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Brave New Nuclear World

The Expansion of Nuclear Power and its Relevance for the Proliferation of Nuclear Weapons

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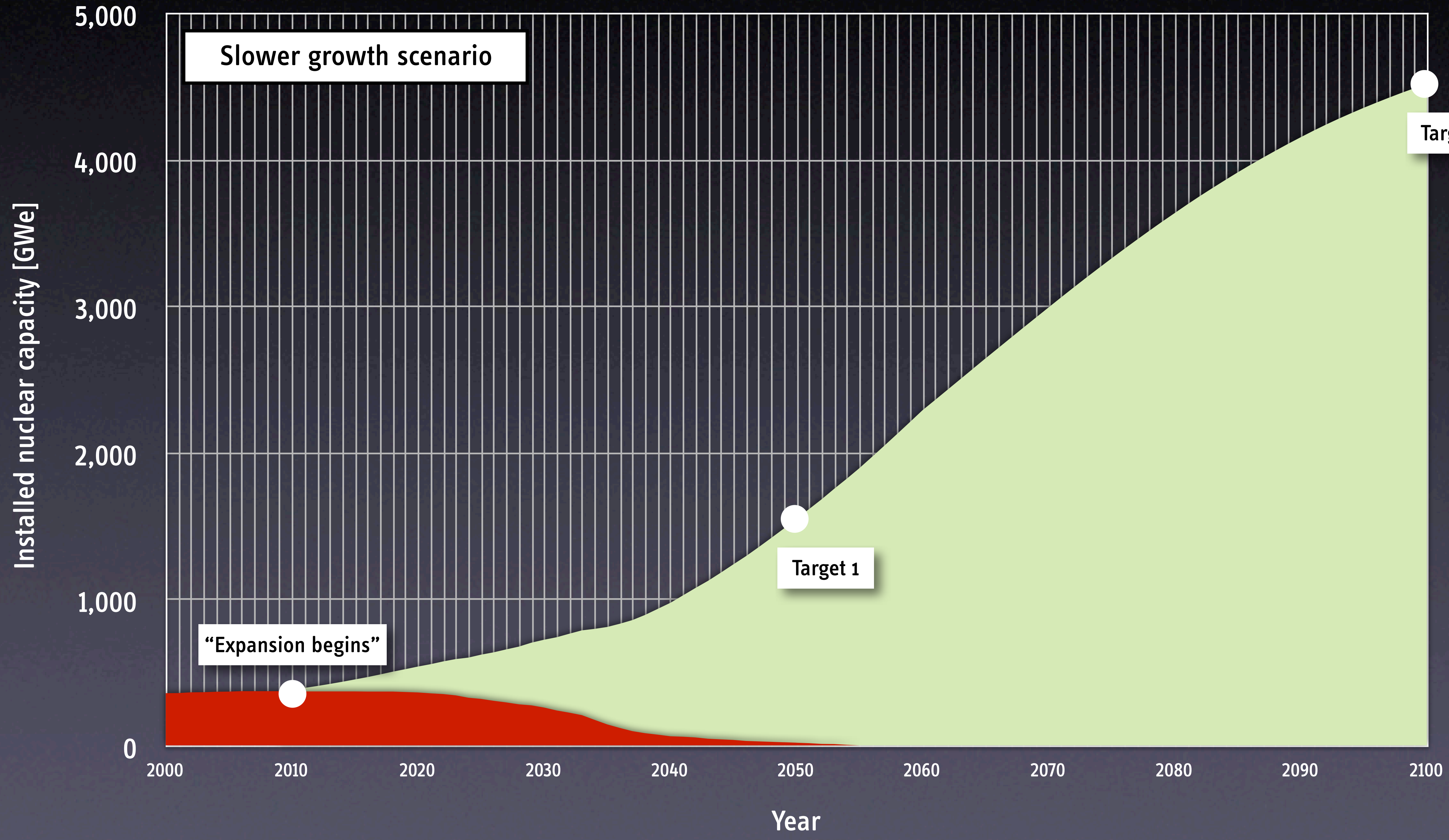
“We would not make atomic weapons, at least not to start with, but we would start out and build enormous plants, and we would call them power plants—maybe they would produce power; and these plants we would design in such a way that they could be converted with the maximum ease and the minimum time delay to the production of atomic weapons, and we would say, this is just in case somebody two-times us; and we would stock-pile uranium, we would keep as many of our developments [as] secret as possible, we would locate our plants, not where they would do the most good for the production of power, but where they would do the most good for protection against enemy attack.”

J. Robert Oppenheimer
(on the prospects of a nuclear weapons convention)
in the Bulletin of the Atomic Scientists
Vol. 1, No. 12, June 1946

