War and Energy

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Glossary

explosives Compounds whose destructive effect results from virtually instantaneous release of kinetic energy that is generated either by internally oxidized chemical reactions that produce large and rapidly expanding volumes of gas (chemical explosives) or by fission of heavy nuclei or fusion of light nuclei (nuclear explosives).

intercontinental ballistic missiles (ICBMs) Missiles that can be launched from fortified silos or nuclear submarines and can carry a single warhead or multiple independently targeted reentry vehicles (MIRVs).

military spending A category of expenses whose definition varies widely among countries and is often greatly undervalued in official accounts; for example, official Soviet military spending included merely operation and maintenance costs, and the real total (including weapons research and development and production) was roughly an order of magnitude higher.

nuclear weapons Both strategic and tactical warheads, bombs, and munitions, carried by intercontinental ballistic and medium- and short-range missiles or delivered by bombers or field artillery, whose destructive power is released either through nuclear fission or, in thermonuclear weapons, through fusion.

Wars demand an extraordinary mobilization of energy resources, they represent the most concentrated and the most devastating release of destructive power, and their common consequence is a major disruption of energy supplies in regions or countries that were affected by combat or subjected to prolonged bombing. Given these obvious realities, it is inexplicable that wars have received very little attention as energy phenomena. At the same time, there is a fairly common perception—one that has been greatly reinforced by the American conquest of Iraq in 2003—that energy is often the main reason why nations go to war. This article addresses all of these concerns. Because the destructiveness of war depends largely on the weapons used, it first outlines their brief history. The energy cost of individual armed conflicts, as well as the peacetime energy cost of preparing for war, is difficult to assess, and the article presents some representative calculations and cites some recent statistics using the major 20th-century wars waged by the United States. Casualties are the most horrifying consequence of wars, and the greater destructive power led to their increase until the recent development of precision-guided munitions made it possible to minimize civilian deaths by careful targeting. Impacts of war on energy use during the conflict and in its aftermath, particularly in defeated countries that suffered a great deal of destruction, are clearly seen in consumption statistics. Finally, the article argues that the wish to be in actual physical control of energy resources has not been the sole reason, or even the primary reason, for any major modern armed conflict.

1. A BRIEF HISTORY OF WEAPONS

Weapons are the prime movers of war. They are designed to inflict damage through a sudden release of kinetic energy (all handheld weapons, projectiles, and explosives), heat, or a combination of both. Nuclear weapons kill nearly instantaneously by the combination of blast and thermal radiation, and they also cause delayed deaths and sickness due to the exposure to ionizing radiation. Classification of wars based on these destructive prime movers divides history into four distinct periods. All prehistoric, classical, and early medieval warfare was powered only by human and animal muscles. Invention of gunpowder led to a rapid diffusion of initially clumsy front- and breach-loading rifles and to much more powerful field and ship guns.

By the late 1860s Nobel's combination of nitroglycerine and diatomaceous earth produced the first practical high explosive, and other variants were soon made into munitions for newly invented machine guns as well as into large-caliber gun shells and airplane bombs. Wars of the 20th century were dominated by the use of these high explosives delivered in shells (from land and ship-borne artillery and tanks), torpedoes, bombs, and missiles. Finally, strategic thinking and the global balance of power changed after World War II with the development of nuclear weapons.

The period of muscle-powered warfare lasted nearly until the very end of the Middle Ages. The daily range of advancing armies was limited less by the stamina of walking or running troops than by the speed of their supply trains, made up of animals ranging from oxen and horses in Europe to camels and elephants in Asia. Men used axes, daggers, swords, and lances in close combat and used spears and bows and arrows for attacking unprotected enemies as far as 200 m away. Much more powerful crossbows were used since the fourth century BC in both Greece and China. Inaccurate targeting and relatively low kinetic energy of these assaults (Table I) limited the magnitude and frequency of injuries that could be inflicted by these weapons. Massed human power was also used to wind winches of catapults and to move assorted siege machines designed to overcome urban fortifications.

