Emerging Energy Requirements for Future C4ISR

R.A. Pfeffer[*]
U.S. Army Nuclear and Chemical Agency
ATTN: ATNA-NU
7150 Heller Loop   Suite 101
Springfield, VA   22150-3198
(703) 806-7860
pfeffer@usanca-smtp.army.mil

W.A. Macon, Jr.*
U.S. Nuclear Regulatory Commission
ATTN: William A. Macon, Jr.
Mail Stop 0-7D3
Washington, DC   20555-0001
(301) 415-3965
wam1@nrc.gov

Abstract

Command, control, communication, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems already play a fundamental role in today's military operations. Modern C4ISR nodes now process enormous quantities of digital data in real time, allowing all levels of Command to better control the battle space. In future C4ISR, even more sophisticated electronics will be used to acquire, process and distribute information in manned and unmanned platforms and systems. In every case, from the more fixed sites at higher echelons to the very mobile battle space sensors and nodes, C4ISR will have to depend upon an energy source that is safe, reliable, and readily available/transported worldwide.

Desert Storm and the low intensity war in Afghanistan clearly illustrate the enormous logistics costs required to provide readily available hydrocarbon-based fuel to military C4ISR and front line shooters. It would be preferable for the military to carry with them the capability to create all their fuel requirements. Even better, the new energy source should be based upon an inexhaustible natural resource and it should be compatible with current, oil-driven internal combustion engine technology, thus making the transition to the new fuel evolutionary, not revolutionary.

The purpose of this article is to identify future military energy requirements, describe how they are driven by fundamental changes in the nation's energy policy, and show how the next generation of mobile nuclear power reactors could be used to generate the future energy transfer medium, hydrogen (H_2), from seawater.

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1. **Introduction**

The days of cheap, seemingly inexhaustible supplies of hydrocarbon-based fuels for use in mobile systems are limited. Already, geologists are making alarming projections. At the present rate of extraction, the world's known reserves of high-grade crude oil could be depleted within this century. Worst-case Middle East reserve estimates range from as little as 60 years (Saudi Arabia) to as low as 12 years (Bahrain). Although not every one agrees with these numbers, these chilling predictions have alarmed both oil producing nations and industrial nations whose economies depend on oil. For the U.S., who now imports over 70% of its ever-increasing oil requirements, it means U.S. policy could be held hostage by international oil producers. To halt this increasing trend, the U.S. must become energy independent by generating alternate fuels using natural resources under its control. Energy independence is essential to implementing national policy; otherwise, nations and international organizations (e.g., OPEC) can hold U.S. policy hostage. One of the primary implementers of U.S. policy and a major user of oil is the Department of Defense.

The first decade of the 21st century may well be remembered as the beginning of the worldwide transition from hydrocarbon-based fuels to what the authors believe will be the ultimate energy transfer medium for transportation – hydrogen (H_2). The transition has already begun, and private industry is leading the way by developing prototype vehicles that use fuel cells and internal combustion engines that run on both liquid H_2 and gasoline [www.hfcletter.com, 2001], [www.cnn.com, 2001], [www.msnbc.com, 2001]. Hydrogen production, for both commercial and military applications, will have to increase in the decades to come as this transition proceeds. The authors further believe production facilities using nuclear energy will play a significant role in the emerging H_2 economy.

Utilities, businesses and developers have already expressed interest in fuel cells, which could make many homes and small businesses virtually independent of the electric power grid. Examples include: hospitals and other businesses that must keep operating when rolling blackouts are necessary during peak power usage, developing countries and rural communities, and other communities and regions with limited reserve power capacity and loath to build new power plants. Building a market for fuel cell generators in homes and businesses may spread the development cost of the technology beyond vehicles and accelerate consumer acceptance. [www.msnbc.com, 2001] In addition, small vehicles supporting stealthy C4ISR missions could use fuel cells to power quiet, low thermal signature engines right now.

So what's the hurry? Hydrocarbon-based fuels (wood, coal, oil, and natural gas) still provide the world with approximately 80% (as of 1997) of their fuel requirements, and coal, oil and natural gas reserves are still being found throughout the world. The problem is the world population is rapidly increasing, depleting more rapidly the finite hydrocarbon-based fuel reserves while causing short-term and, some say, long-term environmental pollution. Let's look at each of these: world population, rapidly increasing energy consumption, and environmental pollution.

