The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific
and Cultural Organization

International Atomic
Energy Agency

Workshop on "Physics for Renewable Energy"
October 17 - 29, 2005

301/1679-33

"Nuclear Power & Sustainable Development"

A. McDonald
IAEA
Vienna, Austria

Nuclear Power and Sustainable Development

ICTP, Trieste, Italy • 28 October 2005

Alan McDonald
Department of Nuclear Energy

IAEA
International Atomic Energy Agency

Three take-aways

- Rising expectations
- One size does not fit all
- “It’s the economics!”

A history of mistaken forecasts

- "The energy produced by breaking down the atom is a very poor kind of thing. Anyone who expects a source of power from the transformations of these atoms is talking moonshine."

Lord Ernest Rutherford
1933

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A history of mistaken forecasts

- “It is not too much to expect that our children will enjoy in their homes [nuclear generated] electrical energy too cheap to meter.”

Lewis Strauss
Chairman
US Atomic Energy Commission
1954

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A history of mistaken forecasts

- After WW2, “America danced the atomic boogie, drank atomic cocktails… The atom was our friend.”
- In 1975 IAEA still forecast, globally
  - 1990: 1000 – 1300 GW(e)
  - 2000: 3600 – 5300 GW(e)
- Actual 2005 capacity is 369 GW(e)

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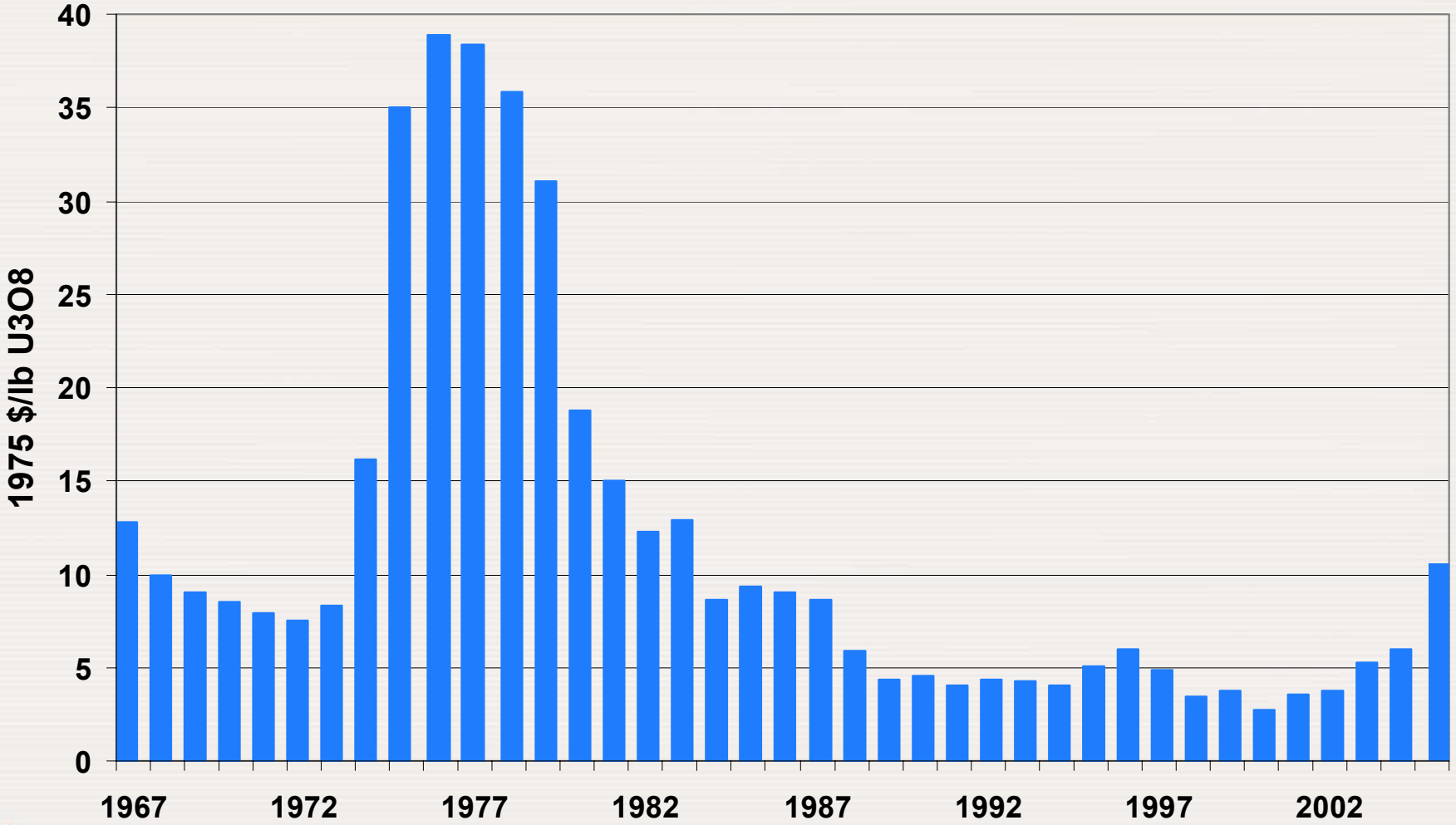
Uranium Price



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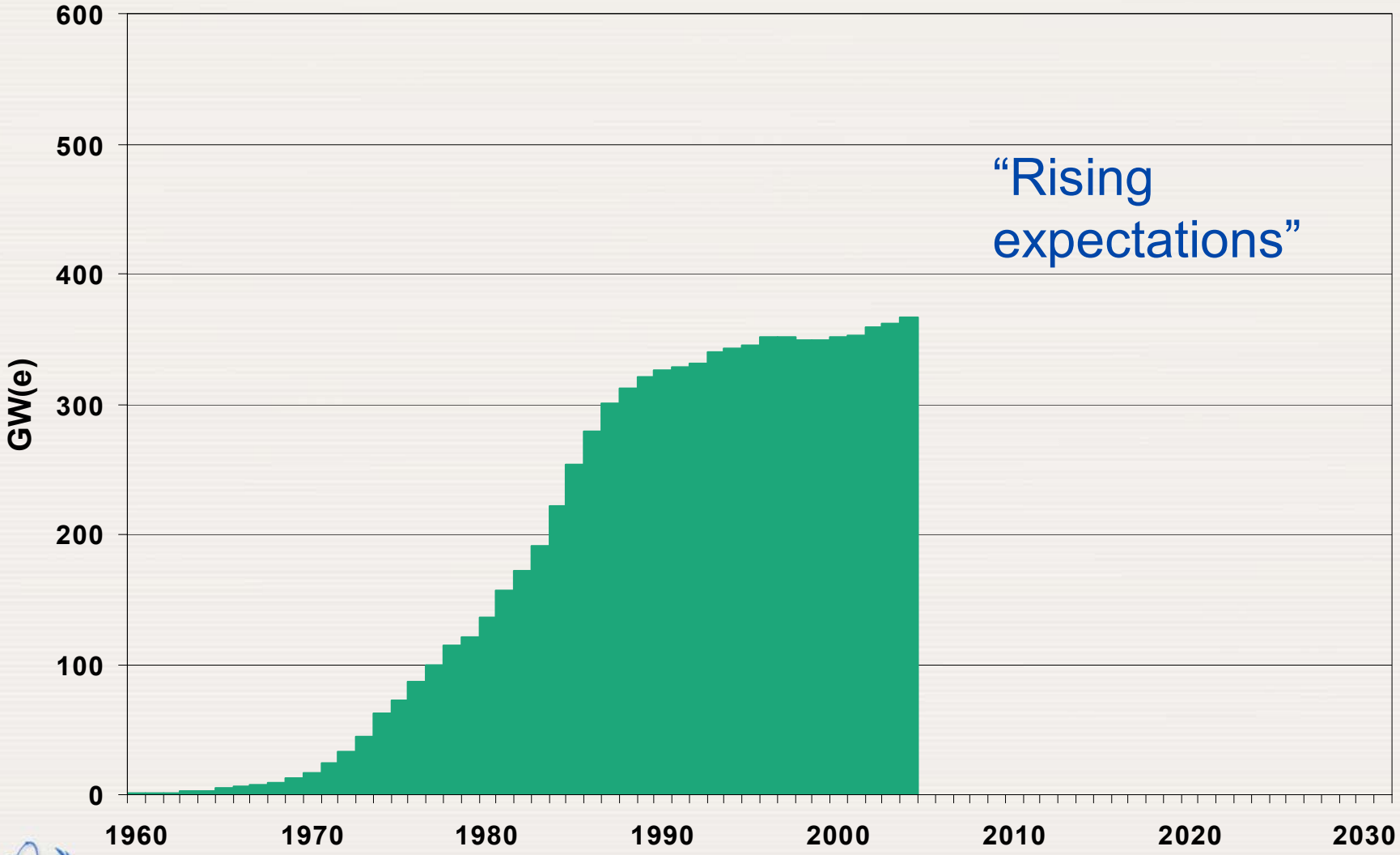
Global nuclear capacity (1960-2004)



