Balancing Risks

Nuclear Energy and Climate Change

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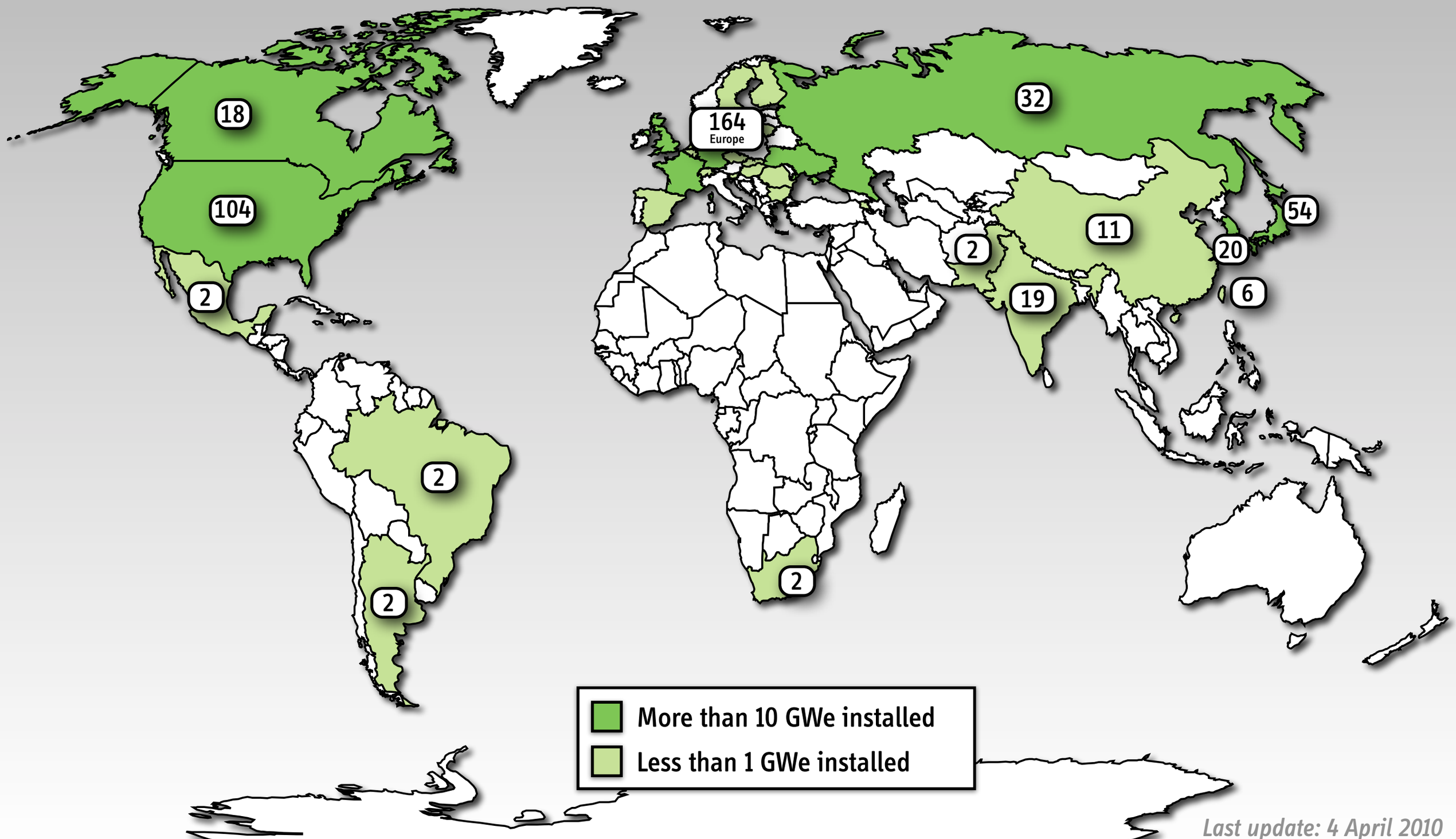
Second Annual Great Issues in Energy Symposium: The Nuclear Option
Dartmouth College, April 9, 2010

Revision 7

Nuclear Energy Today

Nuclear Power Reactors in the World, 2010

(438 reactors in 30 countries)



Last update: 4 April 2010

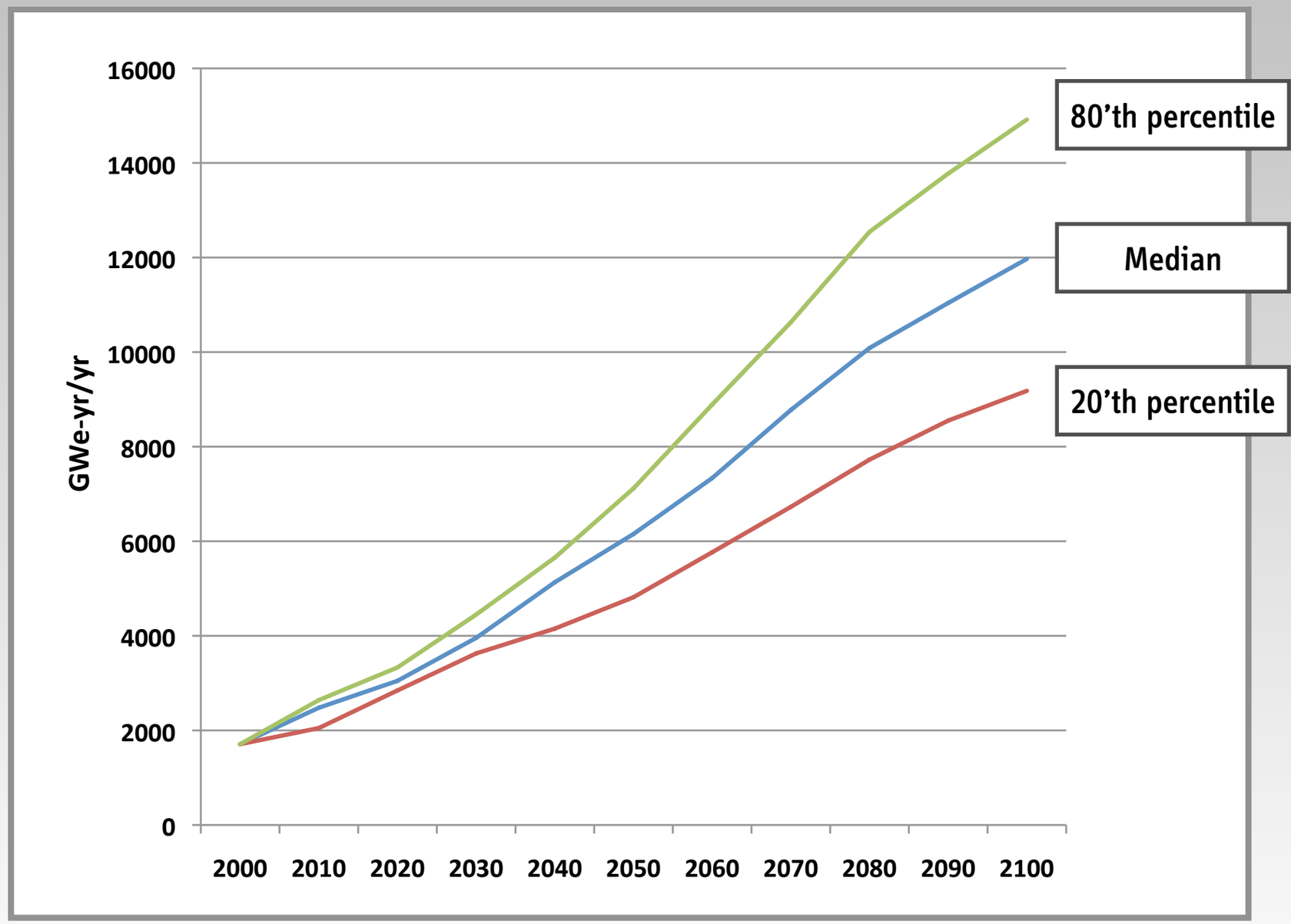
Where Do We Go From Here?

