Nuclear Fuel

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Outline

Part 1

- Overview of the fuel cycle
- Importance of nuclear fuel
- Some trade issues
- Some transport issues

Part 2

Uranium Mining (Cory)

Part 3

Fuel fabrication & Enrichment (Pat)

Part 4

- Uranium market issues (Pat & Cory)

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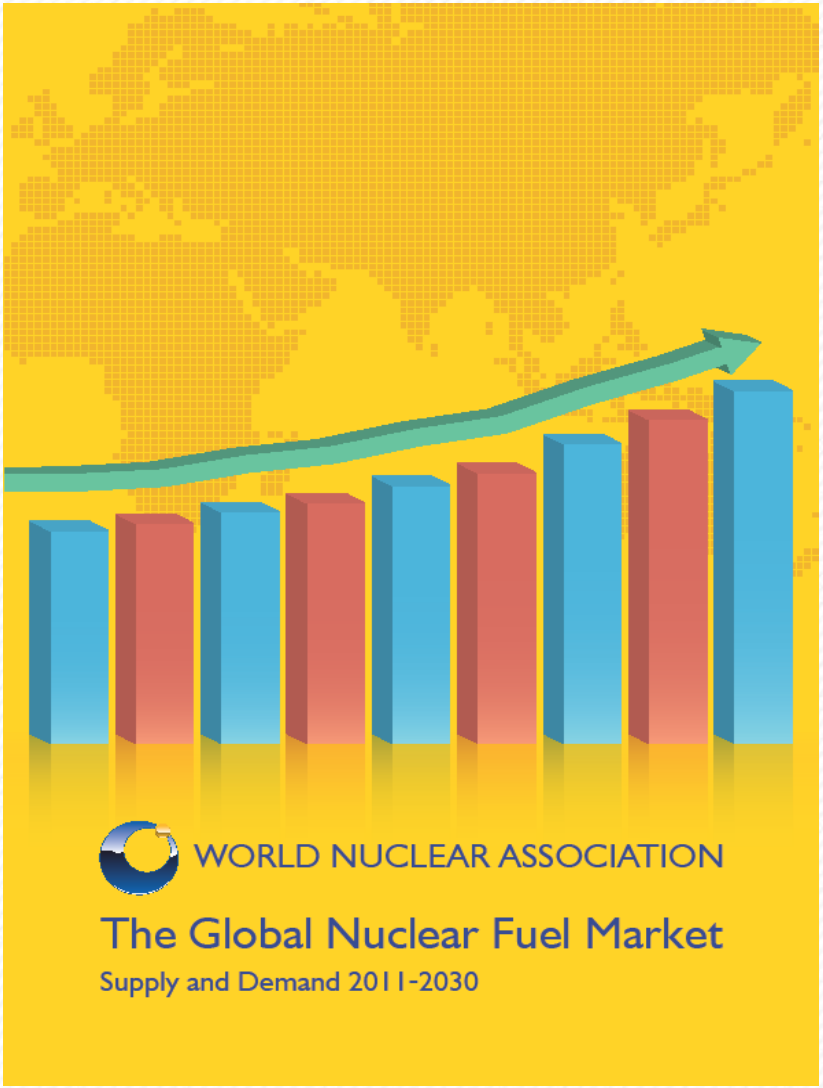
WNA Market Report 2011



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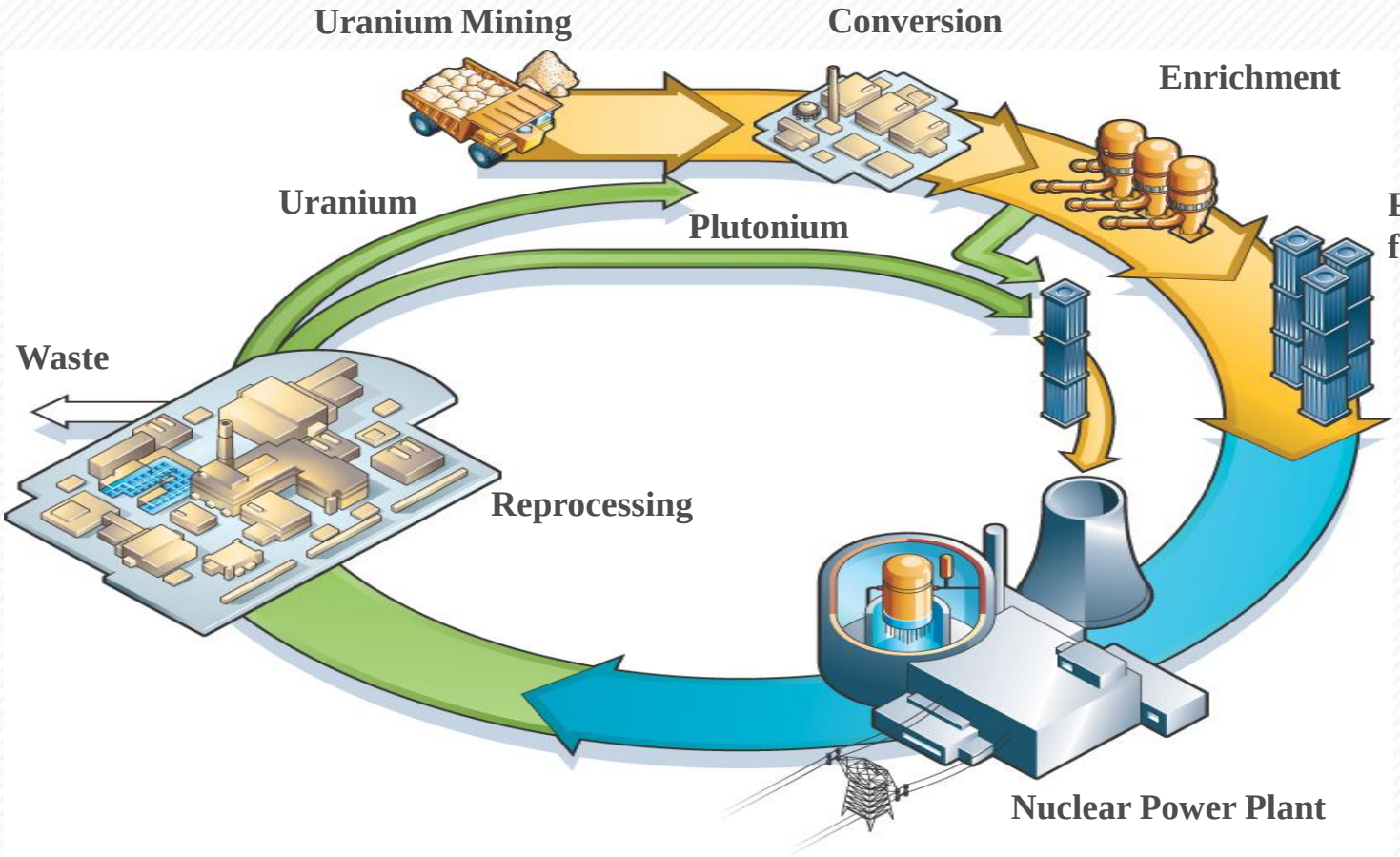
The Nuclear Fuel Cycle - Closed