TABLE I

Kinetic Energy of Projectiles

Weapon	Projectile	Kinetic energy (J)
Bow and arrow	Arrow	20
Heavy crossbow	Arrow	100
Civil war musket	Bullet	1×10^3
Assault rifle (M16)	Bullet	2×10^3
Medieval cannon	Stone ball	50×10^3
18th-century cannon	Iron ball	300×10^3
World War I artillery gun	Shrapnell shell	1×10^6
World War II heavy AA gun	High–explosive shell	6×10^6
M1A1 Abrams tank	Depleted U shell	6×10^6
Unguided World War II rocket	Missile with payload	18×10^6
Boeing 767 (September 11, 2001)	Hijacked plane	4×10^9

Light horses were initially used to pull chariots, and only after the general adoption of stirrups (beginning in the third century AD) did mounted warriors become a particularly effective fighting force. Asian riders were unarmored, but they had small and extraordinarily hardy horses and could move with high speed and maneuverability. These abilities brought the Mongol invaders from the heart of Asia to the center of Europe between 1223 and 1241. In contrast, European knights relied on their heavy armor as they rode increasingly heavier animals. Their most spectacular series of long-distance forays brought them as Crusaders from many countries of Europe to the Eastern Mediterranean, where they established temporary rule (between 1096 and 1291) over fluctuating areas of the littoral. The only important nonanimate energies used in the pre-gunpowder era were various incendiary materials (sulfur, asphalt, petroleum, and quicklime were used in their preparation) that were either fastened to arrowheads or hurled across moats and walls from catapults.

Gunpowder's origins can be traced to the experiments of medieval Chinese alchemists and metallurgists. Clear directions for preparing gunpowder were published in 1040, and eventually the proportions for its mixing settled at approximately 75% saltpeter (KNO_3), 15% charcoal, and 10% sulfur. Whereas ordinary combustion must draw oxygen from the surrounding air, the ignited potassium nitrate provides it internally and gunpowder undergoes a rapid expansion equal to roughly 3000 times its volume in gas. The first true guns were cast in China before the end of the 13th century, and Europe was just a few decades behind. Gunpowder raised the destructiveness of weapons and radically changed the conduct of both land and maritime battles.

When confined and directed in barrels of rifles, gunpowder could impart to bullets kinetic energy an order of magnitude higher than that of a heavy arrow shot from a crossbow gun, and larger charges in field artillery and ship guns could propel even heavy projectiles (Table I). Increasingly accurate gunfire from far beyond the range of archers eliminated the defensive value of moats and walls and did away with lengthy sieges of cities and castles. As a new defense, the fortified structures were built as low spreading polygons with massive earthen embankments and huge water ditches. French military engineer Sebastien Vauban became the most famous designer of these fortifications that embodied large amounts of energy. His largest project, at Longwy in northeastern France, required moving 640,000 m^3 of rock and earth (volume equivalent to about a quarter of Khufu's pyramid) and emplacing 120,000 m^3 of masonry.

The impact of guns was even greater in maritime engagements. Detailed historical accounts document how gunned ships (equipped with two other Chinese innovations, compass and good rudders, as well as with better sails) became the carriers of European technical superiority. By the beginning of the 16th century, they were the principal means of global empire building by the nations of the Atlantic Europe. By the late 17th century, the largest "men-of-war" carried up to 100 guns each. Dominance of these ships did not end until the introduction of naval steam engines during the 19th century.

The next weapons era began with the formulation of high explosives, which are prepared by the nitration of organic compounds such as cellulose, glycerine, phenol, and toluene. Ascanio Sobrero prepared nitroglycerin in 1846, but its practical use did not begin until Nobel mixed it with an inert porous substance (diatomaceous earth) to create dynamite and introduced a practical detonator (Nobel igniter) without which the new explosive would be nearly impossible to use. A single comparison conveys the explosive power of dynamite: its velocity of detonation is as much as 6800 m/s compared with less than 400 m/s for gunpowder (Table II). Slower acting, and preferably smokeless, propellants needed for weapons were produced during the 1880s: *poudre B* (gelatinized and extruded nitrocellulose) by Paul Vieille in 1884, Nobel's own ballistite (using nitroglycerine instead of ether and alcohol) in 1887, and cordite, patented in England by Frederick Abel and James Dewar in 1889.