The Scale of a Hypothetical Expansion

(Long-term vs Short-term)

Today's Long-Term Electricity Projections

are relatively robust against variations of CO_2-emission-reduction objectives



Robert J. Goldston, "Climate Change, Nuclear Power and Nuclear Proliferation: Magnitude Matters," *submitted to Energy Policy*

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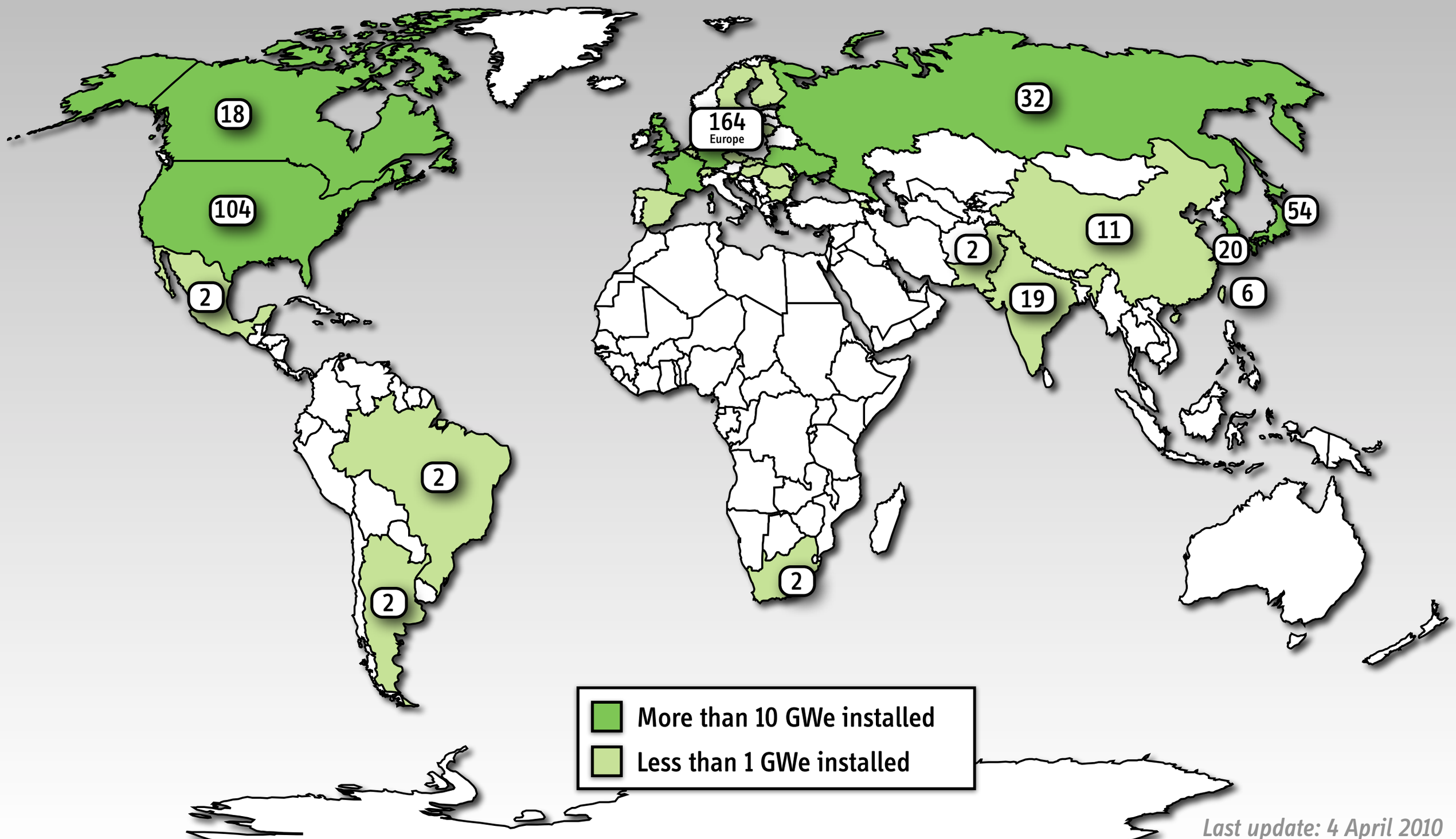
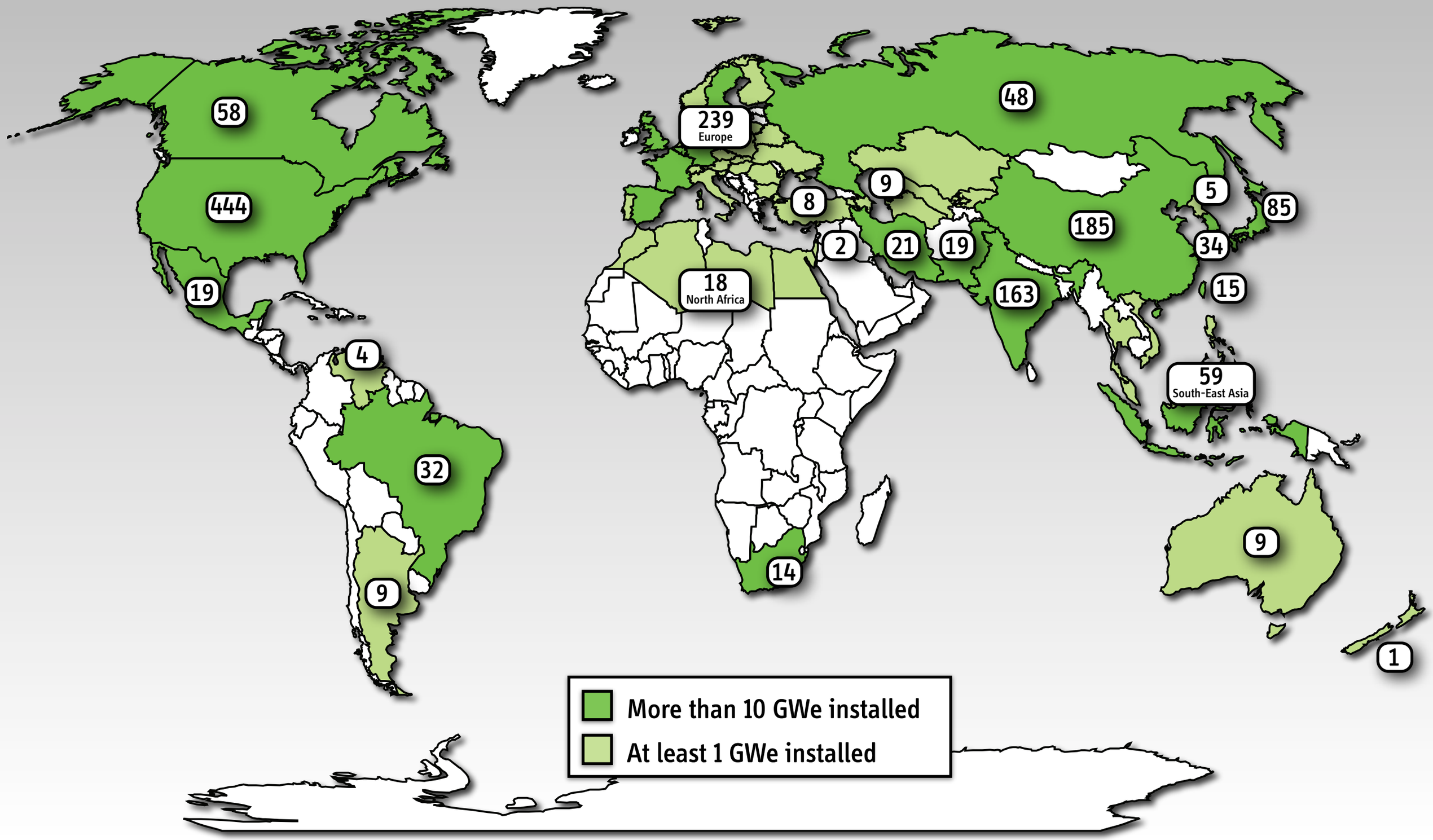