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Key aspects of fuel cycle

- Complexity!
- Specialisation of producers
- International aspects
- Trade rules & regulations?
- Transport difficulties?
- Recycling possibilities
- Historical production levels still relevant
- “Secondary supplies”

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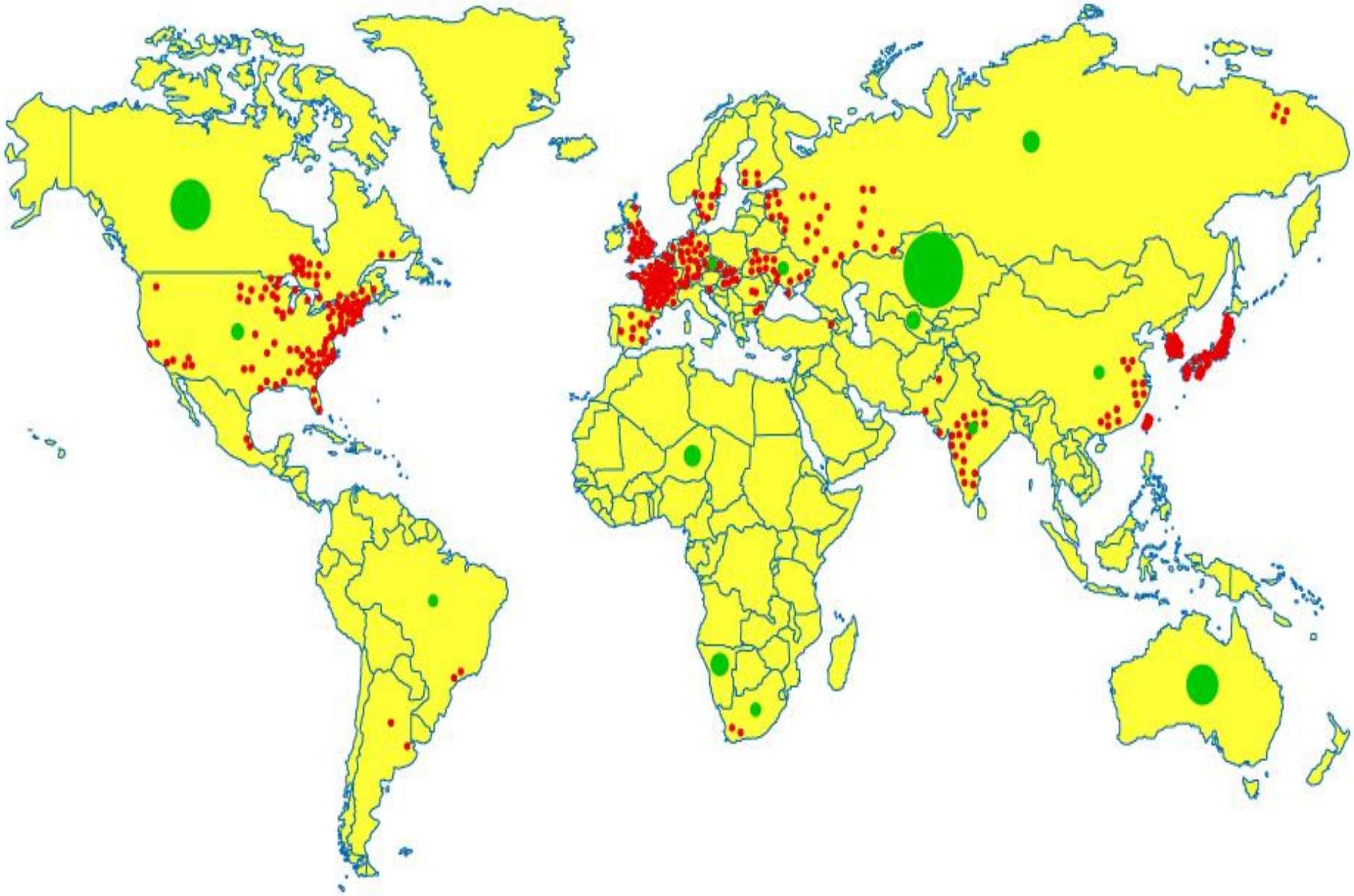
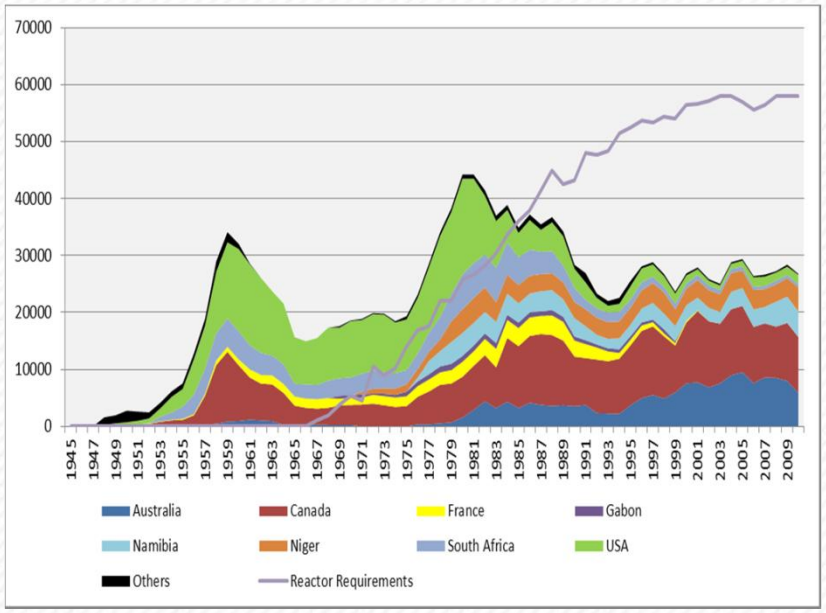
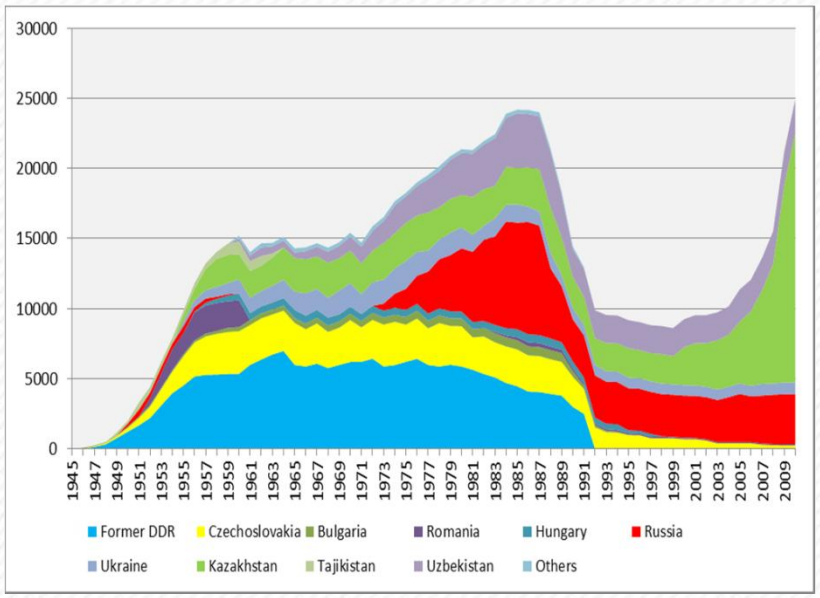
World Nuclear Power Reactors - with Uranium Sources