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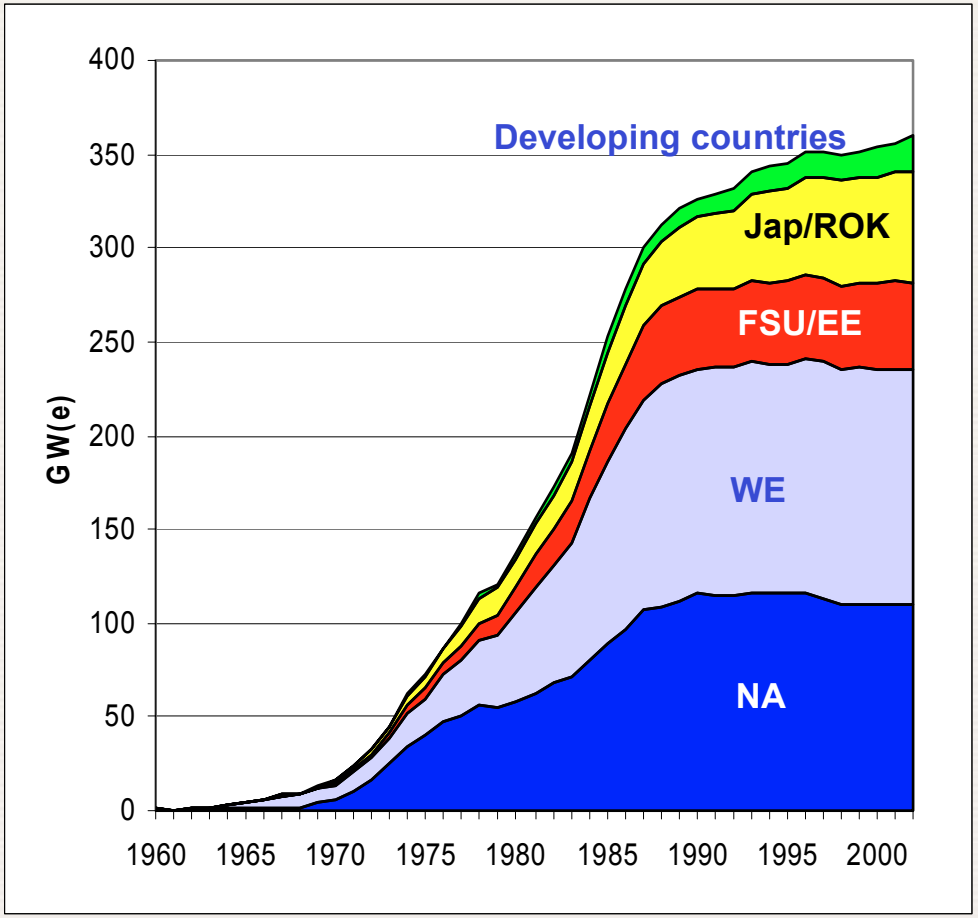
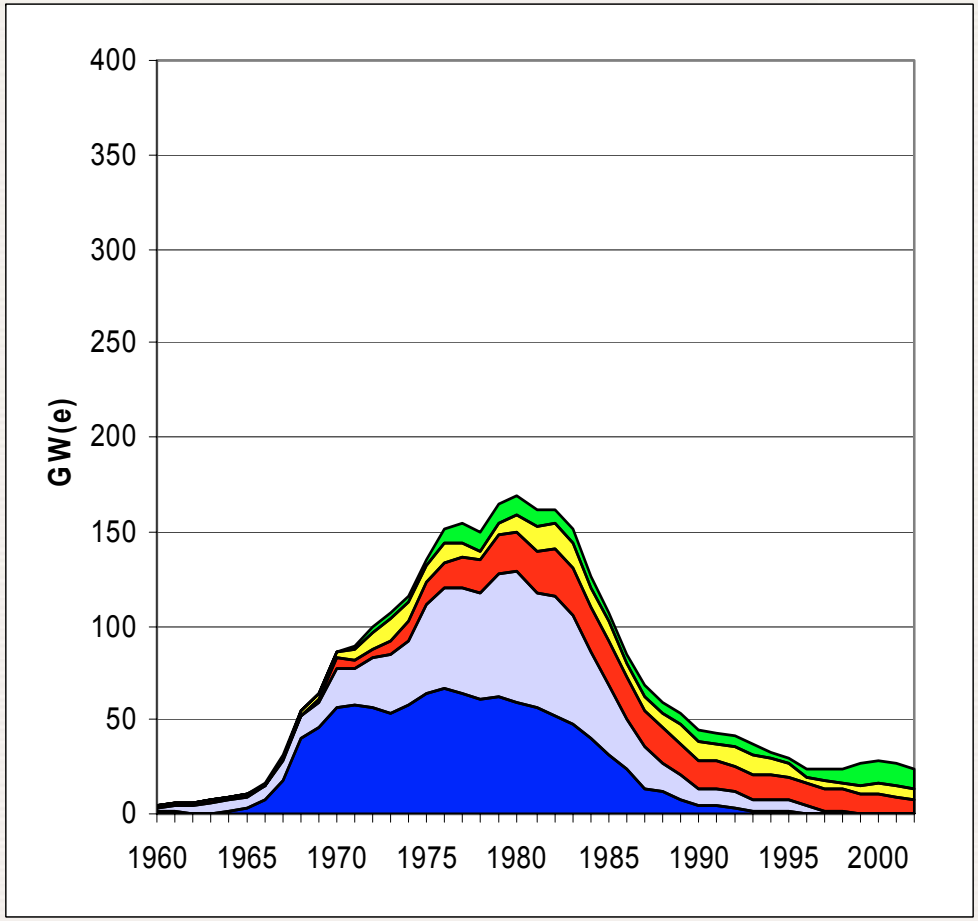
Global capacity and construction



installed



construction

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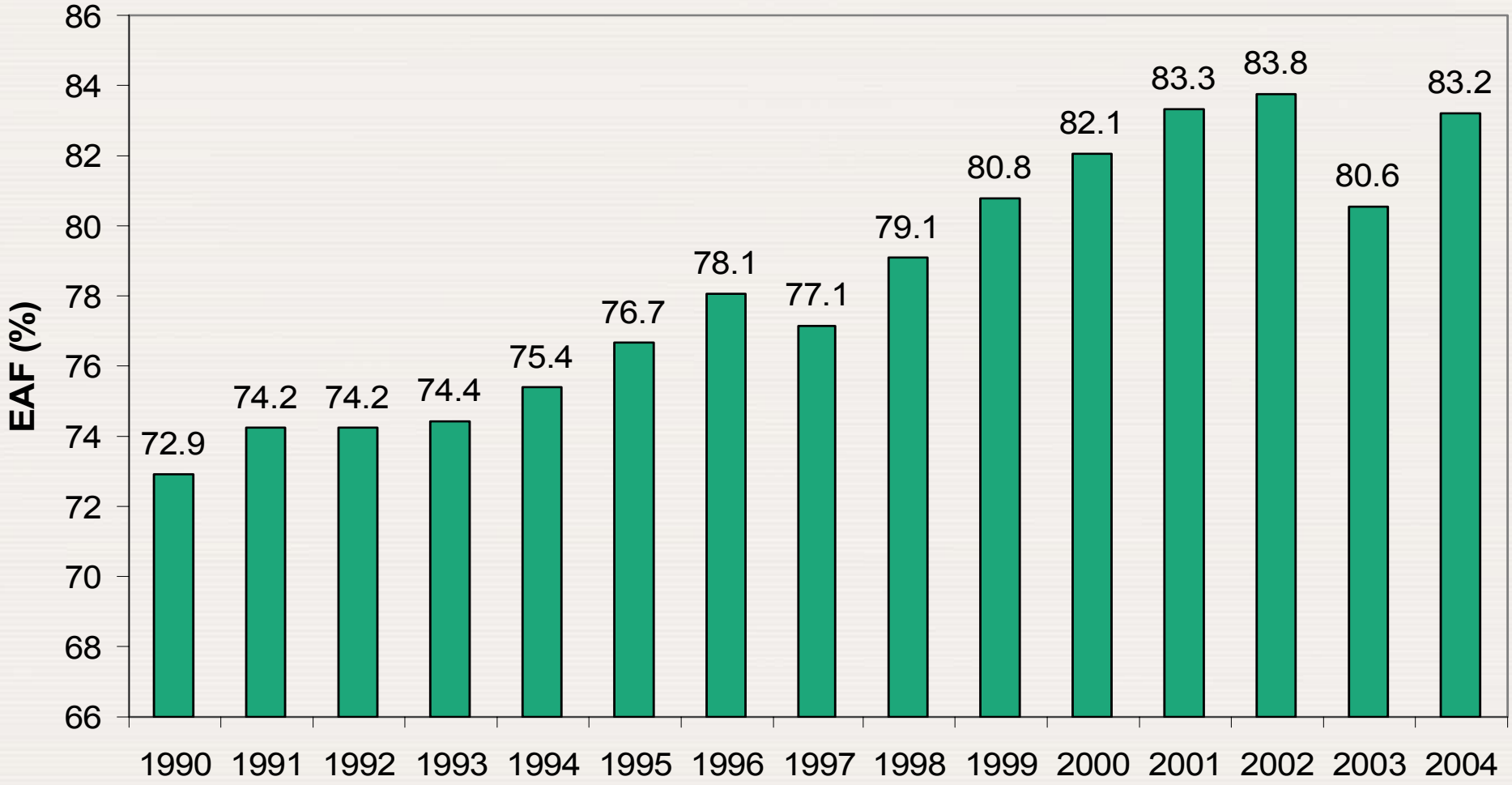
Energy availability factor