Scale of a Hypothetical Global Expansion of Nuclear Power

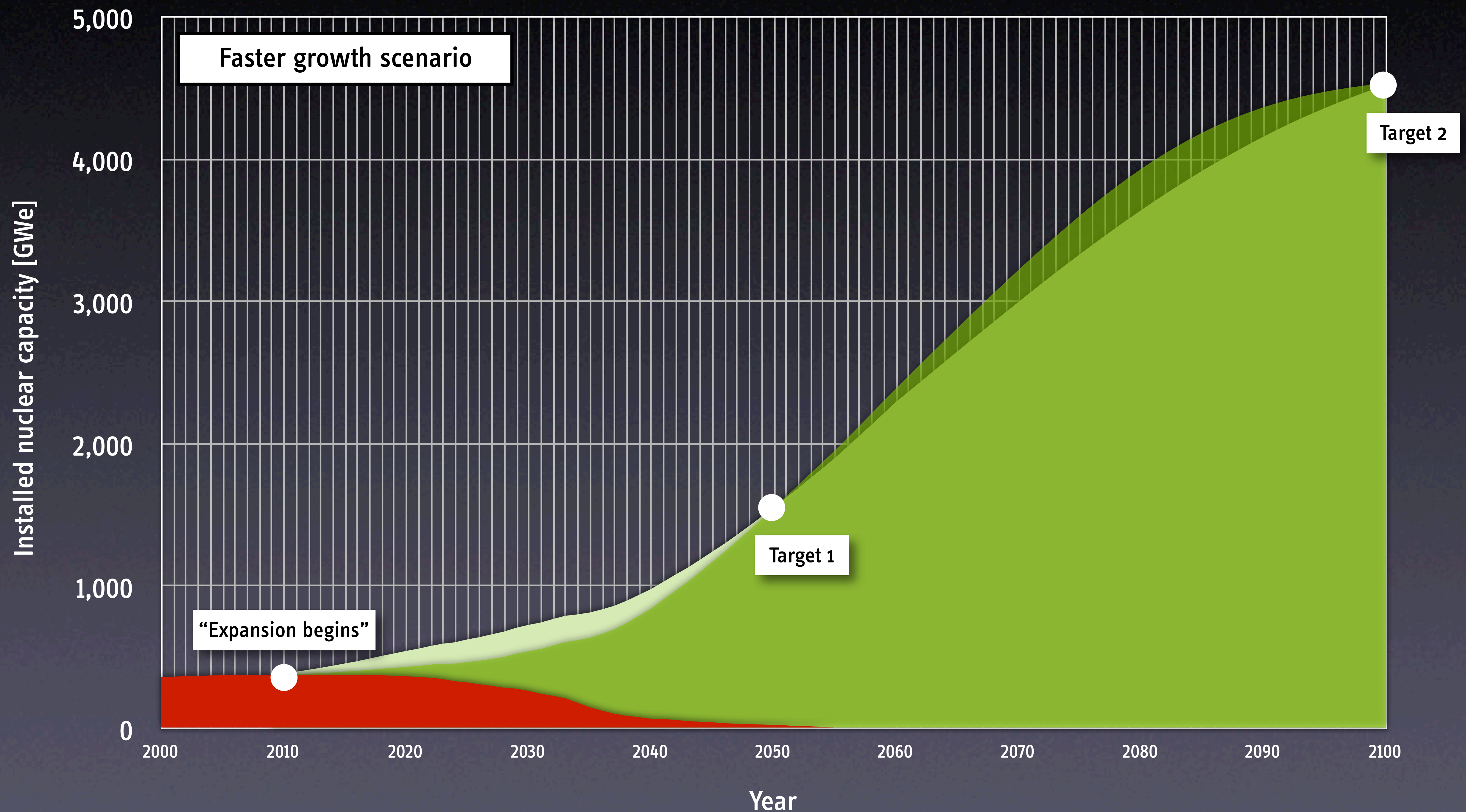
Capacity Buildup

2010-2050-2100



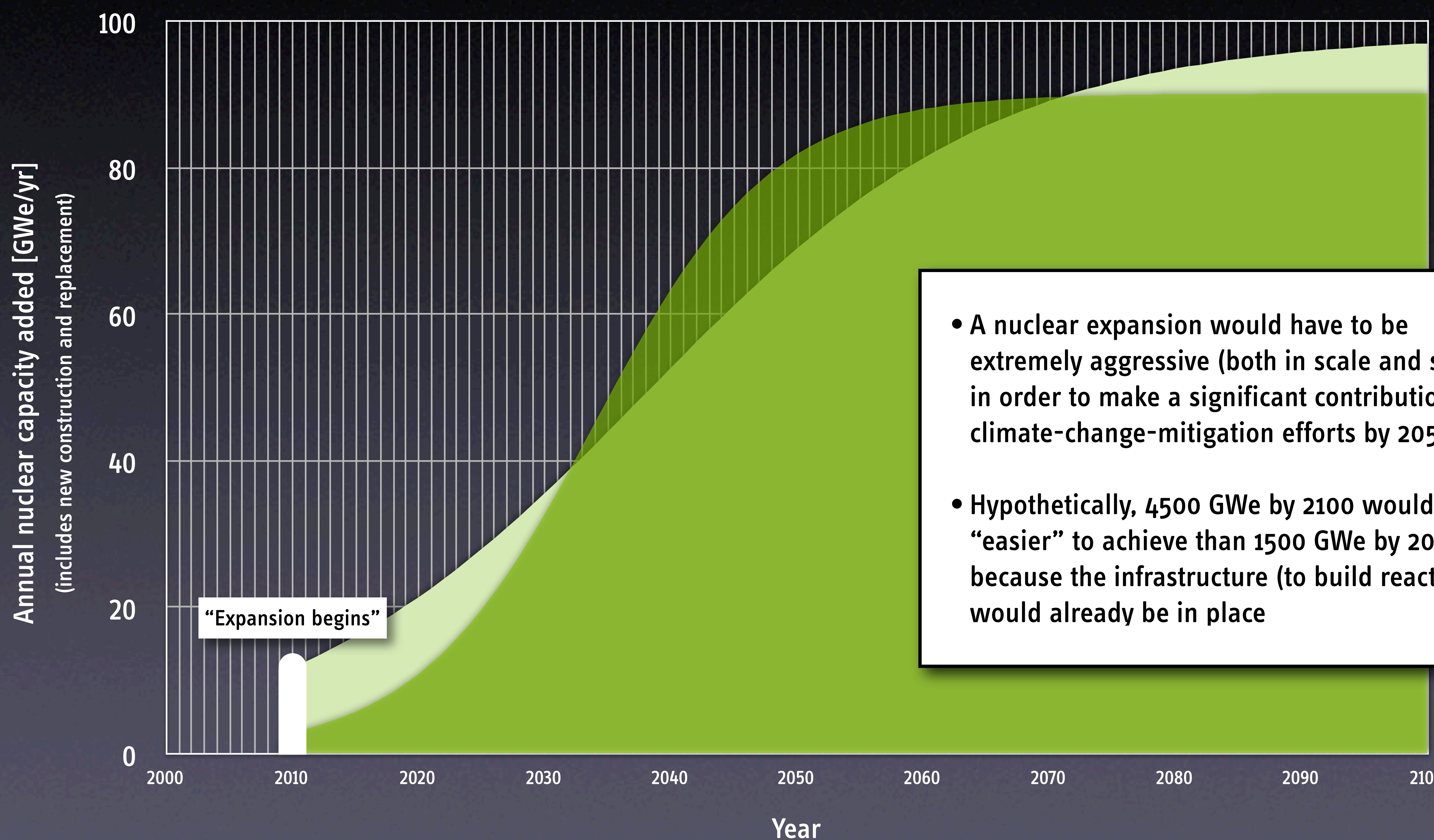
Capacity Buildup

2010-2050-2100



Capacity Buildup

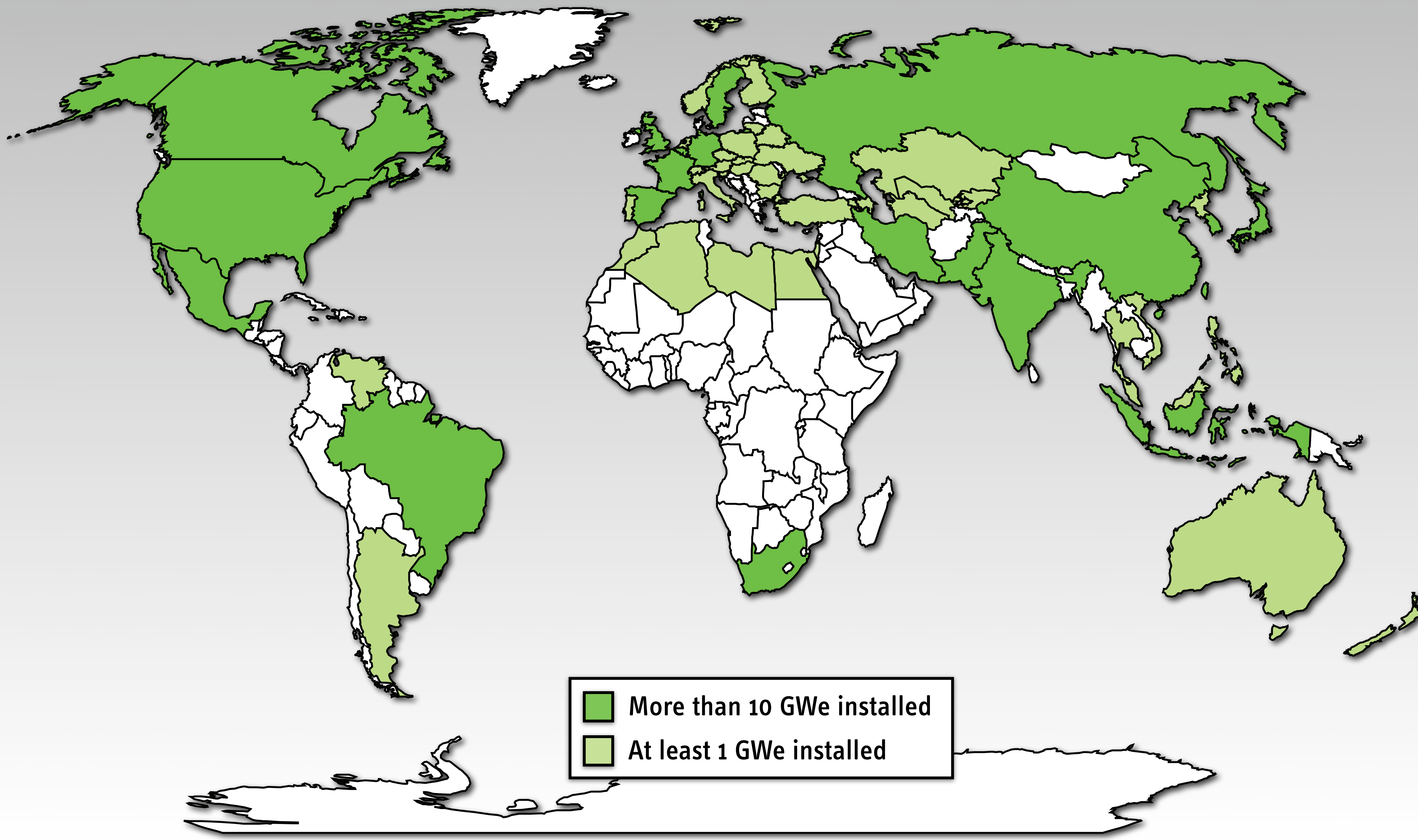
2010-2050-2100



- A nuclear expansion would have to be extremely aggressive (both in scale and speed) in order to make a significant contribution to climate-change-mitigation efforts by 2050
- Hypothetically, 4500 GWe by 2100 would be "easier" to achieve than 1500 GWe by 2050 because the infrastructure (to build reactors) would already be in place