1.1 *The World Population*

By most measures, the earth is already overpopulated. "Humanity has already overshot Earth's carrying capacity by a simple measure: no nation is supporting its present population on *income* – that is, the sustainable flow of renewable resources. Instead, key "renewable" resources, the natural capital of humanity, are being used so rapidly that they have become effectively non-renewable." [Ehrlich, 2000] Even the U.S. must now rely upon other countries to support its current standard of living by importing additional foodstuffs, minerals and, of course, energy. An estimate of the increasing world population is shown in Figure 1. It shows that world population will continue to increase for the next half century before leveling off at about 9 billion by 2055. [Carnell, 2000]

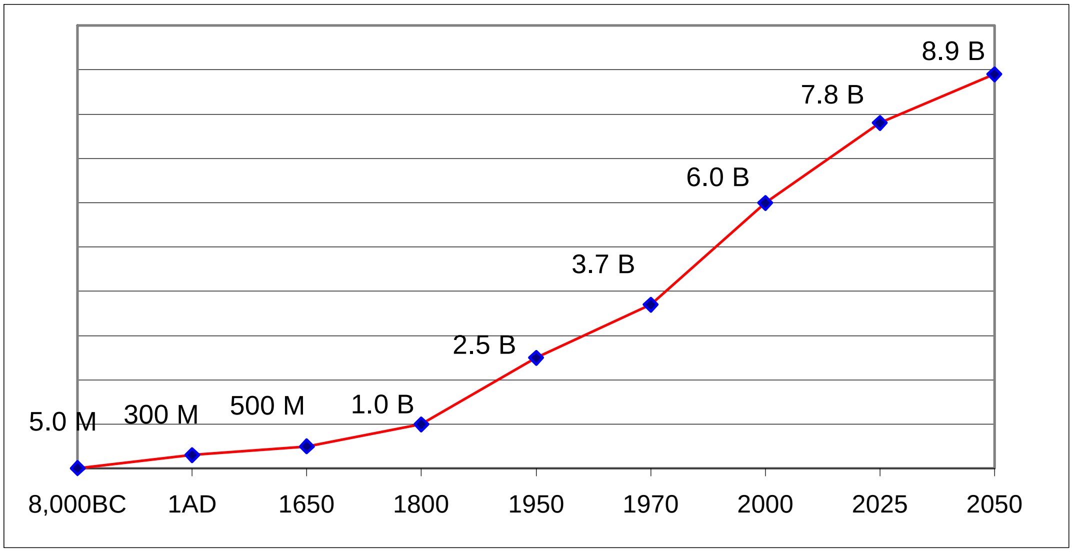


Figure 1. World Population Growth.

China has the largest population now, but a government-imposed birth control program (providing strong penalties to couples with more than one child) has already slowed its future growth. India, however, has yet to enact an effective birth control program. Thus, at the present population growth rate, India is expected to have the world's largest population by 2050.

Superimposed on this massive, third world population increase is the attempt of these countries to catch up with the industrial countries' standards of living. Such a rapid catch up can only occur with enormous expenditures of energy. The result is the civilian population will increase their per-person percentage of energy use.

1.2 *Rapidly Increasing Energy Consumption*

The 21st century was expected to be relatively peaceful, but that changed on 11 September 2001. The threat has changed, not gone away. The U.S. no longer anticipates an all-out nuclear world war involving many nations; instead, the threat is from limited, terrorist organizations fueled by nationalism, religious fundamentalism, and perhaps overpopulation. To address the present worldwide asymmetric terrorist threat, one must first eliminate the political, economic, and military support structure and then turn toward improving global living standards, neither of which can occur without enormous increases in world energy consumption.

Right now, the U.S. consumes a greater percentage of the world's energy than any other country. In fact, the U.S. uses 25% of the world's total energy consumption each year, yet the U.S. population is just 4.6% of the world's 6 billion people. As the rest of the world (China, India, Brazil, etc.) demands more energy, the U.S. will have to compete for that energy. An increased demand for these limited hydrocarbon-based fuels means energy prices will increase even higher (see Figure 2 [Energy Information Administration, 2000]). Already, brownouts and blackouts are occurring more frequently, and unleaded regular gasoline has reached the psychologically significant $2/gallon in California and Illinois…all this while known oil and natural gas reserves are relatively secure.