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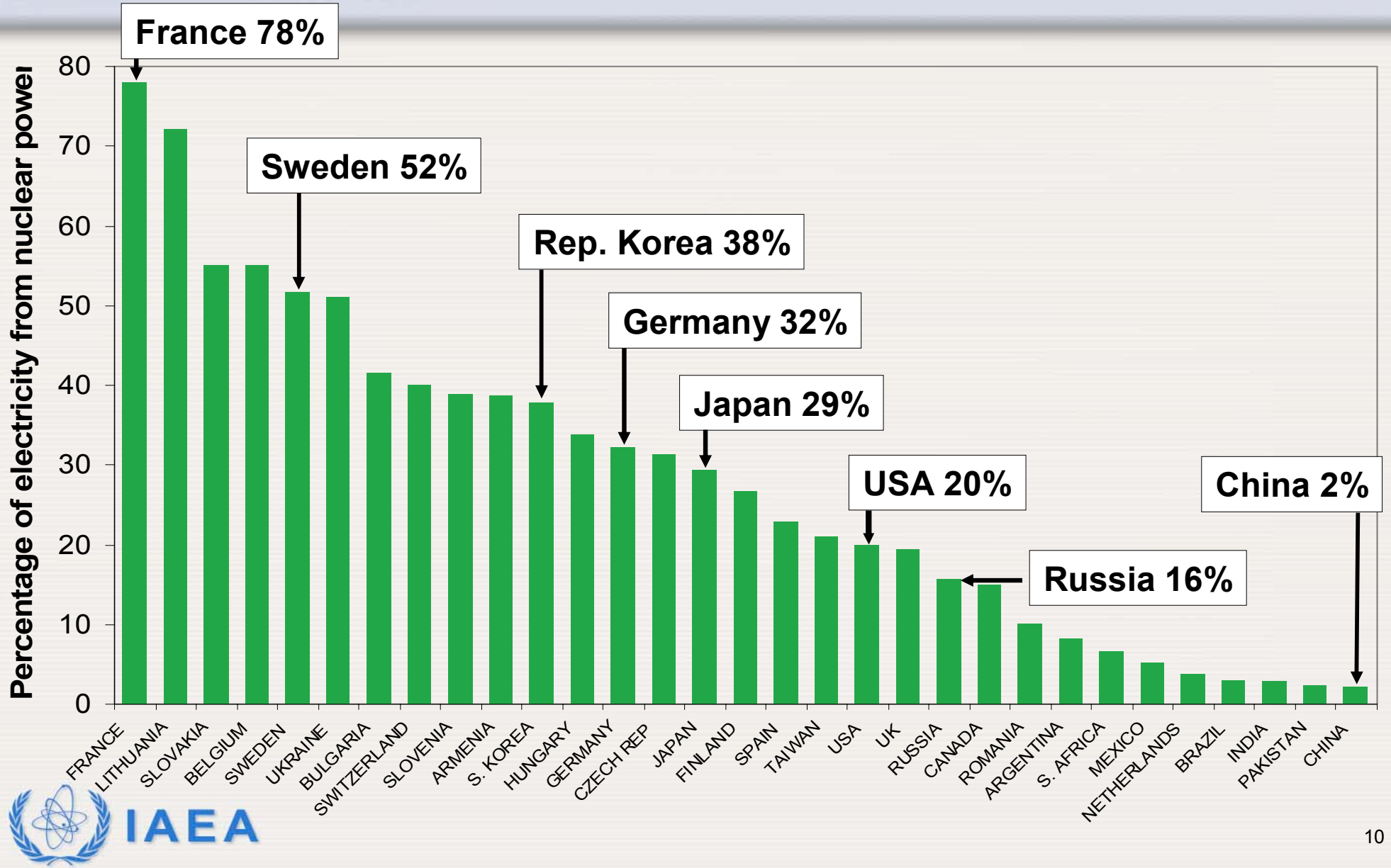
Nuclear share of electricity (2004)



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Current status

- 442 nuclear powe plants
- 24 under construction
- USA 104
- France 59
- Japan 55 (2)
- Russia 31 (4)

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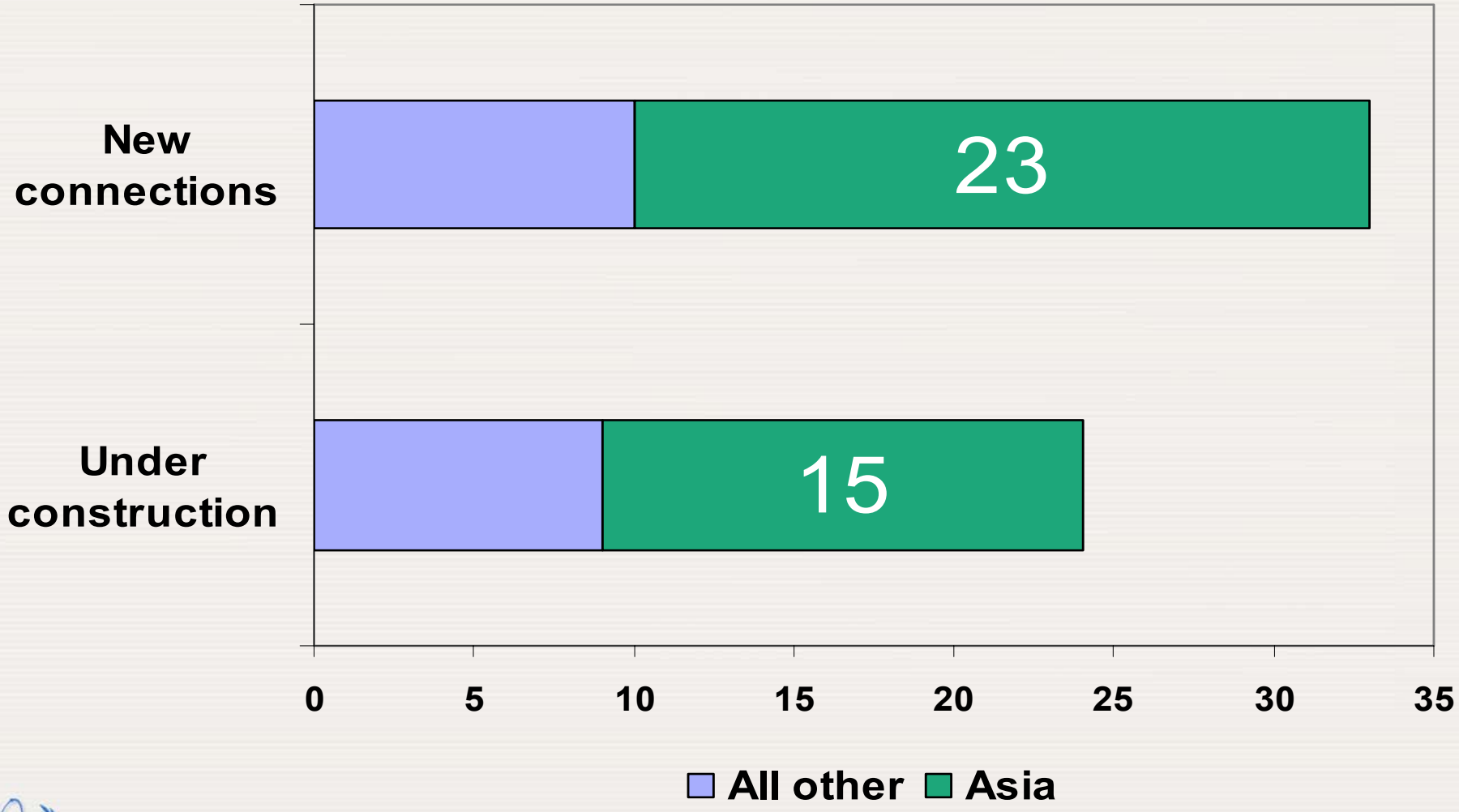
Expansion centered in Asia



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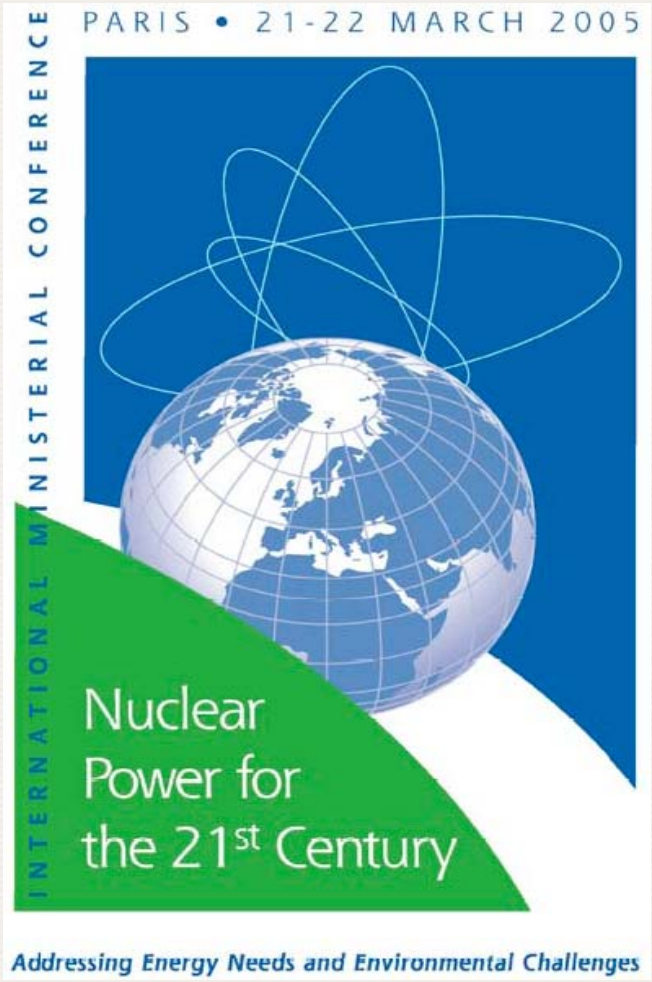
Rising expectations



- Concluding statement
  - *a vast majority of participants affirmed that nuclear power can make a major contribution to meeting energy needs and sustaining the world's development in the 21st century, for a large number of both developed and developing countries*".

