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NONPETROLEUM MOBILITY FUELS AND MILITARY—ENERGY SELF-SUFFICIENCY

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ABSTRACT

Nonpetroleum hydrocarbon fuels will likely serve as transition fuels for a few decades after petroleum sources become scarce. But nonpetroleum hydrocarbon fuels are ultimately either nonrenewable (e.g., coal and oil shale synfuels) or are inefficient to produce. Nuclear sources (supplemented by solar, geothermal, etc., as available) for electric power generation and hydrogen production provide a combination that can be used for military energy needs including mobility fuels, namely liquid hydrogen. This approach can give the military energy self-sufficiency for stationary needs as well as ground vehicles, ships, and aircraft. This paper discusses such system integration concepts, and outlines concepts for a methodology to evaluate source-to-use pathways for different classes of military bases.

NONPETROLEUM MOBILITY FUELS AND MILITARY ENERGY SELF-SUFFICIENCY

I. INTRODUCTION

The impact of the emergence of OPEC as a powerful cartel is understood today by even the average layman. The disruption on US and World economies created by the dramatic rise in cost of curde oil has been devastating. Deregulation of energy prices in the US is resulting in a changing lifestyle for this country--toward conservation and alternate sources of energy. Yet, even with a 22% decrease in the amount of oil we imported during 1980, the US still endured a flow out of our economy into foreign markets of $78 billion to quench our voracious appetite for petroleum products.(1)

In recognition of our strong dependence on these foreign oil supplies, much attention in Congress these days is directed toward strengthening our military forces "to protect our vital interests in the Persian Gulf." There is widespread agreement among our decision-makers that insuring the continued flow of the foreigh crude into our petroleum dependent economy has become of prime importance to US national interests. The ability of our military forces to perform this mission in light of Soviet military strength is in serious question at this time, and CIA projections that the Soviets will become net energy importers within this decade strikes another disconcerting blow for US strategists.

While recent discussion has focused on using military force to maintain fuel supplies for the US, little emphasis has been placed on securing a stable fuel supply to maintain the military forces. Only recently have reports begun to surface that discuss the limited logistical support available to sustain the military war machine during a prolonged conflict on foreign soil.(2) Until now, the dominant mode of thought was that when additional fuel supplies were required at the battle front, the "supply types" would somehow find a way of getting it there.

Oil (like coal, uranium, shale oil, and natural gas) is a nonrenewable resource. When it is gone, there is no more. Can you imagine the scramble that will occur when nations finally realize that the remaining several billion barrels still in the ground is all that is left. The furor over oil that we see in the world today is nothing more than polite squabbling compared to the fight that will occur. Consider the consequences if our military runs out of oil before the Russians do!

The authors of this article believe that the military services must begin to prepare for the day when non-renewable fuel sources are no longer available to run our war machines. While we do not intend to assume the role of prophets of doom, we nevertheless feel that it would be extremely prudent to begin an orderly planning for that inevitable day when non-renewable fuels run out, be it ten, twenty, or even fifty years. The risks of not preparing for that contingency are simply too great to ignore.

II. PATHWAYS FOR DoD AND US ENERGY SECURITY

Various pathways from energy source to end-use are shown in Figure 1. The main energy issue facing the US is mobility fuel supplies; we already have technologies for the long term for stationary energy needs. Nonetheless, we need to think more in terms of integrated systems rather than piecemeal approaches (one item at a time in Figure 1).

Since it is important for national security that our military be energy secure, and since the Department of Defense (DoD) is one of the leading entities that has taken results of R & D to build hardware systems that have frequently resulted in technology spinoffs or transfer to the private sector (with industry production-expansion bringing unit costs down), let us focus on Figure 1 from a DoD perspective.

For the military, can we find pathways such that:

1. Non-CONUS (continental US) bases can have a stand-alone capability, taking care of their own stationary power needs and making mobility fuel for aircraft and land vehicles?
2. CONUS bases can make their own mobility fuel if need be?
3. Aircraft carriers can make aircraft fuel at sea, thus eliminating the conventional liquid fuel supply line to them?
4. Mobility fuels can be made by off-shore production units in support of Marine Corps operations (again eliminating the vulnerable trans-ocean supply lines)?
5. The Navy could make fuel at sea via fuel-factory ships in support of smaller boats (again eliminating the supply tail)?
6. A rapid deployment force (RDF) could make mobility fuels at or near where it lands (at least greatly reducing the length of the supply tail)?
7. There is a common, single Tri-Service (AF, Army, Navy-MC) fuel?
8. The mobility fuel is 100% recyclable and low polluting?
9. Having once changed to such pathways, no further changes would be needed for the very long-term future, if ever?
10. Those technologies could also be adopted by the private/commercial sector of the US, eliminating foreign energy import dependence?

The answer to the above questions is a qualified "YES," with hydrogen as a single, universal mobility fuel.(3) In addition to strategic possibilities of eliminating vulnerable mobility fuel supply tails for the DoD, other reasons for the choice of hydrogen are discussed below.