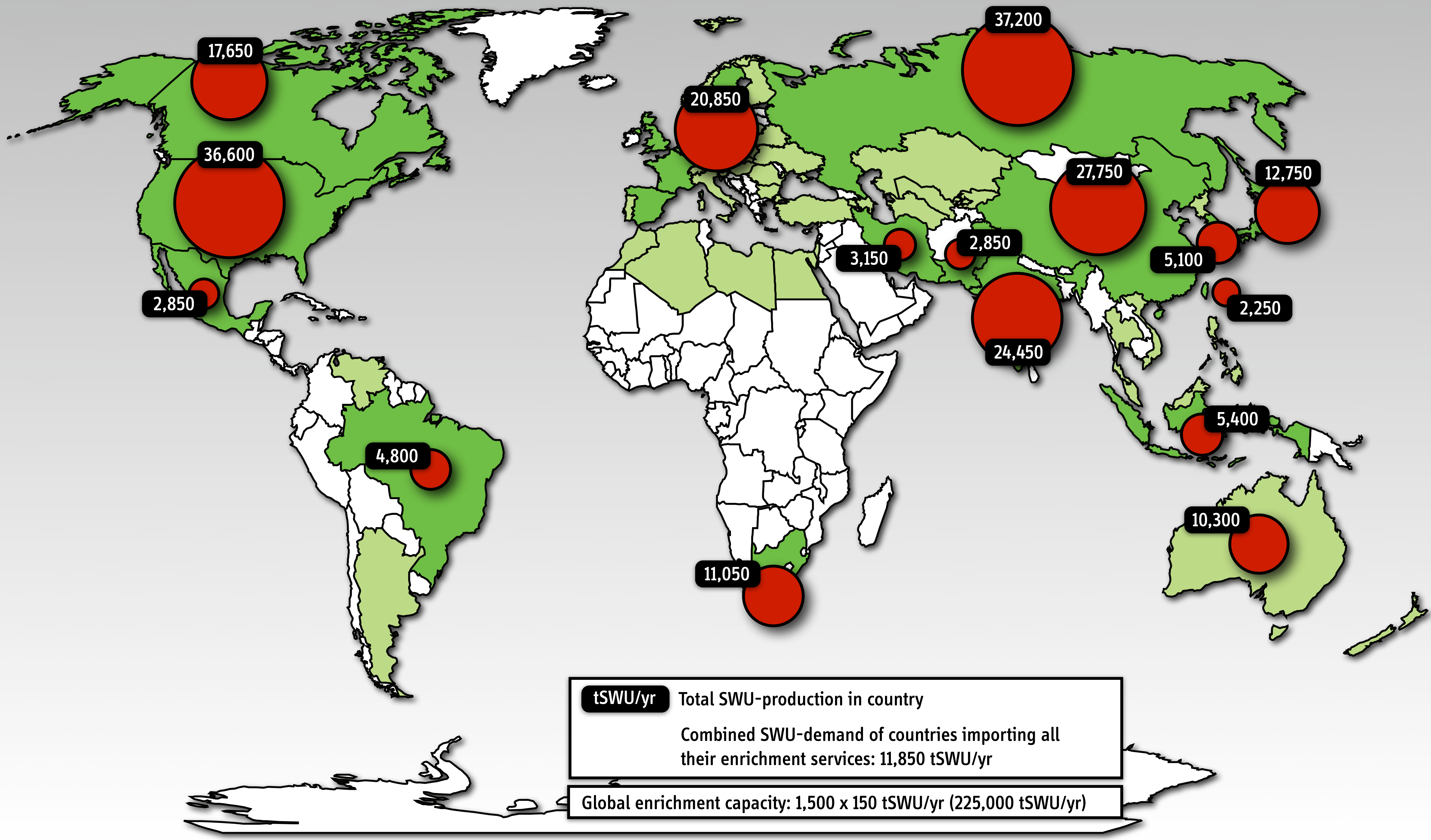
Global Nuclear Expansion Scenario

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



Enrichment Demand and Distribution

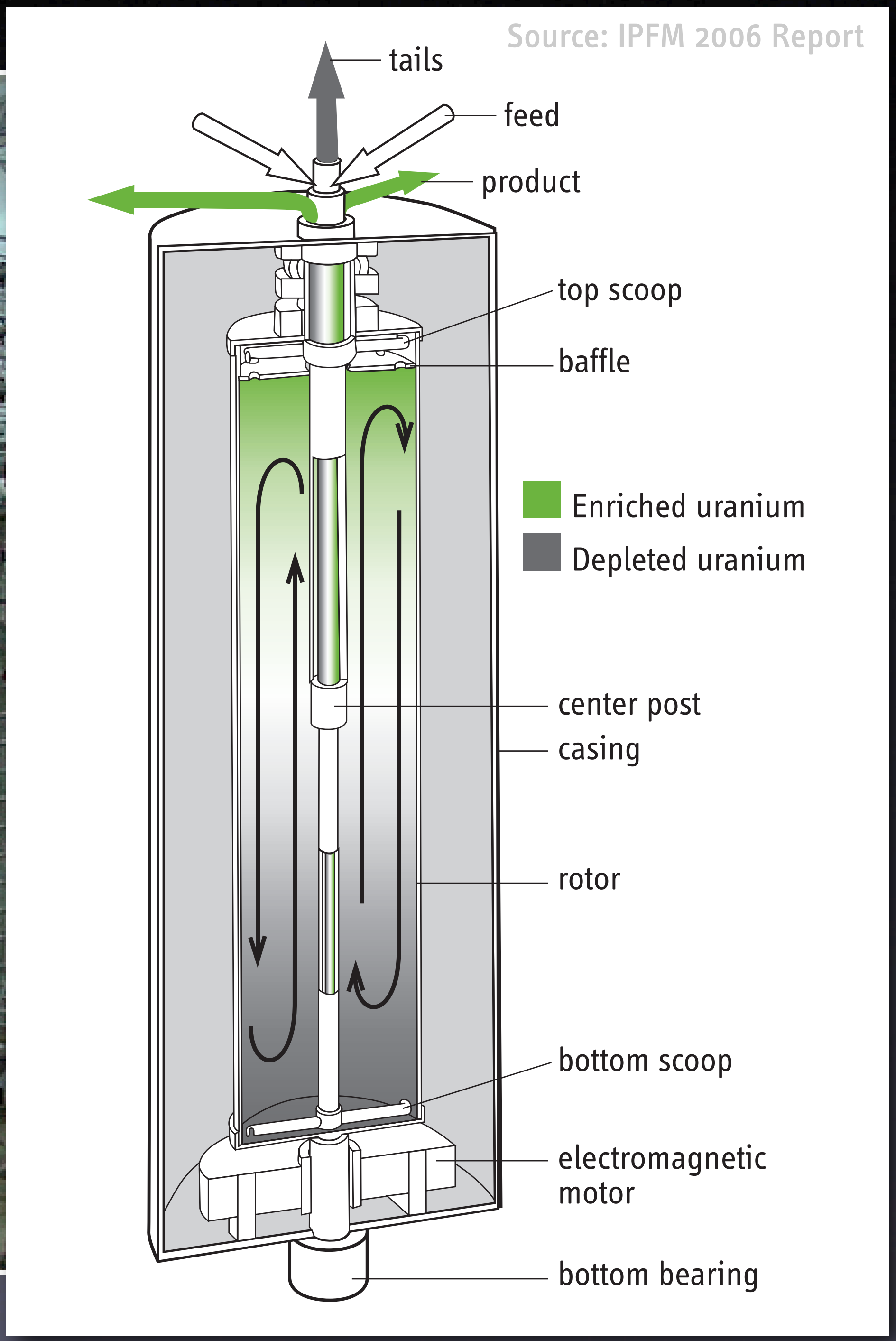
(for 1500 GWe Global Nuclear Expansion Scenario)