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Rising expectations

- A good and lengthening track record
- Growing energy needs
- Security of supply
- Upwardly revised projections
- Plans for expansion in a number of countries
- New environmental constraints
- Increasingly favorable commentary from both politicians and the media

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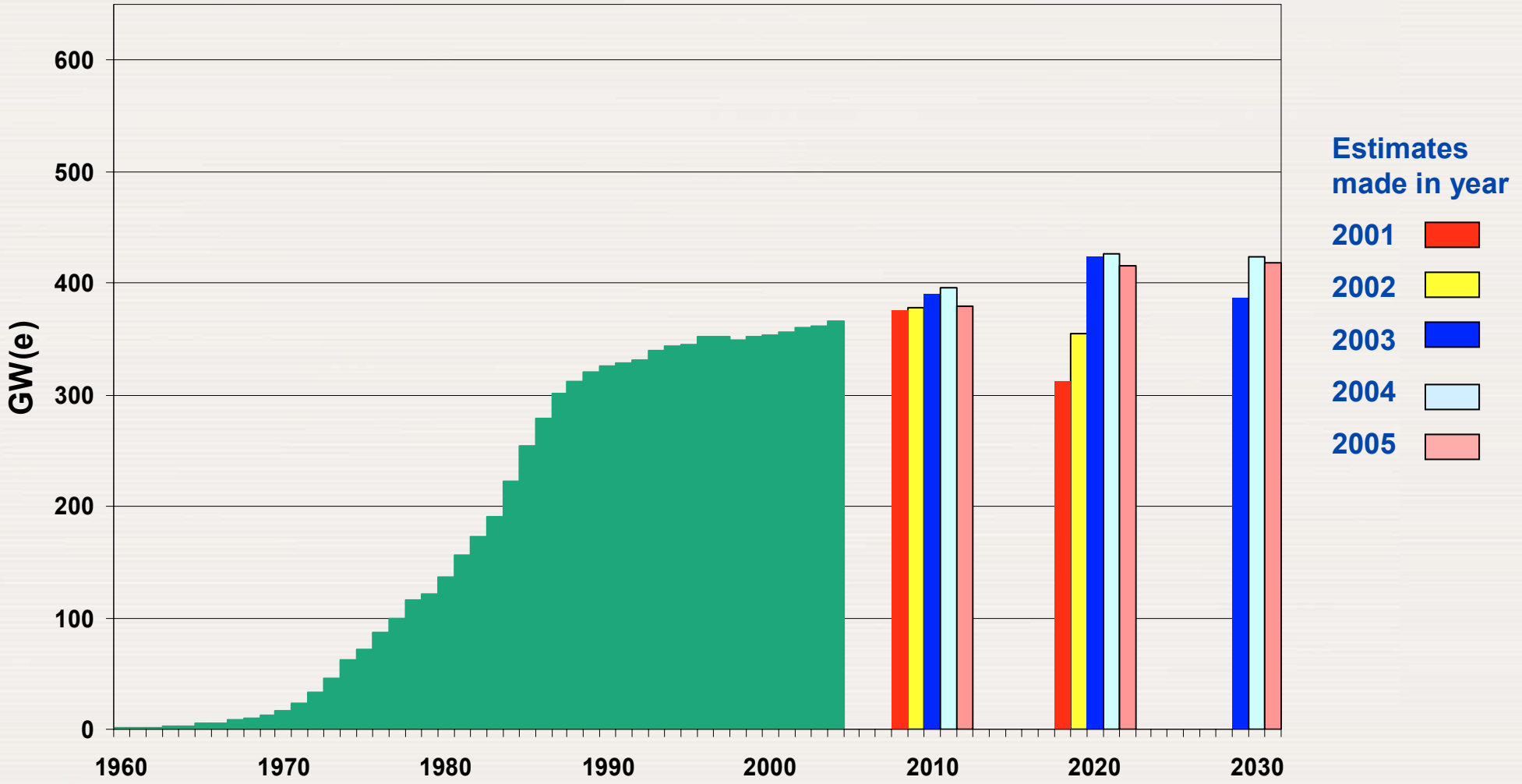
Rising expectations – low projection



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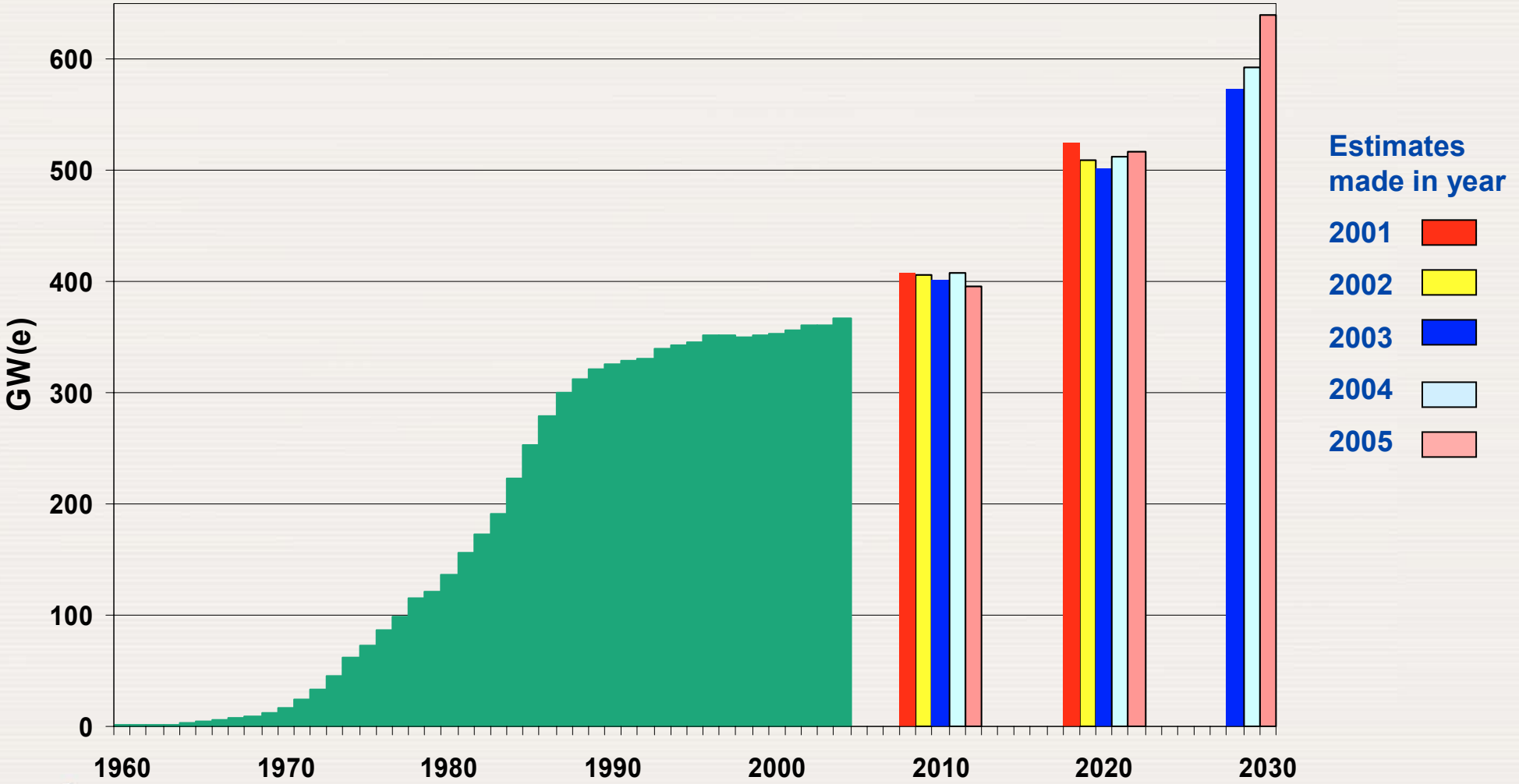
Rising expectations – high projection