Ammonium picrate was prepared in 1886. Trinitrotoluene (TNT), which was synthesized by Joseph Wilbrand in 1863 and which must be detonated by a high-velocity initiator, was used as an explosive by the end of the 19th century. The most powerful of all prenuclear explosives, cyclonite (cyclotrimethylene-trinitramine, commonly known as RDX [royal demolition explosive] and now a favorite of some terrorists), was first made by Hans Henning in 1899 by treating a formaldehyde derivative with nitric acid (Table II). Better propellants and inexpensive, high-quality steels increased the power and range of field of naval guns from less than 2 km during the 1860s to more than 30 km by 1900. The combination of long-range guns, heavy armor, and steam turbines (a superior new prime mover invented by Charles Parsons during the 1880s that made much faster speeds possible) resulted in new heavy battleships, with *Dreadnought,* launched in 1906, being their prototype.

TABLE II

Detonation Velocity of Common Explosives

Explosive	Density (g/cm^3)	Detonation velocity (m/s)
Gunpowder	1.0	1350
Dynamite	1.6	5000
TNT	1.6	6700
RDX	1.8	8800
ANFO	1.0	3200

Other new highly destructive weapons whose use contributed to the unprecedented casualties of World War I included machine guns, tanks, submarines, and the first military planes (e.g., light bombers). The two decades between the world wars brought rapid development of battle tanks, fighter planes, and long-range bombers and aircraft carriers, all of which were the decisive weapons of World War II. The German defeat of France in 1940 and advances of Wehrmacht in Russia in 1941 and 1942 were made possible by rapid tank-led penetrations. Japan's surprising assault on Pearl Harbor on December 7, 1941, would have been impossible without a large carrier force that launched fighter planes and dive bombers. The same types of weapons—Soviet T-42 tanks driving all the way to Berlin and American dive bombers deployed by the U.S. Navy in the Pacific—eventually led to the defeat of the Axis.

The closing months of World War II saw the deployment of two new prime movers and of an entirely new class of weapons. Gas turbines, independently invented during the 1930s by Frank Whittle and Hans Pabst von Ohain in the United Kingdom and Germany, respectively, were installed in the first jet fighters (the British Gloster Meteor and the German Messerschmitt 262) in 1944. During that same year, rocket engines were used in the German ballistic missile V-2 to terrorize England. And the first fission bomb was tested at Alamogordo, New Mexico, on July 11, 1945, with the second one destroying Hiroshima, Japan, on August 6, 1945, and the third one destroying Nagasaki, Japan, 4 days later.

Jet propulsion enabled the fastest fighter aircraft to surpass the speed of sound (in 1947) and eventually to reach maximum velocities in excess of mach 3. The postwar arms race between the United States and the Soviet Union began with the assembly of more powerful fission bombs to be carried by strategic bombers. The first fusion bombs were tested in 1952 and 1953, and by the early 1960s the two antagonists were engaged in a spiraling accumulation of intercontinental ballistic missiles (ICBMs). But these are not technically weapons of war given that their real purpose was to deter their use by the other side. However, to achieve this objective, the superpowers did not have to amass more than 20,000 nuclear warheads. The sudden end of this expensive arms race did not usher in an era of extended peace; ironically, it initiated an era of even more acute security threats.

In a complete reversal of dominant concerns, the most common—and generally the most feared—weapons in the new war of terror are both inexpensive and easily available. A few kilograms of high explosives fastened to the bodies of suicide bombers (often spiked with metal bits) can cause dozens of deaths and gruesome injuries and can create mass psychosis among the attacked population. Simple "ANFO" car bombs are much more devastating (Table III). These devices, some of which weigh hundreds of kilograms and are able to destroy massive buildings and kill hundreds of people, are made from the mixture of two readily available materials: ammonium nitrate (a common solid fertilizer that can be purchased at, or stolen from, thousands of locations around the world) and fuel oil (which is even more widely available).

