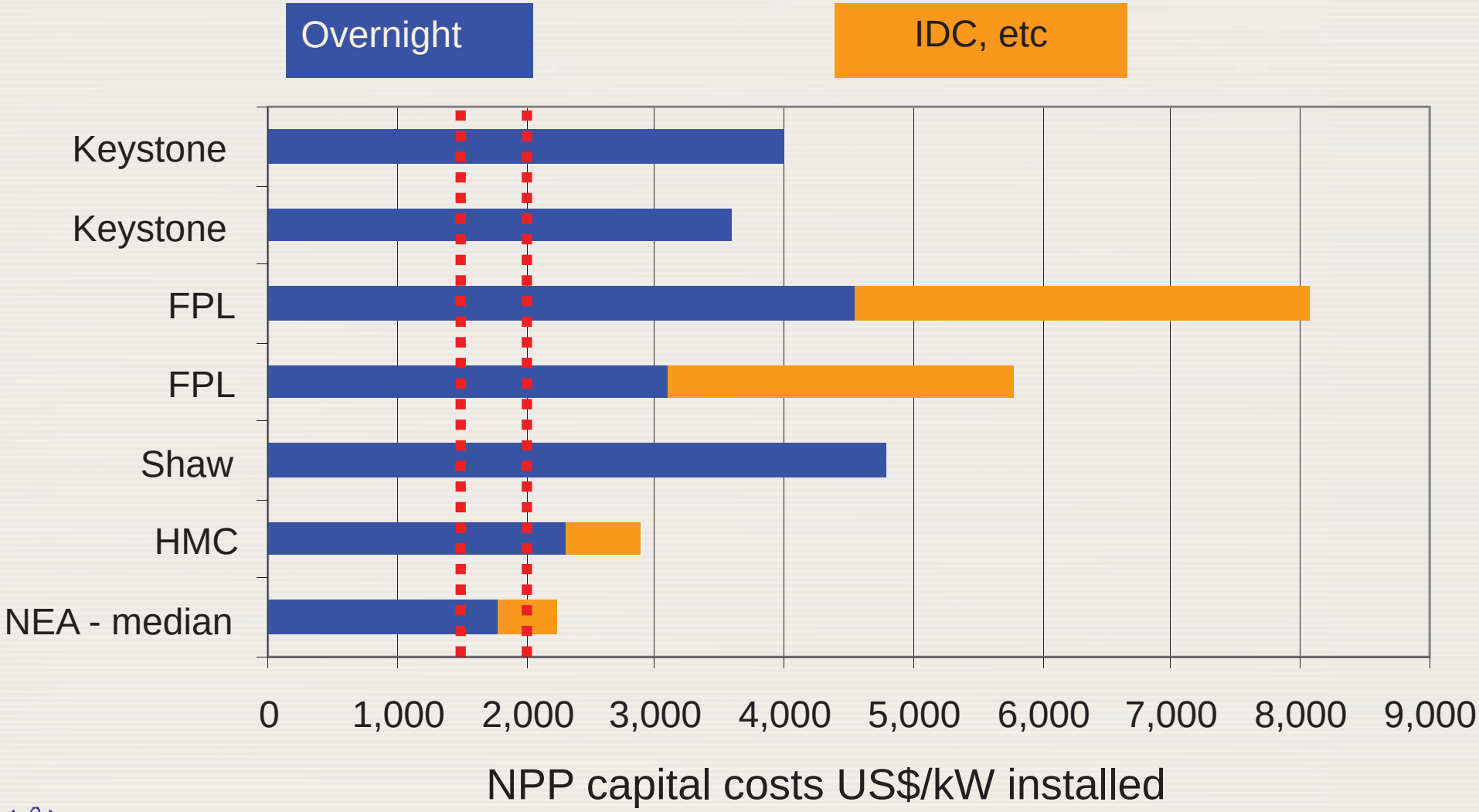
Recently reported NPP investment costs



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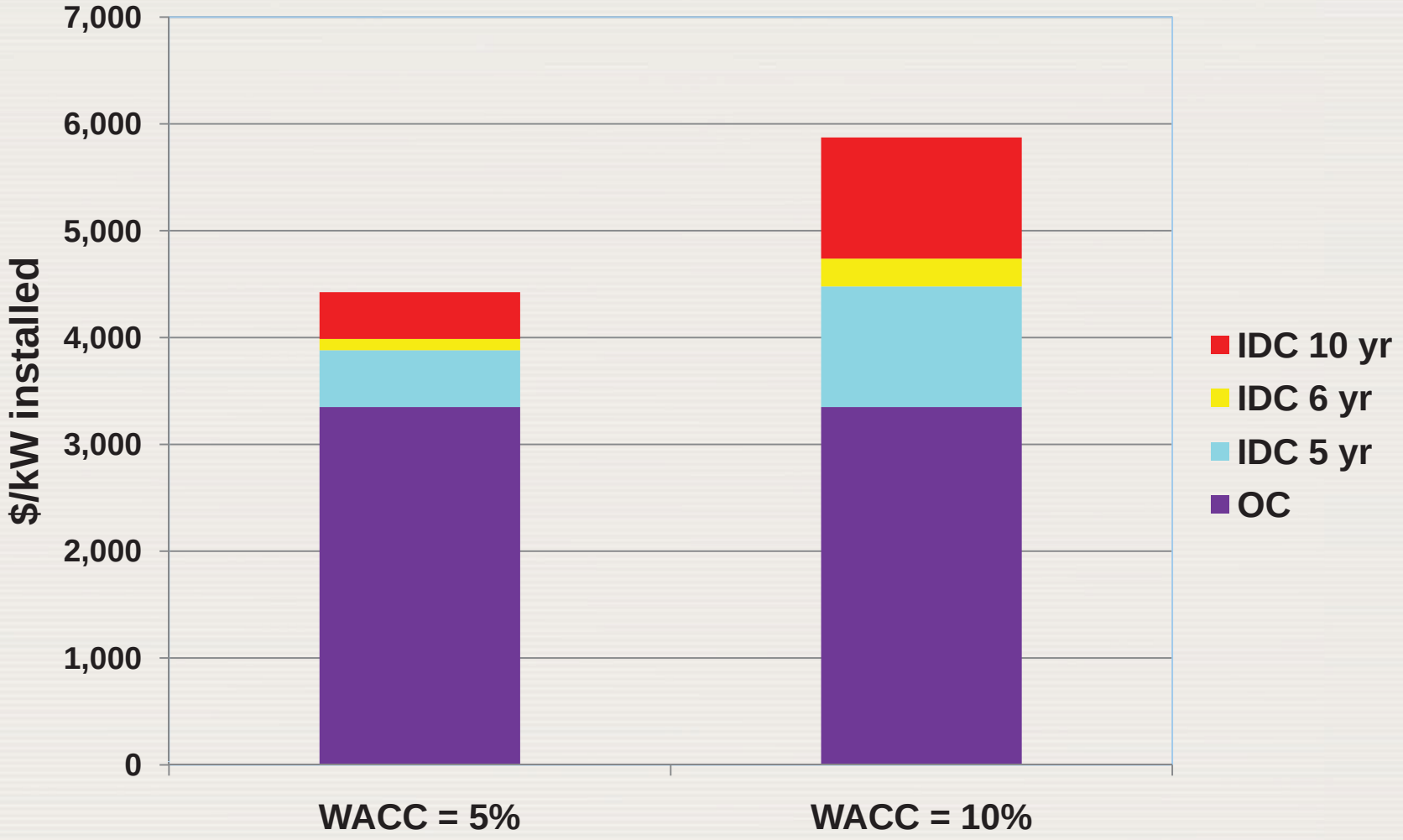
The impact of interest rates and plant construction time