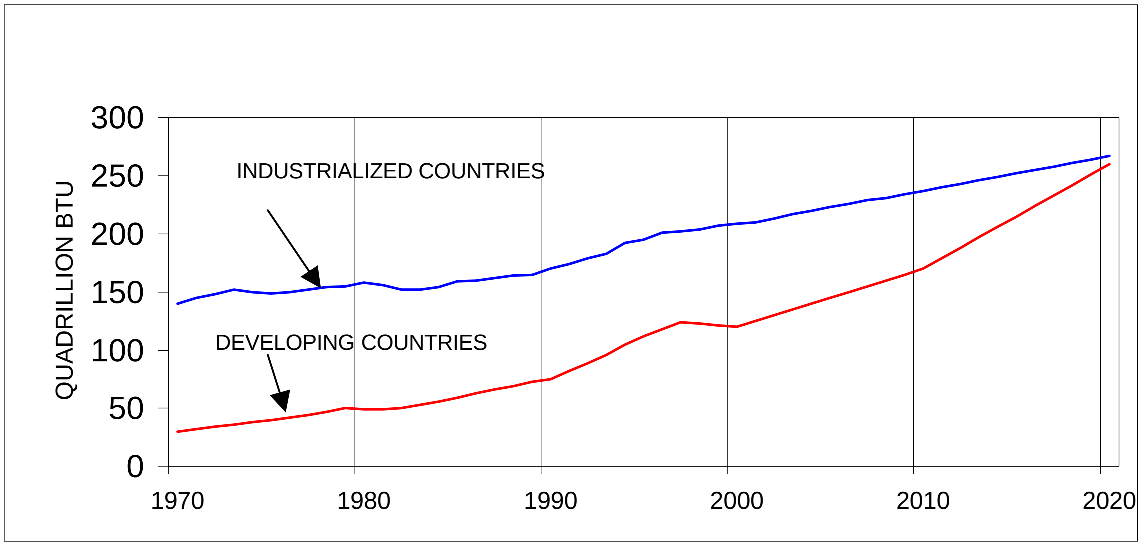


Figure 2. World Energy Consumption by Region (1970-2020).

World oil reserves are difficult to estimate, and no one is certain how much recoverable oil is yet to be found. Nevertheless, the United States Geologic Survey World Energy Report has made a world oil reserve estimate of 1.6 trillion barrels of oil, a large percentage of this reserve is assumed to be heavy, sour crude oil. Oil is not only the basis for gasoline and diesel fuels, it is also the feedstock for the plastics industry and an important raw material for the pharmaceutical and other industries. Burning up this valuable and irreplaceable resource as gasoline and diesel fuels is wasteful and shortsighted.

Complicating the oil supply further, over the last 20 years the number of oil refineries in the United States has declined substantially, for a combination of economic, regulatory, and environmental reasons. Although advanced technologies may allow the capacity of existing refineries to expand marginally in the short term, it is unlikely that many new refineries will be located in the United States. This situation creates a long-term supply and economic security vulnerability. The Unites States currently consumes an average of 19.6 million barrels of oil per day, yet our refining capacity is 16.5 million barrels per day. [U.S. Geologic Survey World Energy Report, 2000]

The picture is somewhat brighter in terms of available coal reserves. The United States has the world's largest proven coal reserves, about 275 billion short tons of recoverable coal. At the current consumption rate of slightly over 1 billion short tons per year, our reserves should last nearly 300 years. Burning coal has serious environmental consequences, however, and much of the US coal reserves are of high sulfur coal, which current environmental regulations discourage burning. [U.S. Geologic Survey World Energy Report, 2000]

