
Can nuclear energy fill critical gaps in the military energy portfolio?

COL Paul E. Roege

Army Capabilities Integration Center

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Future military operations . . .

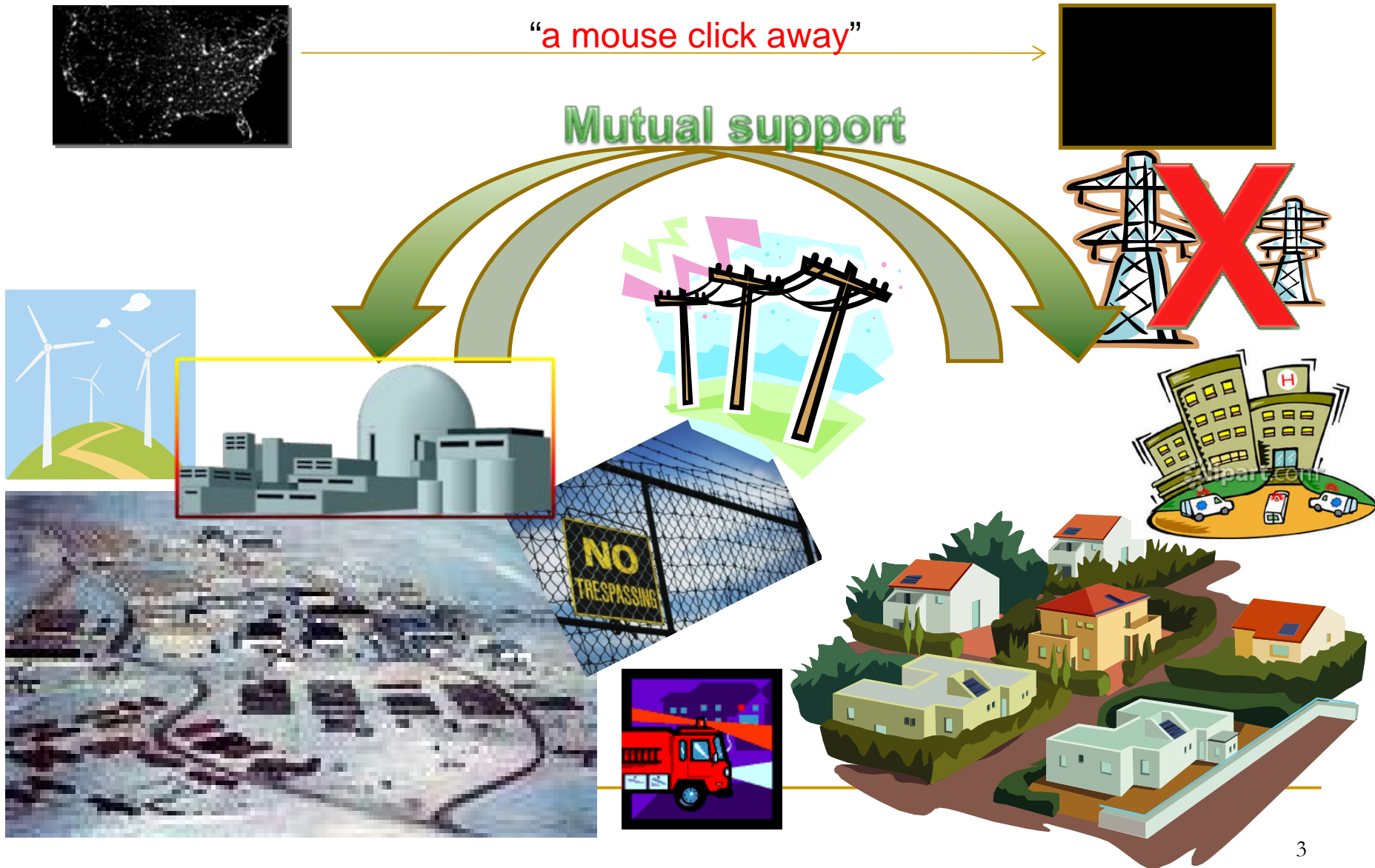
- Dynamic, unpredictable situations
- Varying levels of violence
- Stability and assistance aspects
- Diverse actors
- Asymmetric threats
- Adaptive enemies
- Distributed operations
- Extended supply lines



The need . . .

Build a ground force capable of deploying worldwide, using an integrated full-spectrum suite of effects to execute a range of missions as required to support national security objectives.

Resilient military communities need assured energy



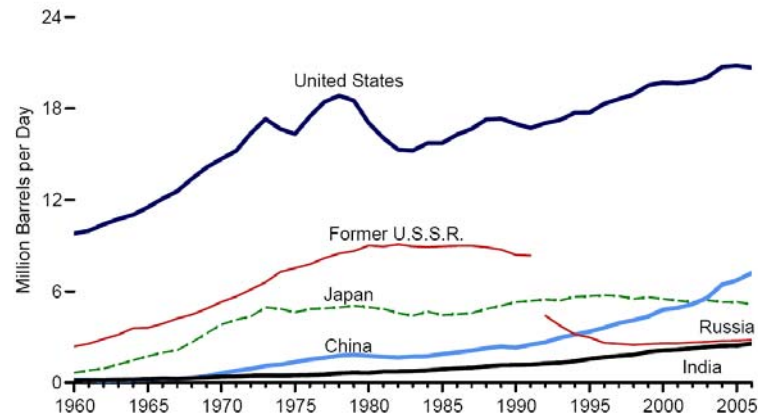
. . . remote sites require secure, sustainable energy



... if petroleum is influence, what is our future?