WACC = Weighted average cost of capital

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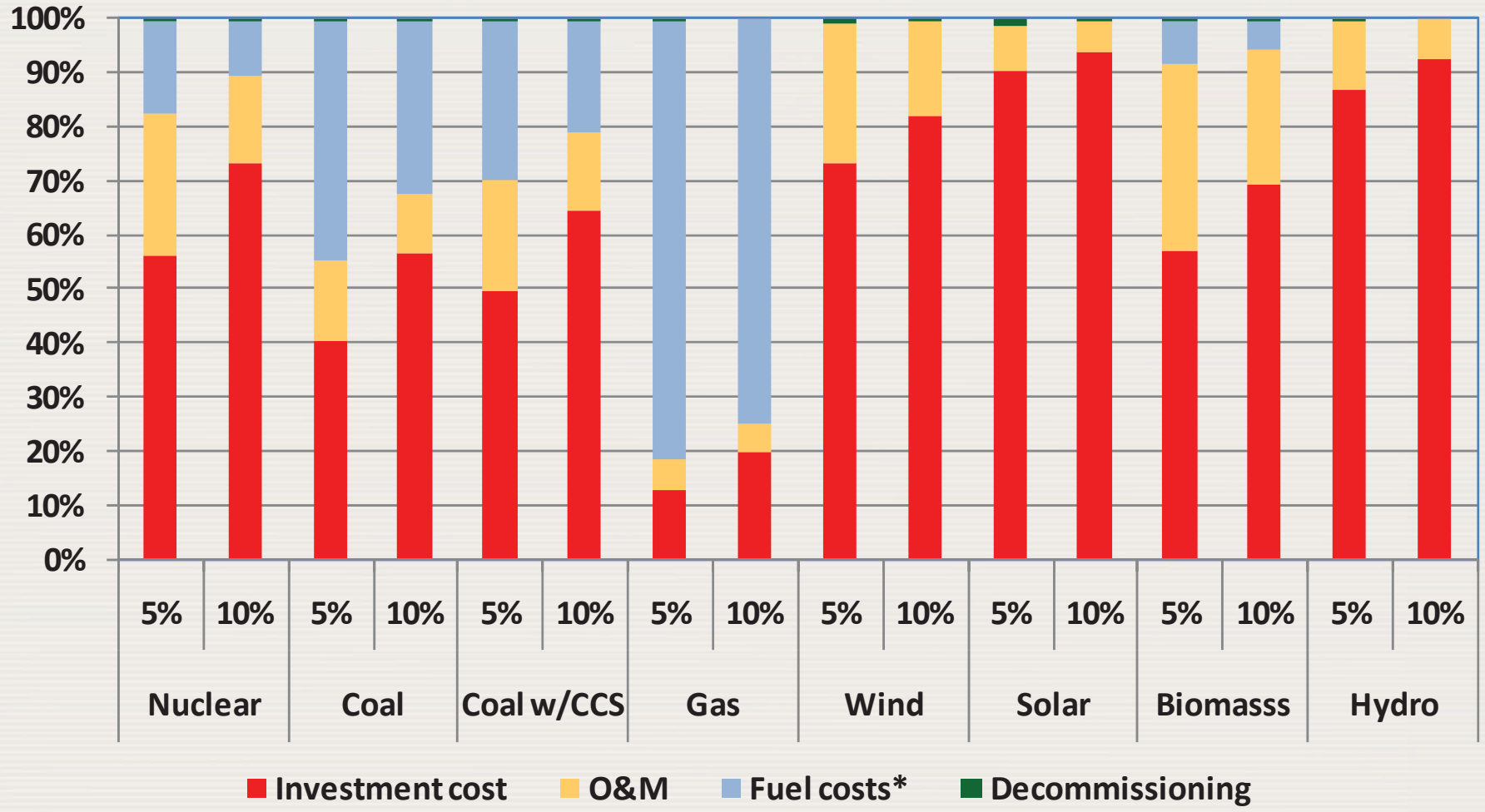
Generating cost structure (including IDC)



*Fuel costs for nuclear comprise the costs of the full nuclear fuel cycle including spent fuel reprocessing or disposal.