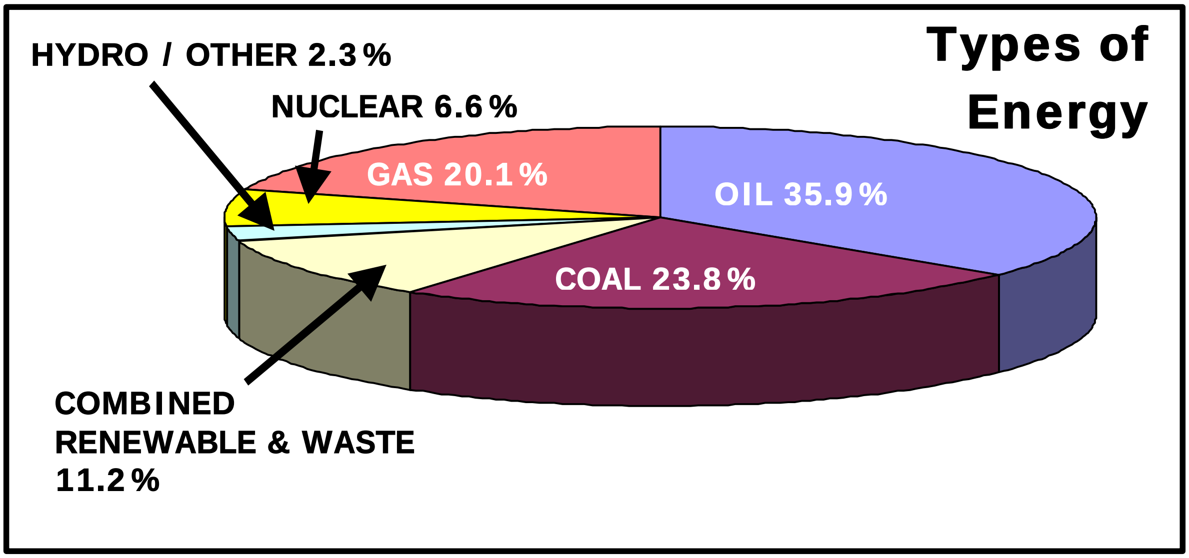
The problem is further complicated by the fact that, even as our fuel consumption increases, our electrical transmission capacity is not keeping up. "Over the next ten years, U.S. demand for electric power is expected to increase by 25 percent, while transmission capacity is expected to increase by only 4 percent." [National Energy Policy, 2001] It is estimated that 1300 new electrical generation plants will have to be constructed in the next 20 years to keep up with the projected demand. [U.S. Geologic Survey World Energy Report, 2000]

1.3 *Environmental Pollution*

The fact that man exists in the environment means that man will change it. A small, environmentally conscious population will not make a significant impact on the environment in a short time. Of course the words small and short are relative terms, since a few hunters almost eliminated the entire U.S. bison population in the Western Plains in a few years. A relatively small population also rendered Dodos and passenger pigeons and numerous other flora and fauna extinct over a very short time frame. In the future, a few tourists could destroy the delicate balance on a coral reef or destroy the Asian lion and tiger populations. Such short-term impacts to the environment by just a few are well documented; what is less apparent is the long-term impact.

2. Alternate Energy Sources

As can be seen in Figure 3 [International Energy Agency, 2001], the great preponderance of the world's energy supply is gas, oil, and coal (approximately 80% as of 1997). Burning "renewable" fuels (wood and waste products) contributed another 11% of the total, but like the other hydrocarbon-based fuels, these combustion type energy sources contribute to atmospheric



pollution such as so called "greenhouse gases". Sources of energy that don't contribute to atmospheric pollution make up only 9% of the total. Of this 9%, most hydroelectric sources have already been developed in the industrialized world, and solar, wind, and geothermal sources have serious technical drawbacks. There are no energy sources other than nuclear that can generate the world's long-term power requirements without causing atmospheric pollution.

Hydrogen is an environmentally attractive energy transfer medium that has the potential to displace hydrocarbon-based fuels. It is a clean, sustainable resource with many potential applications, including generating electricity, heating homes and offices, making lower polluting gasoline and diesel fuels, and fueling surface and air transportation using fuel cells or internal combustion engines. Today, H_2 is produced primarily by steam reforming of natural gas, and is consumed primarily by chemical plants and petroleum refineries. For other applications requiring pure H_2, such as fuel cells, production is done by electrolysis. This is a relatively inefficient process that uses electric current to dissociate, or split, water into its H_2 and oxygen (O_2) components. To achieve a viable H_2 economy, where H_2 demand is expected to increase by one or two orders of magnitude beyond current consumption rates, we must develop advanced technologies to produce H_2 at costs competitive with hydrocarbon-based fuels, using sustainable sources.