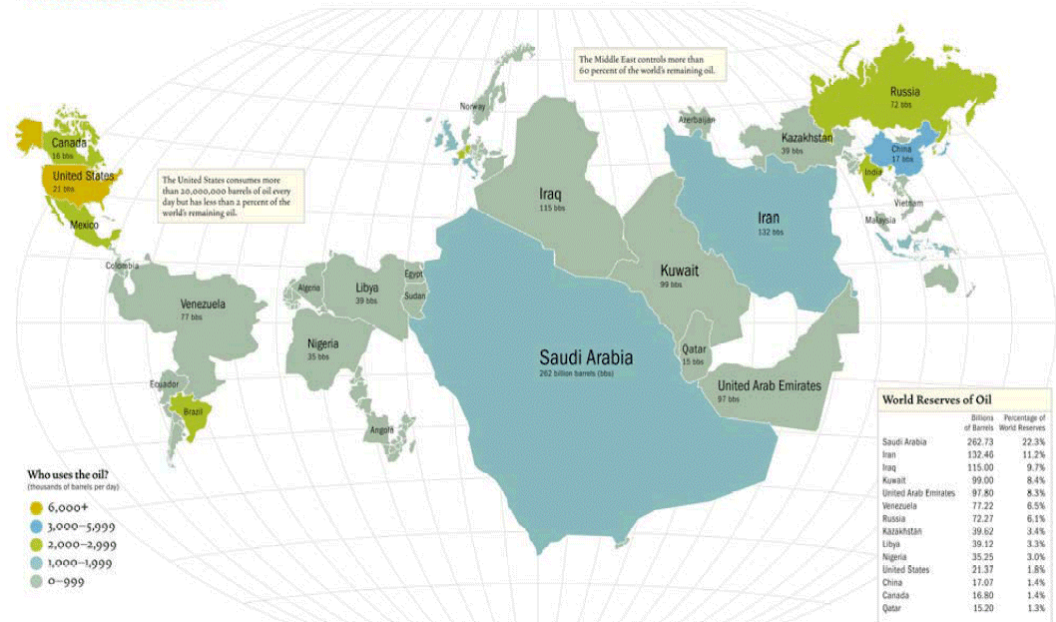
Who wants the oil?

Top Consuming Countries, 1960-2006



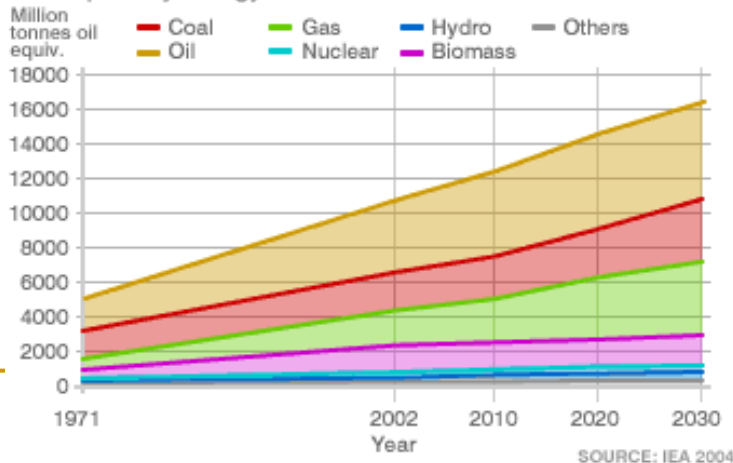
Source: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec11_20.pdf

Who has the oil?



Each country's size is proportional to the amount of oil it contains (oil reserves). Source: BP Statistical Review Year-End 2004 & Energy Information Administration

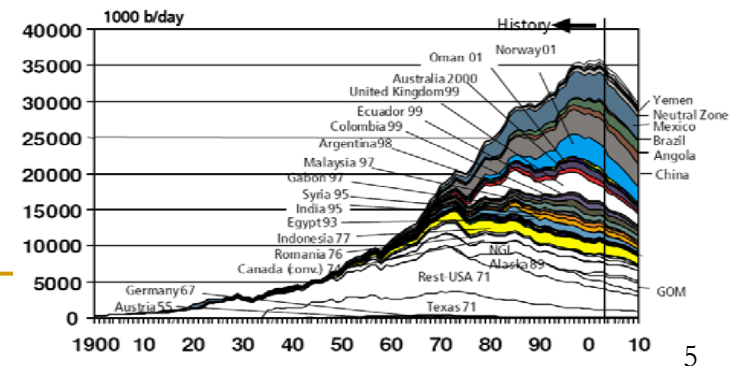
World primary energy demand



SOURCE: IEA 2004

Have we hit peak oil?

Oil Production for Non-OPEC & Non-CIS States (US Department of Energy, 2006)



Source: Industry database, 2003 (IHS 2003)
OGI, 9 Feb 2004 (Jan Nov 2003)

Is the US missing a strategic national security opportunity through its failure to aggressively pursue advanced nuclear reactors?

Ground force power and energy needs are exploding!