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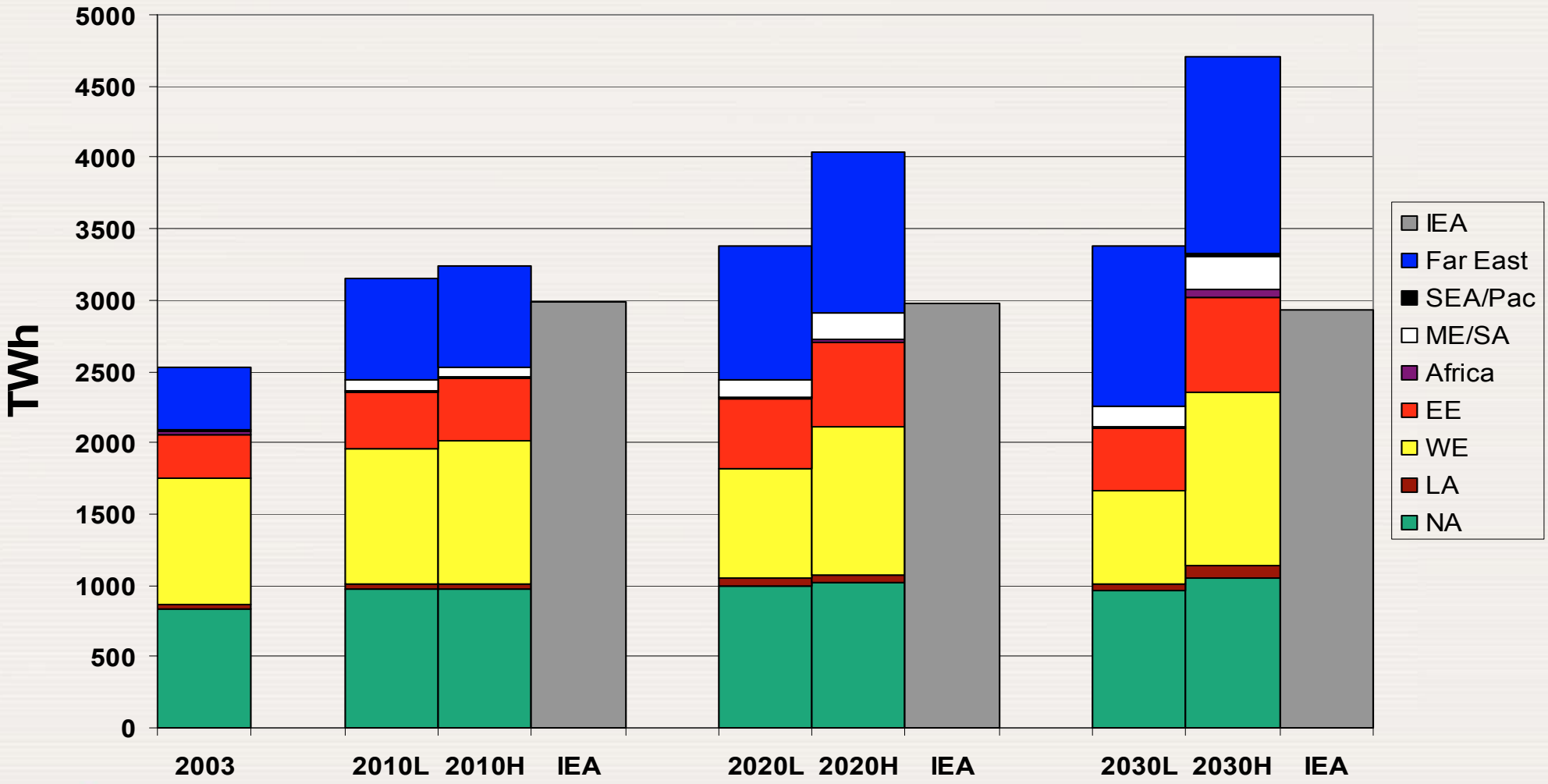
Projections by region



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Specific expansion plans

- India
  - nuclear now 2.8% of electricity
  - 8 reactors under construction
  - 10-fold growth planned 2002-2022
    - 10% of electricity
  - 100-fold growth planned 2002-2052
    - 26% of electricity
  - = 9.2% per year
  - global capacity growth 1970-2004 = 9.2% / year

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Specific expansion plans

- China
  - nuclear now 2.2% of electricity
  - 2 reactors under construction
  - 5-6 fold growth planned by 2020
    - 4% of electricity
- Russia
  - nuclear now 15.6% of electricity
  - doubling planned by 2020

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Rising expectations

- A good and lengthening track record
- Growing energy needs
- Security of supply
- Upwardly revised projections
- Plans for expansion in a number of countries
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Sustainable development politics

- Brundtland definition

- “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

1987

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The debate so far…

- 1987
  - Brundtland
- 1992 - Rio Earth Summit
  - UN Framework Convention on Climate Change (UNFCCC)
  - Agenda 21 *(no energy chapter!)*
  - Commission on Sustainable Development (CSD)

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…continued…

- 1997
  - Kyoto Protocol
- 2001
  - Bonn Agreement (COP6) & Marrakesh Accords (COP7)
  - *"Recognizing* that Parties included in Annex I to the Convention are to refrain from using emission reduction units generated from nuclear facilities to meet their commitments…"

Leila Mead/IISD

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CSD-9: outcomes

Leila Mead/IISD

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

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WSSD

Leila Mead/IISD

- World Summit on Sustainable Development, Johannesburg, August-Sept. 2002
- Reinforced CSD-9 on nuclear

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Does it matter?

- European Constitution
- Article 3: The Union's objectives
  - …
  - 3. The Union shall work for the sustainable development of Europe…
- Many other preambles, objectives, missions, visions, goals…

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Con: nuclear & sustainability

- No long-term solution to waste
- Increased proliferation risks

WIPP

- Safety: countries that consider current nuclear risks excessive do not want more
- Transboundary consequences, decommissioning & transport

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Pro: nuclear & sustainability

- Brundtland about keeping options open
- Expands electricity supplies (“connecting the unconnected”)

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Connecting the unconnected

- Large developing countries

- Concentrated demand in megacities

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Pro: nuclear & sustainability

- Brundtland about keeping options open
- Expands electricity supplies (“connecting the unconnected”)
- Reduces harmful emissions