3. **Nuclear Power**

Nuclear power provides a safe and environmentally neutral power source that could efficiently produce the vast quantities of H_2 fuel required to support the increasing demand for fuel cell applications. The concept of using nuclear reactors with core temperatures greater than 750 degrees Celsius (ºC), combined with a thermochemical water splitting process, is probably the most economically feasible means of breaking down water into its component parts: H_2 and O_2. One of the nuclear power reactor designs, high-temperature, gas-cooled reactors (HTGRs) with coolant exit temperatures in this range, coupled with a system using thermochemical processes, could be used to produce bulk quantities of H_2. Waste heat from the nuclear reactor could be used for the desalination of seawater, removing the minerals and salts from seawater prior to passing it through the water splitting process or storing it as potable water for other uses.

Many types of thermochemical processes for H_2 production exist. The sulfuric acid processes (hydrogen sulfide, iodine-sulfur, and sulfuric acid-methanol) are leading candidates. In each of these processes, the high-temperature, low-pressure endothermic (heat-absorbing) reaction is the thermal decomposition of sulfuric acid to produce O_2. After O_2 separation, additional chemical reactions are required to produce H_2, typically requiring temperatures in the range of 800-1000 ºC for efficient reactions. The leading candidate for thermochemical H_2 generation is the iodine-sulfur process, which uses an additional low-temperature step and an intermediate-temperature step to produce H_2 through chemical reactions. [Forsberg and Petticord, 2001]

$$H_2SO_4 \Rightarrow H_2O + SO_2 + \tfrac{1}{2}O_2$$

(high-temperature step)

$$I_2 + SO_2 + 2H_2O \Rightarrow 2HI + H_2SO_4$$

(low-temperature step)

$$2HI \Rightarrow H_2 + I_2$$
(intermediate step)

The economics of H_2 production strongly depends on the efficiency of the method used. Hydrogen production by common electrolysis is relatively efficient (about 80 percent). But when combined with the required electrical conversion efficiency, which ranges from approximately 34 percent (in current light water reactors) to about 50 percent (for advanced systems), the overall efficiency of electrolysis is only about 25-40 percent. For thermochemical approaches such as the iodine-sulfur process combined with nuclear energy, an overall efficiency of greater than 50 percent may be possible.

Burning coal or oil to generate electricity for production of H_2 by electrolysis would be wasteful and counterproductive by comparison. If the H_2 is produced using energy derived from hydrocarbon-based fuels, there is little or no economic or environmental advantage. Nuclear power plants, however, can provide safe, efficient, and clean power for converting large quantities of seawater into usable H_2 fuel and potable water. Such dual usage (H_2 fuel for equipment and potable water for human consumption) makes this an attractive concept, both for remote communities and military bases on a small scale as well as for regional production facilities on a larger scale.

For the military, a mobile nuclear power plant could be deployed as needed to remote theaters, where it could produce both H_2 fuel and potable water for use by U.S. and coalition forces in time of conflict. In peacetime, these same mobile plants could be deployed for humanitarian or disaster relief operations. These complementary roles make nuclear-generated supplies equally attractive to both military and civilian requirements, and this could foster joint programs to develop modern nuclear power sources for use in the 21st century.

4. Military Applications

The military already has an extensive record of developing and using mobile nuclear power reactors. The Navy nuclear power reactor program has been the largest and most successful. They have an impeccable safety and reliability record over the many years they have used nuclear reactors to power their surface and subsurface ships. They use these nuclear power rectors to provide electrical energy to drive their ships. The Army, on the other hand, had a different experience with nuclear power reactors.

The Army Corps of Engineers ran a Nuclear Power Program from 1952 until 1979, primarily to supply electric power in remote areas. Stationary nuclear reactors built at Fort Belvoir, Virginia, and Fort Greely, Alaska, were operated successfully from the late 1950's to the early 1970's. Portable nuclear reactors were also operated at Sundance, Wyoming; Camp Century, Greenland; and McMurdo Sound, Antarctica. These small nuclear power plants provided electricity and steam heating for remote military facilities and could be operated efficiently for long periods without refueling. [Suid, 1990]

In November 1963, an Army study submitted to the Department of Defense (DoD) proposed employing a military compact reactor (MCR) as the power source for a nuclear-powered energy depot, which was being considered as a means of producing synthetic fuels in a combat zone. While nuclear power could not supply energy directly to individual vehicles, the MCR could provide power to manufacture, under field conditions, a synthetic fuel as a substitute for conventional hydrocarbon-based fuels. The nuclear power plant would be combined with a fuel production system to convert water into H_2 fuel, which could then be used as a substitute for gasoline or diesel fuel in cars, trucks, and other vehicles.