Combat power enhancements:

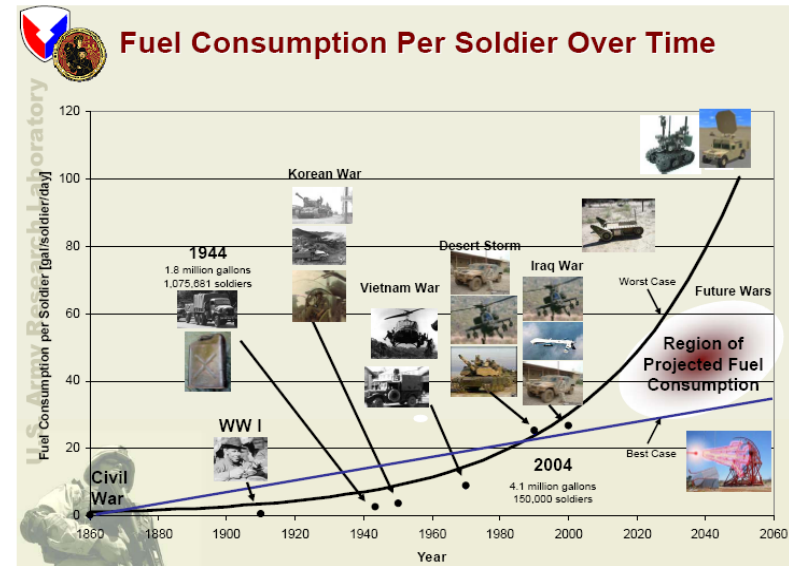
- Sensors, computers, communications
- Platform speed, mobility, survivability
- Automation, unmanned vehicles

Increasing capabilities across the spectrum of operations

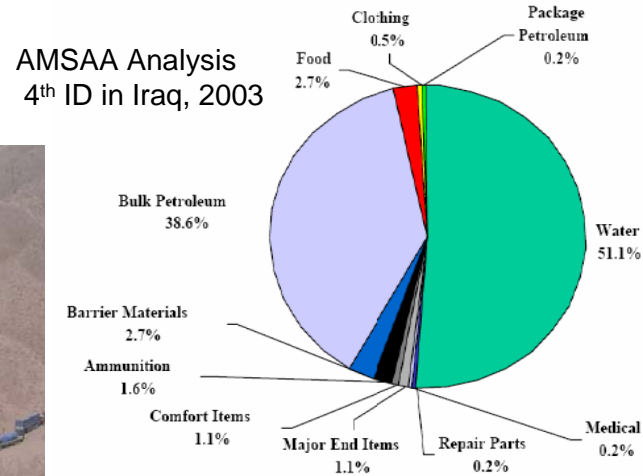
- Consequence management
- Stability operations
- Combating terrorism

Additional contributors:

- Quality of life/readiness
- Contractors on the battlefield



Dramatic reduction in long-haul logistics would provide disruptive force projection capability



- Fuel and water represent over 70% of long-distance resupply.
- Steady-state resupply in Iraq (Mar 2009) still diverts approximately a battalion of combat power from other missions.
- Winter resupply in Afghanistan can take up to 45 days from source of supply to the end user.

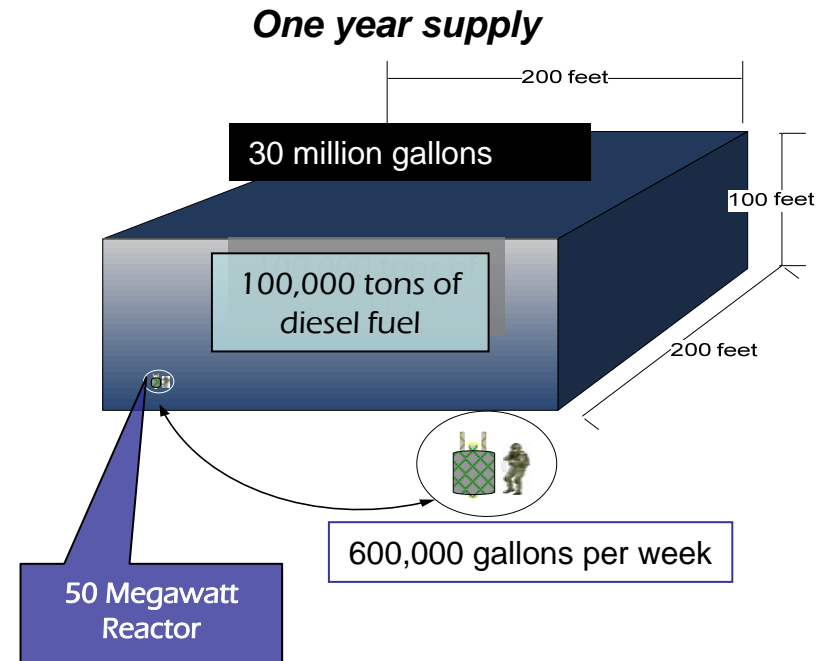


Conceptual nuclear/synfuel system (ARL/BTG)

Energy alternatives

Energy alternatives to produce 50 MW of power in theater

- 3600 gal/hr diesel fuel
- 5 million sq ft of solar array (~ 100 acres)
- 35t/hr biomass (switchgrass)
- 50 t nuclear reactor



Energy Source/Storage	Energy density (MJ/kg)
Mass-energy equivalence ($E=mc^2$)	89,876,000,000
Enriched uranium (3.5% U235)	3,456,000
Diesel fuel	46.2
Household waste	8.8-11
Chemical propellants/explosives	6.5-8.5
Lithium ion battery	0.54–0.72