The Example of the Gas Centrifuge for Uranium Enrichment

Centrifuges for Uranium Enrichment

Source: Presentation by Mohammad Saeidi (AEOI)




Source: Urenco

Centrifuges in the Past

Centrifuge technology for uranium enrichment
has been around for more than 50 years

Technology considered "too complex" to be a proliferation threat

R&D classified since 1960 in those countries that were already exploring the technology

Focus was on the back-end of the fuel cycle

(discouraging reprocessing / separation of plutonium)

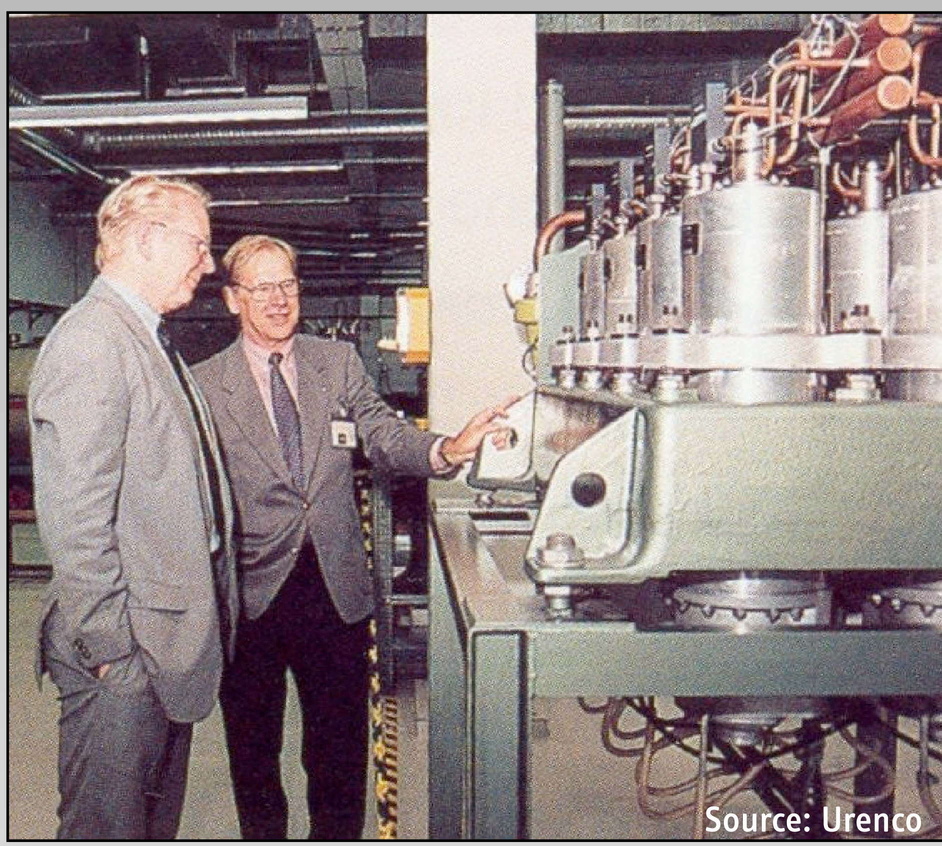
Until recently, export controls were considered "sufficient"
by those who held the technology

Proliferation occurred when export controls were violated

Why Are Centrifuges Different?