By 1966, the practicality of the energy depot remained in doubt because of questions about the cost-effectiveness of its current and projected technology. Additionally, the Atomic Energy Commission (AEC), which supported the Army's efforts because they would contribute to the technology of both military and small commercial nuclear power plants, concluded that the probability of achieving the objectives of the Army program in a timely manner and at a reasonable cost was not high enough to justify continued funding. Cutbacks in military funding for long-range research and development because of the Vietnam War led the AEC to phase out its support. The costs of developing and producing compact nuclear power plants were simply so high they could only be justified if the reactor had a unique capability and met a clearly defined DoD objective. After that, the Army's Nuclear Power Program steadily declined and eventually stopped altogether.

The idea of using nuclear power to produce synthetic fuels, originally proposed in 1963, remains feasible today and is gaining significant attention because of recent advances in (1) fuel cell technology, (2) H_2 liquefaction, and (3) H_2 transport and storage. Meanwhile, nuclear power has become a significant part of the energy supply in more than 20 countries - providing energy security, reducing air pollution, and cutting greenhouse gas emissions. The performance of the world's nuclear power plants has improved steadily and is at an all-time high. Assuming that nuclear power experiences further technological development and increased public acceptance as a safe and efficient energy source, its use will continue to grow.

Commercial, as well as military, demand for cost-effective chemical fuels such as H_2 is expected to grow rapidly. Fuel cell technology, which produces electricity from low-temperature oxidation of H_2 and yields water as the only byproduct, is receiving increasing attention. As the commercial transportation sector increasingly moves toward H_2 fuel cells and other advanced engine concepts, DoD will eventually adopt this approach for its fleet of tactical vehicles and equipment. Using nuclear power to produce H_2, either at large central production facilities or at small remote facilities, offers the potential for a limitless chemical fuel supply with near-zero greenhouse gas emissions.

The demand for desalination of seawater is also likely to grow, as inadequate freshwater supplies become an urgent global concern. Potable water in the 21st century will be what oil was in the 20th century - a limited natural resource subject to intense international competition. In many areas of the world, rain is not always dependable and ground water supplies are limited, exhausted, or contaminated. Such areas are likely to experience conflict among water-needy peoples, possibly prompting the deployment of U.S. ground forces for humanitarian relief, peacekeeping, or armed intervention. A mobile power plant could help prevent conflicts or provide emergency supplies of fuel and potable water to indigenous peoples and deployed ground forces.

5. New Nuclear Power Reactor Designs

Compact reactor concepts based on HTGR designs are attracting attention worldwide and could someday fulfill the role once envisioned for the military energy depot. One proposed design is the pebble bed modular reactor (PBMR) under development by the South African utility Eskom, the South African Industrial Development Corporation (IDC), and British Nuclear Fuels Ltd (BNFL). A similar design is the gas turbine-modular helium reactor (GT-MHR) and remote site-modular helium reactor (RS-MHR) under joint development by General Atomics and the Russian Federation Ministry for Atomic Energy (MINATOM), and also sponsored by Japan and France.

The Modular HTGR concept originated in Germany in 1979, based on a Rankine cycle with steam conditions similar to hydrocarbon-based plants, but failed to demonstrate economic viability. Optimization studies in the 1990's indicated considerable cost savings using a closed-loop gas turbine (Brayton) cycle, compact heat exchangers, manufacturing and electronics. These differences introduce uncertainties and issues that must be addressed and resolved. If proven feasible, the HTGR technology could someday be used to replace retiring power plants, provide power for remote communities, expand the Navy's nuclear fleet, and provide mobile power for military or disaster relief operations. Ideally, modular power plants could be operated by a small staff of technicians and monitored by a central facility through a satellite uplink.