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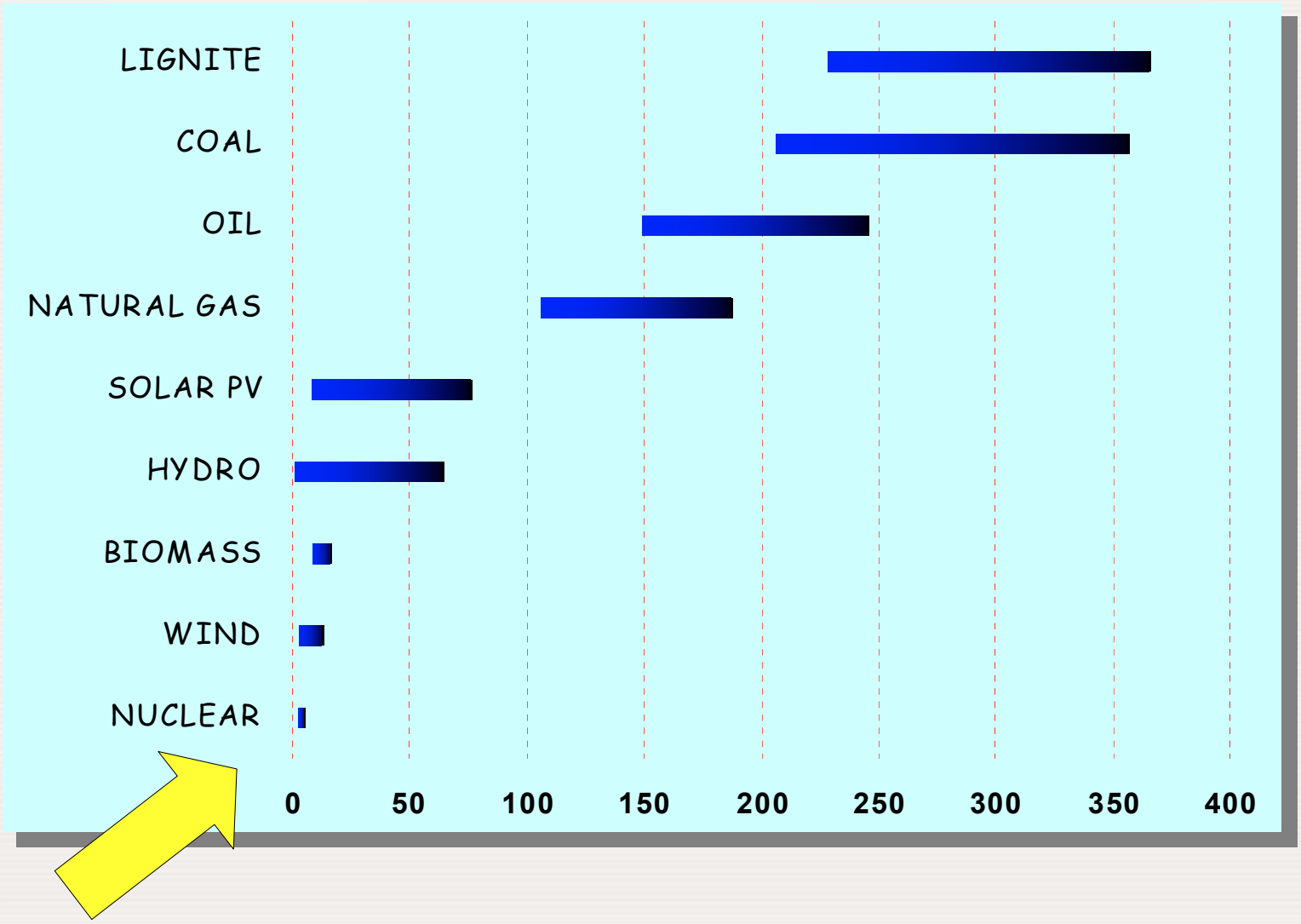
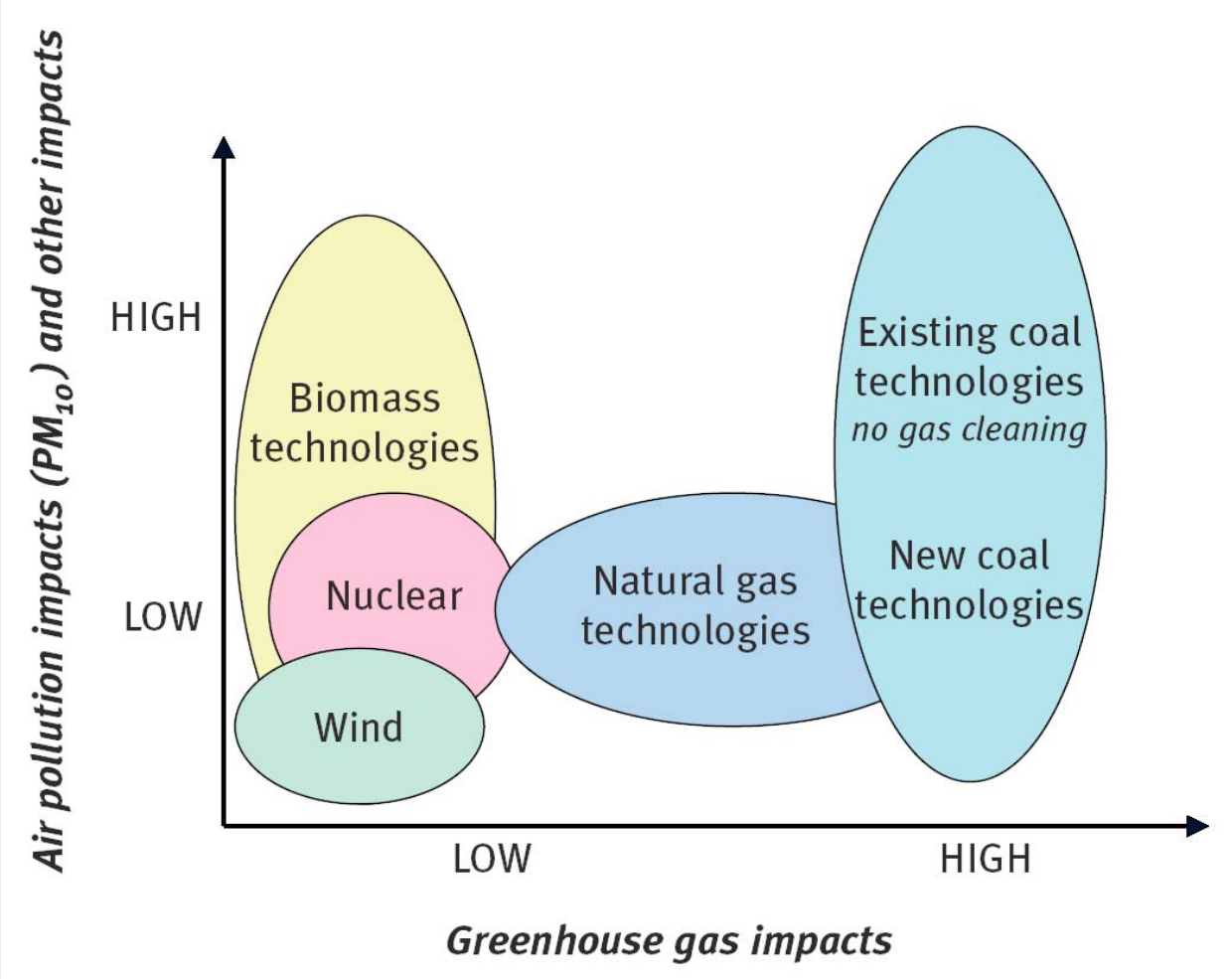
Greenhouse gas (GHG) emissions

GHG
gC_{eq}/kWh



Environmental impacts



Pro: nuclear & sustainability

- Brundtland about keeping options open
- Expands electricity supplies (“connecting the unconnected”)
- Reduces harmful emissions
- Puts uranium to productive use
- Ahead in internalising externalities

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Next round

- CSD-14
  - NY, April 2006, with regional preparations
  - ‘assessment year’
  - energy, industrial development, air pollution climate change
- CSD-15
  - NY, April 2007, with regional preparations
  - ‘policy year’

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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.

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Round-the-world tour

- India
  - 8 reactors under construction
  - 100-fold growth planned 2002-2052
    - 26% of electricity
  - not party to the NPT
  - limited uranium, more thorium
  - high interest in nuclear careers
  - growing role as service provider to the rich world

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Round-the-world tour

- China
  - huge energy growth
  - 2 reactors under construction
  - 5-6 fold growth planned by 2020
    - 4% of electricity
  - NPT member, potential Asian supplier

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Round-the-world tour

- Russia
  - doubling planned by 2020
  - aspiring ‘full fuel cycle services’ provider

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Round-the-world tour

- Japan
- Republic of Korea
- Eastern Europe
  - Bulgaria
  - Ukraine
  - Romania
  - Poland
  - others

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Round-the-world tour

- Western Europe
  - prohibition countries
    - Austria, Italy, Denmark, Ireland
  - phase-out countries
    - Sweden, Germany, Belgium

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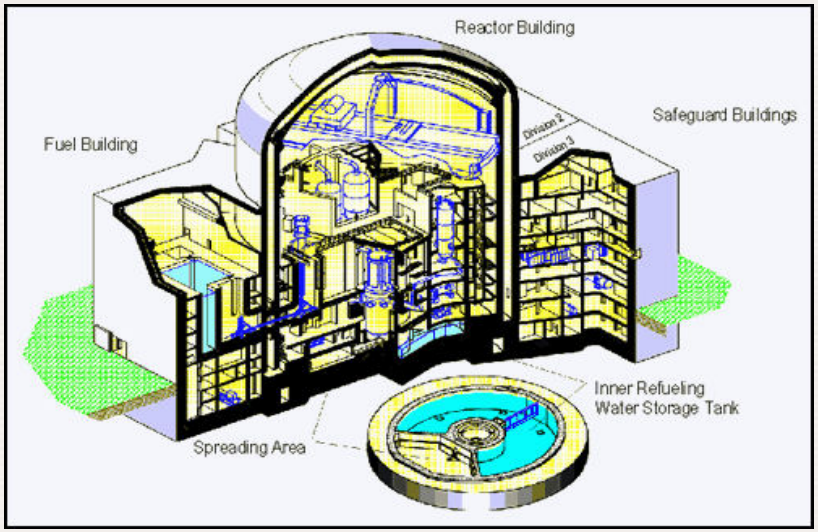
Round-the-world tour

- Western Europe
  - expansion countries
    - Finland, France
  - others
    - UK, Spain, Switzerland



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Round-the-world tour

- USA
  - 104 operating reactors, 20% of electricity
  - last connection: 1996
  - last construction start: 1977
  - 75% of fleet has, is seeking, or plans to seek 20-year license renewals
  - Nuclear Power 2010
  - latest polls: 70% support nuclear

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Round-the-world tour

- USA
  - WIPP, Yucca Mt.
    - parity, proportionality, priority

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Round-the-world tour

- Canada
- Latin America
  - Brazil
    - Angra 1 and 2
    - Angra 3
    - enrichment
  - Argentina
- Africa
  - South Africa

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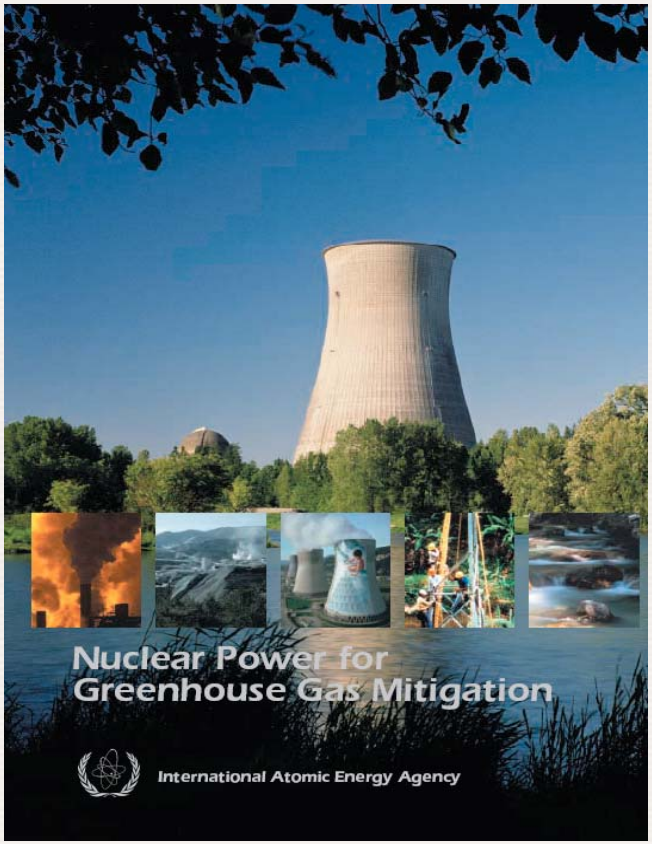
Round-the-world tour