Technically, there are various possible pathways to hydrogen as illustrated in Figure 1. Hardware for most of the pathways is either commercially available (electric generation, electrolysis, liquefaction, storage), exists as "first generation" R & D demonstration hardware,(4) or is technically feasible (e.g., aircraft; Lockheed, Boeing, and Bell Helicopter have designs).

For the DoD, a "strategy hierarchy" for permanent military base energy source options (with hydrogen as the end-use mobility fuel) is illustrated in Figure 2. For the Class I energy strategy, a base could use, for example, a subsurface small reactor (hardened, like emplacement in a missile-silo type structure) for electric generation for stationary power needs, including on-site manufacturing of hydrogen for a mobility fuel. An example of a possible methodology for comparative analysis of source-to-use pathways for Class I military bases given in Section III of this paper. Working down the hierarchy of Figure 2, source options expand. The Class III strategy could also be adopted by the private sector.

For mobile/transportable production units, use of small reactors in conjunction with a source of water would be a logical choice; in fact, the Army had a program in land mobile reactors and Sturges reactors on barges. Nuclear powered aircraft carriers could manufacture LH_2 for their aricraft. Nuclear powered fuel-factory ships could make hydrogen at sea in support of smaller boats, USMC beachhead operations, etc.

Economically, the choice of hydrogen is not clear. The US spent $78 billion for oil imports in 1980, and the cost is risng. The economic implications of spending that money at home in our own economy are interesting to think about.

Every 1¢/gallon increase in costs of liquid fossil fuels impacts the DoD budget by about $90 million annually)peacetime, with curtailed training exercises.(5) Data on the total DoD energy bill is given in Figure 3, and data on DoD energy use is given in Figure 4. As oil prices continue to rise, as the price and timescale-to-significant supply of fossil synfuels (from coal, oil shale, and tar sands) remain uncertain(6,7) and given the fact that the Soviets are just now becoming oil importers and will thus be actively competing with the free world for Middle East oil supplies, hydrogen may well become an attractive alternative. For the DoD, the near-term trade-off is energy cost vs energy security; a policy is not yet established.

Characteristics of several other possibilities for mobility fuels are given in Figure 5. The point here is that it is desirable to stay above the dashed curve, i.e., if you have to sacrifice energy-by-volume, you would want to compensate in energy-by-weight.

In looking to the future, one can ask if it is prudent to burn fossil fuel supplies, or to "protect" them for higher and better use in the manufacture materials, pesticide, and medicines. Note, for example, that the US spent over $25 billion in 1980 on nonfuel mineral imports (and the cost is rising), with many strategic nonfuel minerals coming from Soviet-influenced countries;(8) synthetic petrochemicals from coal and other domestic fossil supplies could be used as feedstock for manufacturing certain substitute materials. Note also that the US alone supplies about 60% of the grain on the world market(9)--a potentially strong international bargaining chip; but in the US, food production is energy, fertilizer, and pesticide intensive. Fertilizers and pesticides could be manufactured from synthetic petrochemicals using coal, oil shale, and tar sand feedstocks.

We can not afford to continue to look at issues such as energy, nonfuel minerals, food, and defense in isolation from each other vis-a-vis domestic and foreign policy. As another example, note that certain "soft" energy technologies take over 40 times the materials to construct as "hard" technologies for the same energy output,(10) and it takes energy to process the mineral ores into engineering materials.

Socially and politically, some of the pathways in Figure 1 need further study. For example, in the next section of this paper, we will show that for Class I Bases, the optimum pathway is nuclear fission reactor-mobil/transportable hydrogen production units. The issue of whether or not foreign countries would allow such reactors on their soil needs to be addressed. Further, since reactors would need an occasional delivery of fissile fuel (a much different form of supply tail than a "flow" of bulky liquid fuel), long-term support of such a program may call for a nuclear breeder program in the US. Will the US public support a program for DOD energy security? Such a program exists today for the US nuclear weapons program. And given the "Hindenberg Syndrome," the question of hydrogen safety is continually raised despite the fact that NASA has employed the use of hydrogen in the space program and the fact that no problems have yet arisen with R & D demonstration vehicles. In this context, the following quote is noteworthy:

> "A new source of power...called gasoline has been produced by a Boston engineer. Instead of burning the fuel under a boiler, it is exploded inside the cylinder of an engine...
>
> "The dangers are obvious. Stores of gasoline in the hands of people interested primarily in profit would constitute a fire and explosive hazard of the first rank. Horseless carriages propelled by gasoline might attain speeds of 14, or even 20 miles per hour. The menace to our people of vehicles of this type hurtling through our streets and along our roads and poisoning the atmosphere would call for prompt legislative action even if the military and economic implications were not so overwhelming... the cost of producing (gasoline) is far beyond the financial capacity of private industry... In addition, the development of this new power may displace the use of horses, which would wreck our agriculture..."
>
> --- The 1875 Congressional Record

III. A FURTHER LOOK AT CLASS I TECHNOLOGY OPTIONS

Figure 2 of the previous section identified energy sources that are appropriate for each class of military base. The identification of nuclear and geothermal (if available) as viable energy sources for Class I sites is based on an analysis of the various technology options, weighted against selected evaluation criteria. Table 1 is a listing of evaluation criteria as used in this example. Definitions of each term are given in Table 2.