~100,000x



Solar array

Imagine



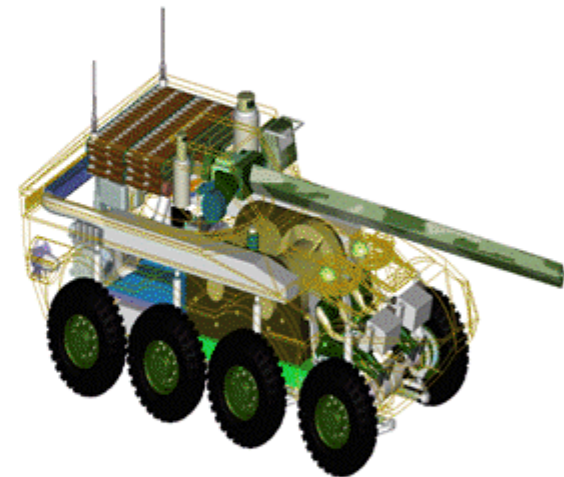
Fuel & Water



Electronic Systems



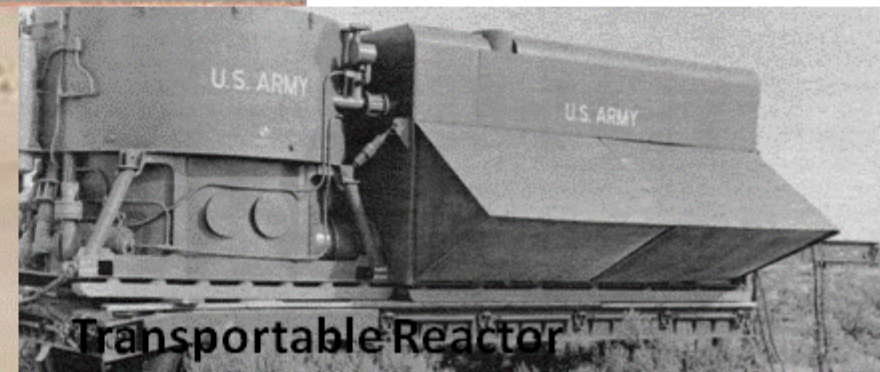
Power Grid



EM Weapons



Forward Operating Base



Transportable Reactor

Small Nuclear Power Plants Were First Developed for Defense Applications

- The United States began developing small nuclear reactors for naval propulsion beginning in the early 1950s
- The U.S. Air Force explored nuclear powered aircraft, but discontinued the program in 1961
- The U.S. Army built 7 small stationary power plants and 1 floating power plant for remote operations:

Reactor	Power (MWe)	Type	Location	Startup	Shutdown
SM-1	2	PWR	Fort Belvoir, Virginia	1957	1973
SM-1A	2	PWR	Fort Greely, Alaska	1962	1972
PM-1	1	PWR	Sundance, Wyoming	1962	1968
PM-2A	1	PWR	Camp Century, Greenland	1960	1962
PM-3A	1.5	PWR	McMurdo Station, Antarctica	1962	1972
SL-1	1	BWR	Arco, Idaho	1958	1960
MH-1	10	PWR	Panama Canal (Sturgis)	1967	1976
ML-1	0.5	GCR	Arco, Idaho	1961	1966

Navy Nuclear Power Program

11 Nuclear Powered Carriers



69 Nuclear powered Submarines



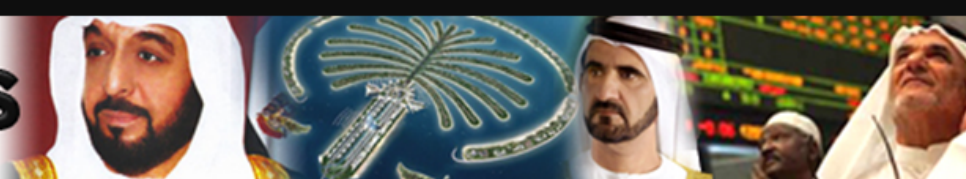
More than 5500 reactor years without accident

International Nuclear Energy Growth

US influence?

- Operating nuclear reactors worldwide (Dec 2008): 438 (US: 104)
- Worldwide nuclear generating capacity 14% (US: 20%)
- Greatest reliance upon nuclear energy:
 - France – 76%
 - Lithuania – 72%
 - Slovakia – 56%
- New construction starts in 2008: 10
 - China – 6
 - Russian Federation -2
 - Republic of Korea -2
- First Generation 3 reactor, largest in the world – Olkiluoto 3, Finland (1600MWe, built by Areva/Siemens)
- New Expansion – UAE awarded \$40B+ project to KEPCO (Dec 2009)
- India seeks energy independence based upon nuclear energy from Thorium by 2030 (with “help”) from United States

Capacity statistics from Nuclear Technology Review 2009, International Atomic Energy Agency, Vienna, 2009



Korea Gets UAE Nuclear Plants Project



Submitted by Akilah Amiri on Tue, 12/29/2009 - 04:57

[United Arab Emirates](#), in a highly competitive bidding process, has awarded its landmark nuclear power project to a Korean-led consortium on Sunday, which is aimed to build **four nuclear reactors in UAE for ensuring its long term energy security**.

A Korean consortium led by Korea Electric Power Corp (Kepco) watched stiff competition from Asian, French and US bidders for marking the first ever international deal in Asia with the help of Samsung and Hyundai business groups and Toshiba Corp's unit Westinghouse Electric Co.