- Iran
  - Bushehr-1

- Indonesia, Vietnam, …



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“It’s the economics”

- Nuclear is expensive to build, cheap to run
- New nuclear most attractive where
  - energy demand growth in rapid
  - alternative resources are scarce
  - energy supply security a priority
  - reducing air pollution and GHGs a priority
  - financing can look longer-term
  - low risk premium

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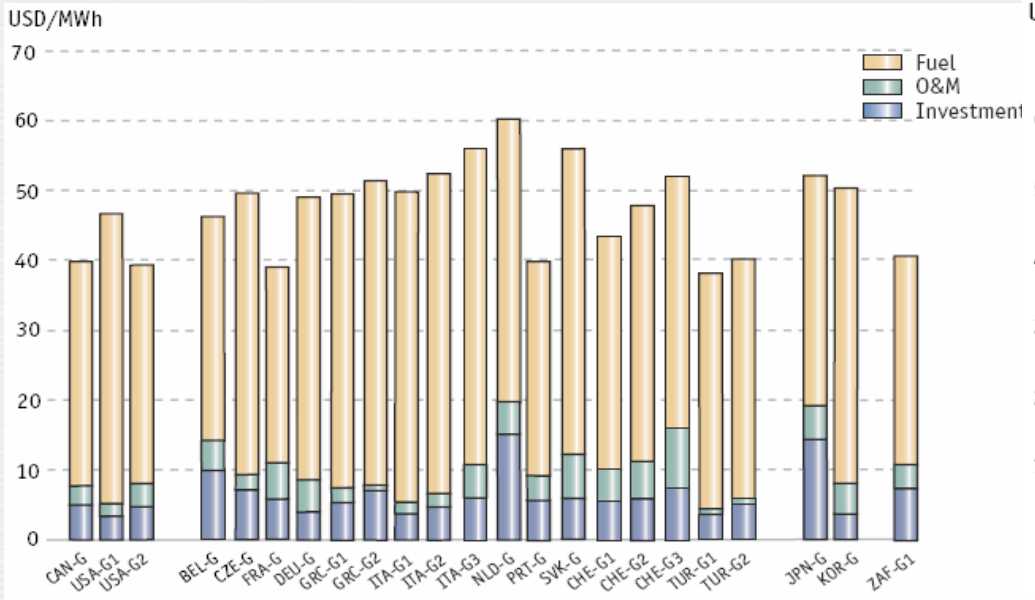
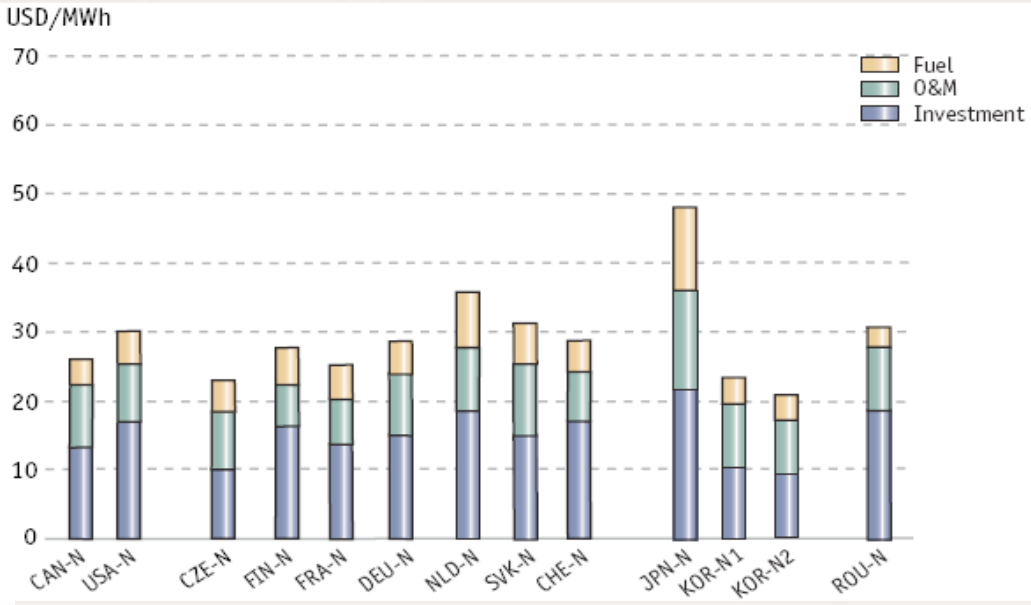
Front-loaded cost structure

- Levelized costs (USD/MWh), 5% discount

Gas



Nuclear



Source: Projected Costs of Generating Electricity 2005 Update, NEA/IEA

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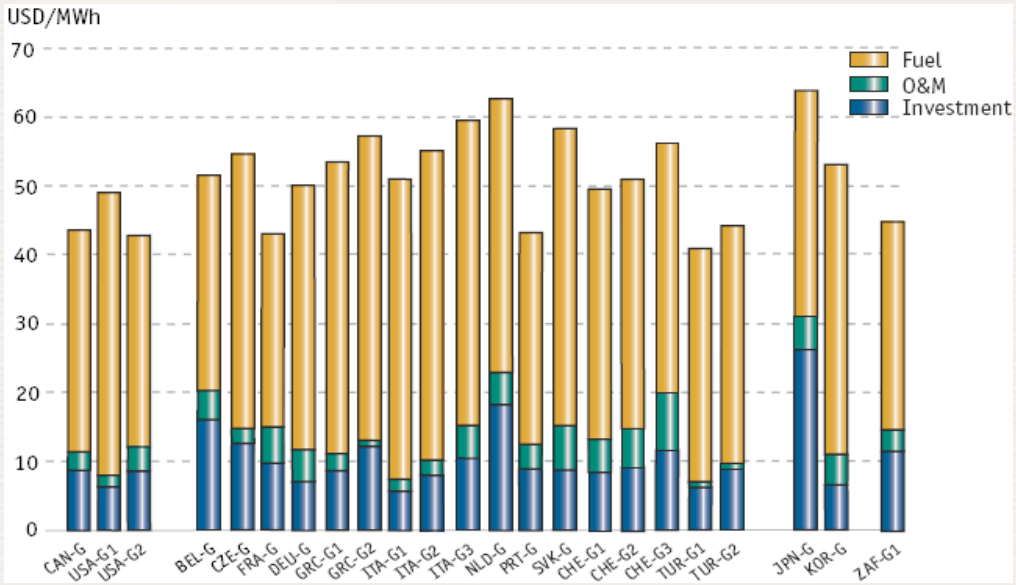
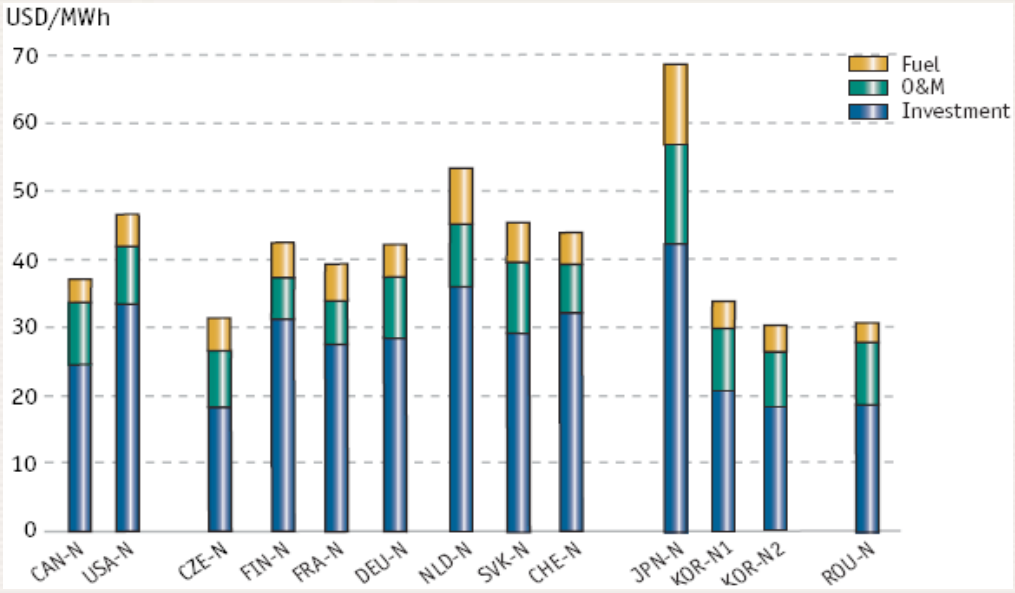
Front-loaded cost structure

- Levelized costs (USD/MWh), 10% discount

Gas



Nuclear



Source: Projected Costs of Generating Electricity 2005 Update, NEA/IEA

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Liberalized markets

- Value rapid returns
- Front-loaded cost structure a disadvantage
- Common market failures
  - myopia
  - R&D under-investment
  - ignore external costs
  - can’t price insurance without actuarial data
- When markets fail, governments intervene
- Risk premiums

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Less liberalized markets

- Government investors can
  - look longer term
  - absorb investment risk
  - take externalities directly into account
    - energy security
    - pollution
    - GHG emissions
    - jobs and social impacts
    - high technology development

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Interventions in liberalized markets