The weighting coefficient for each evaluation criteria is a qualitative selection at this stage but is useful for a "first cut" analysis. Future studies should be directed toward quantitatively formalizing the coefficient values as well as the evaluation criteria itself. The coefficients as presented in Table 1 are used here for Class I bases only (Figure 2) and would change somewhat for Class II and III bases.

With identification of evaluation criteria and weighting coefficients, the next step is to identify the figures of merit for each evaluation criteria for use later in a decision matrix.

Figure 6 lists the Figures of Merit (scale of 0-10) by these authors for this illustrative example. Development of documentable figures of merit graphs will require an extensive research effort and these graphs should be regarded as only a departure point for additional investigation.

We are now prepared to develop our decision matrix to identify the optimum technology options for Class I bases. From Figure 1 of Section II, we observe that there are a number of candidate energy source-to-use pathways to be evaluated.

For this discussion, the energy options for satisfying stationary electric and thermal needs will be limited to the following technologies: nuclear, geothermal, solar thermal-electric, wind turbines, solar photovoltaic systems, solar ponds, and biomass systems. For comparison, we also include coal-fired power plants, diesel generators, and purchased electricity, noting, however, that the premise of this paper is to look beyond fossil fuels, and that purchased power is not compatible with Class I self-sufficiency, assuming that it comes from an off-site source.

When evaluating candidate mobility fuels, hydrogen (liquid) via electrolysis, will be compared to petroleum-based fuels and synthetic fuels.

Using Figures of Merit for each evaluation criteria, the results for determining the ratings of energy source-to-use pathways for Class I bases are given in Table 3, wherein the weighting coefficients are copied from Table 1. The numbers in the columns under each energy source are approximate Figures of Merit for each source as determined from Figure 6. For each source, the totals in Table 3 were then obtained by summing the products of the Weighting Coefficients multiplied by the assessed Figure of Merit. For example, for nuclear: Total = 525 = (10 x 10; survivability) + (10 x 10; self-sufficiency) +.....+(5 x 3; mobility enhancement).

From the qualitative analysis outlined above, the maximum possible "score" is 650 for each source, and a combined total maximum of 1300 for stationary and mobility needs. The totals in Table 3 indicate that the highest-rated pathways for Class I bases would be nuclear and hydrogen with a combined score of 1008.

Another decision matrix for Class II and Class III bases would be required with different weighting coefficients to reflect different priorities such as less emphasis on survivability and more on reducing cost.

The results of the above analysis are not to be taken as a final recommendation. Rather, the purpose is to present a conceptual framework for a comparative-analysis methodology for use in further studies.

IV. CONCLUSION

Looking into the future and recognizing that the world will require mobility fuels, the question is not IF renewable fuels such as hydrogen will be used, the question is WHEN. At accelerating rates of depletion, high-grade world fossil supplies may be depleted by the year 2030.(11) Thus, even fossil synthetic fuels from oil shale, coal, and tar sands will only serve as transitional solutions to a long-term need.

The question is, "How do we get there from here?" That is, what is the best transition plan? For the US, the DoD may be a viable entry point. Certainly DoD energy security should be given a very high priority. Though such a transition to hydrogen as a mobility fuel will take many years, with fossil synfuels playing a role in the transition, the base technology exists today to do integrated-system engineering demonstrations for options such as the nuclear/electric/hydrogen pathway of Figure 1. Given instabilities and uncertainties in world oil supplies, it is absolutely essential to do some hardware-system demonstrations with these options to get up the learning curve in case such alternatives become needed sooner than expected.(12)

"The future belongs to those who plan it, not just for it."

--- Dean Geroge M. Parks
School of Business Administration
Emory University, Atlanta, GA

* * * * *

This work was performed under the auspices of the US Department of Energy.

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1. Monthly Energy Review, US DOE, Washington, DC 20585, March 1981.

2. See, for example, "Joint Chiefs Fret About Oil Tankers In Wartime," The Energy Daily, p. 5, April 1, 1981.

3. Hydrogen is not an energy source; it is an energy "carrier." Energy is needed to make it. There are various ways to make hydrogen. Making gaseous hydrogen (GH_2) from water electrolysis is about 30-40% efficient (fuel into electrical generating station-to-hydrogen energy out). Liquefied hydrogen (LH_2) for a mobility fuel requires additional energy for liquefaction; the overall production efficiency for LH_2 is about 25%.

4. See, for example, "Alternative Transportation Vehicles for Military-Base Operations," by David A. Freiwald and William J. Barattino, Los Alamos National Laboratory report no. LASL-80-45, October 1980, Los Alamos, NM 87545; this gives a brief discussion of the liquid-hydrogen-fueld Buick and the fuel-cell/electric test bed vehicle at Los Alamos. Other hydrogen-fueled vehicles also exist in the US--over 15 total.