The successful deal makes a **diplomatic win for the South Korean President** Lee Myung-bak who is on his State visit to UAE, possibly, for building consensus to bag the prestigious contract. The move has been seen as **a stepping stone for the South Korean global nuclear business** which is, by and large, dominated by French, Japanese, U. S. and Russian companies.

Hailing the \$40 billion deal, the U. A. E. President Sheikh Khalifa bin Zayed al Nayan said that it would help to strengthen **strategic partnership between two nations**.

Mohamed al-Hammadi, Chief Executive of the Emirates Nuclear Energy Corporation added, "We were impressed with the Kepco team's **world-class safety performance**, and its **demonstrated ability to meet the UAE program goals**."

Sampling of SMR Concepts Under Development

World-Wide

- Integral PWR: CAREM (Ar), IMR (Jp), IRIS (US), NuScale (US), mPower (US), SCOR (Fr), SMART (RoK)
- Marine derivative PWR: ABV (RF), KLT-40S (RF), NP-300 (Fr), VBER-300 (RF)
- BWR/PHWR: AHWR (In), CCR (Jp), MARS (It)
- Gas-cooled: GT-HTR-300 (Jp), GT-MHR (US), HTR-PM (Ch), PBMR (SA)
- Sodium-cooled: 4S (Jp), BN-GT-300 (RF), KALIMER (RoK), PRISM (US), RAPID (Jp)
- Lead/Pb-Bi-cooled: BREST (RF), ENHS (US), LSPR (Jp), STAR/SSTAR (US), SVBR-75/100 (RF)
- Non-conventional: AHTR (US), CHTR (In), Hyperion (US), MARS (RF), MSR-FUJI (Jp), TWR (US)

SMR Economic Benefits

- Total project cost
 - Smaller plants should be cheaper
 - Improves financing options and lowers financing cost
 - May be the driving consideration in some circumstances
- Cost of electricity
 - Economy-of-scale (EOS) works against smaller plants but can be mitigated by other economic factors
 - Accelerated learning, shared infrastructure, design simplification, modular, factory producible,
 - Cost/KWH- ~ 30-50% less
- Investment risk
 - Maximum cash outlay is lower and more predictable
 - Maximum cash outlay can be lower even for the same generating capacity
- Operational Flexibility
 - Site Selection
 - Load Demand
 - Grid Stability
 - Demand Growth

SMR Challenges – Institutional

- Too many competing designs
- Mindset for large, centralized plants
 - Fixation on economy-of-scale
 - Economy-of-hassle drivers
 - Perceived risk factors for nuclear plants
- Traditional focus of regulators on large, LWR plants
 - Standard 10-mile radius EPZ (in the U.S.)
 - Staffing and security force size
 - Plant vs module licensing
- Fear of first-of-a-kind
 - New business model as well as new design must be compelling

*DoD could again take a leading role –
meeting military needs while advancing critical civilian energy capabilities.*

Nuclear Energy Leadership:

potential national security implications

❖ **Defense:** assured energy to support continued domestic and expeditionary military capability

❖ **Economy:** clean, sustainable domestic energy source, diversified industrial capability; reversed trade imbalance

❖ **Nonproliferation:** US participation in global fuel cycle selection, supply chain and safeguards protocols

❖ **Safety:** input to international design and operational standards (TMI vs. Chernobyl)

Conclusions

- Global energy demand is growing faster than reserves
- DoD needs to re-think energy requirements for continuity of operations
- Would nuclear energy be appropriate for DoD applications?:?
 - Expeditionary Forces
 - Remote Sites
 - Resilient communities
- Nuclear Energy production and technology development is accelerating worldwide—increasingly without the benefit of US engineering
- New safer, reliable, smaller, modular, factory producible, and lower cost reactors could provide distributed generating capability...
 - built using domestic capabilities
 - powered by plentiful domestic fuel

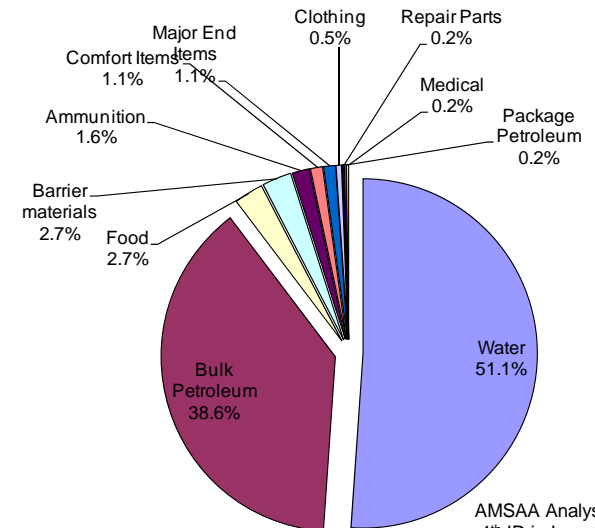
... would strengthen national security, grow the economy and strengthen US political and economic positions internationally

BACKUP

How prominent are energy, power and water?