The technology of the HTGR designs features small, modular, helium-cooled reactors powered by ceramic-coated fuel particles capable of handling temperatures of 1,600ºC that are inherently safe and cannot melt under any accident scenario. Limiting thermal power density and allowing sufficient heat losses from the reactor vessel can accomplish the key safety function of residual heat removal without the need for active safety systems. This approach results in simpler plant design and lower capital costs than existing light water reactors and proposed advanced designs. The PBMR and GT-MHR, coupled with a direct-cycle gas turbine generator, would have a thermal efficiency of about 42-45 percent and would produce about 110 megawatts of electricity (MWe) and 285 MWe, respectively. The smaller RS-MHR would produce about 10-25 MWe, which is sufficient for powering remote communities and military bases. Multiple modules can be installed on existing sites and refueling can be performed online, since the fuel pebbles recycle through the reactor continuously until they are expended and replaced. Both designs also feature coolant exit temperatures between 900ºC and 950ºC, high enough to support efficient thermochemical water splitting cycles necessary for H_2 production.

For military applications, a small HTGR based on the RS-MHR design could be coupled to a thermochemical H_2 production facility, using the iodine-sulfur process or another of the chemical processes discussed earlier. Because the nuclear plant and the chemical plant would have significant inventories of hazardous materials, each must be isolated and protected from the other. This requirement would impose significant constraints on the plant, making any dual capability combining both electricity production by a turbine-generator and H_2 production by a chemical process unlikely. An energy depot would probably be a pure H_2 production facility, with waste heat from the reactor producing potable water primarily as the source supply for H_2 and the remainder available for human consumption.

There are many challenges to commercialization of an HTGR plant. The proposed gas turbine HTGR designs represent an advanced nuclear power concept that has not been demonstrated with an actual plant. Achieving successful deployment of this plant type will require careful development of the systems and components comprising the design, many of which are either new to the nuclear power industry, involve recent technological advancements, and/or consist of component applications operating in environments and configurations never before demonstrated. This fact is particularly evident with the gas turbine power conversion system components, where physical size, orientation and operating environment challenge the existing experience base. A proposed HTGR design coupled to a H_2 production system is even more speculative and will require extensive development, but should be compatible once the challenges to the gas turbine HTGR are resolved. [International Atomic Energy Agency, 2001]

Assuming an HTGR plant based on the RS-MHR or similar design can be coupled to a thermochemical H_2 production facility, equipment could be transported inland by truck or railroad, or single modules could be built on vessels and deployed as needed to coastal regions. The Army's floating nuclear power plant on the barge *Sturgis*, which provided electric power to the Panama Canal from the mid-1960s to the mid-1970s, demonstrated the feasibility of this concept. The compact RS-MHR reactor vessel measures approximately 3.4 m in diameter and 8.0 m high. The entire reactor and H_2 production system should be able to fit into two small pressure vessels contained within a shielded reactor building. Dimensions for a compatible H_2 production system, helium purification system, desalination system, and necessary connections and infrastructure are not defined, but the total plant may be expected to occupy at least 1300-1400 m^3. This would be small enough for a mobile above-grade facility mounted on a single basemat or onboard a single ocean-going vessel.

Figure 4. The MH-1A Sturgis Mobile Nuclear Power Plant Used a 45 MW Pressurized Water Reactor.

The efficiency of a large H_2 production facility is expected to be about 50 percent, with a 600 megawatts-thermal (MWt) reactor producing about 75 million standard (std) ft^3 of H_2 per day.

For a 30-60 MWt RS-MHR plant, approximately 3-7 million std ft^3/day could be expected. This output should meet the expected sustained energy demands of a deployed Task Force equipped with vehicles and other equipment powered by H_2 fuel cells or internal combustion engines.

6. Implementation Steps

Nuclear power is expected to grow in the 21st century, with potential benefits applicable to military as well as commercial sectors. Small, modular nuclear power plants in mobile or portable configurations, coupled with H_2 production and desalination systems, could be used to produce H_2 fuel and potable water for military forces deployed in remote areas to reduce logistical requirements. During times of conflict, the reactors would be on board naval ships protected by the fleet. In blue or littoral waters, these nuclear power reactors would generate H_2 and O_2. The H_2 would be compressed/liquefied and placed on other ships and transported to port, where it would be delivered to C4ISR and front line shooters. During peacetime, these same reactors could be placed on shore and used to generate electricity for homes or private industry during peak hours and H_2 fuel during off-peak hours. Assuming the inevitability of H_2 displacing hydrocarbon-based fuels, a clearly defined objective for developing a chemical fuel production capability now exists that was missing in 1966.