Last update: 4 April 2010

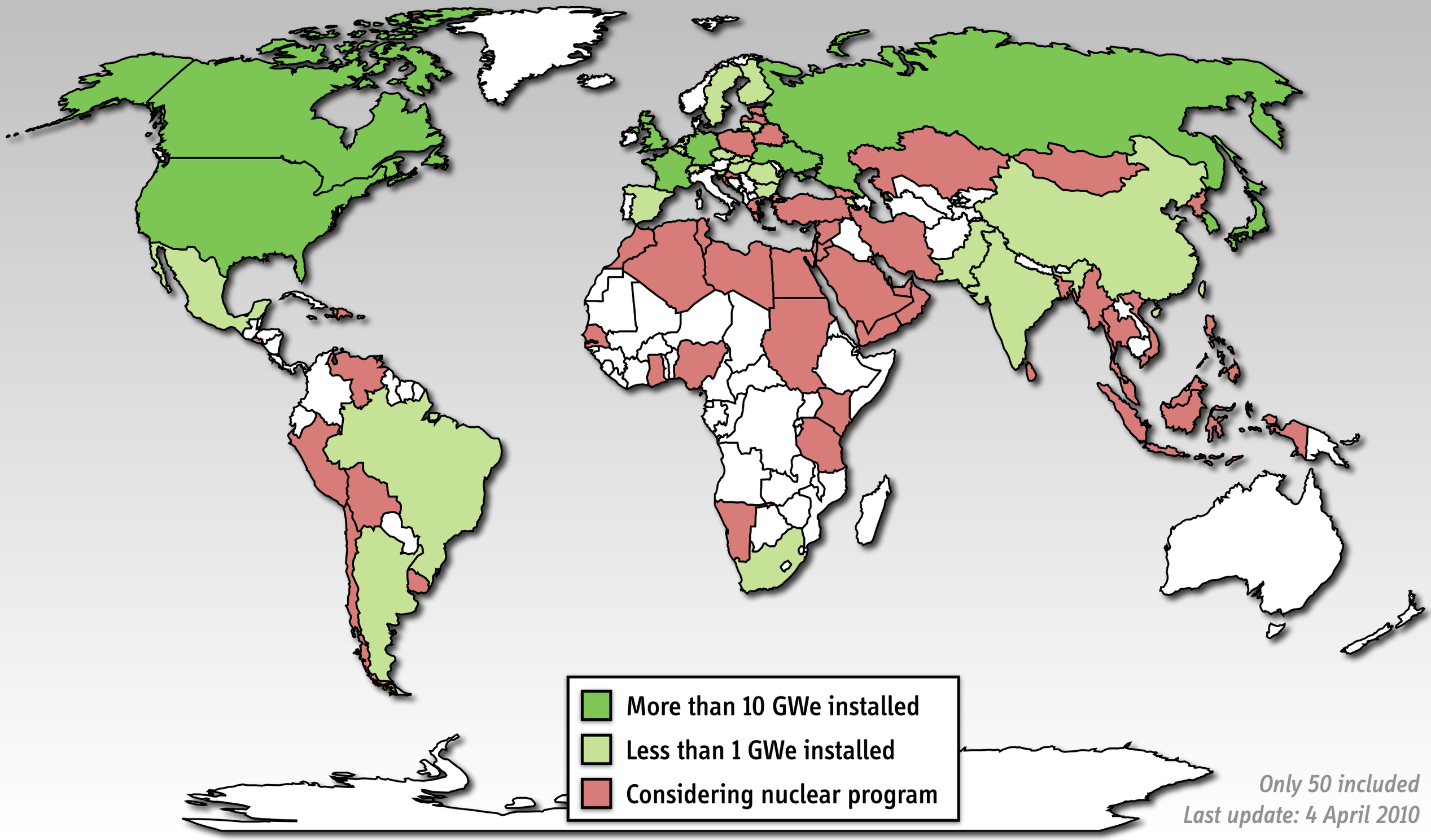
Global Nuclear Expansion Scenario

(1500 GWe in 58 countries, based on 2003 MIT study)



Nuclear “Newcomer” Countries

According to the IAEA, 60+ countries are currently considering nuclear programs



Only 50 included
Last update: 4 April 2010

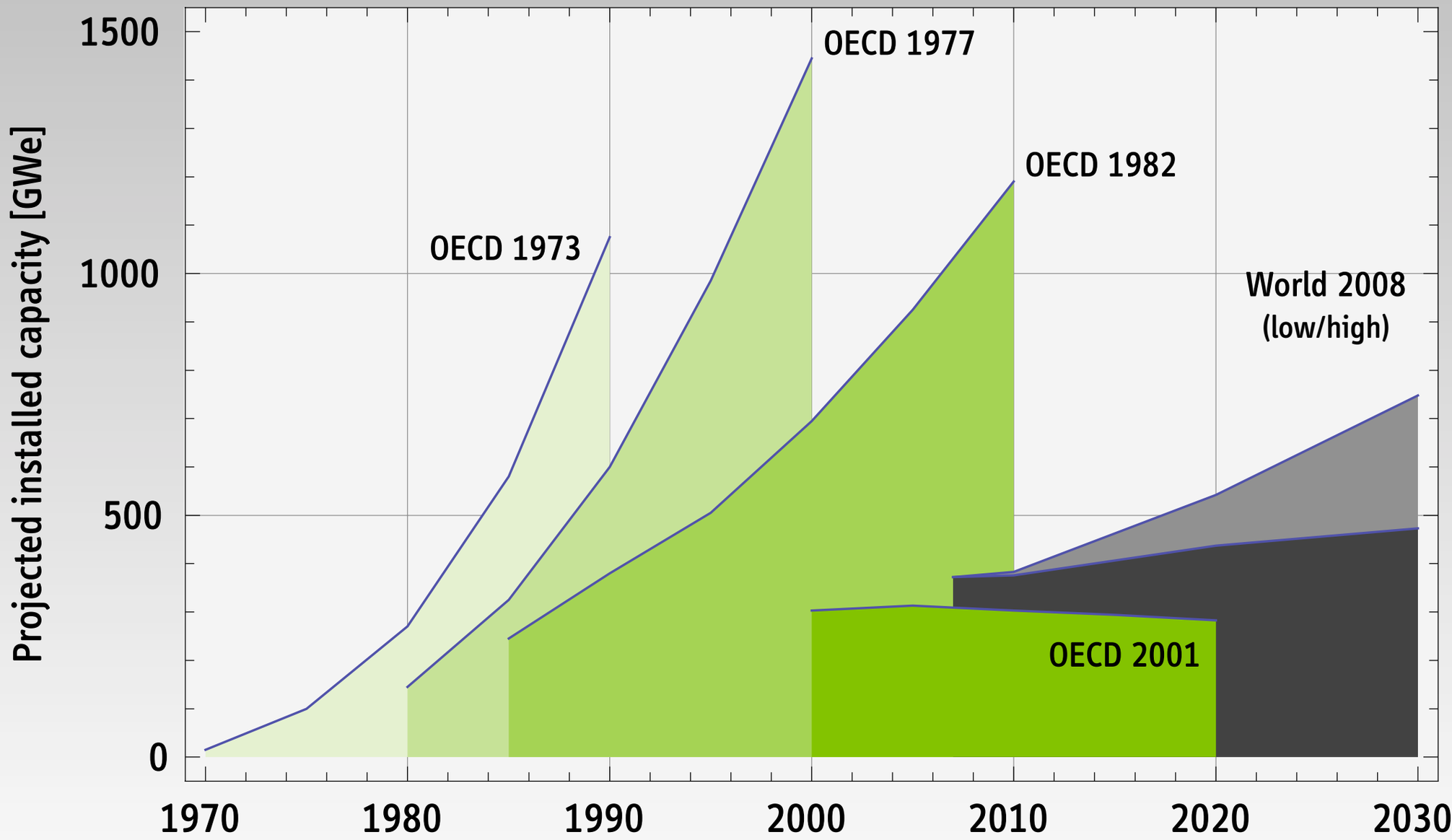
Legacies of the First “Atoms for Peace” Era