Source: NEA/IEA, 2010

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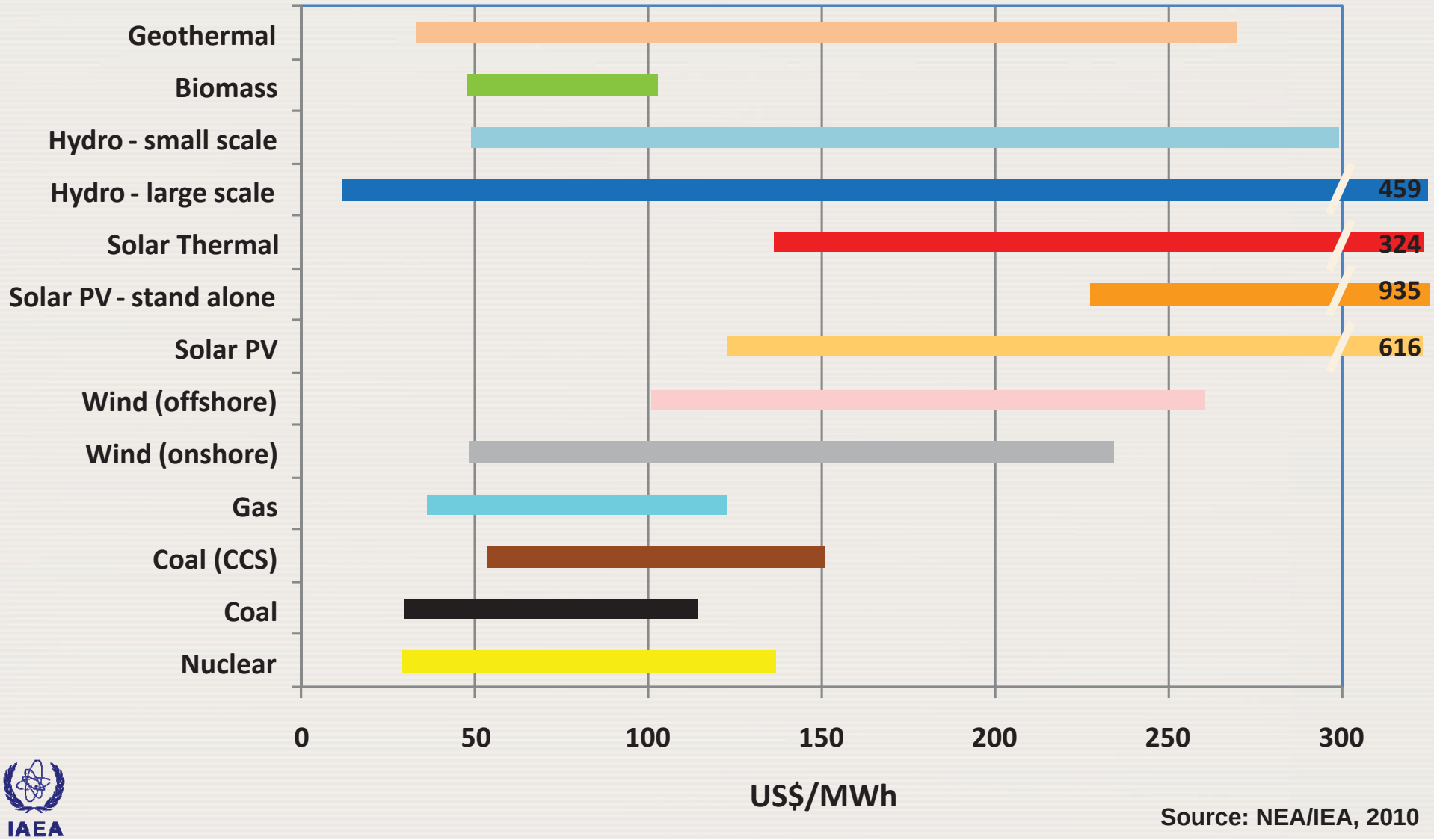
Range of levelized generating costs of new electricity generating capacities



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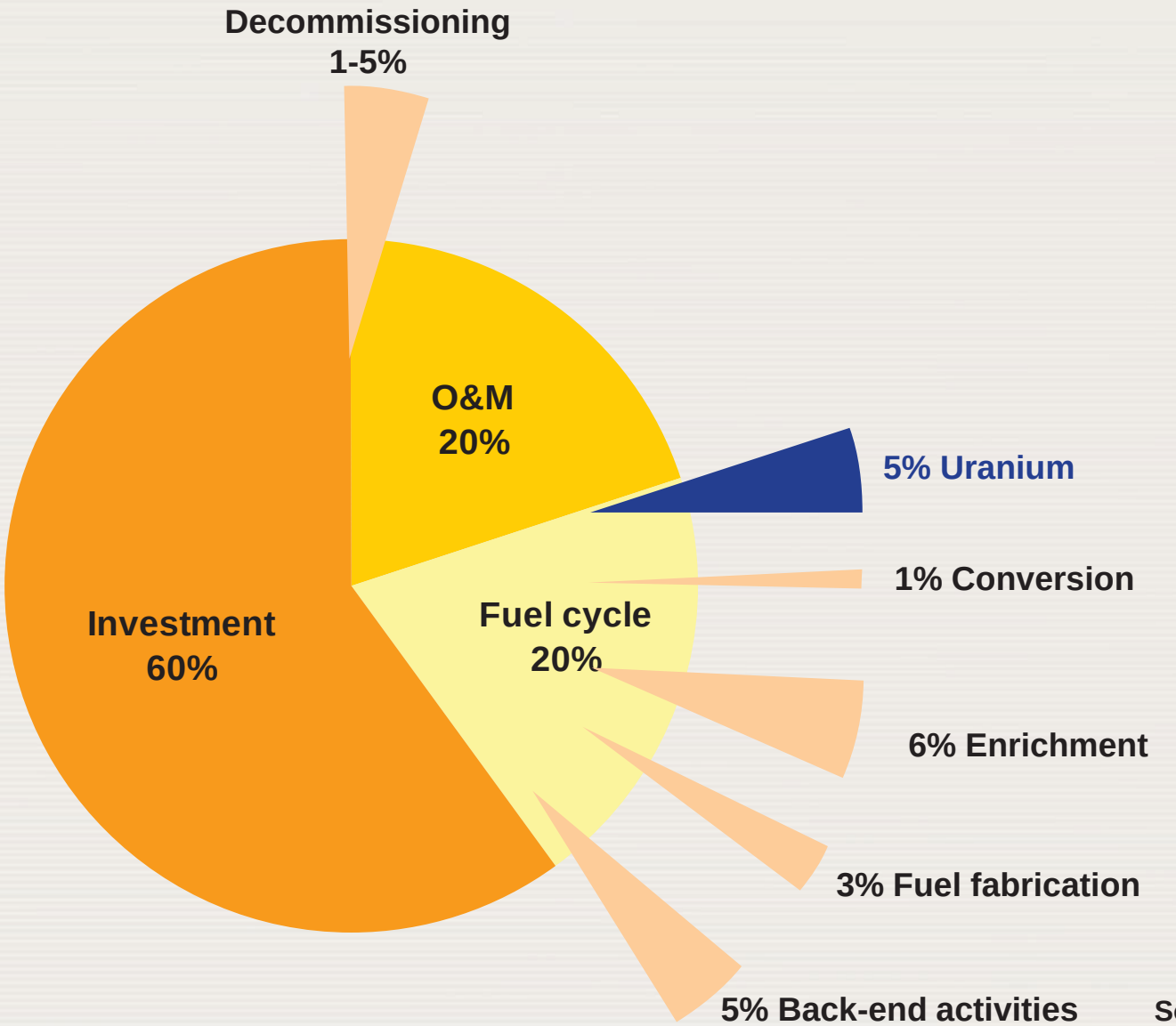
Source: NEA/IEA, 2010