- Fully-burdened cost of fuel in Iraq typically \$5-30; as high as \$400 reported in Afghanistan
- Security for supply convoys in Iraq required an average of 1 combat battalion on a continuing basis (2009 estimate)
- Ground resupply has accounted for over approximately 35% of US casualties in Iraq
- Winter resupply in Afghanistan can take up to 45 days from source of supply to the end user.
- Fuel and water comprise 70-80% of ground resupply volume, after initial combat
- Per soldier demand in Iraq 16 gal fuel/day
- Water demand variable, but at least 3 gal (23 x ½ liter bottles)/day/soldier
- >50% of fuel is used to produce electricity
- Fueled generators typically <40% efficient
- Base camp power systems' overall efficiency closer to 10%

Representative battlefield logistics volume



World Energy Consumption is growing faster than reserves

In 2007, the world consumed:

5.3 billion tonnes of coal
(128 quads*)



31.1 billion barrels of oil
(180 quads)



Dominated by Hydrocarbons

2.92 trillion m³ of natural gas
(105 quads)



65 million kg of uranium ore
(25 quads)



2007 – 467 Quads
2030 – 695 Quads
2050 - ???

29 quads of hydroelectricity



In a global warming environment, where will the world turn for safe, abundant, low-cost energy?

TABLE A-1. Nuclear power reactors in operation and under construction in the world (as of 31 December 2008)^a

Country	Reactors in Operation		Reactors under Construction		Nuclear electricity Supplied in 2008		Total operating Experience through 2008	
	No of units	Total MW(e)	No of units	Total MW(e)	TW-h	% of Total	Years	Months
Argentina	2	935	1	692	6.9	6.2	60	7
Armenia	1	376			2.2	39.4	34	8
Belgium	7	5 824			43.4	53.8	226	7
Brazil	2	1 766			13.2	3.1	35	3
Bulgaria	2	1 906	2	1 906	14.7	32.9	145	3
Canada	18	12 577			88.3	14.8	564	2
China	11	8 438	11	10 220	65.3	2.2	88	3
Czech Republic	6	3 634			25.0	32.5	104	10
Finland	4	2 696	1	1 600	22.1	29.7	119	4
France	59	63 260	1	1 600	419.8	76.2	1 641	2
Germany	17	20 470			140.9	28.8	734	5
Hungary	4	1 859			13.9	37.2	94	2
India	17	3 782	6	2 910	13.2	2.0	301	4
Iran, Islamic Republic of			1	915				
Japan	55	47 278	2	2 191	241.3	24.9	1 386	8
Korea, Republic of	20	17 647	5	5 180	144.3	35.6	319	8
Lithuania	1	1 185			9.1	72.9	42	6
Mexico	2	1 300			9.4	4.0	33	11
Netherlands	1	482			3.9	3.8	64	0

TABLE A-1. Nuclear power reactors in operation and under construction in the world (as of 31 December 2008)^a (cont.)

Country	Reactors in Operation		Reactors under Construction		Nuclear electricity Supplied in 2008		Total operating Experience through 2008	
	No of units	Total MW(e)	No of units	Total MW(e)	TW·h	% of Total	Years	Months
Pakistan	2	425	1	300	1.7	1.9	45	10
Romania	2	1 300			10.3	17.5	13	11
Russian Federation	31	21 743	8	5 809	152.1	16.9	963	4
Slovakia	4	1 711			15.5	56.4	128	7
Slovenia	1	666			6.0	41.7	27	3
South Africa	2	1 800			12.8	5.3	48	3
Spain	8	7 450			56.5	18.3	261	6
Sweden	10	8 996			61.3	42.0	362	6
Switzerland	5	3 220			26.3	39.2	168	10
Ukraine	15	13 107	2	1 900	84.5	47.4	353	6
United Kingdom	19	10 097			48.2	13.5	1 438	8
United States of America	104	100 683	1	1 165	806.7	19.7	3 395	9
Total ^{b, c}	438	371 562	44	38 988	2 597.8	14	13 475	7

^a Data are from the Agency's Power Reactor Information System (<http://www.iaea.org/pris>)

^b The total includes the following data in Taiwan, China:

- 6 units, 4949 MW(e) in operation; 2 units, 2600 MW(e) under construction;
- 39.3 TW·h of nuclear electricity generation, representing 17.5% of the total electricity generated there;
- 164 years, 1 month of total operating experience at the end of 2008.

^c The total operating experience includes also shut down plants in Italy (81 years) and Kazakhstan (25 years, 10 months).

The World is now entering into a new nuclear age...

Weinberg Study – 1985*

- Motivated by lessons learned from the *first nuclear era*
- Explored emerging reactor designs that were inherently more forgiving than large LWRs
- Main findings:
 - Incrementally-improved, post-TMI LWRs pose very low risks to the public but investor risks and high, uncertain capital cost may limit market viability
 - Large LWRs are too complex and sensitive to transients
 - Inherently safe concepts are possible and should be pursued, such as:
 - The Process Inherent Ultimately Safe (PIUS) reactor
 - The Modular High-Temperature Gas-Cooled Reactor (MHTGR)

Mr. Weinberg, The inventor of the LWR reportedly stated, “I hope that in a second nuclear era the [fluoride-reactor] technology will be resurrected”

...will the US lead or follow?