Kinshasa Research Reactor, DR Congo, 2007

Source: AFP/Getty Images

The Next Decade

Evolution of IAEA/OECD Forecasts



America's Energy Future: Technology and Transformation
National Academy of Sciences; National Academy of Engineering; National Research Council
Washington, DC, July 2009
www.nap.edu/catalog.php?record_id=12091

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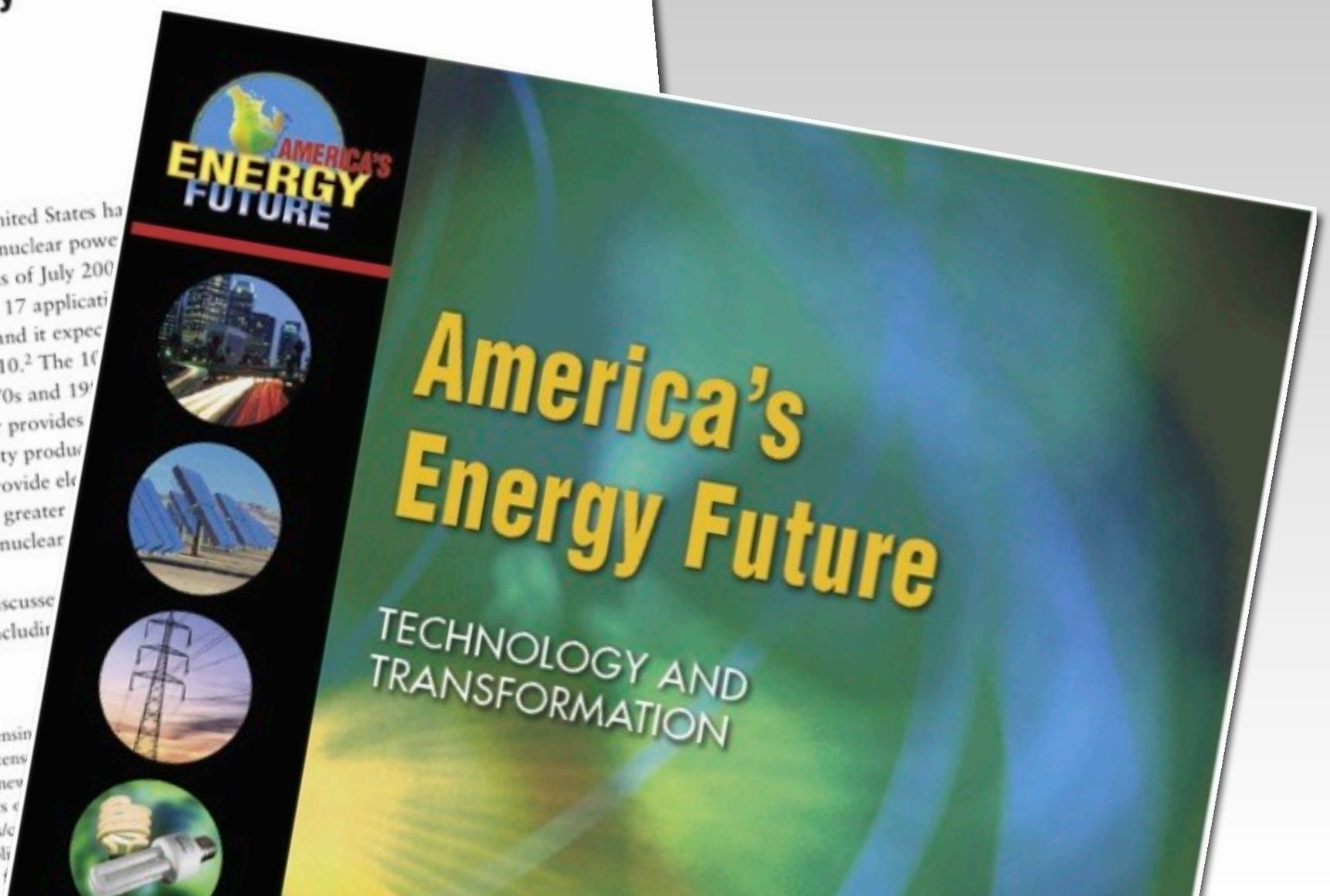
Nuclear Energy

Utilities in the United States ha
in adding new nuclear powe
tion sources. As of July 200
(USNRC) had received 17 applicati
licenses[1] for 26 units, and it expec
units by the end of 2010.[2] The 1
constructed in the 1970s and 19
supply: nuclear power provides
70 percent of electricity produ
tions. These plants provide ele
with capacity factors greater
remain, and no new nuclear
than 30 years.

This chapter discusse
the United States, includi

[1]Previously, the licensin
required a different licens
part of the USNRC's new
[2]The USNRC's lists
reactors/new-reactors/c
expected-new-rx-appli
[3]The net capacity



America's Energy Future

National Research Council, July 2009, Executive Summary

"The viability of two key technologies must be demonstrated during the next decade to allow for their widespread deployment starting around 2020:

- Demonstrate whether CCS technologies ... are technically and commercially viable for application to both existing and new power plants. [...]

- Demonstrate whether evolutionary nuclear plants are commercially viable in the United States by constructing a suite of about five plants during the next decade."

The Next Decade

Little new capacity will be added in the United States
and (even less so) in Western Europe

Little (if any) capacity will come online in “newcomer” countries

By the end of the decade, we will understand better the
economics and some other constraints for both nuclear and its competitors