- Remove non-market barriers
  - provide waste repositories, streamline regulatory process
- Subsidies
  - direct, regulatory costs, production credit, regulatory risk insurance, accident risk insurance, government R&D
- Internalize external costs
  - limits on pollution, GHG emissions, import dependence

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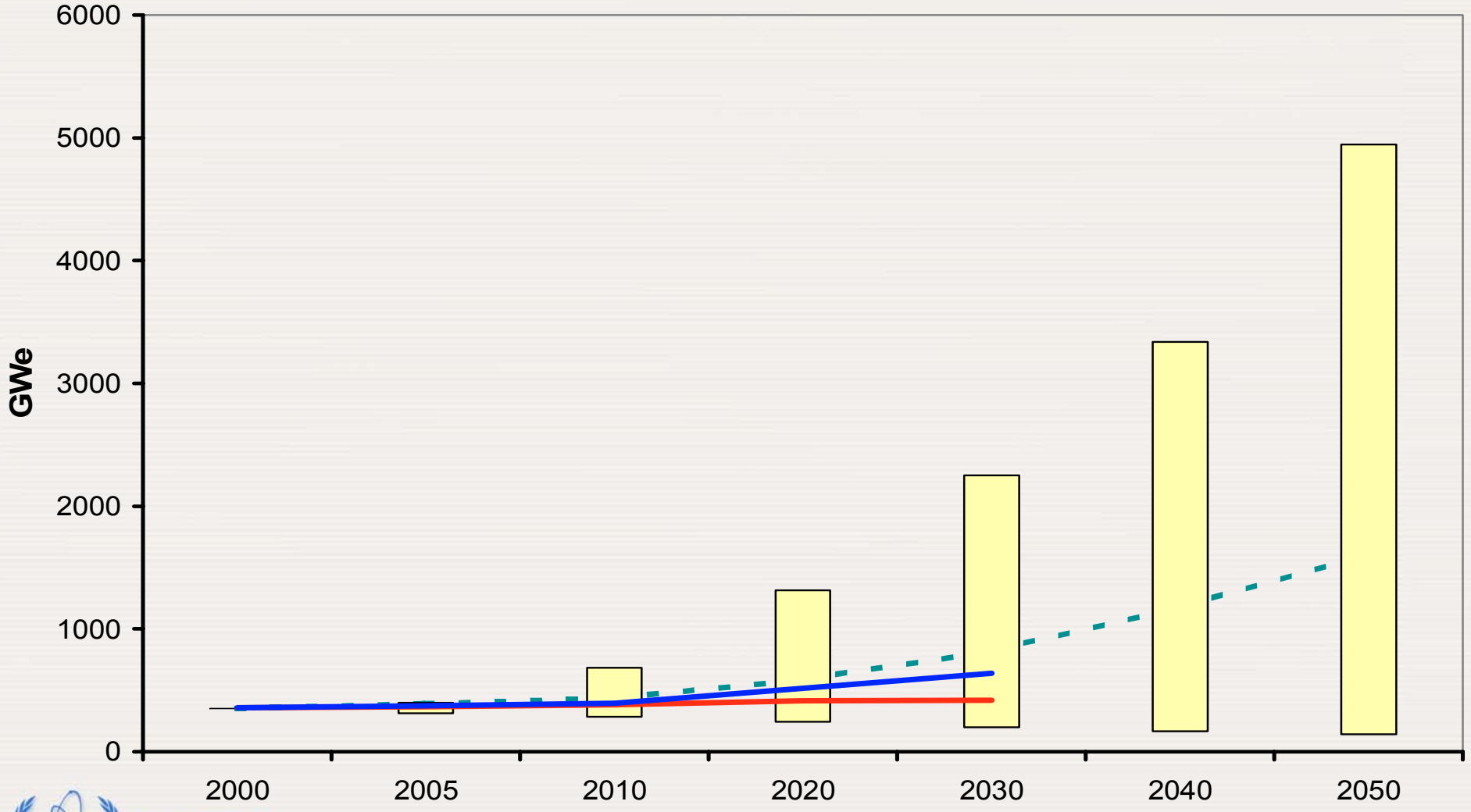
Projection gap



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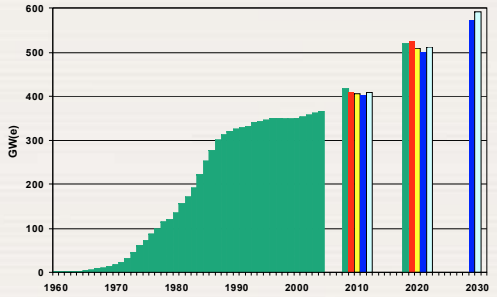
Three take-aways

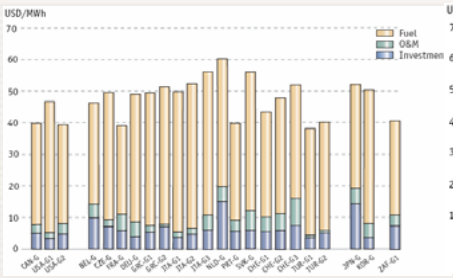
- Rising expectations



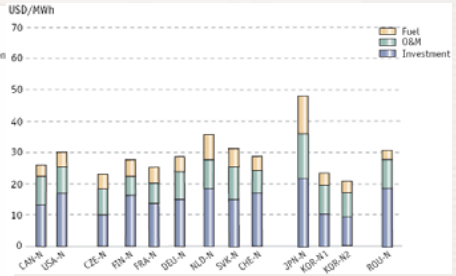
- One size does not fit all

- "It's the economics!"

Gas



Nuclear



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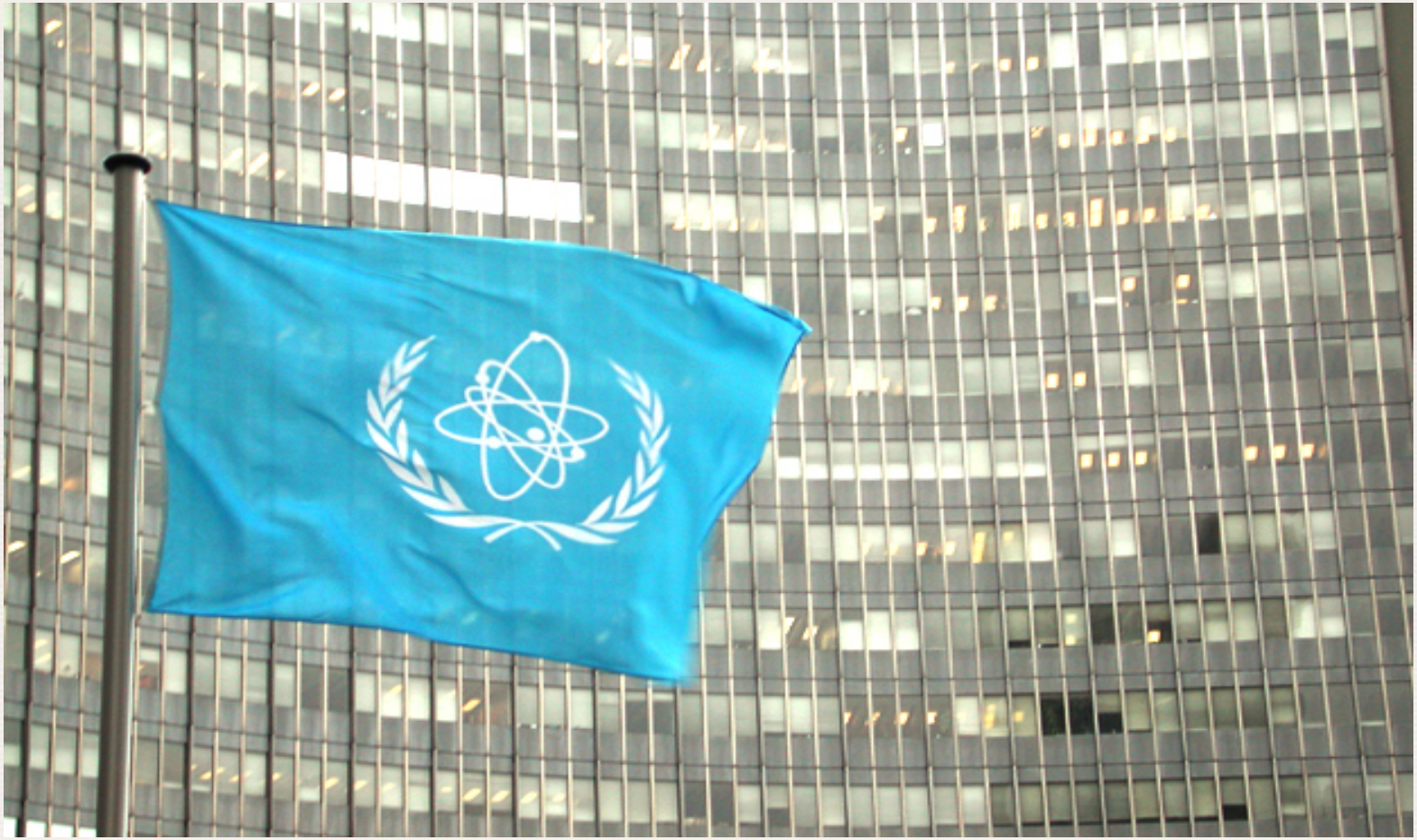

…atoms for peace.

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