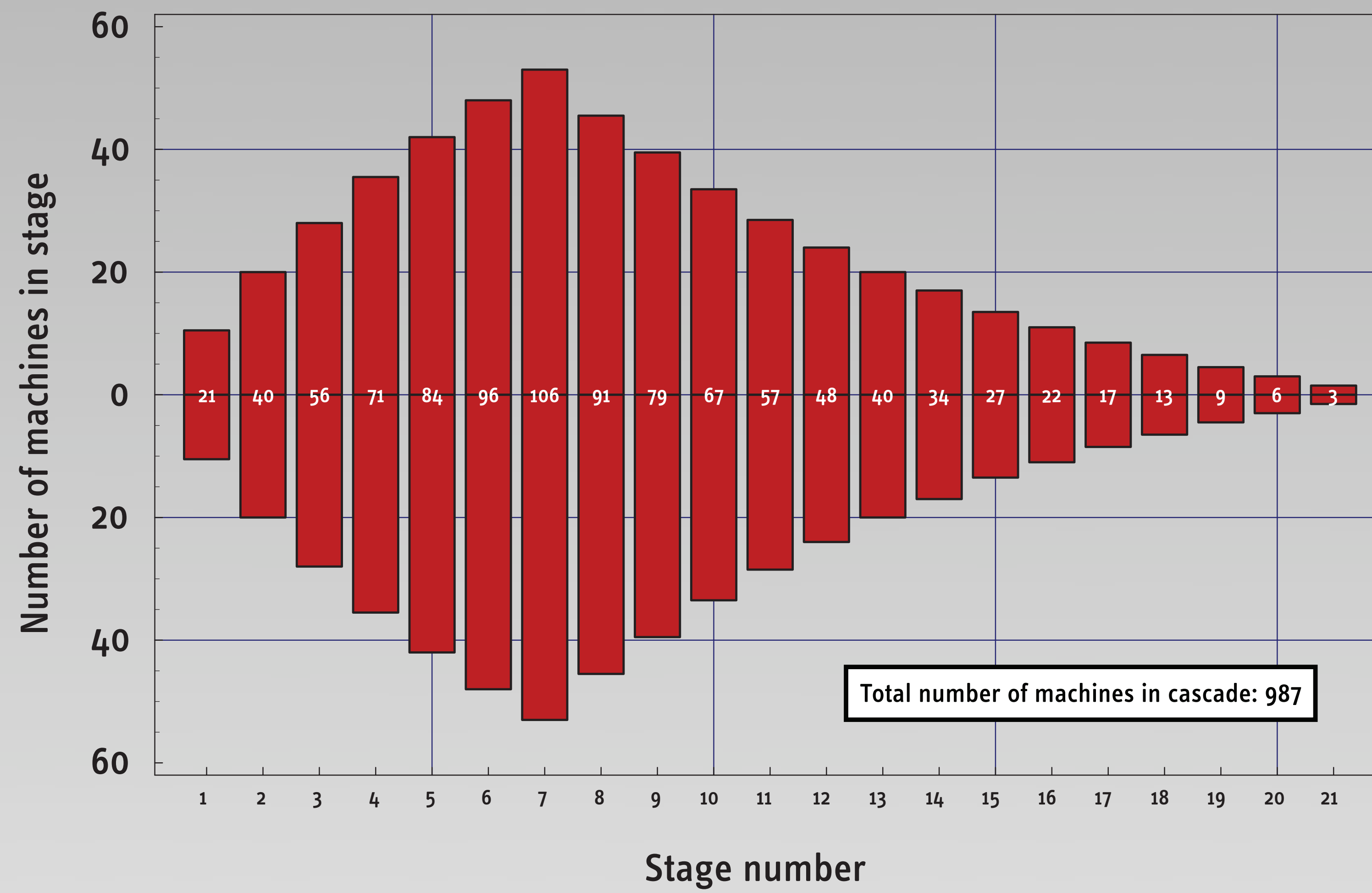
Crude Breakout Scenario

(using an early-generation machine)



Assumed characteristics of P-2-type machine

peripheral velocity = 485 m/s
rotor diameter = 15 cm
rotor height = 100 cm
separative power = 5 SWU/yr

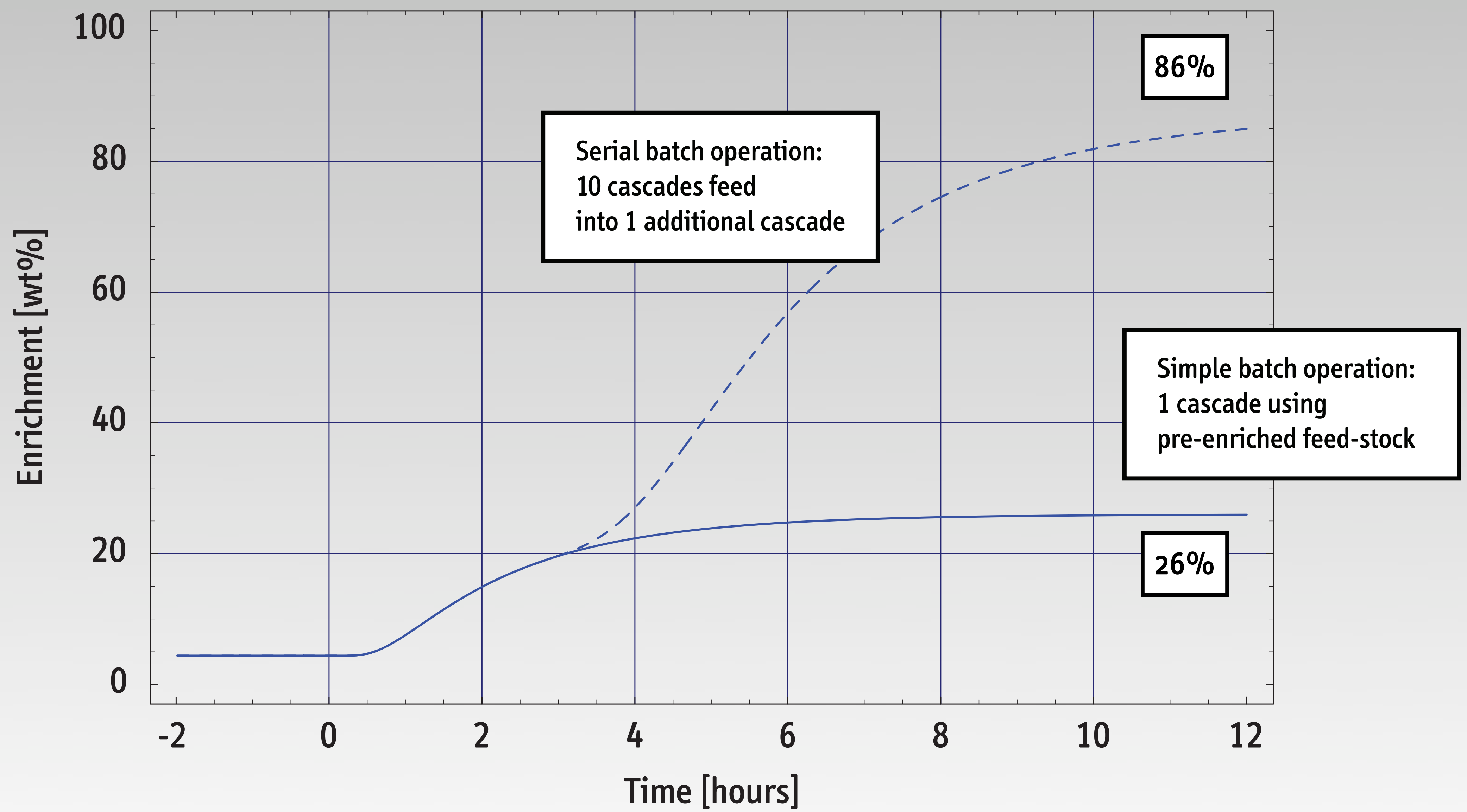


Performance of reference LEU-cascade

Feed = 32.4 kg/d of UF_6 w/ natural uranium
Product = 3.3 kg/d of UF_6 w/ 4.4%-enriched uranium

Crude Breakout Scenario

(using an early-generation machine)



(compare to equilibrium time for gaseous diffusion process, which is on the order of months)