5. U.S. News & World Report, p. 23, Nov. 10, 1980.

6. Liquid synfuels production for the US is estimated to be 400,000 barrels per day by 1990, and 2.4 MM barrels per day by the year 2000--SYNFUELS newsletter, Dec. 26, 1980.

7. A recent Congressional Research Service study concludes that synfuels would cost more than oil even at $100 per barrel--SYNFUELS newsletter, March 27, 1981.

8. See, for example, "Mineral Self-Sufficiency: The Contrast Between the Soviet Union and the United States," by S. D. Strauss, Mining Congress Journal, Nov. 1979.

9. Dan Morgan, Merchants of Grain, Viking Press, NY, 1979.

10. David A. Freiwald, "U.S. Energy Sources and Materials Needs," Los Alamos National Laboratory report no. LASL-80-10, April 1980, Los Alamos, NM 87545.

11. J. O'M Bockris, Energy Options, p. 29, Australia and New Zealand Book Company, 1980.

12. Note, for example, that a terrorist-group act of sinking 2-3 tankers in the Straits of Hormuz could suddenly shut off about 25% of US oil supplies; an even higher percentage for many free-world nations.

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TABLE 1

EVALUATION CRITERIA

Criteria	Weighting Coefficient
Survivability	10
Self-Sufficiency	10
Reliability/Resource Availability	10
Cost	10
Logistical Advantage	8
Tactical Compatibility	7
O&M Practicality	5
Mobility Enhancement	5

TABLE 2

EVALUATION CRITERIA DEFINITIONS

Survivability--relative probability of retaining operational capability as compared to other energy systems with respect to attacks by nuclear, conventional, sabotage, vandalism, and natural disasters.

Self-Sufficiency--ability of the energy system to meet load requirements at the particular location for a minimum of six months without any external logistical support.

Reliability/Resource Availability--relative probability that an energy system will have the resources to operate and will operate at rated output with a minimum of maintenance requirements for a six-month period. The rated output includes consideration of the system capacity factor and variations in the output for renewable energy systems based on expected resource availability.

Cost--life cycle costs, including first costs and O & M costs.

Logistical Advantage--potential for integrating the energy system into the existing DoD logistical system with emphasis on the advantages of reducing support requirements and supply lines.

Tactical Compatibility--measure of the capacity of the energy system to be integrated into the military environment without degrading the mili-

TABLE 3
ANALYSIS OF TECHNOLOGY OPTIONS FOR CLASS I BASES

STATIONARY ELECTRIC AND THERMAL ENERGY OPTIONS

Evaluation Criteria	Weighting Coefficient	Nuclear	Geo-thermal	Solar Thermal Electric	Wind	Photo-Voltaic	Solar Ponds	Biomass	Coal	Diesel Generator	Purchased Electricity
Survivability	10	10	10	3	6	2	5	9	9	6	5
Self-Sufficiency	10	10	10	10	10	10	10	6	6	2	1
Cost	10	8	6	4	8	2	6	6	9	10	10
Logistical Advantage	8	8	8	9	9	8	10	8	3	5	10
Tactical Compatibility	7	8	10	10	5	10	10	8	10	8	10
O & M Practicality	5	6	7	4	6	8	10	6	8	10	10
Mobility Enhancement	5	3	3	8	8	8	1	3	1	8	3
Total (max: 650)		525	504	412	457	414	475	455	469	466	455

For Comparison (Coal, Diesel Generator, Purchased Electricity)

MOBILITY FUEL OPTIONS

	Weighting Coefficient	H_2 Via Elec-trolysis	Petroleum	Synfuels
Survivability	10	8	7	7
Self-Sufficiency	10	10	3	1
Reliability	10	8	10	10
Cost	10	4	8	6
Logistical Advantage	8	9	6	5
Tactical Compatibility	7	10	10	10
O & M Practicality	5	5	8	8
Mobility Enhancement	5	7	8	8
Total (max: 650)		502	478	430

For Comparison (Petroleum, Synfuels)