We may take options off the table at that point

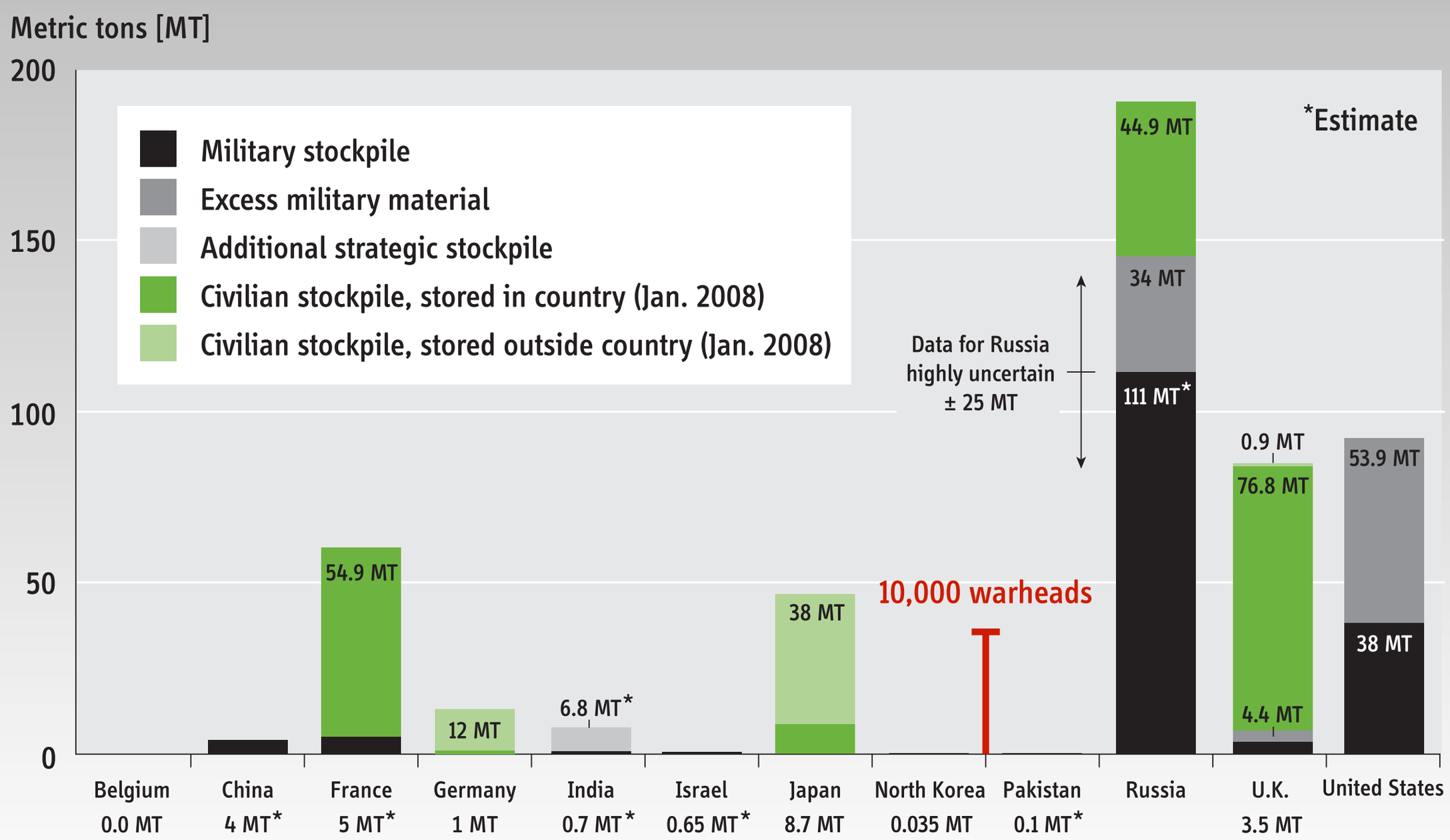
In particular, nuclear power may have to be taken off the table
if “global deployment scenario” remains unacceptable

What Should Be Done In the Meantime?