Historical uranium production



Western world total 1,520 ths.tU



USSR and Eastern Europe- 928 ths.t U

Since 1945	Ths. tU
Produced	2 449
Consumed	1 933
Stockpiled	516

Production was substantially ahead of reactor requirements until 1985, but has since fallen below. Since 1985, requirements have exceeded production by approximately 450,000 tU. The difference was covered by inventories and other secondary sources

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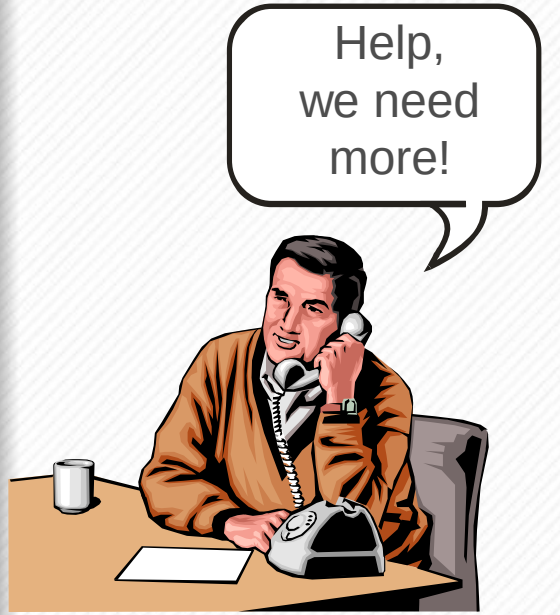
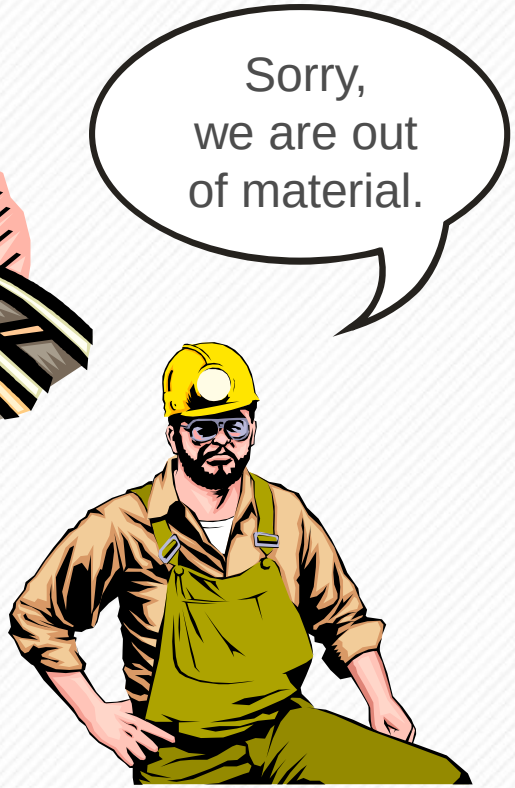
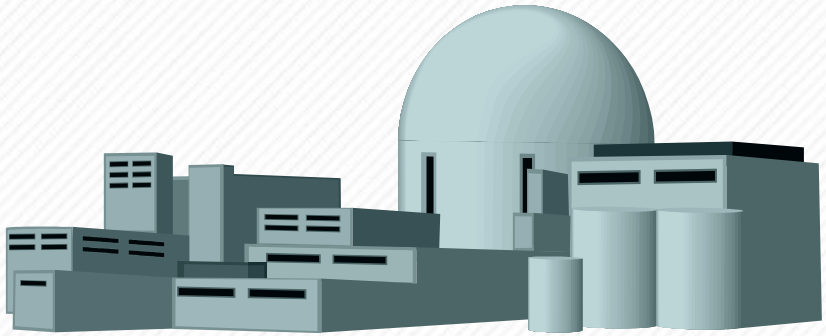
Will the future look like this?







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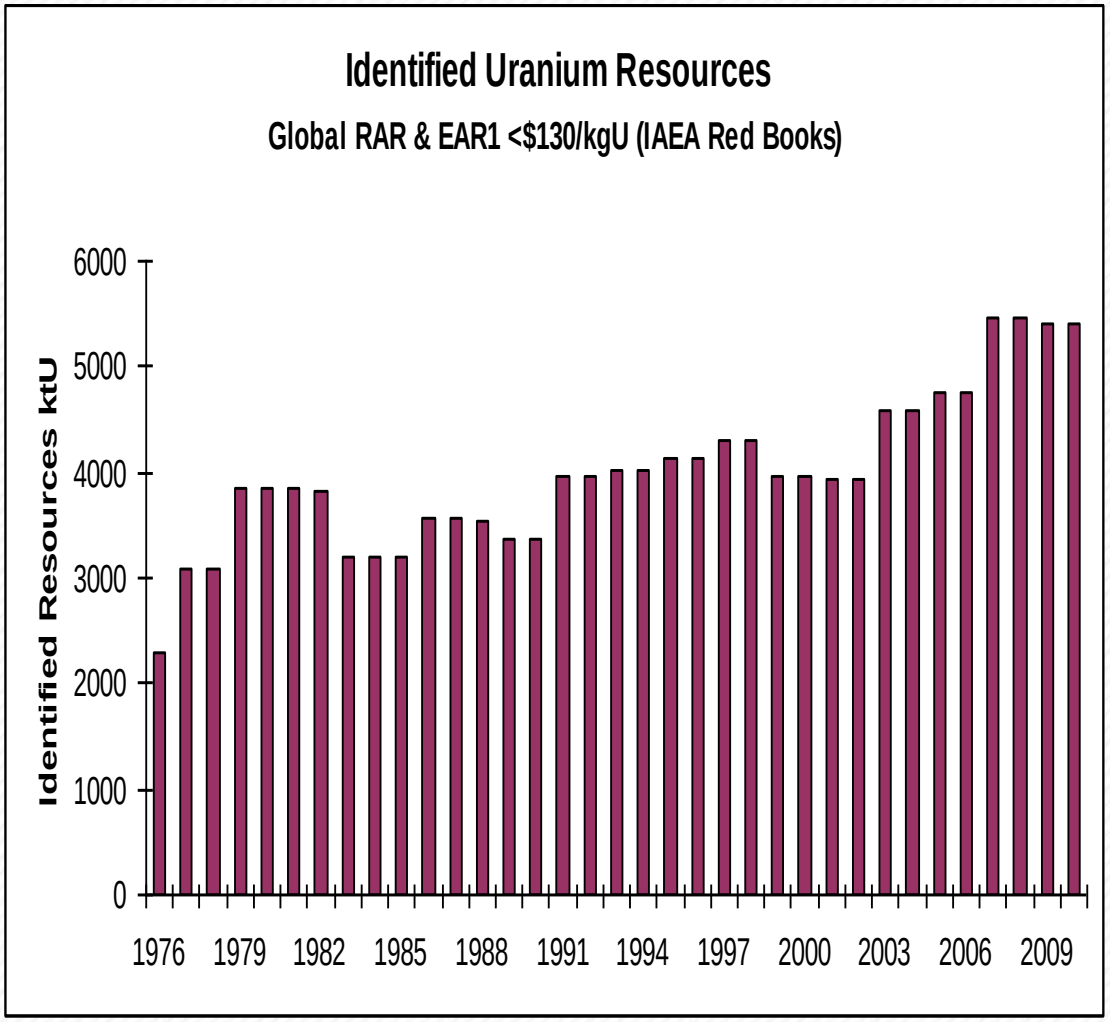
Uranium Resources have increased over time