Typical nuclear electricity generation cost breakdown



Source: NEA

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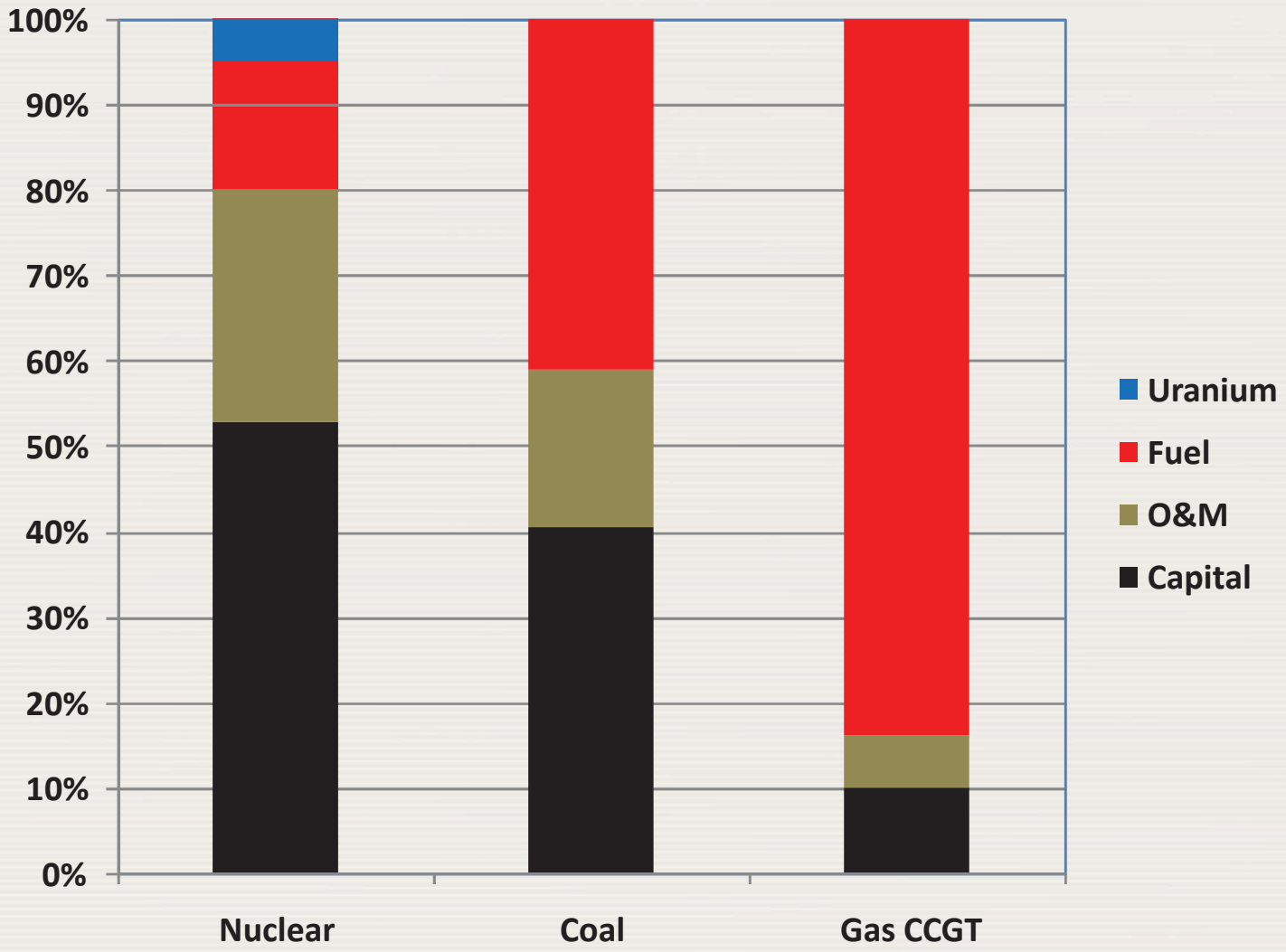
Cost structures of different generating options



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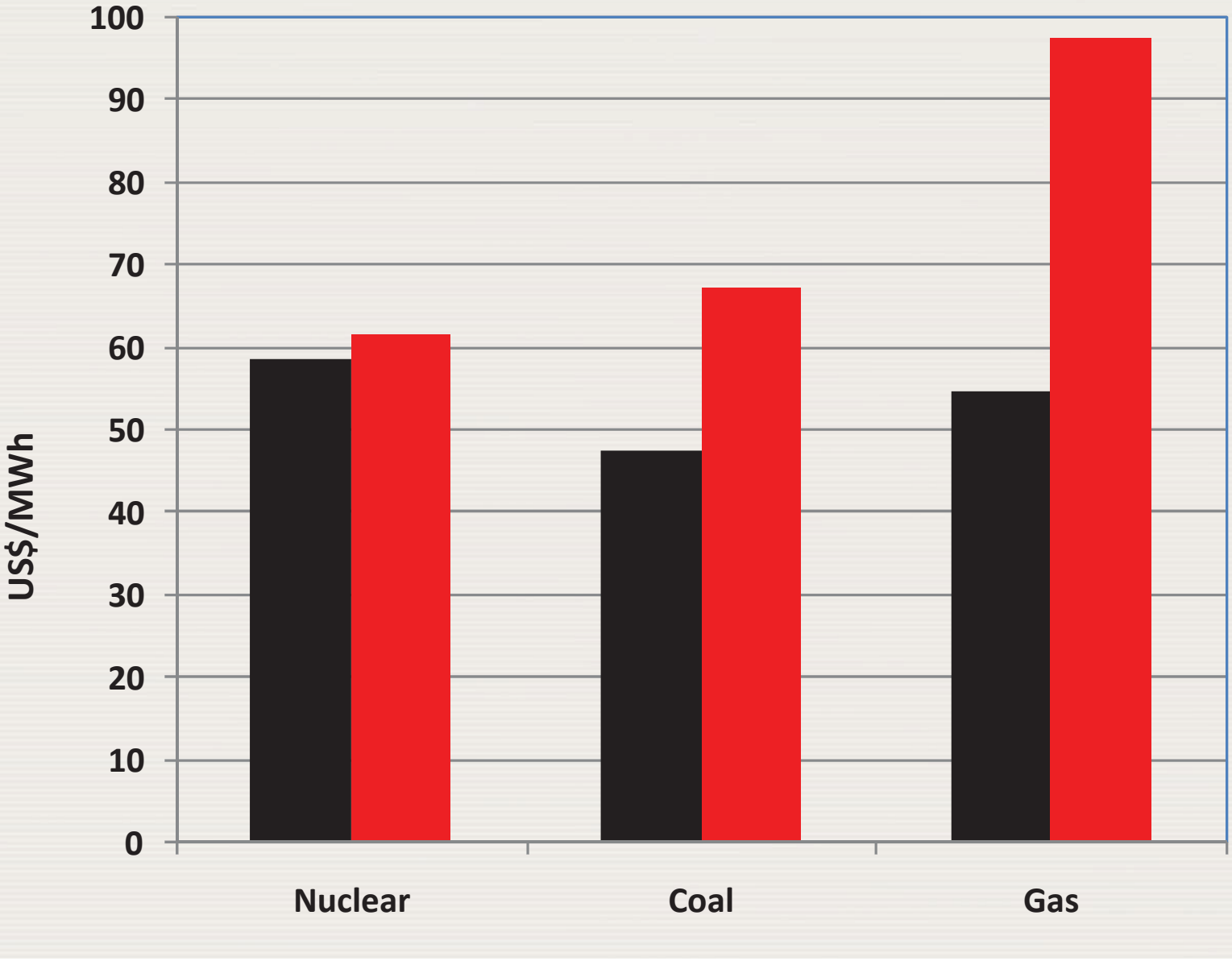
Impact of a doubling of resource prices on generating costs