<u>Summary</u>: <u>Optimum Source To Use Pathways</u>

1. Nuclear Fission - H_2 (1) via electrolysis
2. Geothermal - H_2 (1) via electrolysis

Figure 1 -
SOURCE - TO - USE ENERGY PATHWAYS

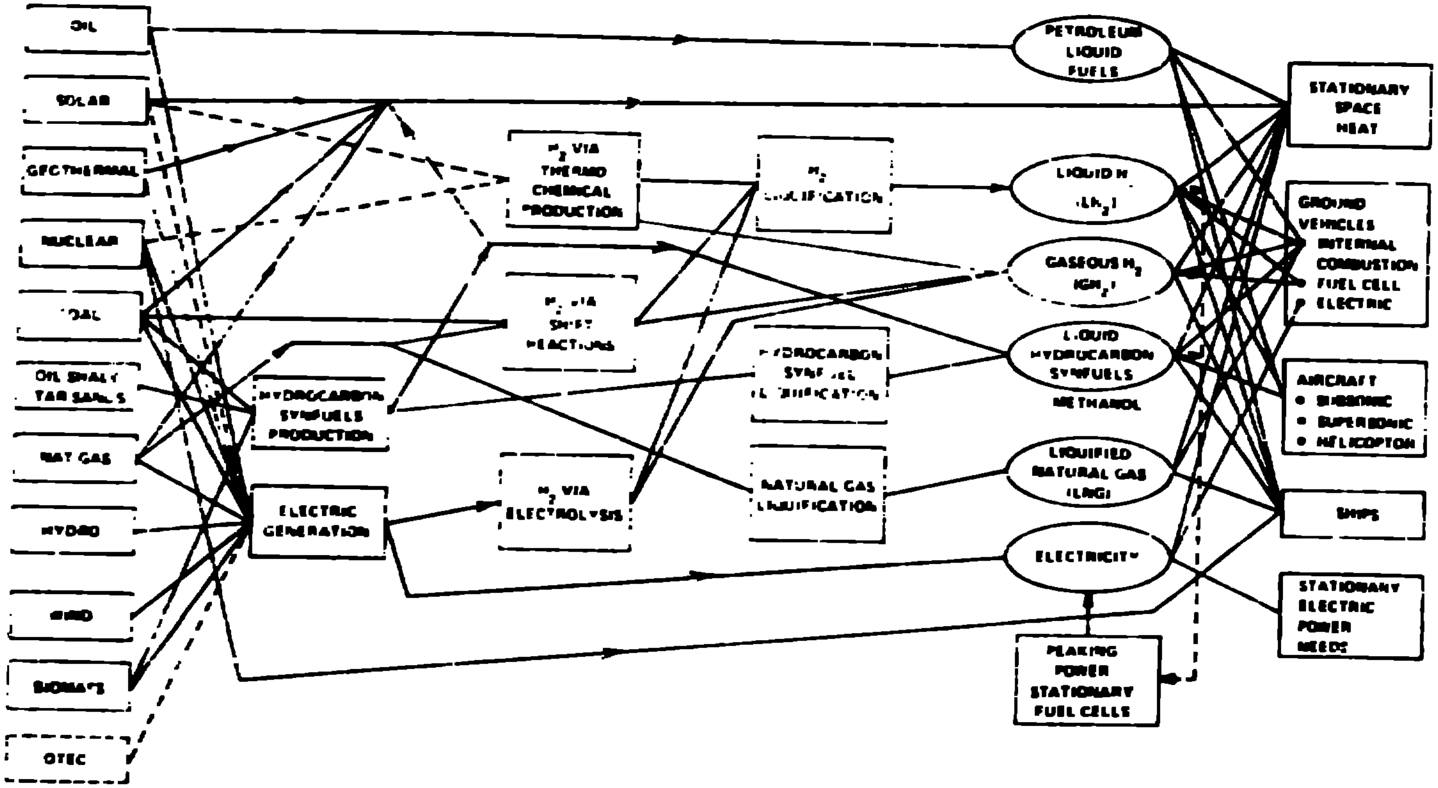


Figure 2 -