- Over the period 1976 – 2010 Uranium resources increased from 2.3 to 5.4mtU at <$130/kgU
- Equivalent to an additional 94ktU/yr (greater increase than annual reactor demand)
- The real cost to mine these resources is about 25% of the level in 1976

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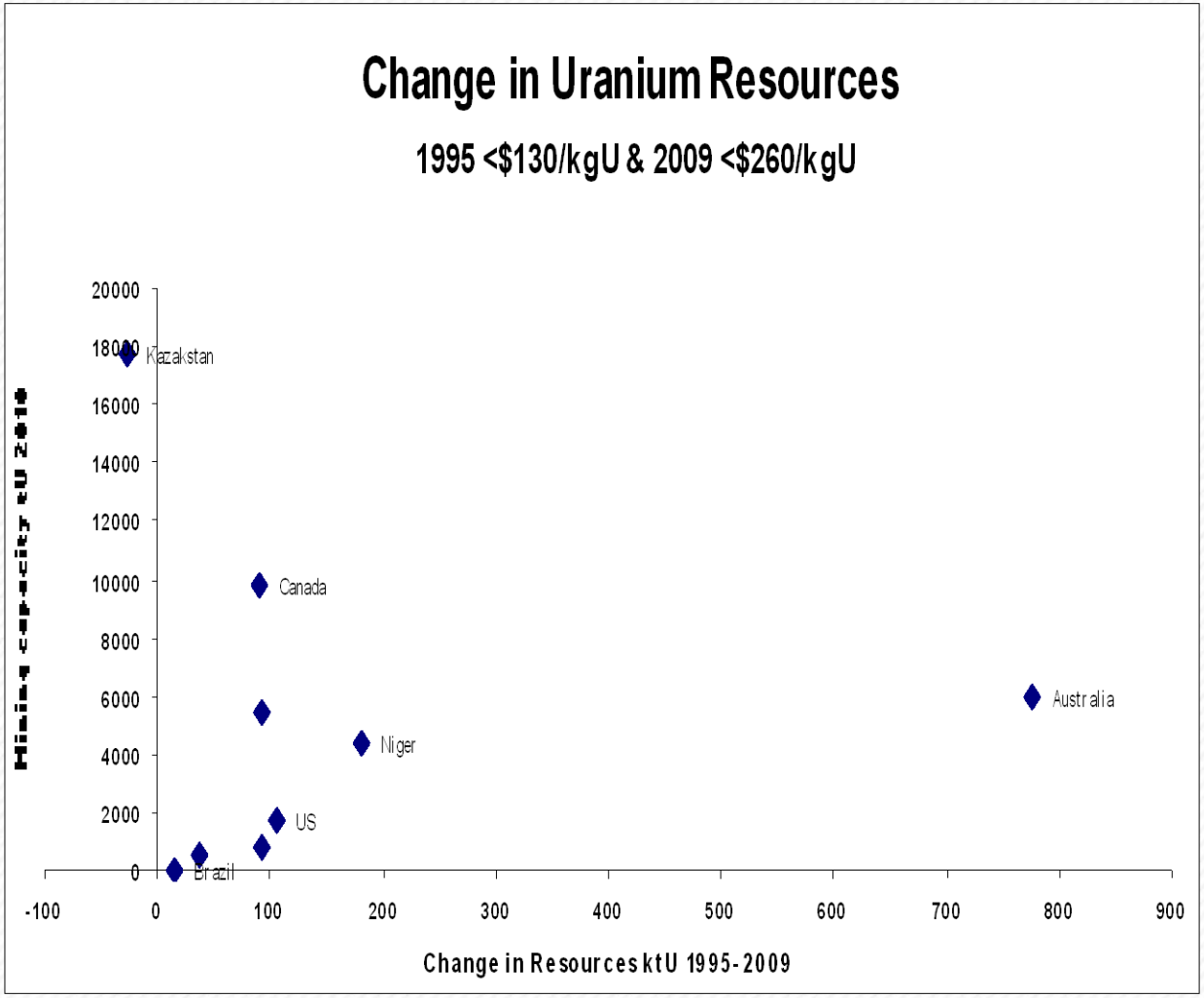
The More You Mine, the More You Find!



- Uranium resources have increased most rapidly in the principal mining countries.
- Only in one country (Kazakhstan) have resources declined over the 1995-2009 period.

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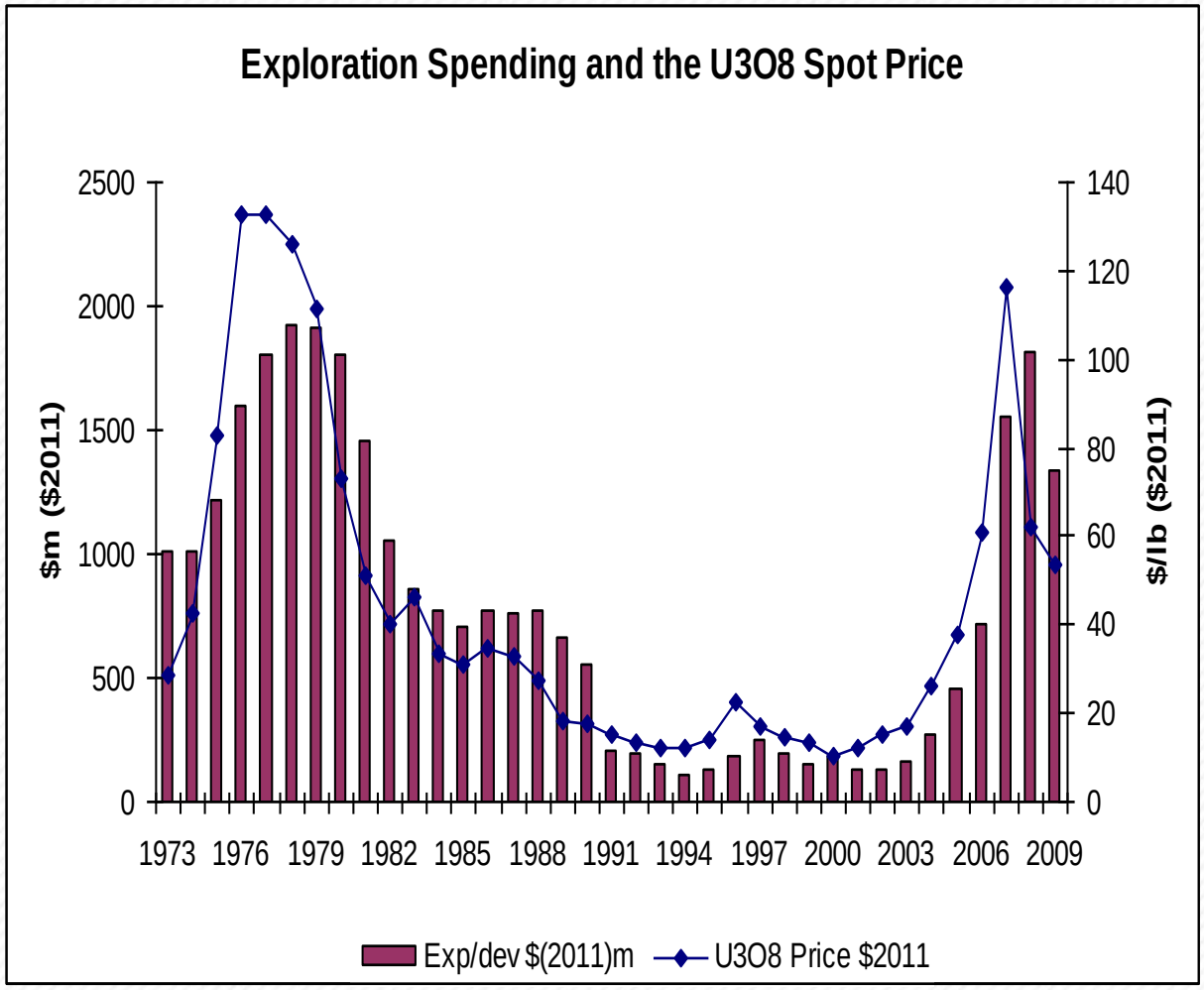
Exploration Spending responds quickly to the uranium price