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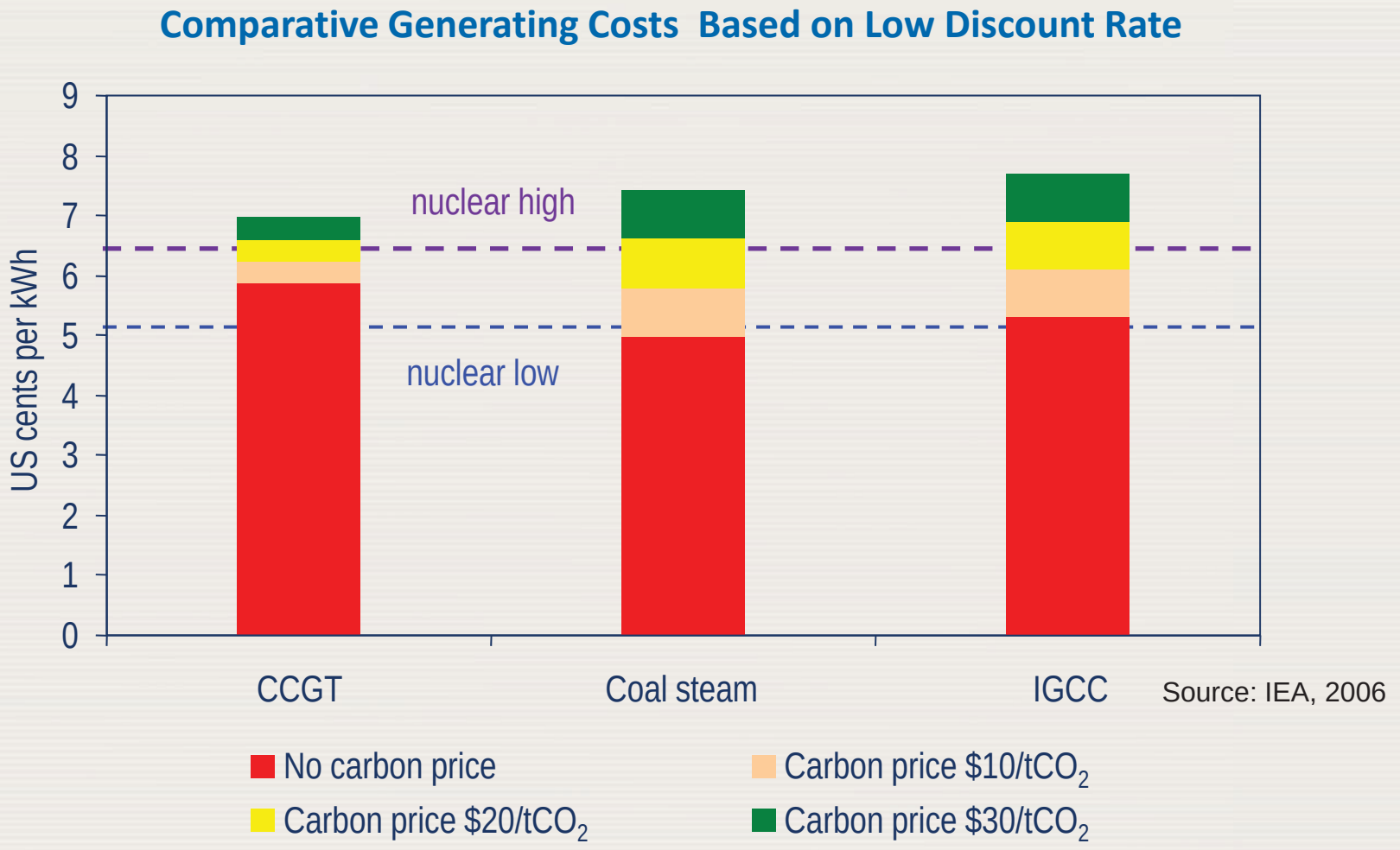
Impact of CO_2 penalty on competitiveness of nuclear power



