Famed World War II U.S. Gen. Omar Bradley is often cited as the originator of the famous military quote: “Amateurs study tactics, professionals study logistics.” Irrespective of its origins, the adage holds true for most extended conflicts — and World War II is no exception. Managing logistics for the production, movement and consumption of energy was one of the critical determinants of success during the war.

**How Oil and Water Helped the U.S. Win World War II**

Fred Beach and Michael E. Webber

Above: U.S. bombing squadron during World War II. Below: U.S. P-51 aircraft used during the war.

For example, in 1939, the U.S. Navy consisted of a grand total of 380 ships. By the end of the war, the fleet had grown to 6,700, of which 1,200 were auxiliary ships used for transporting fuel, ammunition and food. In the same six-year span, the U.S. produced more than 300,000 aircraft, 100,000 armored vehicles and tanks, and several hundred thousand bulldozers, halftracks, trucks and jeeps. Amidst this massive industrial mechanized mobilization, the U.S. also managed to conduct the largest single government development effort ever undertaken at that time: the Manhattan Project. Employing more than 130,000 people and requiring $22 billion in today’s dollars, the project developed the atomic bomb in just three and a half years.

This explosion of production leading up to and during the war was not unique to the U.S. Both Germany and Japan worked feverishly to supply their armies and navies with war material to counter the production of the U.S. and its allies, with a high degree of success. The Germans’ technical and industrial prowess in designing and manufacturing was legendary, and led to breakthroughs in armor, artillery, aviation, rocketry, submarines and small arms. Likewise, the Japanese produced some of the most capable aircraft and ships of the era. Although Germany and Japan made great quantitative and qualitative strides in arming and supplying their forces, the U.S. had two key strategic and logistical advantages: oil and water. Of course other factors played a major role in the U.S. and its allies winning the war, but these two natural resources played a larger role than many people realize.

On Sept. 2, 1945, spectators and correspondents from all over the world crowded on the deck of the USS Missouri in Tokyo Bay to watch the formal Japanese surrender ceremony marking the end of World War II.

The Tulsa Aircraft Assembly Plant at Tinker Airfield in Oklahoma City, Okla., quickly mobilized from producing civil works to building aircraft, ordnance, cantonments and much more after Pearl Harbor was attacked.
Oil for Petroleum

World War II was the first heavily mechanized war, and unlike World War I, was fought on a truly global scale. Powering and supplying such immense and globally disparate military forces required vast amounts of energy, something the U.S. — as the world’s largest petroleum producer at the time — had in much greater abundance than Germany or Japan.

Powering the broad range of ships, planes and land vehicles with their equally broad range of petroleum-based fuels and lubricants required millions of barrels of oil. Transporting people, munitions, food and fuel around the planet to multiple theaters of operation required even more.

Fortunately, in the early 20th century, the U.S. had begun an oil boom. And for enough oil to fuel the war, the U.S. looked to East Texas.

The Texas oil boom began in the early half of 1901 with the Spindletop oil discovery in eastern Texas. Although the discovery was large, production peaked in 1927 with an annual production of 21 million barrels and was nearly played out by 1936. Fortunately, Spindletop was followed by the 1930 Bradford discovery in Rusk County, also in eastern Texas. Bradford became the most significant find in the larger East Texas Field. By the summer of
1931, more than 1,200 wells were in production, supplying 900,000 barrels per day and driving oil prices down to just 13 cents per barrel (it had been as high as $1.10 when the field first started producing). In spite of state and federal attempts at limiting production to prevent further price collapse, the field produced more than 121 million barrels of oil and 627 million cubic feet of gas in 1931 alone.

Throughout the 1930s, the field continued to expand while state and federal regulations on production slowly took hold. By 1938, with more than 11,000 wells in operation, annual production was limited to stabilize the price at about $1.10 per barrel. In addition to Texas production, fields in Oklahoma, Louisiana and California pushed total U.S. oil production in 1935 to 900 million barrels. At that time, the U.S. was already using nearly all of its domestic production and in 1935 exported 50 million barrels while also importing 32 million barrels. Between 1935 and 1945, in order to support war efforts, annual production increased more than 50 percent to more than 1.6 billion barrels.