ENERGY STRATEGY HIERARCHY FOR MILITARY BASES

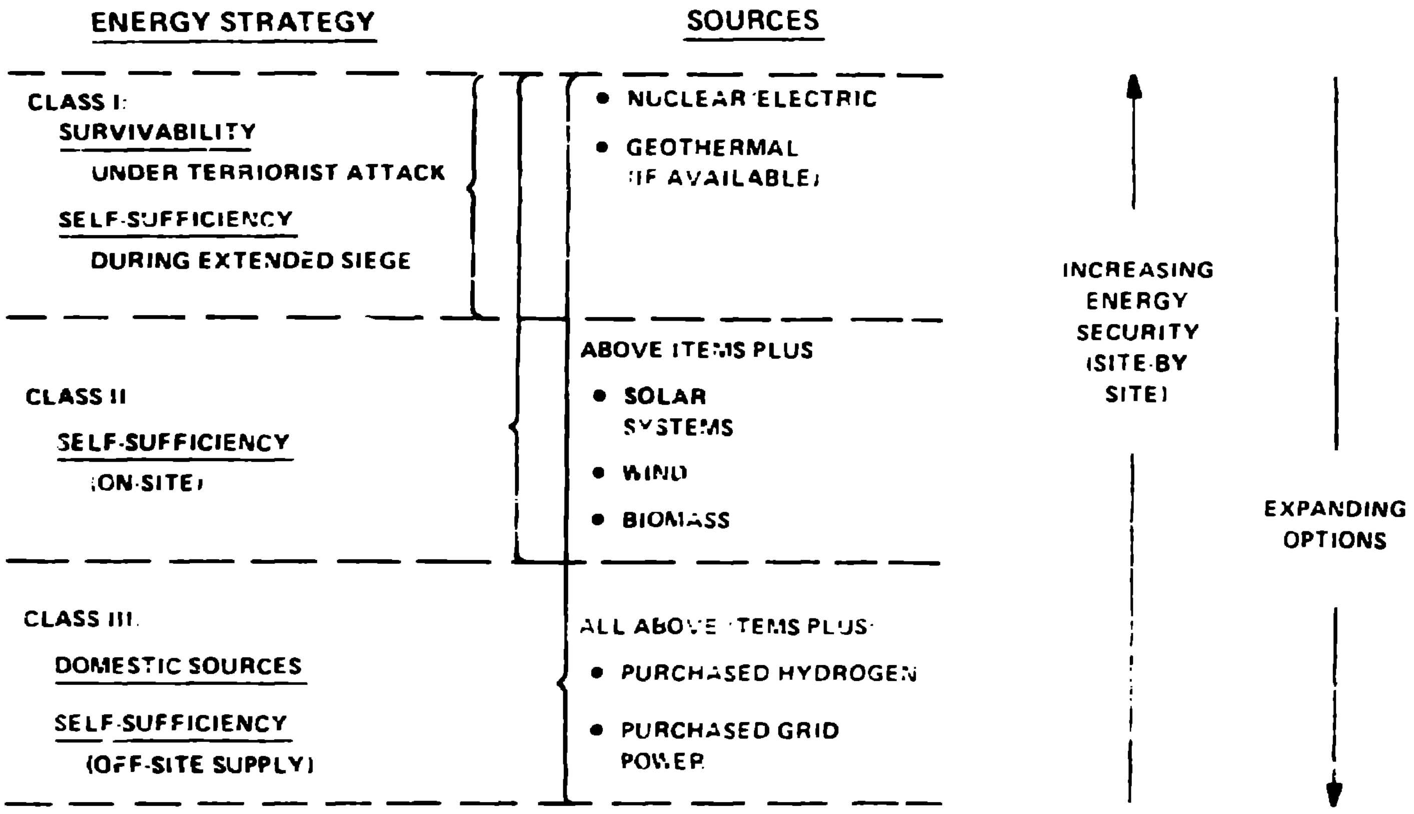


Figure 3 -
DEPARTMENT OF DEFENSE ENERGY CONSUMPTION AND COSTS
From: 1980 DoD Energy Management Plan, DASD(E,E,S)
The Pentagon, Washington, D.C. 20301