The most shocking weapons were fashioned on September 11, 2001, by 19 Islamic hijackers simply by commandeering rapidly moving massive objects, Boeings 757 and 767, and steering two of them into the World Trade Center in New York and one into the Pentagon in Washington, D.C. The World Trade Center towers were designed to absorb an impact of a slow-flying Boeing 707 lost in the fog and searching for a landing at the JFK or Newark airport. Gross weight and fuel capacity of that plane are just slightly smaller (15 and 5%, respectively) than the specifications for the Boeing 767-200, and the structures performed as intended even though the impact velocity of hijacked planes as they rammed into the buildings was more than three times higher (262 vs 80 m/s) than that of a slowly flying plane close to the landing.

As a result, the kinetic energy at impact was approximately 11 times greater than envisaged in the original design ($\sim$4.3 GJ vs 390 MJ). But because each tower had the mass of more than 2500 times that of the impacting aircraft, the enormous concentrated kinetic energy of the planes acted much like a bullet hitting a massive tree. That is, it penetrated instead of pushing; it was absorbed by bending, tearing, and distortion of structural steel and concrete; and the perimeter tube design redistributed lost loads to nearby columns. Consequently, it was not this instantaneous massive kinetic insult but rather a more gradual flux of the ignited fuel (each 767 carried more than 50 metric tons (t) of kerosene whose heat content was more than 2 TJ) that weakened the columns of structural steel.

Unfortunately, an eventuality of such a fire was not considered in the original World Trade Center design. Moreover, no fireproofing systems to control such fires were available at that time. Once the jet fuel spilled into the building, it ignited an even larger mass of combustible materials (mainly paper and plastics) inside the structures, and the fires burned with a diffuse flame with low-power densities of less than 10 W/cm^2. This left enough time for most people to leave the buildings before the thermally weakened structural steel (the fuel-rich, open-air fire could not reach the 1500°C needed to actually melt the metal), thermal gradients on outside columns, and nonuniform heating of long floor joists precipitated the staggered floor collapse that soon reached the free-fall speed as the towers fell in only approximately 10 s.

Although the preparation of the most feared viral and bacterial weapons of mass destruction requires a fair degree of scientific expertise and a high degree of technical expertise (particularly to prepare the cultured pathogens for widespread dispersal), the overall energy cost of their development is very low in comparison with their potential impact, be it measured in terms of actual casualties and ensuing population-wide fear or in terms of long-term economic losses. There is no doubt that even a largely failed large-scale smallpox or anthrax attack

TABLE III

Kinetic Energy of Explosives and Total Energy Released by Nuclear Weapons

Explosive device	Explosive	Kinetic energy (J)
Hand grenade	TNT	2×10^6
Suicide bomber	RDX	100×10^6
World War II gun shrapnell	TNT	600×10^6
Truck bomb (500 kg)	ANFO	2×10^9
Nuclear bomb	**Reaction**	**Total energy (J)**
Hiroshima bomb (1945)	Fission	52×10^{12}
U.S. ICBM	Fusion	1×10^{15}
Novaya Zemlya bomb (1961)	Fusion	240×10^{15}

on a major urban area would send property values falling and would lead to the flight of residents and businesses to less crowded locations.

2. ENERGY COSTS AND CONSEQUENCES OF WAR

Preindustrial land wars, fought largely by foot soldiers with simple weapons, did not require large amounts of energy embodied in arms and equipment, but even so, that investment was often a significant part of annual energy use in many poor subsistence societies. Large armies in transit, or during periods of prolonged sieges, almost always had a deep, and often quite ruinous, effect on regional supplies of food and fuelwood as they commandeered their provisions from the surrounding countryside. In contrast, maritime forays far from friendly shores always required careful planning of supplies that had to be carried by the ships during months of self-sufficient sailing.