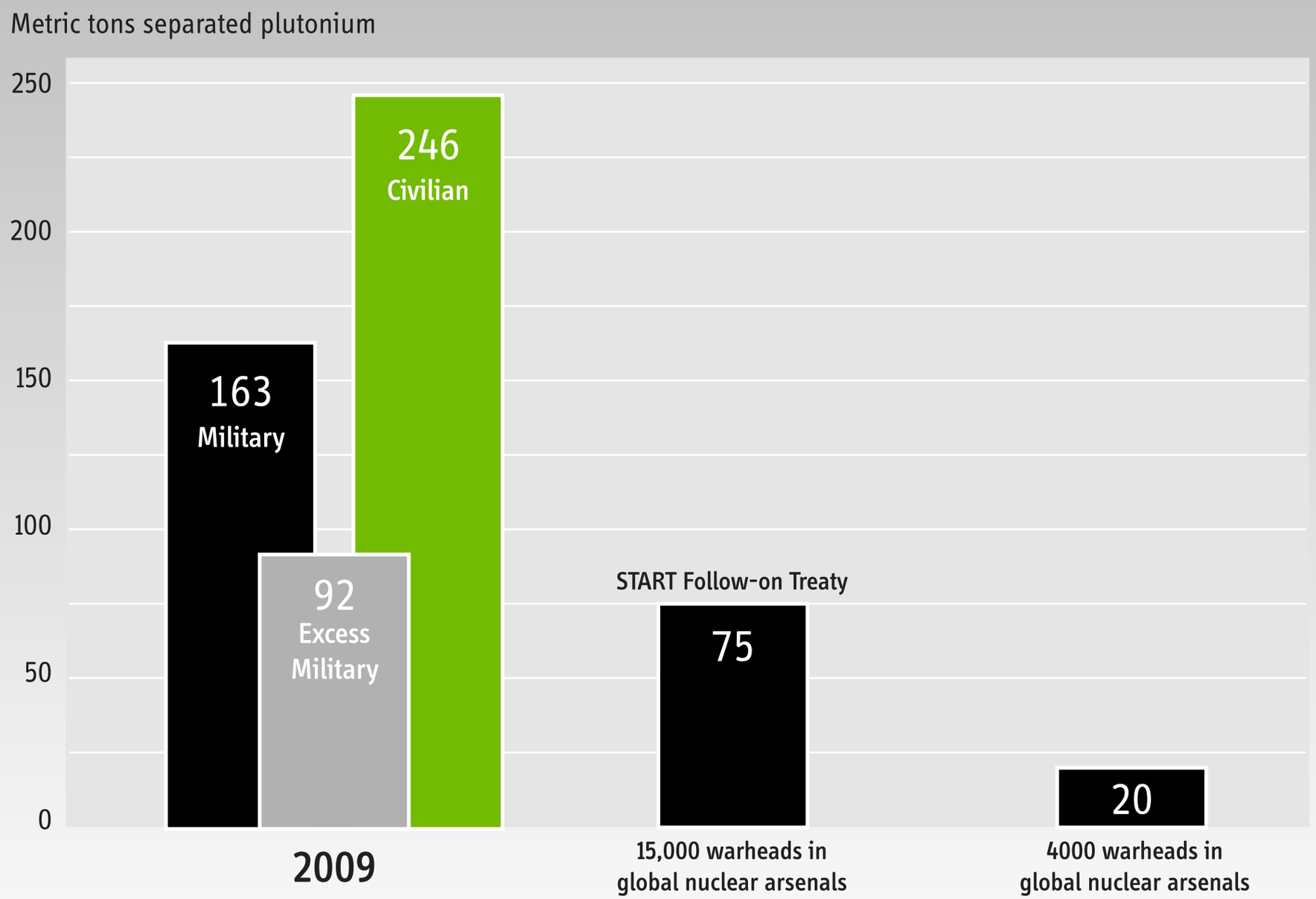
Refrain From Reprocessing

Stockpiles of Separated Plutonium, 2009

Global stockpile is 500 tons, half is civilian and this stock is growing



Civilian Separated Plutonium in a Disarming World



R. Socolow and A. Glaser, "Balancing Risks: Nuclear Energy and Climate Change," *Daedalus*, 2009.

Material Flows for Nuclear Options

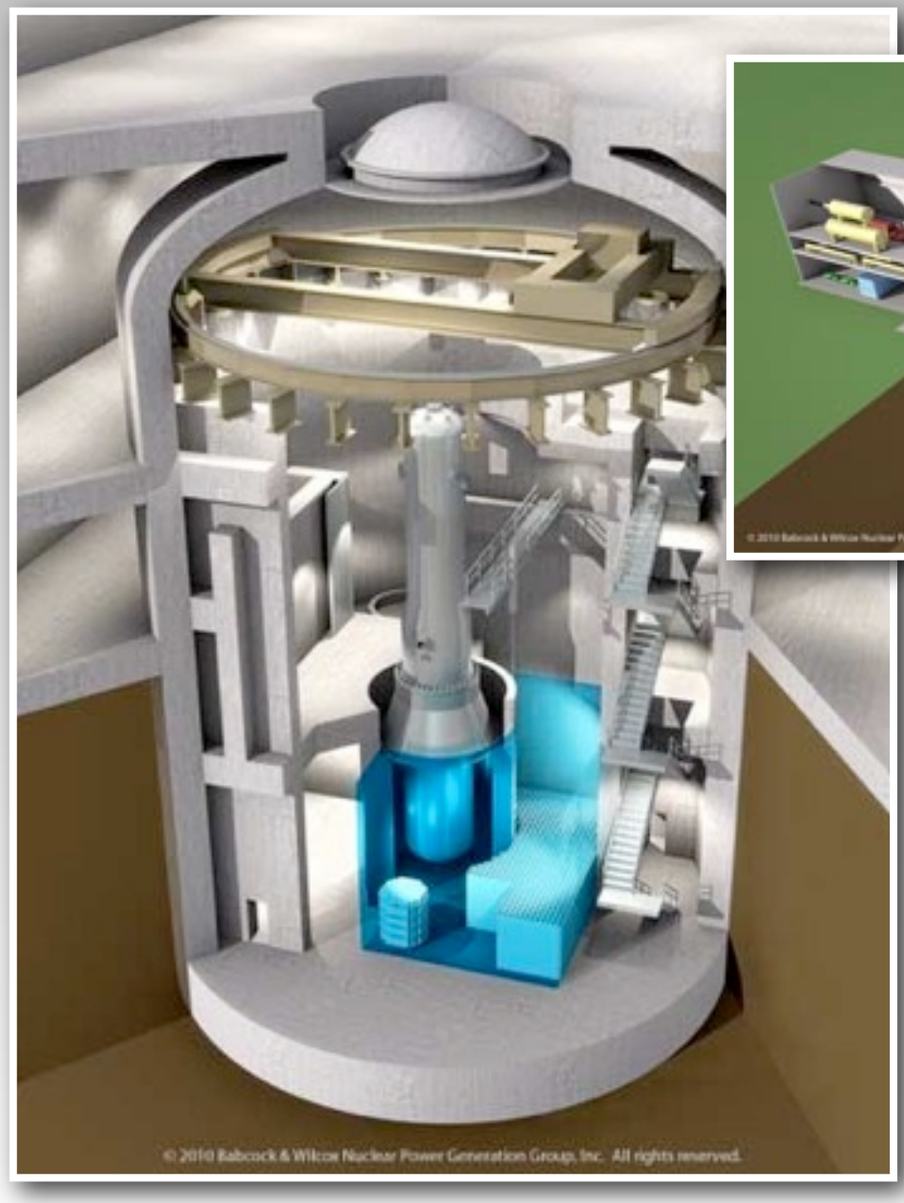
Annually for Reference Capacity of 400 GW (electric)

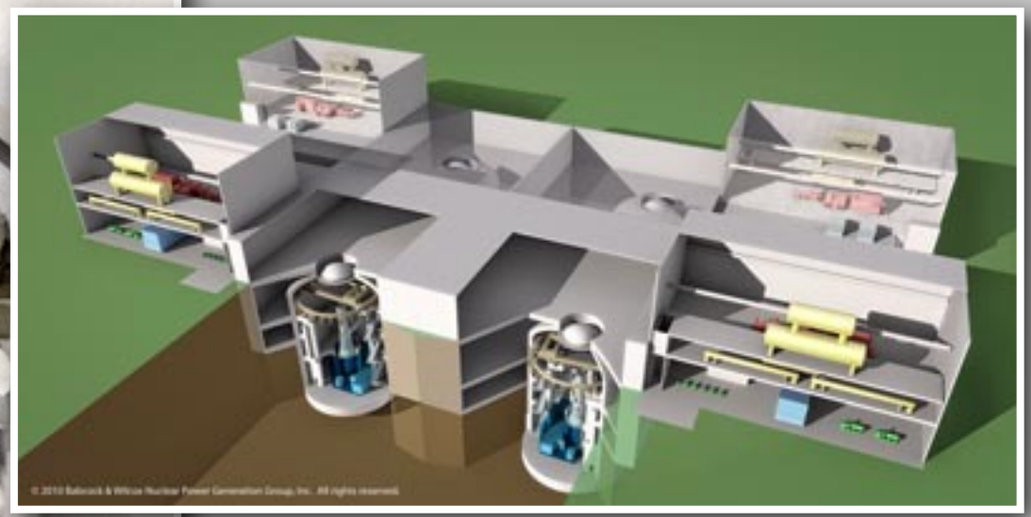
	400 GW CANDU	400 GW LWR	240 GW LWR 160 GW Fast Reactors
Uranium Requirements	60,000 MT (25% reduction)	80,000 MT (reference value)	48,000 MT (40% reduction)
Enrichment	--	48,000 tSWU	28,800 tSWU
Plutonium Separation Rate	--	--	**280 MT** **(35,000 Significant Quantities)**
Waste	400 MT FP + 200 MT Pu embedded in 60,000 MT of spent fuel	400 MT FP + 100 MT Pu embedded in 80,000 MT of spent fuel	400 MT FP in process waste (ideally no Pu/TRU)

MT = Metric Tons / SWU = Separative Work Units / FP = Fission Products

Could Small Nuclear Reactors Play a Role?