Crude Breakout Scenario

(using an early-generation machine)

Batch operation in series

11 cascades (10 cascades feeding into 1 additional cascade)
about 11 000 machines or 55 000 SWU/yr

Production of 25 kg HEU in less than 12 days

(contained in 37 kg of UF_6 and requiring 3900 kg of UF_6 LEU feed-stock)

PREPARATION FOR BREAKOUT

Collection of LEU feed-stock over a period of less than 4 months (110 days)

Note: up to 2500 kg of enriched UF6 can be
stored in one standard product cylinder (Type 30B)

Clandestine Options

(Undeclared centrifuge facilities are virtually impossible to detect)

		Detectability (Selected Criteria)		
		Identifiable Structure	Thermal Signature	Effluents
Plutonium Production	Reactor	Yes	Yes	No
	Reprocessing	No	No	(Yes)
Uranium Enrichment	Calutron/EMIS	No	Yes	Yes
	Gaseous diffusion	Yes	Yes	Yes
	Centrifuge	No	No	No

What Are Our Options?

Possible Strategies to Limit the Front-End Proliferation Risks of the Nuclear Fuel Cycle

STRATEGY	TARGET / OBJECTIVE
• Increase the effectiveness of (and the confidence in) safeguards	Preclude covert misuse
• Increase the ability to detect undeclared facilities	Deter clandestine activities
• Contain technology to existing or selected producers	Know-how held by "trusted users"
• Focus on the demand side (i.e. "devalue" nuclear weapons)	Motivation

Containment Strategies

Have and have-not approaches

Bush Proposal (2004) or other “criteria-based” proposals

Black Box approaches

with or without “Poison Pills” and combined with multinational operation of facilities

Export Controls

Deter, delay, detect procurement efforts

Containment Strategies
(cont'd)

PROBLEMS

Strategies do not effectively address the unique proliferation concerns of centrifuge technology (breakout and clandestine option)

Since the idea of further restrictions on nuclear fuel cycle technologies has been revitalized in 2004 (e.g. supplier-/client-state arrangements), several countries have expressed renewed interest in domestic enrichment

In addition to Iran and Brazil, these are Argentina, Australia, Canada, Kazakhstan, South Africa and the Ukraine

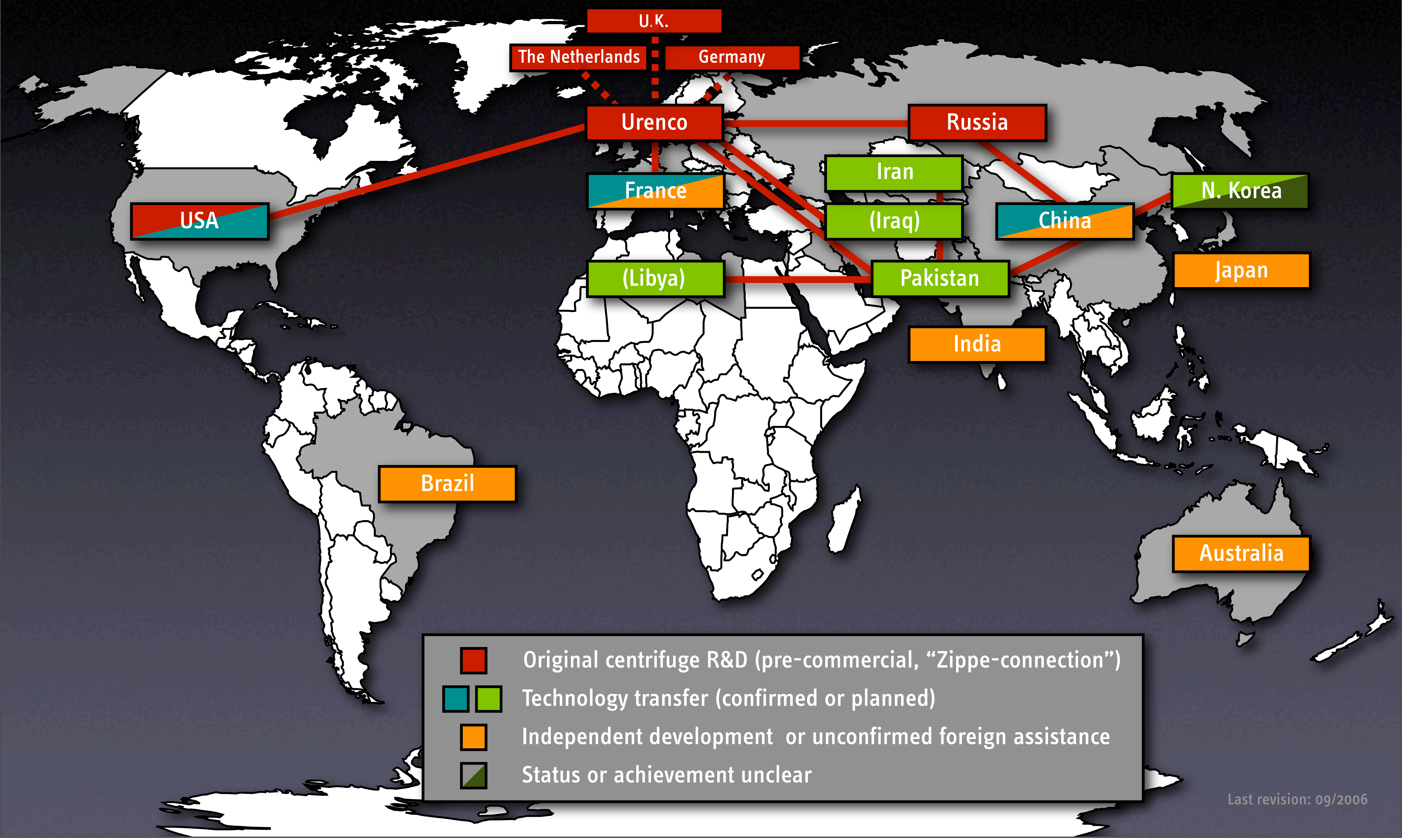
Economic incentives to forego domestic enrichment (e.g. assurances of supply) are largely irrelevant

Even if a country is willing to pay *five* times the market-price for enrichment services in order to have a domestic uranium enrichment capability, this would only raise the overall cost of electricity by about 10%

To what extent are containment strategies durable anyway?