The only threat to the security of this oil was associated with its transport to the East Coast via the Gulf of Mexico. In 1942 and early 1943, several oil tankers were sunk by German U-boats off the East Coast. To circumvent this risk — in a feat that would be hard to duplicate today — the U.S. built a 2,300-kilometer-long pipeline more than half a meter in diameter between the East Texas fields and the nation’s major refineries and distribution hubs in Philadelphia. The project was completed in less than 20 months, between August 1942 and March 1944. The pipeline carried more than 350 million barrels of oil by the end of the war.

In contrast to this secure, cheap and nearly limitless supply of oil in the U.S., Germany and Japan had to fight for and import nearly all of their oil. The Germans were heavily dependent on the Soviet Union and Romania, drawing 75 percent of their oil supplies from them. This was one of the main reasons Nazi Germany signed a nonaggression treaty with the Soviets at the start of the war. In response to the difficulty in securing the supplies of petroleum it needed in the face of embargoes and relentless attacks by the Allies on oil supply lines, Nazi Germany started an ambitious program to turn abundant domestic coal into liquid fuels.

Likewise, in the late 1930s, Japan had relied on the U.S. for 80 percent of its oil (16.4 million barrels in 1935). The U.S. had been shipping oil and aviation fuel to Japan from the West Coast under a 1911 trade agreement. After Japan invaded Indochina in 1941, however, the U.S. issued an oil embargo against Japan. Japan retaliated with an attack on Pearl Harbor months later. Following that turn of events, Japan relied almost solely on oil from the Netherlands East Indies. This primary source was almost completely shut off by the end of the war through American submarine attacks on Japan’s oil tankers.

The United States’ secure supply of domestic oil and natural gas therefore became a crucial strategic factor in the logistics of the war.
Prior to Japan’s aggressions during World War II, the U.S. had been exporting oil to Japan, probably out of its tanks in Hawaii (right) among other places. It is likely that part of the reason Japan attacked Pearl Harbor (below) is because of the U.S. oil embargo.

**WATER FOR ALUMINUM AND PLUTONIUM**

Just as the mechanization of the highly mobile U.S. military and the ability to deploy and operate it around the planet would not have been possible without abundant and secure sources of petroleum, the ability to build an aerial armada of more than 300,000 advanced aircraft would not have been possible without enormous quantities of aluminum. And that, in turn, required enormous amounts of electricity and thus water. Likewise, the development of the atomic bomb also required tremendous water resources — something the U.S. had in abundance.

In 1935, the U.S. was producing more than 45,000 metric tons of aluminum a year. By 1943, that production had grown by more than a factor of 16 to more than 726,000 metric tons a year. Obtaining the bauxite ore to support this expansion in production was not a problem as there were ample sources throughout the U.S. Producing the electricity necessary to turn it into aluminum was a different matter. The difference between steel — made with metallurgical coal — and aluminum is that steel is smelted with heat and aluminum is smelted using an electrolytic process that requires 10 kilowatt-hours of electricity for every pound produced. Consequently, in the early decades of the 20th century, America’s principal aluminum producer (ALCOA) had been building not only smelting factories but also hydroelectric dams to provide them electricity.

By the mid 1930s, ALCOA had built three dams on the Little Tennessee River as well as two in western North Carolina. The three dams in Tennessee alone provided a combined 265 megawatts of power to ALCOA’s smelters in Tennessee. With the outbreak of World War II and the increase in demand for aluminum, ALCOA joined forces with the Tennessee Valley Authority to obtain even more hydroelectric power to run their rapidly expanding smelting facilities. But even this build-out was not producing enough aluminum to meet the insatiable demands of the military.