Some concepts are based on light-water reactor technology





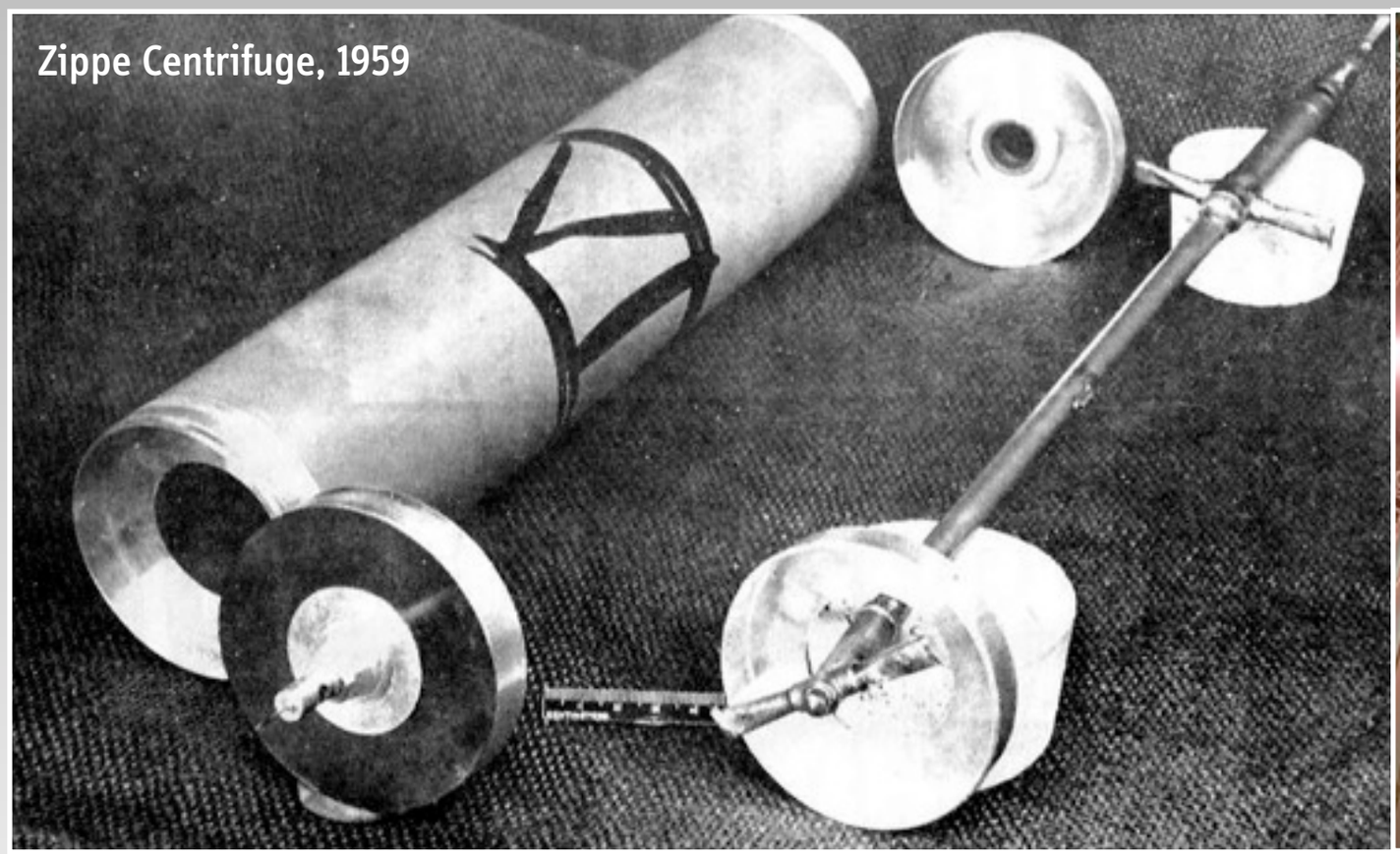
Babock & Wilcox mPower Concept

- Light-water cooled
- 125-750 MWe
- Underground construction
- 60-year spent fuel storage onsite
- Quasi-standard LWR fuel

Source: www.babcock.com/products/modular_nuclear/

Build a New Framework for the Nuclear Fuel Cycle

Why Centrifuges Are Different



Characteristics of centrifuge technology relevant to nuclear proliferation

Rapid Breakout and Clandestine Option

The Natanz Site in Iran (2007)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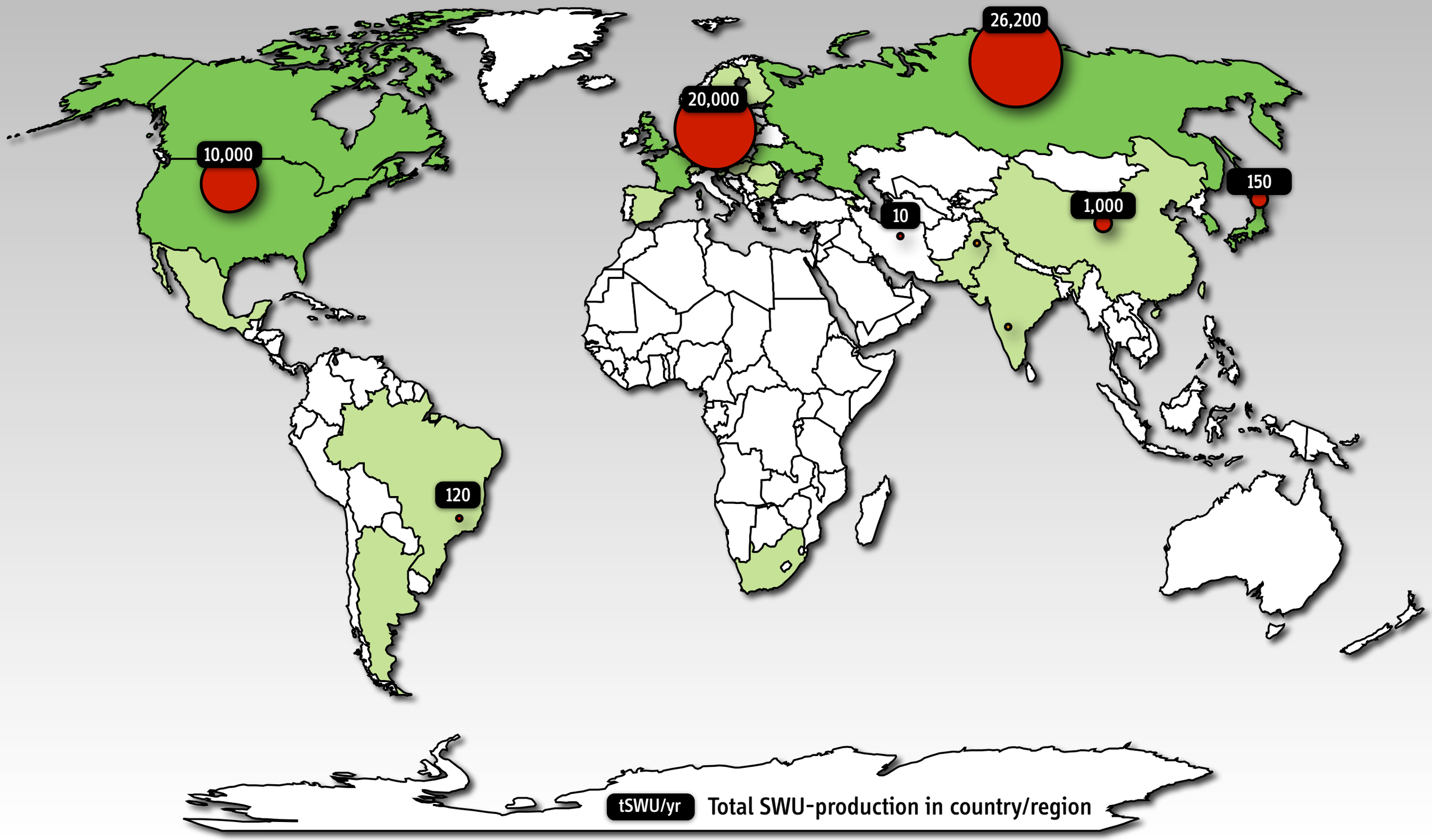
www.President.ir