Modern wars are waged with weaponry whose construction requires some of the most energy-intensive materials and whose deployment relies on incessant flows of secondary fossil fuels (e.g., gasoline, kerosene) and electricity to energize the machines that carry them and to equip and provision the troops who operate them. Production of special steels in heavy armored equipment typically needs 40 to 50 MJ/kg, and obviously, the use of depleted uranium (for armor-piercing shells and enhanced armor protection) is much more energy intensive. Aluminum, titanium, and composite fibers, the principal construction materials of modern aircraft, typically embody 170 to 250 MJ/kg, as much as 450 MJ/kg, and 100 to 150 MJ/kg, respectively.

The most powerful modern war machines are naturally designed for maximized performance and not for minimized energy consumption. For example, America's 60-t M1/A1 Abrams main battle tank, powered by a 1.1-MW AGT-1500 Honeywell gas turbine, needs (depending on mission, terrain, and weather) 400 to 800 L/100 km; in comparison, a large Mercedes S600 automobile consumes approximately 15 L/100 km, and a Honda Civic needs 8 L/100 km. Jet fuel requirements of highly maneuverable supersonic combat aircraft, such as the F-16 (Lockheed Falcon) and F-18 (McDonnell Douglas Hornet), are so high that no extended mission is possible without in-flight refueling from large tanker planes (the KC-10, KC-135, and Boeing 767).

Moreover, these highly energy-intensive weapons have been used in increasingly massive configurations; hence, the overall energy cost of a conflict can mount rapidly. The most concentrated tank attack during the final year of World War I involved nearly 600 machines, whereas nearly 8000 tanks, supported by 11,000 planes and by more than 50,000 guns and rocket launchers, took part in the final Soviet assault on Berlin in April 1945. During the Gulf War in 1991 ("Desert Storm," January–April 1991) and the months leading to it ("Desert Shield," August 1990–January 1991), some 1300 combat aircraft flew more than 116,000 sorties and the supporting transport and aerial refueling planes logged more than 18,000 deployment missions.

Another historically recurrent phenomenon is the necessity to expand the mass production of these energy-intensive machines in the shortest possible period of time. In August 1914, Britain had only 154 airplanes, but just 4 years later, the country's aircraft factories were sending out 30,000 planes per year. Similarly, when the United States declared war on Germany in April 1917, it had fewer than 300 second-rate planes, none of which could carry machine guns or bombs on a combat mission, but 3 months later Congress approved what was at that time an unprecedented appropriation ($640 million or ~$8 billion in 2000 dollars) to build 22,500 Liberty engines for new fighters. The situation was reprised during World War II. American industries delivered just 514 aircraft to the U.S. forces during the final quarter of 1940, but the total wartime production reached more than 250,000 planes, exceeding the combined output of Germany and Britain.

There are no detailed reasoned studies of energy cost of modern wars. This is not surprising given that even their financial costs cannot be accounted for with a fair degree of accuracy. This has to do primarily with deciding what to include in such accounts. When the very physical survival of a society is at stake, it becomes impossible to separate the output of such a wartime economy into easily identifiable civilian and military sectors and then to assign approximate energy costs to these activities. Available aggregates show the total U.S. expenditures on major 20th-century conflicts as approximately $250 billion for World War I, $2.75 trillion for World War II, and $450 billion for the Vietnam war (all in constant 2000 dollars). Expressing these costs in monies of the day and multiplying the totals by the adjusted averages of respective average energy intensities of the country's gross domestic product (GDP) during those periods sets the minimum energy costs of these conflicts.

Adjustments to average energy intensities are necessary because the war-related industrial production and transportation require considerably more energy per unit of output than does the rest of economic activity. Given the typical sectoral energy intensities of past GDPs, this article uses the conservative multiples of 1.5 for World War I, 2.0 for World War II, and 3.0 for the Vietnam war. Although this procedure cannot yield any accurate figures, it conveys well the most likely magnitude of the energy burden. This burden was approximately 15% of the total U.S. energy consumption during the 1917–1918 period (World War I), averaged roughly 40% during the 1941–1945 period (World War II), but was definitely less than 4% during the 1964–1972 period (main combat action of Vietnam war). Naturally, these shares could be significantly higher during the years of peak war endeavor. For example, the peak World War II spending, expressed as a share of national economic product, ranged from 54% in the United States (in 1944) to 76% in the Soviet Union (in 1942) and in Germany (in 1943).