- The spot price reflects near term supply / demand pressures
- Exploration and development follows with a 1-2 year lag as junior mining companies find it easier/harder to raise finance
- Exploration spending has risen to historic highs

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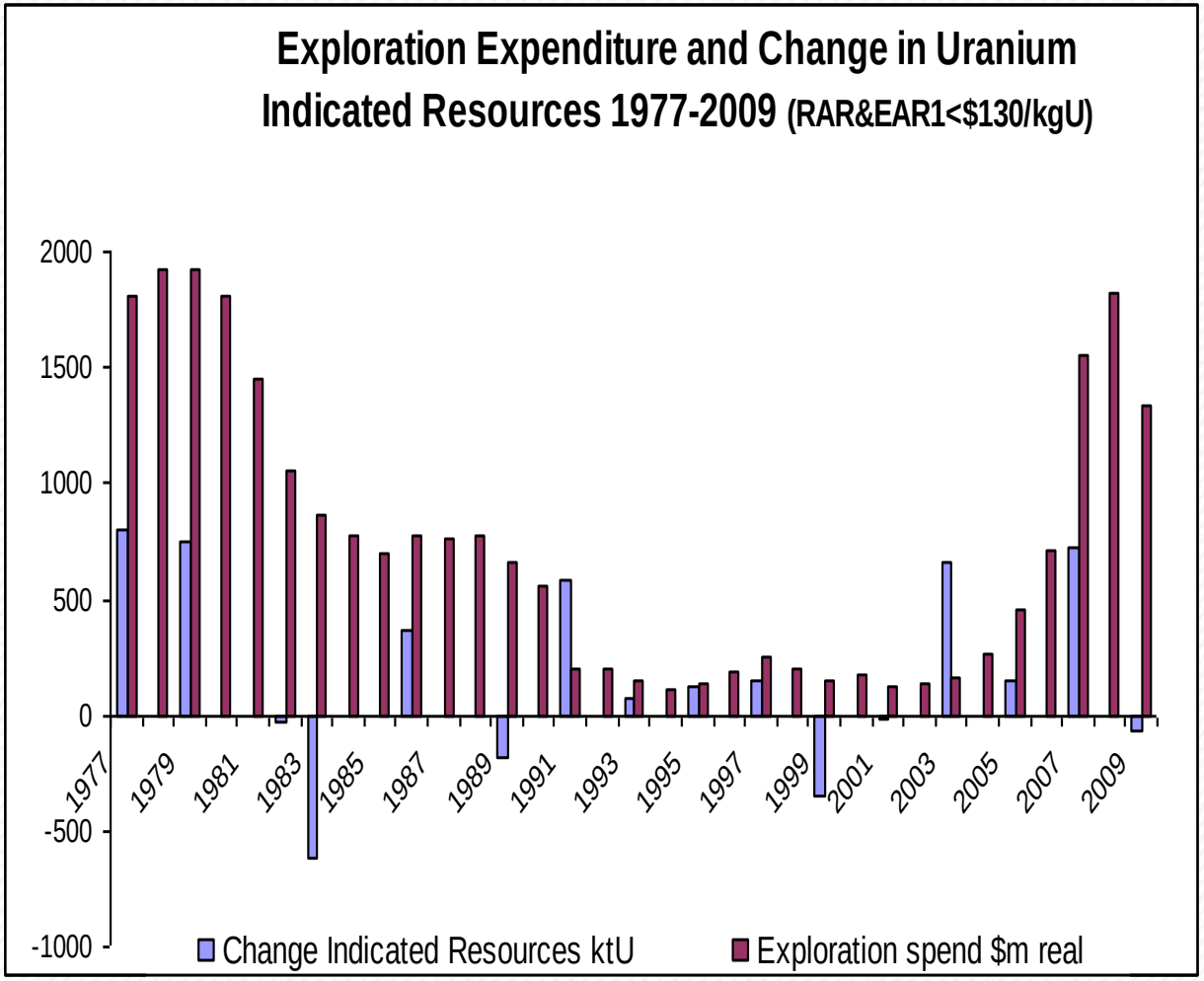
The productivity of exploration has increased



- The cost of finding uranium mineable at less than $130/kg has fallen:

1976-1993

$10.27m/ktU

1994-2009

$5.74m/ktU

- Developments in surveying and drilling technology increase productivity, even as deposits are found at greater depths

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Relative Cost Structure of Power Generation

General shares	Nuclear	Gas CCGT	Coal
Investment	50-70%	15-20%	40-50%
O&M	20-35%	5-10%	15-25%
Fuel	15-20%	70-80%	35-40%