The Department of Energy (DOE), in its May 2001 Report to Congress on Small Modular Nuclear Reactors, recognized the initial research into nuclear reactor technology and small reactors made by the U.S. Army in the 1950s and 1960s and showed that nuclear power facilities can be safely constructed and operated in remote areas. The former AEC's Power Reactor Development Program demonstrated that new reactor designs of small size could be constructed, tested, and placed on the electric power grid in a relatively short time frame (e.g., less than four years). The United Kingdom experience of applying a standardized gas-cooled reactor technology shows that HTGR designs can be expanded to provide a stable source of nuclear power in today's economic environment. However, the DOE report was made in response to Senate Report 106-395 to evaluate the feasibility of small nuclear power plants to provide electric power to remote areas and did not address the long-range feasibility of producing H_2 fuel.

The partnership between DoD and the former AEC to develop Army nuclear reactors contributed to the technology of both military and small commercial nuclear power plants for electricity generation. This historical relationship should be renewed to develop a prototype H_2 fuel production capability using nuclear energy based on recent technological advances and projected logistical requirements, as well as projected increases in consumer demand for H_2. DoD logistics planners should reconsider military applications of nuclear power and support ongoing DOE research and development initiatives to develop small modular nuclear reactors such as RS-MHR and others. For the Army to fight and win on tomorrow's distant battlefields, nuclear power will have to play a significant role, either directly or indirectly.

Would this necessarily lead to a rebirth of the old Army Nuclear Power Program, with soldiers trained as reactor operators and reactor facilities managed by the Corps of Engineers? Probably not. A more likely scenario would be a small fleet of nuclear power barges or other mobile power plant configurations developed by DOE, operated and maintained by Government technicians or civilian contractors as a part of the fleet during wartime, and deployed during times of peace as necessary to support the Federal Emergency Management Agency, the Department of State, and DoD. Construction, licensing, refueling, and decommissioning issues could be managed under DOE stewardship and/or Nuclear Regulatory Commission (NRC) oversight. These and other issues would have to be addressed and resolved as research and development proceeds. As an end user of these proposed mobile nuclear reactors, however, the Army should understand their capabilities and limitations and provide designers with appropriate military requirements for their possible deployment to a combat zone.

7. **Conclusion**

Increased logistics costs and the ever-increasing realization of depleting hydrocarbon-based fuel reserves will force the military to consider energy alternatives. Already, private industry has proven the viability of using hydrogen-based fuel cells to power small vehicles and internal combustion engines that run on liquid H_2 or gasoline to power heavier vehicles. The military transition to hydrogen-driven platforms and systems can be expedited by placing commercially developed mobile nuclear power reactors on Navy ships, protecting them by the fleet, and moving them to blue or littoral waters closer to the battlespace to produce liquid H_2 and potable water. Mobile C4ISR and front line shooters could then be supplied by existing energy distribution networks. A look at the national energy policy and how it drives changes in the military shows the following:

(a) Improved global economies and an increasing global population will increase worldwide demand for all forms of energy.
(b) Increased energy use will further deplete hydrocarbon-based fuel reserves and aggravate an already polluted global environment.
(c) The only viable alternative to hydrocarbon-based fuels as the ultimate energy source is seawater,
(d) Hydrogen derived from seawater is the ultimate fuel for mobile equipment, including military C4ISR, sensors, and mobile electric power.
(e) Nuclear power provides the most efficient, most environmentally neutral power for electricity generation as well as the production of liquid H_2 and potable water anywhere in the world.
(f) The military (both the Navy and Army) has years of experience with the development, operation and maintenance of transportable nuclear power plants.
(g) Recent nuclear reactor designs improve reactor safety and efficiency. In addition, some provide the necessary high temperature heat to generate commercial quantities of liquid H_2 and O_2.
(h) DoD, DOE and the NRC must begin work now to look at ways to develop and deploy new, mobile nuclear power plant designs.

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