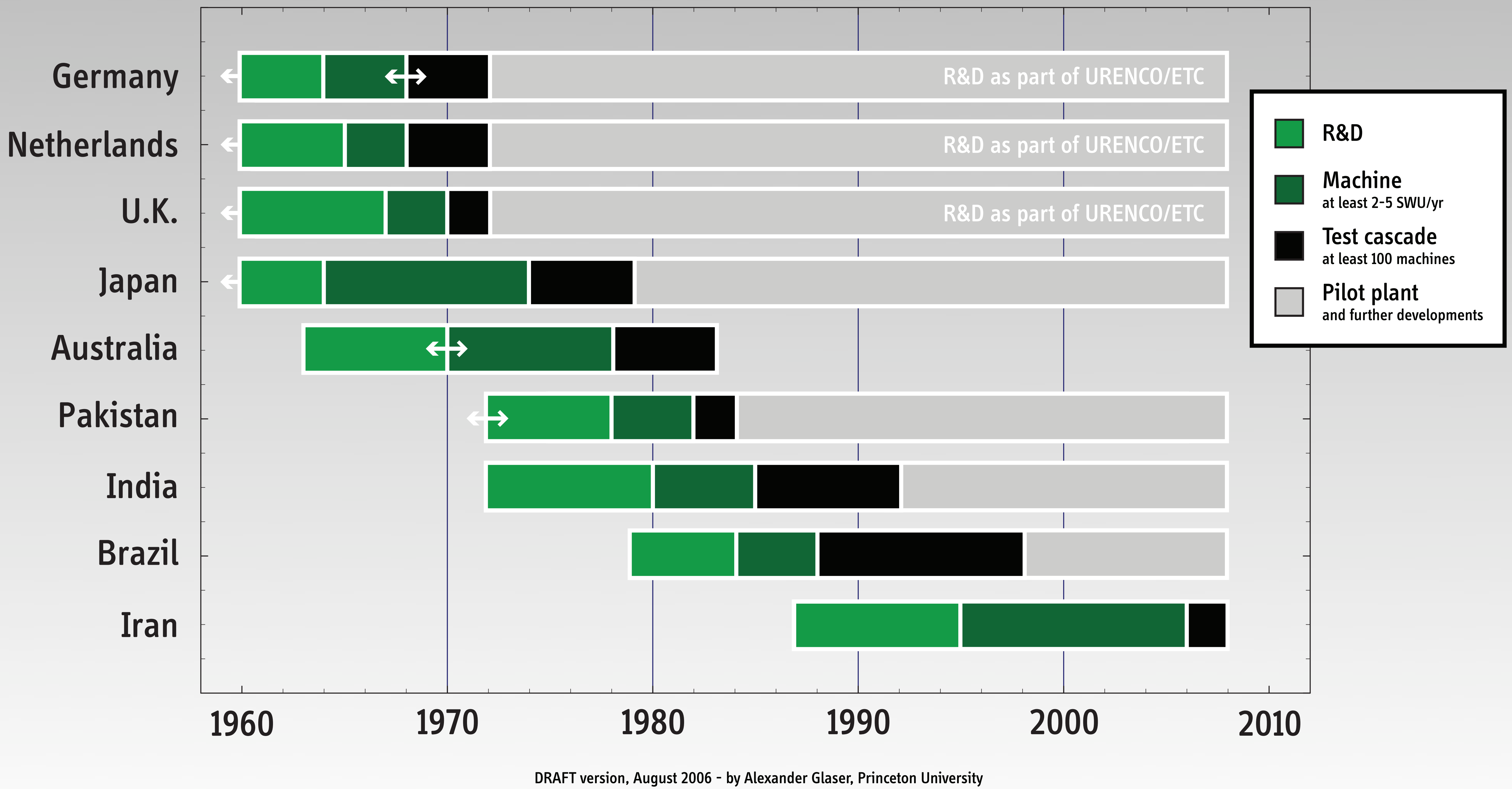
Underlying assumption that indigenous R&D efforts are irrelevant/insufficient

Genealogy of the Gas Centrifuge



Last revision: 09/2006

Timeline of Centrifuge Programs



(arrows indicate uncertain dates of respective events or milestones)

Timeline of Centrifuge Programs
(cont'd)

How long does it take to develop centrifuge technology?

Length of required R&D-period has not significantly changed over the past decades
(It takes about 15-20 years to go through all phases of the R&D-process)

Even important outside assistance does not shorten the R&D-period excessively
(possibly up to 50%, e.g. the case of Pakistan)

Will more countries be able to successfully develop centrifuge technology?

Timeline suggests that countries may begin to pursue a centrifuge program sooner or later, depending on when they feel sufficiently confident to be able to carry out such an R&D project

Key technologies that were previously used specifically for centrifuge-component manufacturing are expanding into additional sectors of modern industry and/or require less experience or expertise to be operated

(Examples are rotor balancing and flowforming techniques)

Possible Strategies to Limit the Front-End Proliferation Risks of the Nuclear Fuel Cycle

STRATEGY	TARGET / OBJECTIVE
• Increase the effectiveness of (and the confidence in) safeguards	Preclude covert misuse
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Viability of a Nuclear Expansion

Conclusion and Outlook

Despite current efforts to set-up a system of assurances of supply, incentives to acquire national enrichment capabilities remain high

If the incentives to acquire national enrichment capabilities, for either peaceful *or* military purposes, continue to exist, we can indeed expect successful independent development and deployment of centrifuge technology in more states

The only effective approach to reduce these incentives is to increase the countries sense of security

Progress in nuclear disarmament has to be a central element of such an agenda

To consider a global expansion of nuclear energy *before* one reestablishes confidence in the future of the nuclear nonproliferation and disarmament regime is an imprudent proposition