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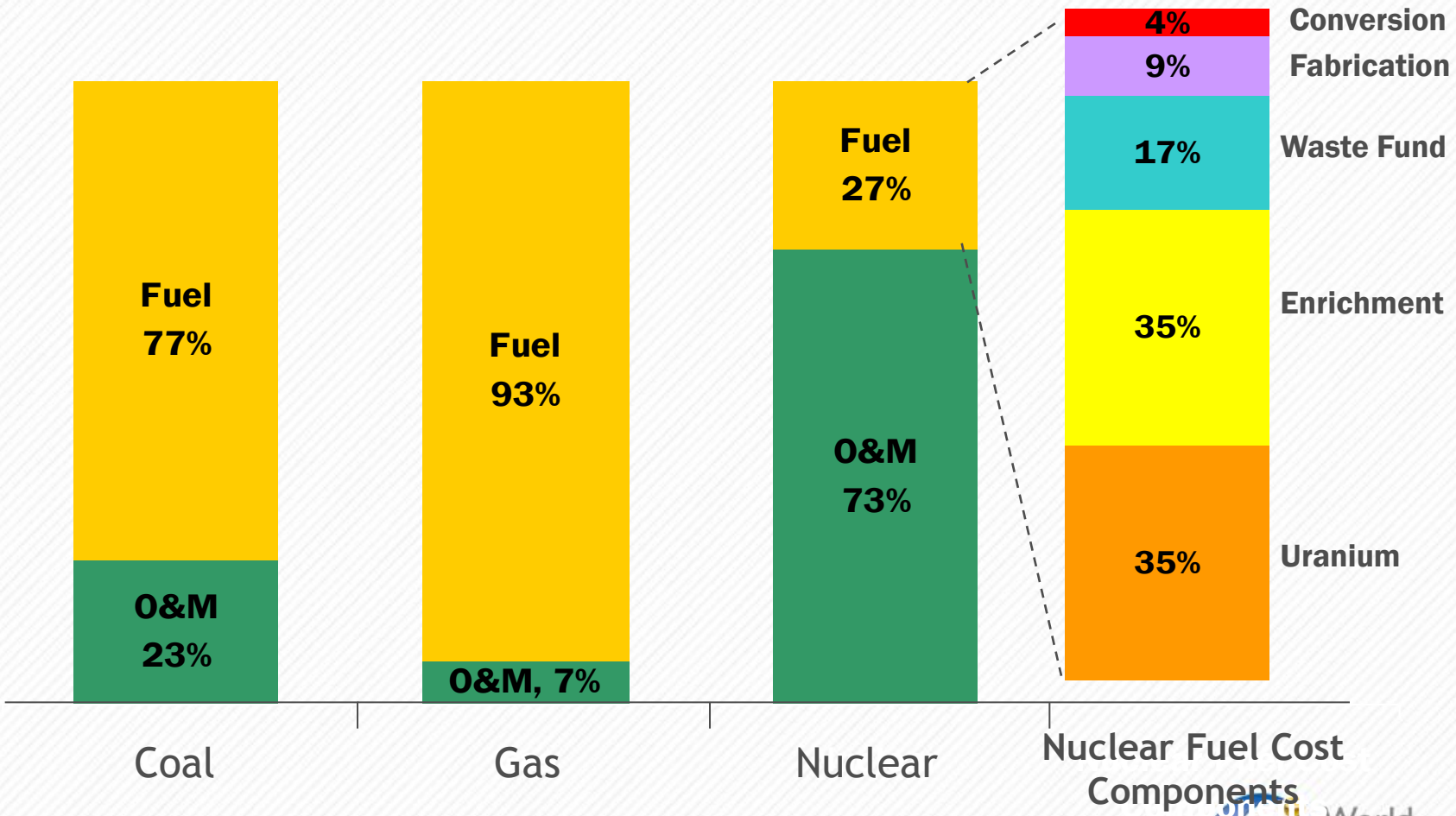
Fuel as a Percentage of Electric Power Production Costs



Source: Global Energy Decisions; Energy Resources International, Inc.
Updated: 5/08

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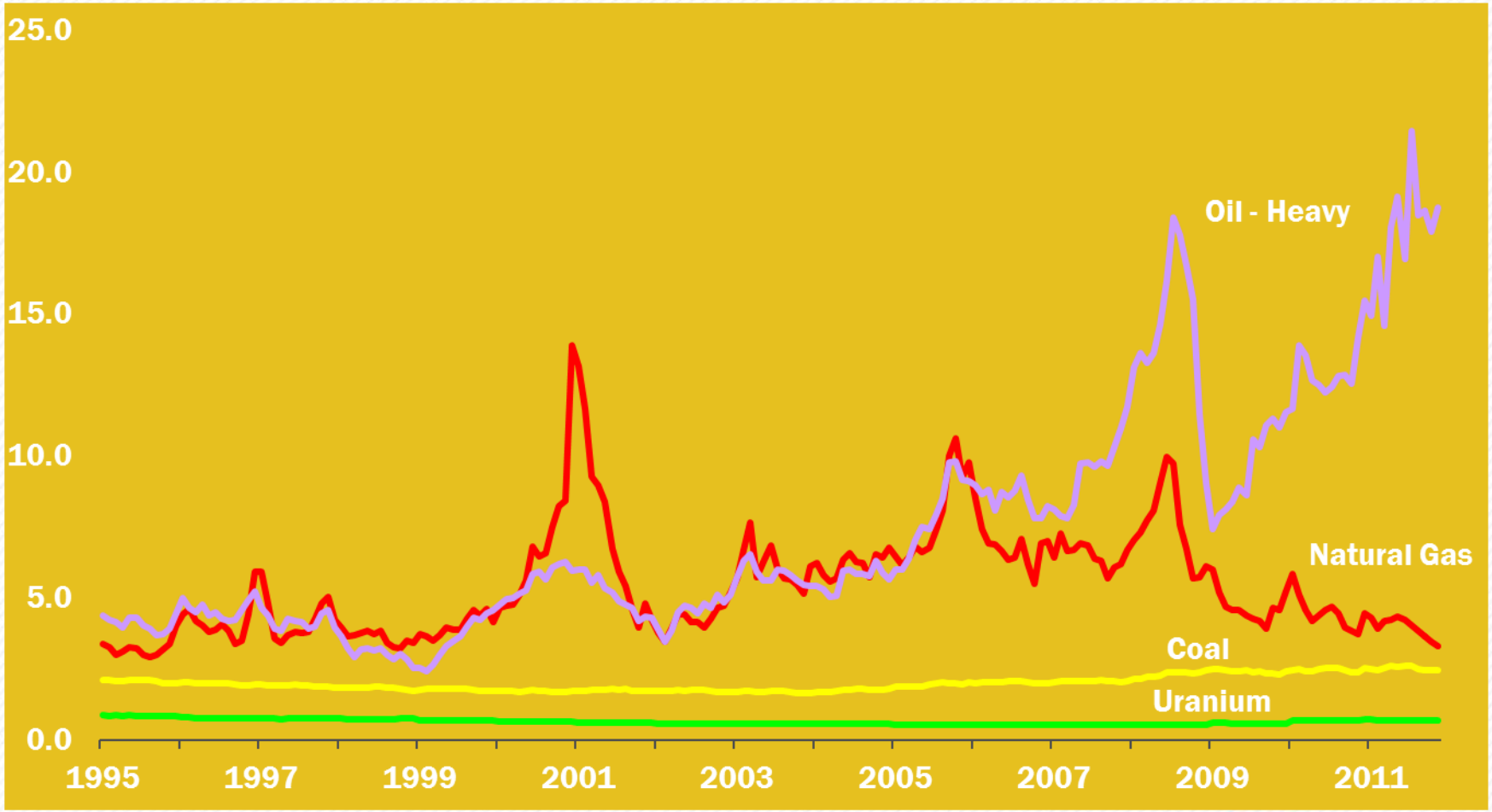
Monthly Fuel Cost to U.S. Electric Utilities