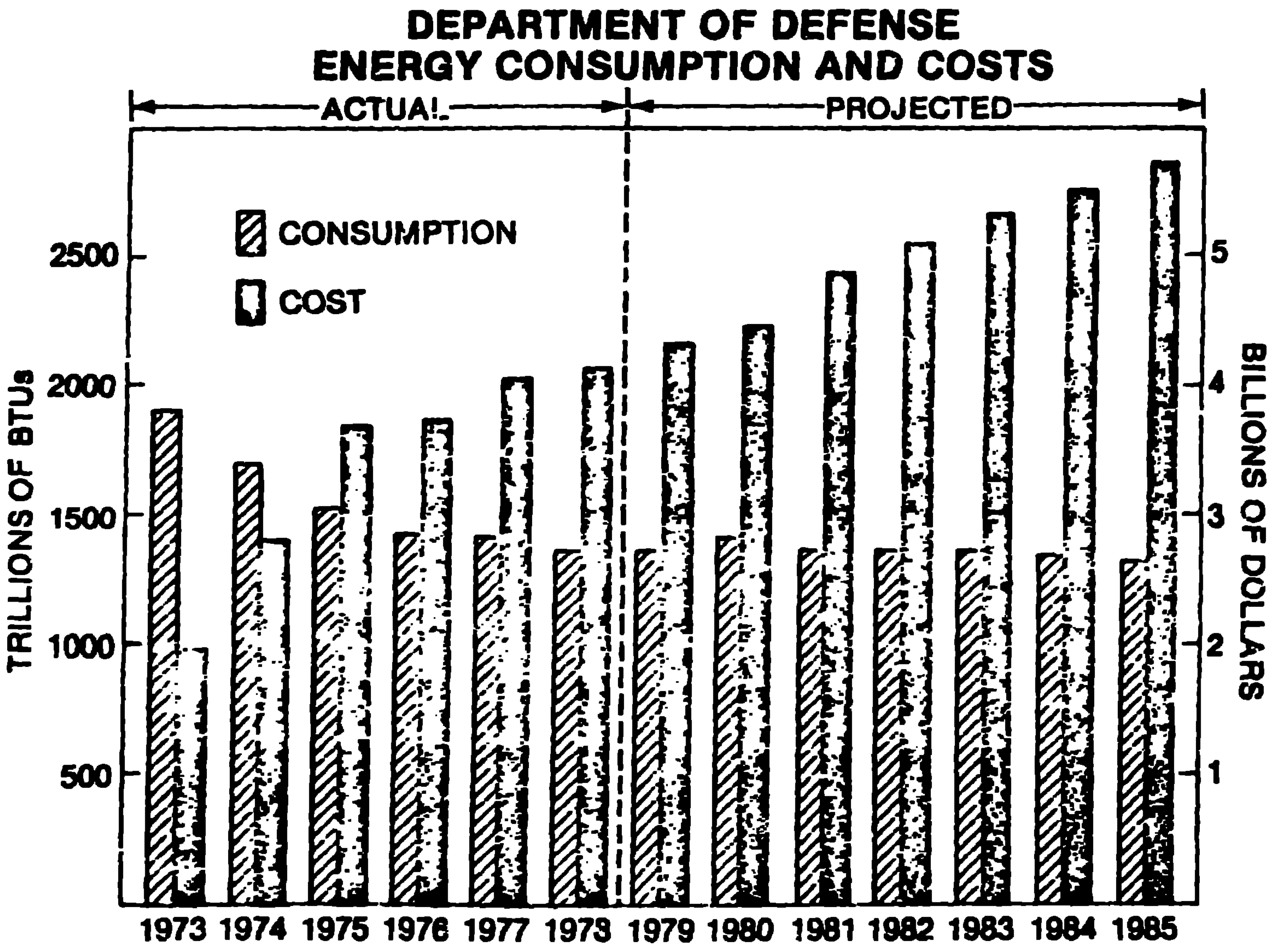
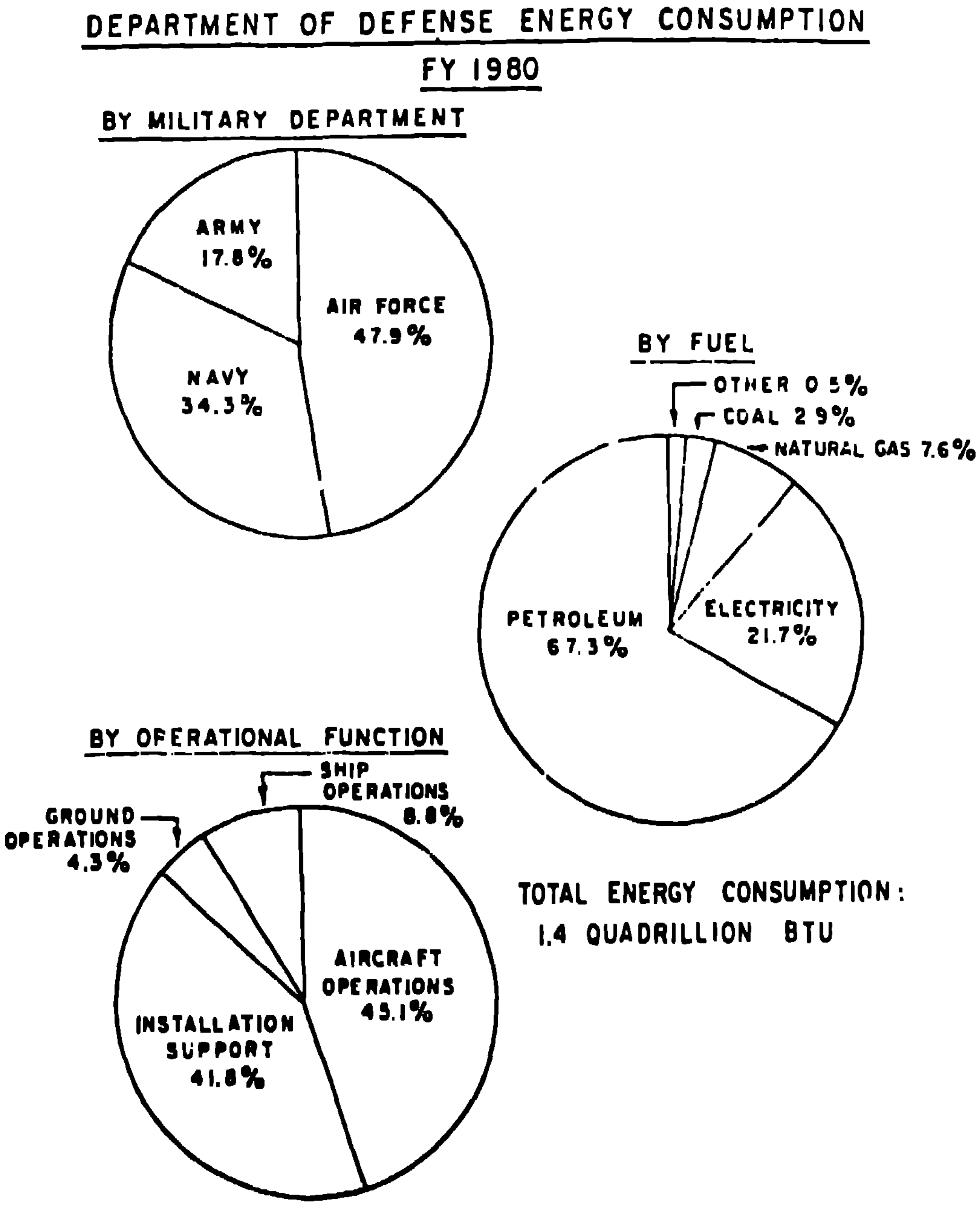