Source: IEA, 2006

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

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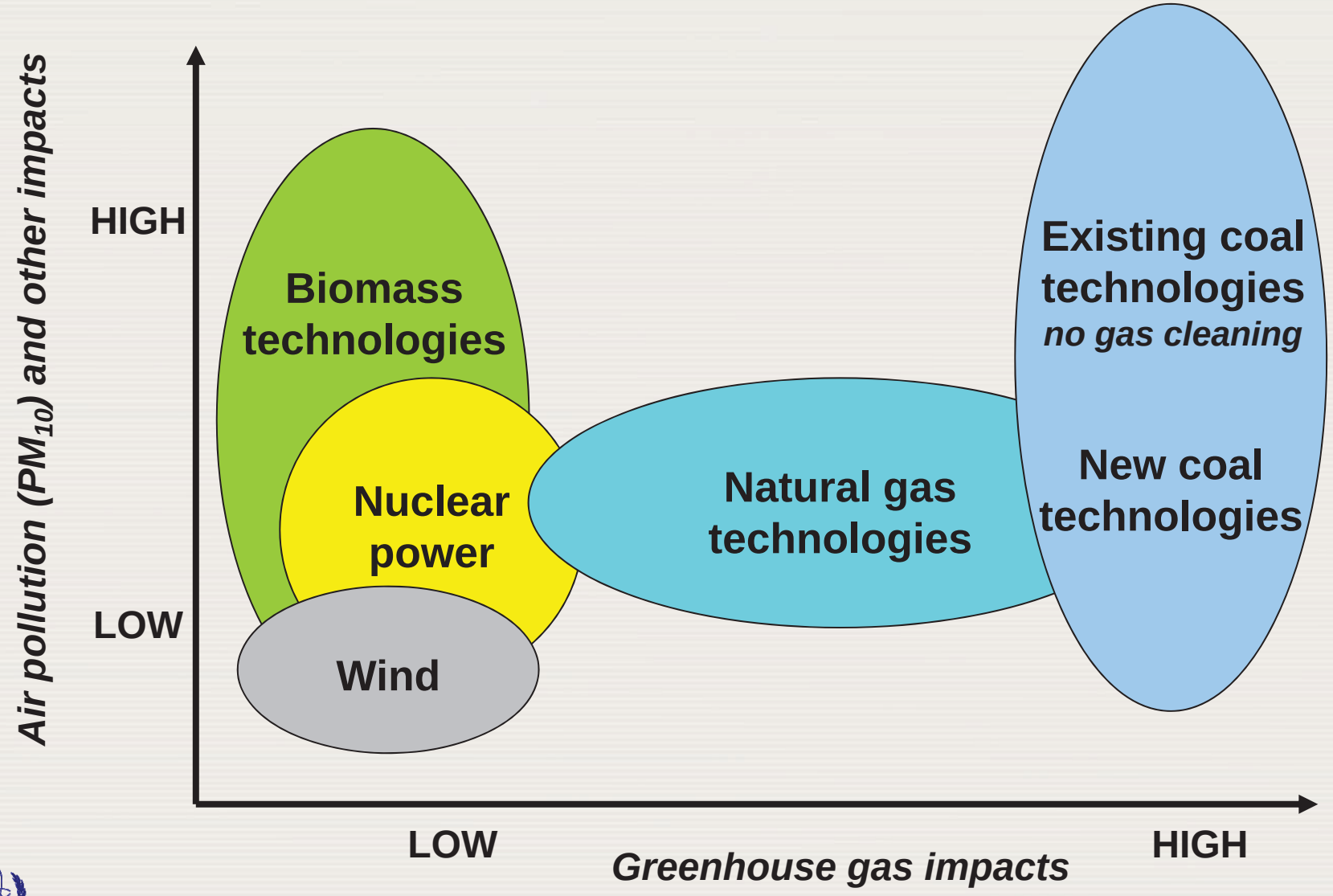
Externalities of different electricity generating options



Source: EU-EUR 20198, 2003

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What are externalities?

- Externalities are changes of welfare generated by a given activity without being reflected in market prices. They may be positive (benefits) or negative (costs)
- A cost (benefit) is external when it is not paid (enjoyed) by those who have generated it
- Negative externalities are borne by society: they should be reduced, and passed on to those who generate them (application of the “polluter pays principle” through internalisation)

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Examples of external costs

Air pollution increases hospital admissions for respiratory illness

- Costs of health care
- Lost productivity
- Own pain and suffering
- Pain and suffering of others

Water pollution leads to loss of fish

- Reduced recreational opportunity
- Commercial losses
- Impact on biodiversity

Congestion leads to loss of time, productivity

Consequence of large scale accidents

- Evacuation, loss of income
- Increased health costs, psychological impacts, etc

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Examples of controversial/difficult to estimate external effects

- Severe accidents, terrorism, risk aversion
- Value of loss of life
- Visual intrusion
- Resource depletion
- Nuclear proliferation
- Biodiversity losses
- Security of supply
- Social justice and conflict potential

➢ Serious attempts to estimate the corresponding costs mostly lead to low estimates but this does not resolve the controversy!

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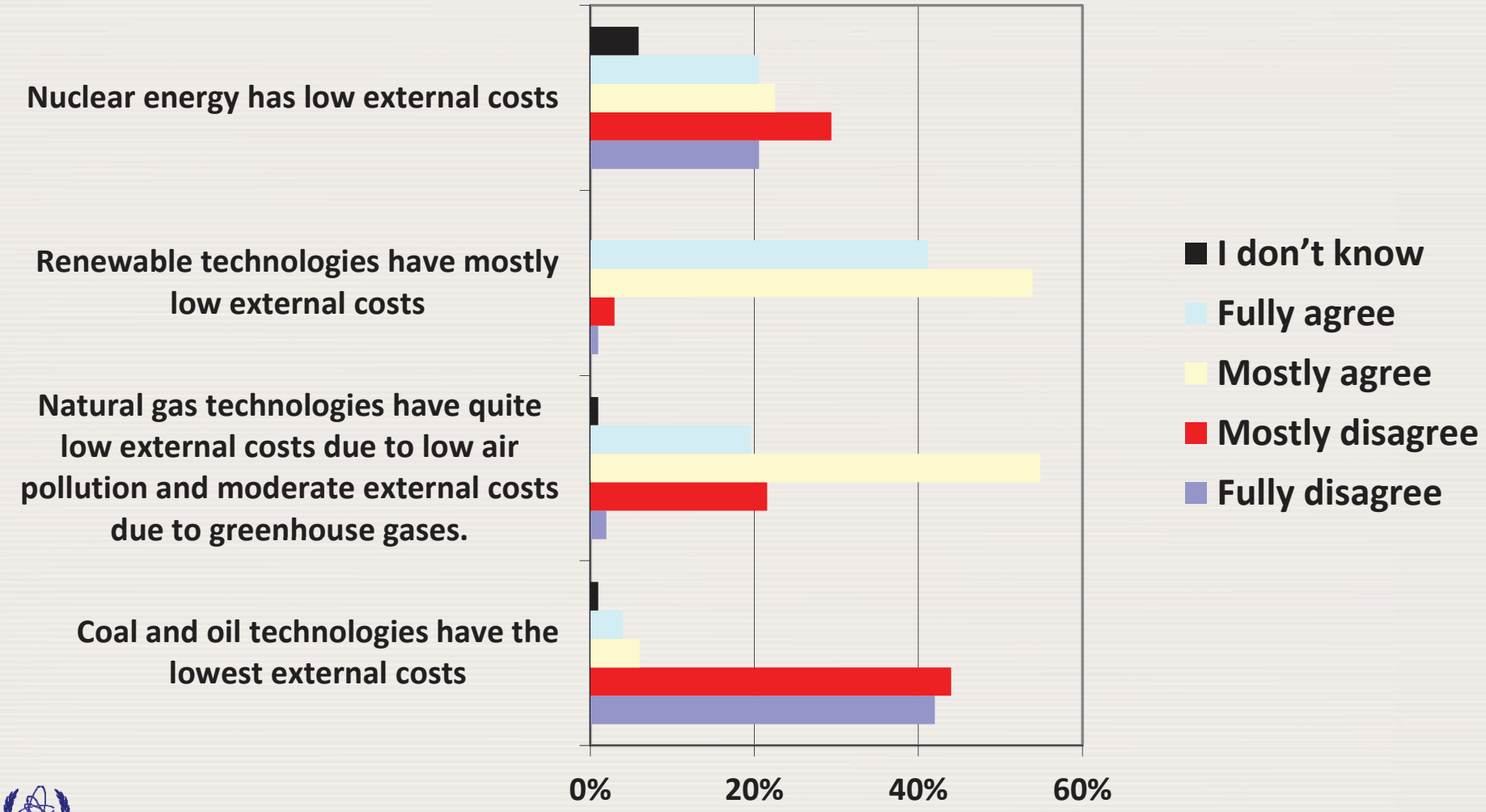
NEEDS Survey I: Externality Concept, Results & Uses