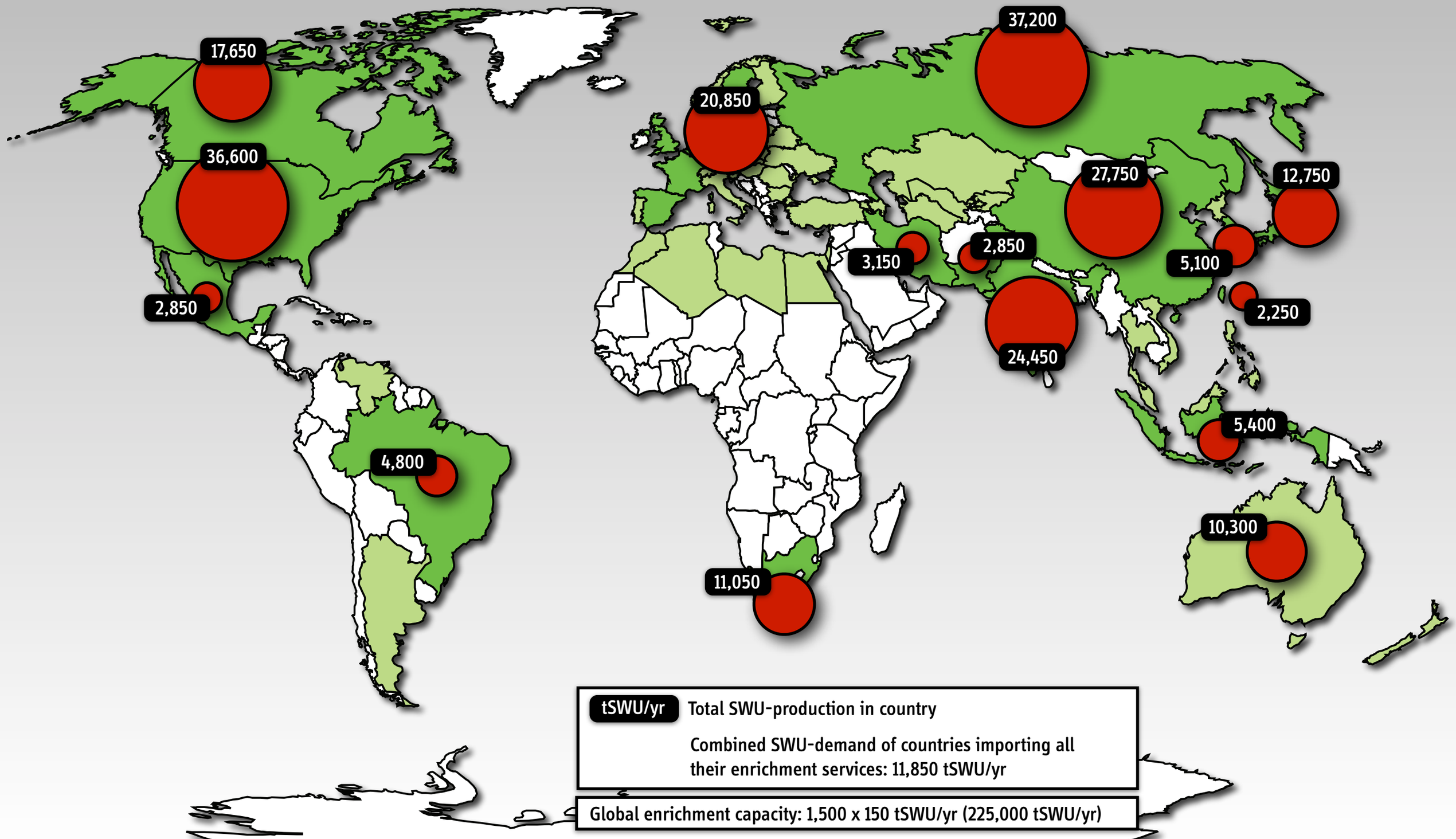
Global Enrichment Capacities, 2010

(14 operational plants in 10 countries, not including two military plants)



Enrichment Demand and Distribution

(for 1500 GWe Global Nuclear Expansion Scenario based on light-water reactors)



Preventing the Further Spread and Assuring Peaceful Use

Preventing Further Spread

- Tighten export controls (further)
- Delegitimize enrichment in today's "non-enrichment" states
- Increase the ability to detect undeclared facilities
- Encourage multilateral approaches to the nuclear fuel cycle

Assuring Peaceful Use

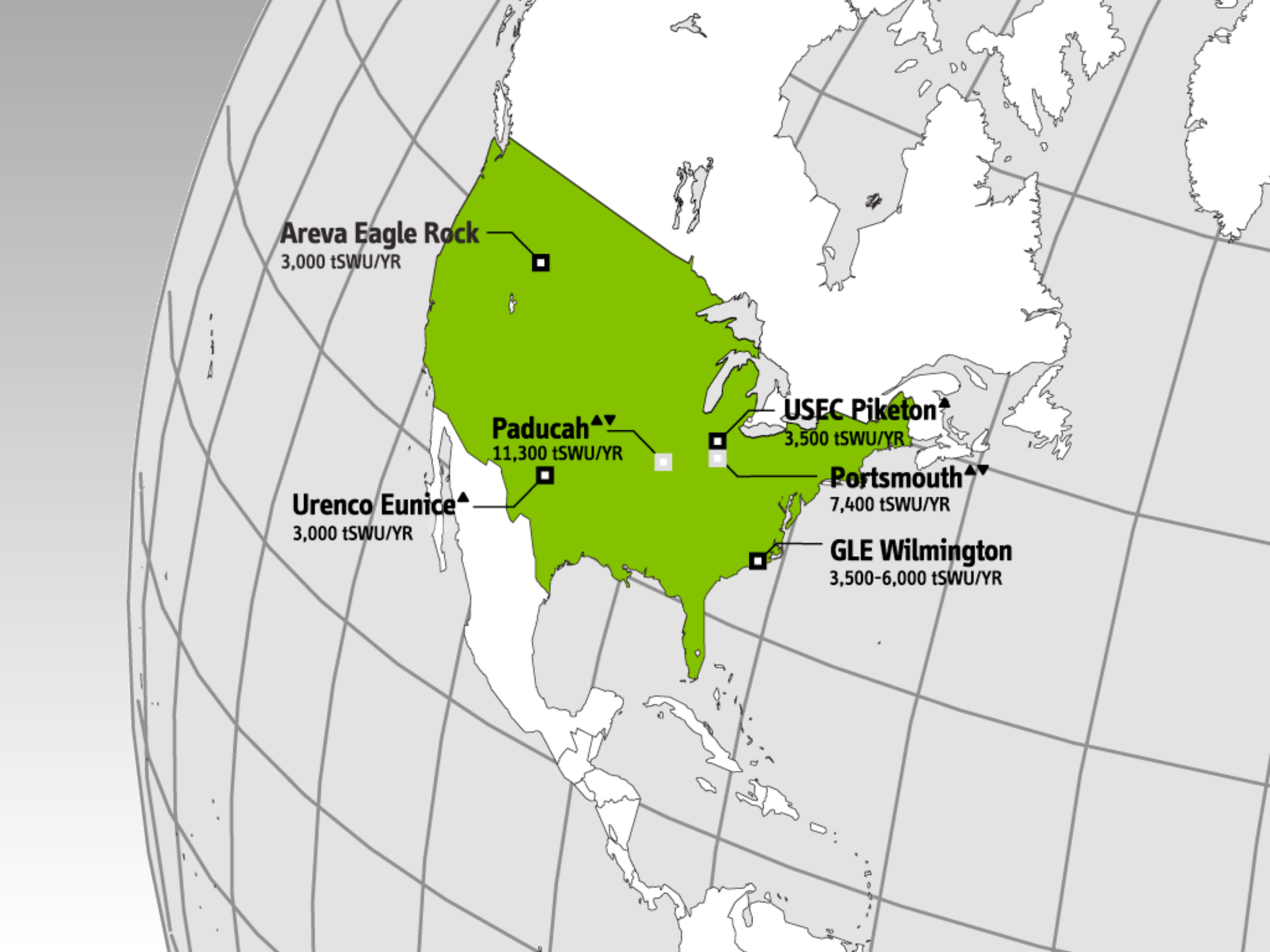
- Increase the effectiveness of IAEA safeguards
- Revisit alternative "proliferation-resistant" technologies

Statement by the Group of 77

(representing interests of 130 developing countries at the United Nations)

during the June 2009 IAEA Board of Governors Meeting

"The Group, in principle, reiterates its strong rejection of any attempts aimed to discourage the pursuit of any peaceful nuclear technology on the grounds of its alleged 'sensitivity.' ... The Group is of the view that any proposal for the assurance of supply should not be designed in a way that discourages States from developing or expanding their capabilities in the area of the nuclear fuel cycle, nor to hamper research and development and international cooperation in the field of peaceful nuclear activities."


Areva Eagle Rock
3,000 tSWU/YR
Paducah
11,300 tSWU/YR
Urenco Eunice
3,000 tSWU/YR
USEC Piketon
3,500 tSWU/YR
Portsmouth
7,400 tSWU/YR
GLE Wilmington
3,500-6,000 tSWU/YR

Concluding Remarks

Nuclear power could make a significant contribution to climate-change mitigation

Nuclear power would have to be deployed extensively, including in the developing world

The next decade is critical

Not much new nuclear capacity will be added in the United States and Europe

Time to establish economics, adequate technologies, and new norms of governance

Nuclear disarmament as an opportunity

Deeper cuts in the nuclear arsenals could encourage weapon (and non-weapon) states to embrace serious multilateral approaches to the civilian nuclear fuel cycle