Figure 4 -

FY 1980 DEPARTMENT OF DEFENSE ENERGY CONSUMPTION

From: 1981 DoD Energy Management Plan, DASD(E,E,S)
The Pentagon, Washington, D.C. 20301



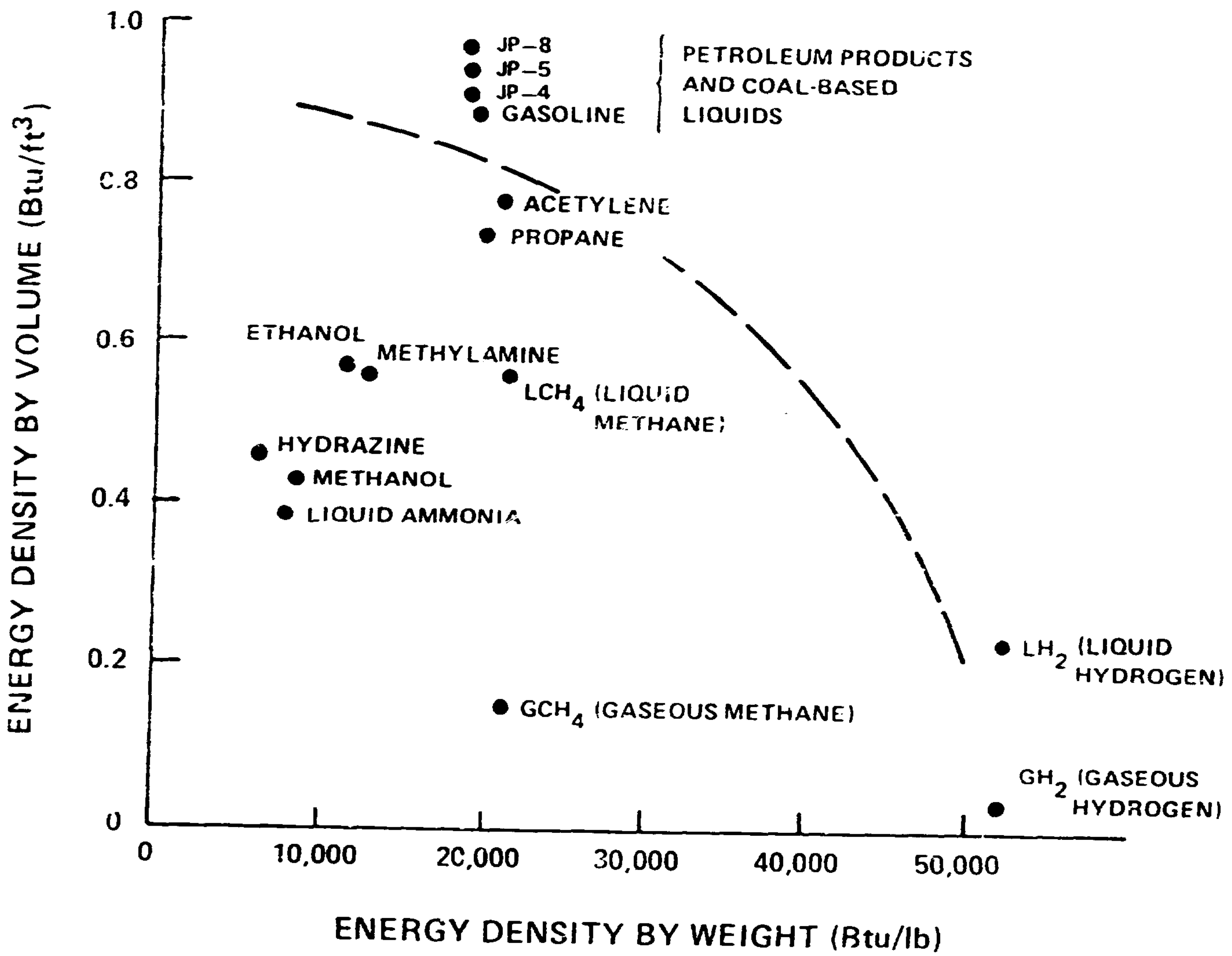


Figure 5 -
ENERGY DENSITY BY VOLUME ($x10^{-6}$) vs ENERGY DENSITY BY WEIGHT FOR VARIOUS CANDIDATE MOBILITY FUELS
From: "Production of Marine and Aviation Fuel by Factory Ships at Sea" by J.F. Bald and J.P. Kuspa, U.S. Naval War College report, June 1980, Newport, R.I.

FIG. 6: FIGURE OF MERIT GRAPHS FOR EVALUATION CRITERIA