In spite of the limitations, there is general acceptance of the concept of externalities, of the internalisation of external costs and of most results, but…



Source: Faberi et al., 2007

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New nuclear plants

- **If operating plants are so profitable, why are there not more current orders?**
- Perception of risk versus alternatives
- Nuclear has high investment costs, takes long time to come into operation, then has low and stable operating costs over long pay-back periods
- Gas plants have low investment costs, are built quickly, then have high and variable operating costs
- Coal fits between nuclear and gas – average investment costs and average marginal costs
- Hydro plants – high investment costs and very low marginal costs – no fuel cost!
- Renewables such as wind and solar have high investment costs, low marginal costs but intermittent availability

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New generating plants

- To be economic, new plants must cover investment costs including interest charges, fixed O&M and marginal costs – "full costs"
- Compare these full costs against the likely electricity price to be received over the lifetime of the plant
- When considering different options for new generating capacity, they are assessed on these full costs
- But the timing of the costs, as well as their magnitude, is crucial

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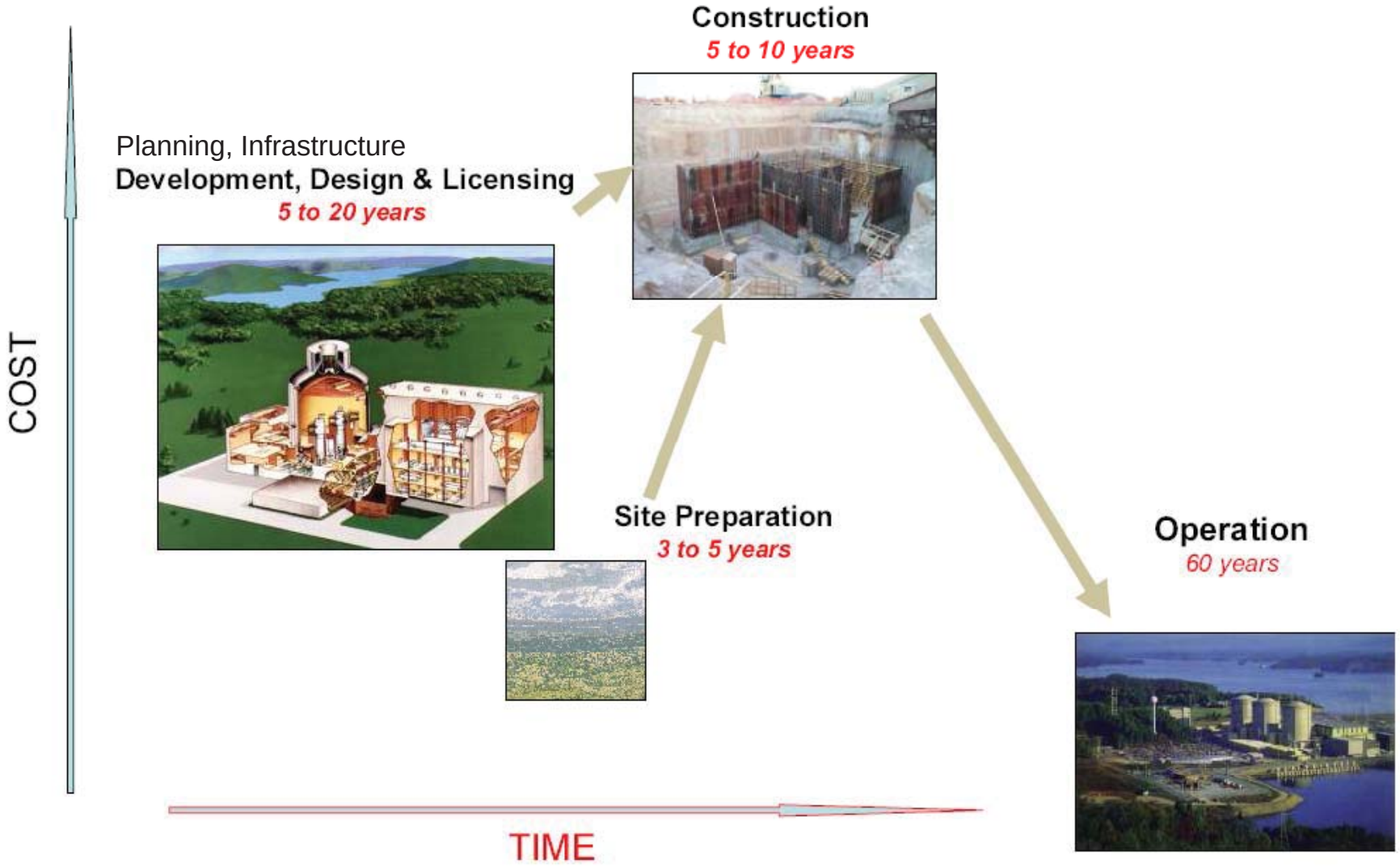
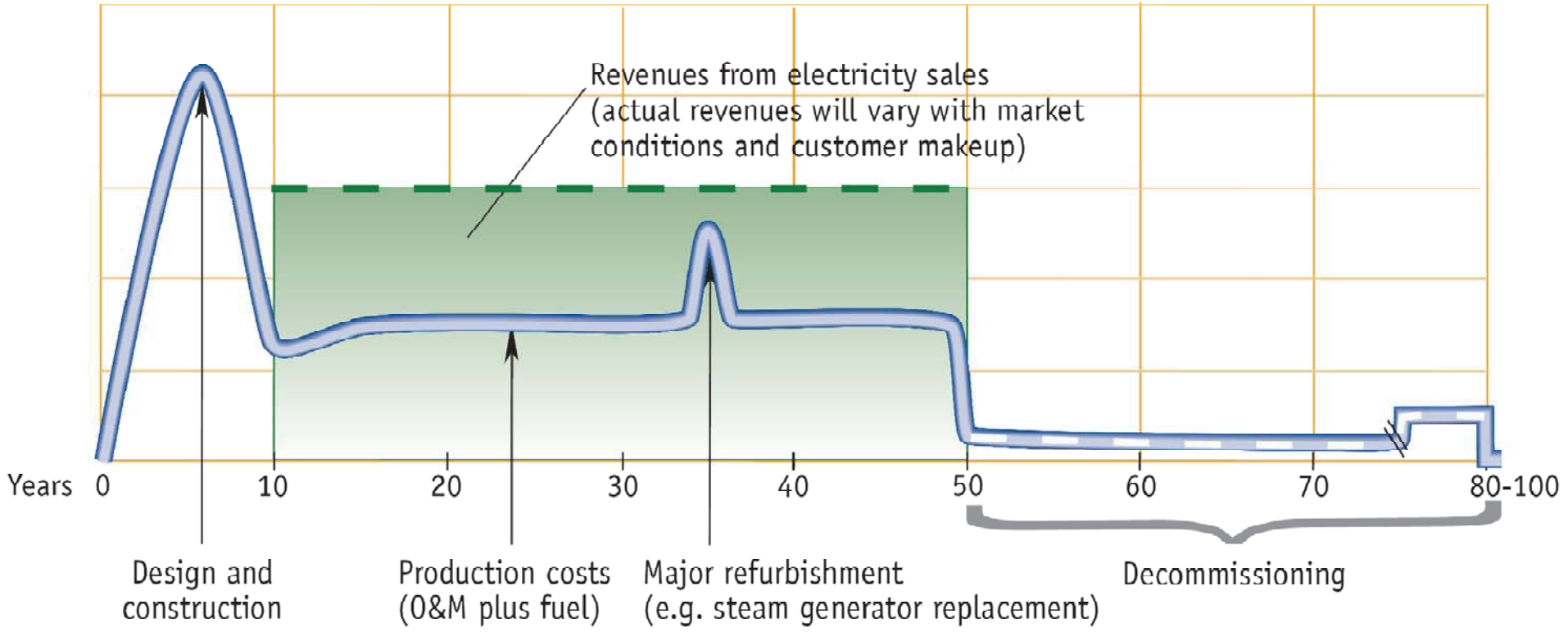
Steps in advanced plant deployment - all attempt to reduce schedule & capital costs



Illustrative life cycle cash flow for a nuclear power plant



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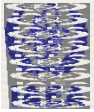
Project Stakeholders

- Government
  - Responsible for overall policy and, in some cases, financing
- Market (Electricity customers)
  - Need electricity and are prepared to pay a fair price
- Utility (Generator)
  - Responsible for developing projects and producing electricity for the benefit of customers
  - Takes total project risk if balanced by good structure and attractive markets
- Vendor
  - Responsible for technology, project delivery to schedule and budget
- Regulator
  - Responsible for protecting public safety in a manner that enables projects to proceed
- Lenders
  - Provide funds subject to adequate risk profile

A successful project meets the needs of all stakeholders



Old Model

- **Governments assume all risks and costs**
- **Vendors built on cost plus basis (Contract Structure)**
- **Utilities (Generators) borrowed on balance sheet (Financing Structure)**