*A. M. Weinberg, et al, *The Second Nuclear Era*, Praeger Publishers, 1985

Public Acceptance of Nuclear Power – “haves”

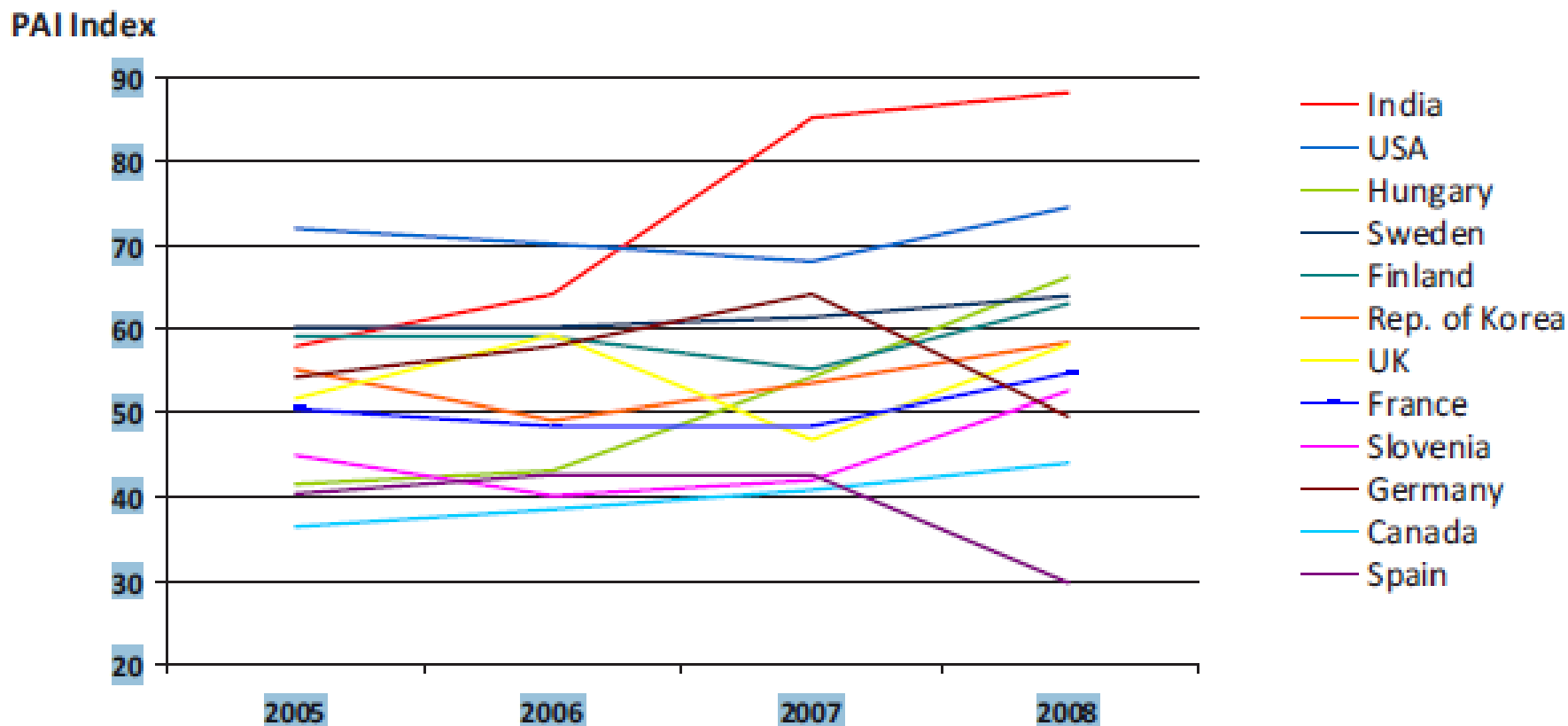


FIG. A-5. Public acceptance in a number of countries using nuclear power.

Public Acceptance of Nuclear Power – “have-nots”