Peacetime expenditures directly attributable to the preparation for armed conflicts can also be significant. For decades, the highly militarized Soviet economy was spending on the order of 15% of its GDP on the development, procurement, and maintenance of weapons and on its large standing army and border guard and paramilitary forces. In contrast, the U.S. defense spending reached nearly 10% of GDP during the peak year of the Vietnam war, fell to below 5% by 1978, rose to 6.5% during President Reagan's mid-1980s buildup, and has stayed below 5% since 1991. Given the enormous U.S. energy consumption (equivalent to $\sim$2.5 Gt of oil in 2000), the direct peacetime use of fuel and electricity by the U.S. military is a tiny fraction of the total. For example, the U.S. Department of Defense claimed less than 0.8% of the country's total primary energy supply in 2000.

But the comparison looks different in absolute terms. The average direct annual consumption of primary energy by the U.S. armed services was equivalent to approximately 25 Mt of oil during the 1990s. That is roughly the same amount of primary energy consumed annually by Switzerland or Austria; more remarkably, it is a total higher than the commercial energy consumption in nearly two-thirds of the world's countries. Naturally, operations such as the Gulf War, the war in Afghanistan, and the Iraq war boost the energy use by military not only due to the combat but also due to enormous long-distance logistic support. And of course, there are additional (and not easily quantifiable) expenditures of energy for the military research and development (R&D) and the procurement of weapons.

The link between energy use and success in modern war (or in preventing war) is far from being a simple matter of strong positive correlations. Of course, there is no doubt that the possession of nuclear weapons (the MAD [mutually assured destruction] concept) was the main reason why the two superpowers did not fight a thermonuclear war, but the nuclear stockpiles, and hence their energy cost, went far beyond any rational deterrent level. Development and deployment of these weapons, beginning with the separation of the fissile isotope of uranium and ending with the construction of nuclear submarines to carry them with nearly complete invulnerability during the extended submerged missions, has been highly energy intensive.

A conservative estimate might be that at least 5% of all U.S. and Soviet commercial energy that was consumed between 1950 and 1990 was claimed by developing and amassing these weapons and the means of their delivery. And the burden of these activities continues with expensive safeguarding and cleanup of contaminated production sites. Estimated costs of these operations in the United States have been steadily rising, and much greater investment would be needed to clean up the more severely contaminated nuclear weapons assembly and testing sites in Russia and Kazakhstan. Even so, given the potentially horrific toll of a thermonuclear exchange—even when limited to targeting strategic facilities rather than cities, the direct effects of blast, fire, and ionizing radiation would have caused 27 million to 59 million deaths during the late 1980s—one could argue that the overall cost/benefit ratio of the nuclear arms race has been acceptable.

Of course, there is no doubt that the rapid mobilization of America's economic might, which was energized by a 46% increase in the total use of fuels and primary electricity between 1939 and 1944, was instrumental in winning the war against Japan and Germany. In contrast, the Vietnam war was a perfect illustration of the fact that to win a war, it is not enough to use an enormous amount of explosives (the total was nearly three times as much as all bombs dropped by the U.S. Air Force on Germany and Japan during World War II) and to deploy sophisticated weapons (state-of-the-art jet fighters, bombers, helicopters, aircraft carriers, defoliants, etc.). The attacks of September 11, 2001, on the World Trade Center and the Pentagon illustrate the perils and penalties of the aptly named asymmetrical threats. In those attacks, 19 Muslim *jihadis*, at the cost of their lives and an investment that might not have surpassed \$100,000, caused approximately 3000 virtually instantaneous deaths (and the death toll could have easily surpassed 10,000 if the towers were not so structurally sound), created enormous direct and indirect economic dislocations, and led to costly deployments of military and covert power.