- **All costs - construction and operations – are passed on to the customer (Market Structure)**

Essentially 100% risk on the customer
Many projects had long delays and significant overruns

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Market Structure

- Regulated markets
  - Costs are passed through to the customer
  - Only “prudent” costs are accepted
  - Regulator to determine if costs are “prudent”
- De-regulated markets
  - Merchant plant
    - Prices vary daily or hourly
    - Long project schedules make predicting prices very difficult
    - Project completion uncertainty
    - Once completed: full competitive risks
  - Power Purchase Agreement (PPA)
    - Fix prices at the start of the project
    - Difficult to accommodate project overruns and changes in cost over the life of the project
    - Tendency of re-negotiation

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New nuclear plants

- **Which type of plants are the most economic depends on several factors**

1. **Nuclear investment cost**
2. **Public/political acceptance**
3. **Performance of renewables**
4. **Gas/coal prices & expectations**
5. **Interest/discount rates**
6. **Market structure**
7. **Policy (energy security, protection of the environment, renewable directives, etc.)**
8. **Carbon capture and storage (CCS)**

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Summary: Nuclear Power

- Nuclear *base load* electricity can be economically competitive
- 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
- Nuclear needs firm public policy support (*level playing field*)

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Economics of NP after Fukushima

- **Existing reactors:**
  - **Stress tests will determine additional safety upgrade requirements**
  - **Refurbish/upgrade costs may render some plants uneconomic (early closures or no license extensions)**
- **New builds**
  - **Costs of generation III and III^{+} designs are unlikely affected (other than due to siting considerations)**
  - **Regulatory/policy uncertainty increase investor risks**
  - **Shift to SMRs could potentially lead to lower investment risks (and costs)**

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Finally: One size does not fit all

- Countries differ with respect to
  - energy demand growth
  - alternatives
  - financing options
  - weighing/preferences
- All countries use a mix. All are different.
- Local conditions determine the optimal supply and technology mix
- Energy analysis & planning help identify optimal energy demand & supply strategies

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…atoms for peace.

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