1995 – 2011, *In 2011 cents per kilowatt-hour*



Source: Ventyx Velocity Suite

Updated: 5/12

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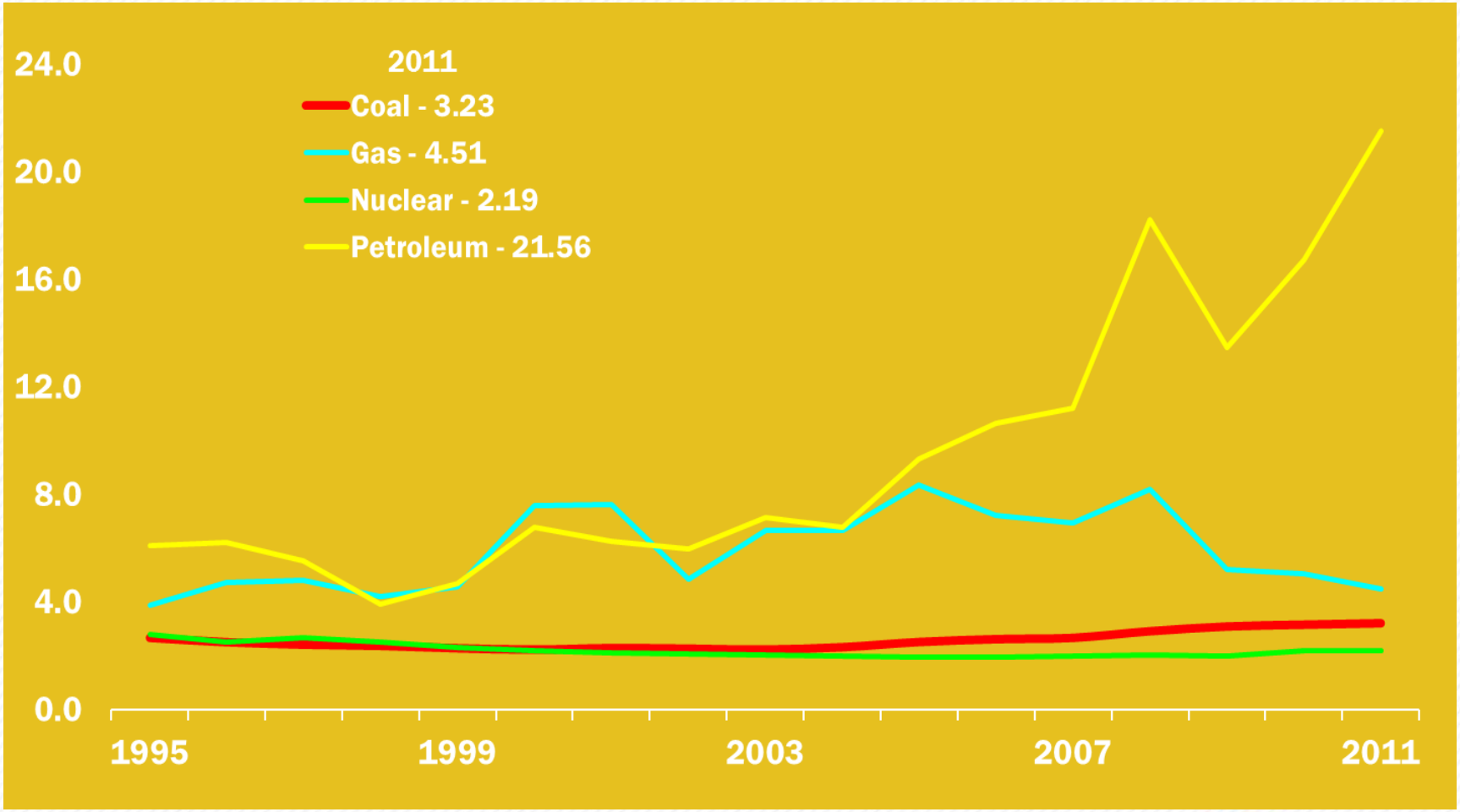
U.S. Electricity Production Costs

1995-2011, *In 2011 cents per kilowatt-hour*



Production Costs = Operations and Maintenance Costs + Fuel Costs. Production costs do not include indirect costs and are based on FERC Form 1 filings submitted by regulated utilities. Production costs are modeled for utilities that are not regulated.

Source: Ventyx Velocity Suite
Updated: 5/12

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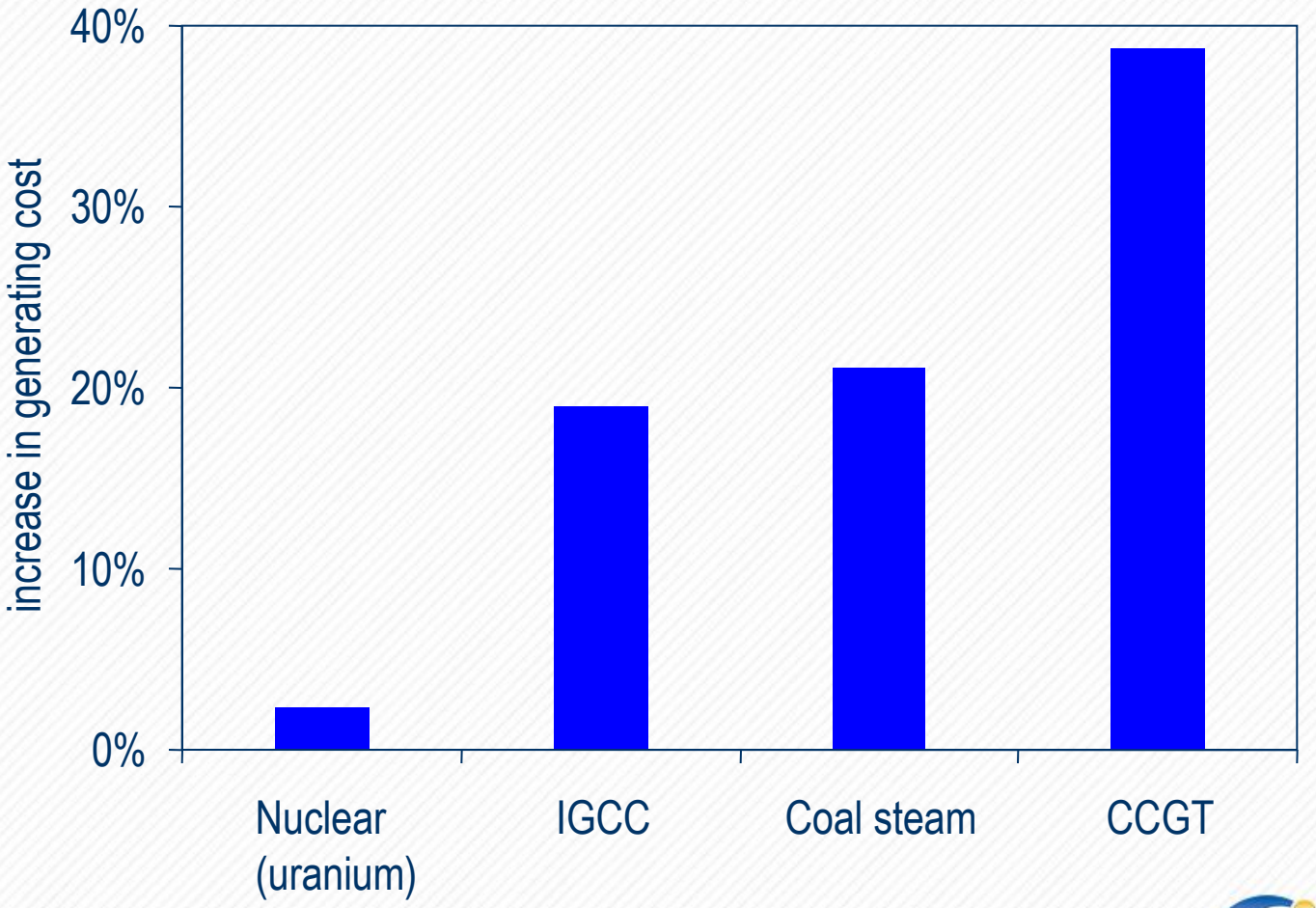
Impact of 50% increase in fuel cost



Sources: IEA "World Energy Outlook 2006" - " Reference Scenario "

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Why is nuclear fuel important?