During the 2 years following the terrorist attacks, these costs (including the stock value declines and the lost economic output) could be estimated at nearly \$2 trillion—and the count keeps rising. Airlines still operate well below their pre-September 11 capacity and are not expected to recover, even in the absence of further attacks, before the year 2007. At the time of this writing, the proposed U.S. 2004 budget envisions nearly \$40 billion for the new Department of Homeland Security and approximately \$100 billion in additional spending for Iraq and Afghanistan besides the increased baseline spending on defense. Unfortunately, there is no easy military solution for this predicament. Both the classical powerful weapons and the new "smart" machines are of very limited use in this new, highly asymmetric global war, as are most of the security checks and precautions that have been taken so far at the airports.

The two most important and unprecedented consequences of warfare waged by modern societies are the just noted extent of economic mobilization for major armed conflicts and the growing magnitude of destructive power. The latter trend has brought increased casualties, including larger numbers of noncombatants, and huge material losses. World War I was the unmistakable divide. Enormous resources had to be rapidly diverted to war production, and the death toll, in both absolute and relative terms, surpassed that of any previous experience. The increasing destructiveness of modern wars is best illustrated by comparing the overall conflict casualties. Battle deaths, expressed as fatalities per 1000 men of armed forces fielded at the beginning of a conflict, were less than 200 during the Crimean War of 1853–1856 and the Franco–Prussian War of 1870–1871. They surpassed 1500 during World War I and 2000 during World War II (when they were more than 4000 for Russia).

Civilian casualties of modern warfare grew even faster. During World War II, they reached approximately 40 million, more than 70% of the 55 million total. Roughly 100,000 people died during nighttime raids by B-29 bombers using incendiary bombs that leveled approximately 83 square kilometers of Japan's four principal cities between March 10 and March 20, 1945. Five months later, the explosion of two nuclear bombs, which killed at least 100,000 people, released energy of 52.5 and 92.4 TJ, respectively (Table III). At that time, only a few people envisioned how much more powerful these weapons would get. Expressed in common units of TNT equivalents (1 t TNT = 4.184 GJ), the two bombs dropped on Japan rated 12.5 and 22 kt, respectively. The most powerful thermonuclear bomb tested by the Soviet Union, over the Novaya Zemlya on October 30, 1961, rated 58 Mt, equal to 4600 Hiroshima bombs, and by 1990 the total power of U.S. and Soviet nuclear warheads surpassed 10 Gt, the equivalent of 800,000 Hiroshima bombs.

Effects of major wars on energy consumption, be it in defeated countries or in the aftermath of major civil conflicts, are usually quite pronounced. The Soviet Union after the civil war of 1918–1921 and Germany and Japan after their defeat during the late 1940s are the best documented examples. Japan's accurate historical statistics reveal the magnitude of this impact. In 1940, the country's primary energy supply was an equivalent of approximately 63 Mt of oil; by 1945, the total had fallen nearly exactly by half; and in 1946, the aggregate declined by another 10%. The 1940 level was not surpassed until 1955, 10 years after the surrender.

3. *ENERGY AS THE CAUSE OF WAR*

Finally, this article concludes with a few paragraphs on energy resources as the *cassus belli*. Many historians single out Japan's decision to attack the United States in December 1941 as a classic case of such causation. In January 1940, President Roosevelt's administration, determined to aid the United Kingdom that was under Nazi attack, abrogated the 1911 Treaty of Commerce and Navigation with Japan. In July 1940, Roosevelt terminated the licenses for exports of aviation gasoline and machine tools to Japan, and in September the ban was extended to scrap iron and steel. Already by July 1940, some of Japan's top military officers warned that the navy was running out of oil and that they wanted a quick decision to act. An attack on the United States was to clear the way for the assault on Southeast Asia with its Sumatran and Burmese oilfields.

Although it would be wrong to deny the proximate role that Japan's declining oil supplies might have played in launching the attack on Pearl Harbor, it is indefensible to see Japan's aggression as an energy-driven quest. The attack on Pearl Harbor was preceded by nearly a decade of expansive Japanese militarism (so clearly demonstrated by the 1933 conquest of Manchuria and by the attack on China in 1937), and Marius Jansen, one of the leading historians of modern Japan, wrote about a peculiarly self-inflicted nature of the entire confrontation with the United States. No convincing arguments can made to explain either Hitler's serial aggression—against Czechoslovakia (in 1938 and 1939), Poland (in 1939), Western Europe (beginning in 1939 and 1940), and the Soviet Union (in 1941)—or his genocidal war against Jews by concerns about energy supplies.