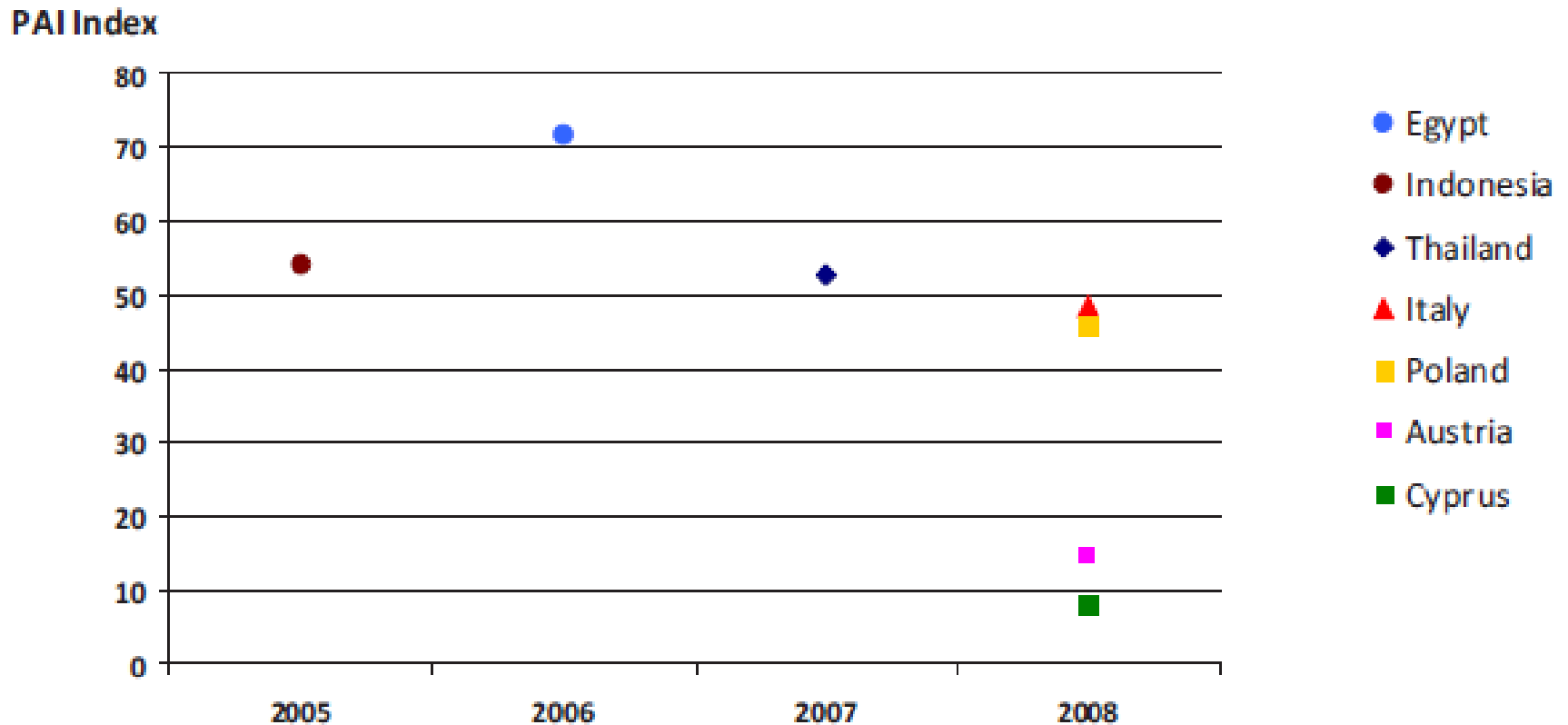
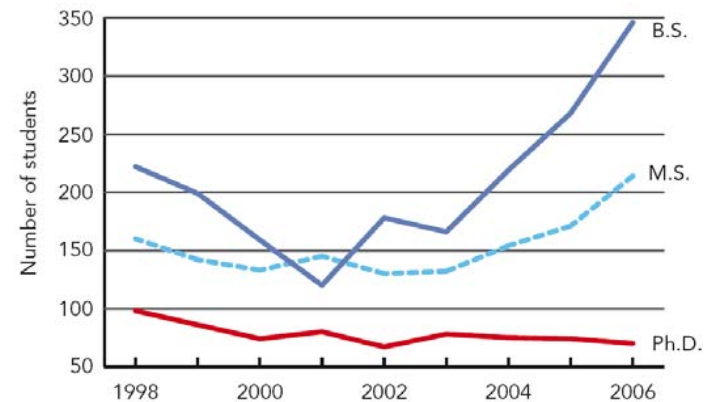
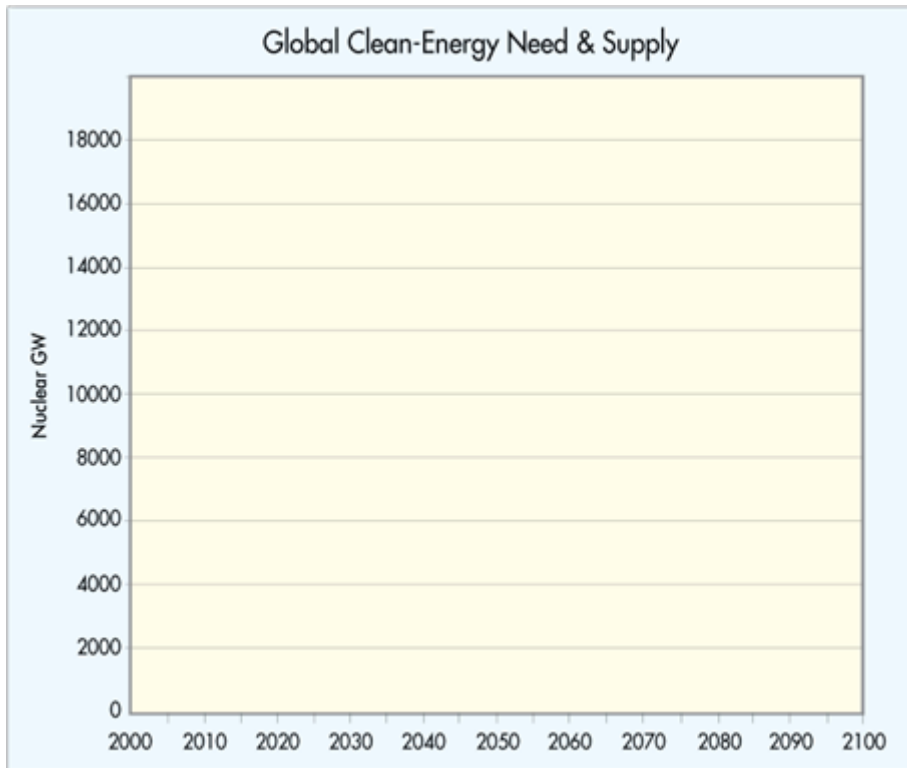


FIG. A-6. Public acceptance in a number of countries without nuclear power programmes.

Who will lead the industry?



Nuclear engineering degrees at US universities
(source: OECD Nuclear Energy Agency, *Nuclear Energy Outlook 2008*, OECD, Paris (2008))