- Without it the reactor will not operate!
- Relative cheapness crucial to nuclear economics – everything else connected with nuclear costs more
- Stability of fuel cost and ability to store easily vital to security of supply
- But a possible paradox – fuel is essentially nuclear's key advantage, but potentially also its biggest drawback (waste management issue)

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Cost of 1 kg of enriched uranium

Uranium	9 kg U308	$50 per lb	990
Conversion	7.6 kg U	$13 per kg	99
Enrichment	7 SWU	$150 per SWU	1050
Fabrication	1 kg	$300 per kg	300
Total			$2439

Need about 20 tonnes of enriched uranium for an average large reactor refuel, so cost will be about $50 million

Total front end world market is now worth about $22 billion annually

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Trade in the nuclear fuel cycle

- Specialisation of production is essential for economic reasons
- Security of supply is essential - therefore buyers pursue supply diversity
- Disputes have to be solved bilaterally - cannot go to WTO
- Restrictions not necessarily more stringent than in other energy commodities worldwide

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Market segmentation

- Russia fuels nearly all the reactors it sells around the world
- Complete fuel service in many cases
- Gradually breaking down as reactor owners seek supply diversification
- Competition in Czech Republic and the Ukraine
- But strong former Soviet Union sales to Western markets

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Trade restrictions - direct

- Import tariffs on fabricated fuel (10-15%)
- Australian & Canadian export monitoring
- Need for reciprocal nuclear cooperation agreements
- US restrictions on supply from the former Soviet Union
- Former US trade actions on enrichment from Europe
- Euratom controls in Europe

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Trade restrictions – political & indirect

- No direct sanctions today – in contrast to the past - eg South Africa/Namibia
- Strategic and defence-related restrictions are also now weaker
- Historic “Three Mines Policy” in Australia
- State ownership common in the nuclear fuel producers
- State ownership of power utilities too
- Foreign ownership restrictions

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Non-proliferation and safeguards

Non-Proliferation Treaty (NPT)

(Signed 1970; Extended indefinitely 1995. Currently 187 Signatories)

- To stop the further spread of nuclear weapons
- To provide security for non-nuclear weapons states which have given up the nuclear option
- To encourage international cooperation in the peaceful uses of nuclear energy
- To pursue negotiations towards nuclear disarmament leading to the eventual elimination of nuclear weapons

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Nuclear Suppliers Group (NSG)

" … a group of nuclear supplier countries which seeks to contribute to the non-proliferation of nuclear weapons through the implementation of Guidelines for nuclear exports and nuclear related exports…"

1974	Creation of NSG with 7 members (currently 45 members)
1978	NSG Guidelines published as IAEA Document INFCIRC/254, covering export of items especially designed or prepared for nuclear use
1992	NSG Guidelines for "dual use" technology published as IAEA Document INFIRC/254, Part2

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Nuclear Suppliers Group (NSG)

Impact of the NSG

1. Severe limitations on nuclear trade with India and Pakistan, neither of which signed the NPT
2. Each country has had to develop its domestic nuclear sector without substantial recourse to outside assistance
3. The lack of good quality uranium resources has forced India to meet its ambitious NPP programme by relying on the maximum use of recycled fuel, notably in fast reactors, and, potentially, through the development of thorium-based reactors
4. The NSG has now approved changes to its Guidelines, after the US/India nuclear deal was signed and approved.

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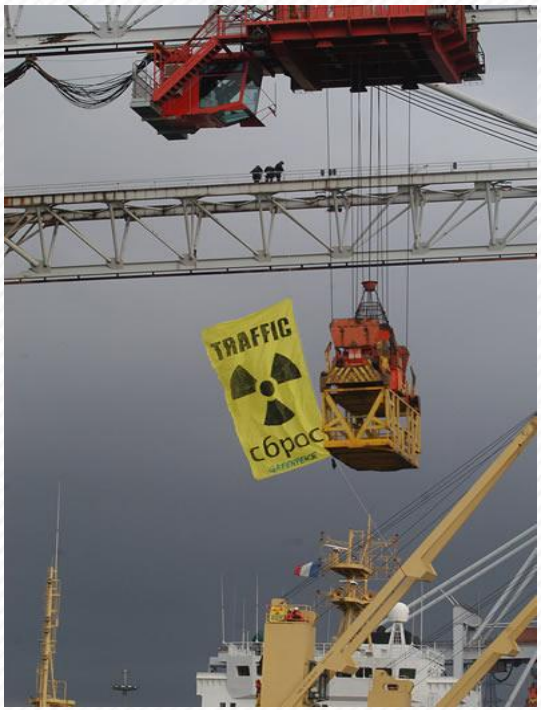
Transport Issues

- **Public Opposition:** Transport viewed by opponents as the industry's Achilles heel; transport is the area where our goods interact the closest with the public; phrases like "mobile Chernobyl" conjure up public fear.



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Transport Issues - Opposition of Coastal States

- **Coastal states (e.g NZ, Peru):**
  - Feel threatened by used fuel / HLW shipments passing off their coastline. Demand info:
    - Details of vessel and planned route
    - Type and volume of cargo
    - Non-entry into Exclusive Economic Zone (EEZ)
    - Details of emergency response and security plans
- **Industry** says this breaches principle of *UN Convention on the Law of the Sea* which requires all countries to allow freedom of passage through the EEZ

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Transport Issues - Delay and denial of shipments

- **Delay and denial of shipments**
  - Inability to ship RAM packages in a timely way despite compliance with regs
  - More an issue of international shipments, and mainly applies to air and maritime mode
  - Back end often use dedicated ships so can bypass some of the problems
  - RAM considered “too much bother” (segregation of cargo; fixed route; radiological protection programmes) vis a vis small financial gain
  - IAEA Steering Committee on Shipment Denials set up Nov. 2006. Members include Member States, Modal Organizations (IMO, IATA etc.), industry associations (WNA, ISSPA, WNTI etc.)
    - Network of National Focal Points

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Transport Issues - Consequences of denial

1. Packages left on the quay
2. Lack of short-lived isotopes for diagnosis and treatment
3. Non-availability of potentially life-saving or pain-relieving radiotherapy / Sterile single use medical devices
4. Safety-critical non-destructive testing of vehicles, buildings etc. cannot be carried out
5. Sources from unstable regions cannot be repatriated
6. IAEA Safeguards samples cannot be shipped to labs for analysis
7. Countries remote from nuclear fuel cycle facilities decide to develop full nuclear fuel cycle. Proliferation risk.
8. Etc.

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Summary

- Major international market in nuclear fuel
- Not completely free trade
- Solving difficulties on transport will save time and costs
- Assuming they stick to IAEA Safeguards, new nuclear countries should look forward to free supply of fuel from a competitive market
- Fuel banks, international fuel cycle centres could constitute an unnecessary restriction on free trade

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