The same is true about the geneses of the Korean War (North Korea is the coal-rich part of the peninsula), the Vietnam war (waged by France until 1954 and by the United States after 1964), the Soviet occupation of Afghanistan (1979–1989), and the U.S. war against the Taliban (launched in October 2001) as well as about nearly all cross-border wars (e.g., Sino–Indian, Indo–Pakistani, Eritrean–Ethiopian) and civil wars (e.g., Sri Lanka, Uganda, Angola, Colombia) that have taken place (or are still unfolding) during the past two generations in Asia, Africa, and Latin America. And although it could be argued that Nigeria's war with the secessionist Biafra (1967–1970) and Sudan's endless civil war had clear oil components, both were undeniably precipitated by ethnic differences and the latter one began decades before any oil was discovered in the central Sudan.

On the other hand, there have been various indirect foreign interventions in the Middle Eastern countries—through arms sales, military training, and covert action—that aimed at either stabilizing or subverting governments in the oil-rich region. Their most obvious manifestation during the cold war was the sales (or simply transfers) of Soviet arms to Egypt, Syria, Libya, and Iraq and the concurrent American arms shipments to Iran (before 1979), Saudi Arabia, and the Gulf states. During the 1980s, these actions included strong and, as it turned out, highly regrettable Western support of Iraq during its long war with Iran (1980–1988). This brings us to the two wars where energy resources have been widely seen as the real cause of the conflicts.

By invading Kuwait in August 1990, Iraq not only doubled crude oil reserves under its control, raising them to approximately 20% of the world total, but it also directly threatened the nearby Saudi oilfields (including the four giants—Safania, Zuluf, Marjan, and Manifa—that are on- and offshore just south of Kuwait) and, hence, the very survival of the monarchy that controls 25% of the world's oil reserves. Yet even in this seemingly clear-cut case, there were other compelling reasons to roll back the Iraqi expansion. At that time, the United States was importing a much smaller share of its oil from the Middle East than were Western Europe and Japan (25% vs more than 40% and 67%, respectively, in 1990), but the Iraqi quest for nuclear and other nonconventional weapons with which the country could dominate and destabilize the entire region, implications of this shift for the security of U.S. allies, and risks of another Iraqi–Iranian or Arab–Israeli war (recall Saddam Hussein's missile attacks on Israel designed to provoke such a conflict) certainly mattered a great deal.

There is one very obvious question to ask: if the control of oil resources was the sole objective, or at least the primary objective, of the 1991 Gulf War, why was the victorious army ordered to stop its uncheckable progress as the routed Iraqi divisions were fleeing north, and why did it not occupy at least Iraq's southern oilfields? Similarly, more complex considerations were behind the decision to conquer Iraq in March 2003. Although the *ex post* perspectives may question a justification based on the Iraqi development of weapons of mass destruction, it could be argued that Hussein's past actions and the best available prewar evidence did not leave any responsible post-September 11 leadership in the United States with the luxury of waiting indefinitely for what might happen next. Such a wait-and-see attitude was already assumed once, with fatal consequences, after the World Trade Center bombing in February 1993.

Of course, a no less important reason for the Iraq war has been the grand strategic objective of toppling the Baathist regime and to eventually replace it with a representative government that might serve as a powerful and stabilizing political example in a very unsettled region. Once again, after the events of September 11, one could argue that no responsible U.S. leadership could have ignored such a risky but potentially immensely rewarding opportunity to redefine the prospects for a new Middle East. And so even this instance, which so many commentators portray so simplistically as a clear-cut case of energy-driven war, is anything but that—yet again confirming the conclusion that in modern wars, resource-related objectives have been generally determined by broader strategic aims and not vice versa.

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