To find more electricity, ALCOA looked west to the hydroelectric dams on the Columbia River in Oregon and Washington. They built a string of factories between Longview and Spokane, Wash., powered by dams such as the Bonneville and Grand Coulee. The hydroelectric power plant at the Grand Coulee dam in particular, which generates 6.8 gigawatts of power, equivalent in size to about six nuclear power plants, is still the nation’s largest power plant.
The proximity of these Columbia River-powered aluminum smelters to the growing aviation industry of the Pacific Coast was symbiotic. The bulk of the aluminum from these plants traveled a short distance by rail, either north to Boeing’s aircraft plants on Puget Sound or south to the plants of Douglas, Consolidated, North American, Curtis, Lockheed, Northrop, Hughes and others in the Los Angeles Basin (all powered with electricity from Boulder, now Hoover, Dam on the nearby Colorado River). Wartime aluminum production peaked in 1943 at 834,600 metric tons in a year; aircraft production peaked in 1944 with 96,318 planes. In 1943, the aluminum industry became the single-largest consumer of electricity in the country, requiring 22 billion kilowatt-hours annually.

This dramatic growth in the aluminum industry was nearly eclipsed by another engineering feat: By 1944, the nation’s second-largest consumer of hydropower was an industry that hadn’t even existed in 1943. It was also the nation’s most highly guarded secret.

The development of the atomic bomb under the Manhattan Project was unique in that from the outset, no one knew how to build an atomic bomb or even if it could be done. As a consequence of this uncertainty and the exigency of the effort, under fear that the Germans might succeed before the U.S., two different design approaches were pursued. One bomb used uranium-235 (U-235) as the fissile material and another used plutonium-239 (Pu-239).

Both potential fissile materials are difficult to procure. Because U-235 constitutes only about 0.7 percent of naturally occurring uranium, with the other 99 percent being unusable U-238, huge amounts of uranium would have to undergo an enrichment process to separate out the U-235. Similarly, because plutonium doesn’t exist in nature, it would have to be
produced artificially in nuclear piles (the predecessors of nuclear power reactors) that had yet to be designed or built. Both options would require electricity and water.

Instead of choosing just one approach to obtaining U-235, the Manhattan Project leaders decided to simultaneously pursue three different methods of uranium enrichment to minimize risk should any one approach fail. The three most promising methods — gaseous diffusion, electromagnetic separation and thermal diffusion — would all require a great deal of electricity.

Just like ALCOA, the Manhattan Project turned to the power of water to generate vast amounts of cheap electricity to meet its mission. In particular, they saw what the Tennessee Valley Authority was doing with its dams, and began construction of what would become Oak Ridge National Laboratory just a few tens of kilometers to the west of ALCOA. By the end of the war, Oak Ridge had grown to be the fifth-largest city in Tennessee, and the three separate enrichment facilities located there were consuming one-seventh of all power produced in the nation.

But even this level of effort could not produce enough highly enriched U-235 for more than one uranium bomb by 1945. The second path to a nuclear weapon, plutonium, proved to be a good bet. To produce large amounts of plutonium, the Manhattan Project engineers planned to build three nuclear reactors specifically designed to enhance the production of Pu-239 as a byproduct of fission between U-235 and U-238. As the plutonium would have to be chemically separated, they also needed two large facilities to handle this very dangerous work.

Again, the Manhattan Project followed ALCOA’s lead and this time they turned to the Pacific Northwest. A remote site of more than 2,000 square kilometers was chosen in southern Washington due to its proximity to the Columbia River for cooling water and the Bonneville and Grand Coulee Dams for electrical power. Known as the Hanford site, it is today also the location of the U.S. Department of Energy’s (DOE) Pacific Northwest National Laboratory, which continues to produce significant scientific and technological breakthroughs.

The three reactors were placed on the banks of the Columbia River for access to cooling water, at several kilometers apart for safety reasons. The reactors were designed to produce plutonium, not power, and consequently, the enormous amount of heat they generated in the fission process had to be removed. During operation, each of the three reactors required a continuous flow of 75,000 gallons per minute of the Columbia’s chilly water. The two enormous separation facilities also needed cooling and electricity, both supplied by the Columbia River.

The atomic efforts ongoing at Oak Ridge and Hanford came together at Los Alamos in New Mexico (now the location of DOE’s Los Alamos National Laboratory, another world-class center for innovation). The production of the Little Boy uranium bomb used against Hiroshima and the Fat Man plutonium bomb dropped on Nagasaki would not have been possible in such a short time period were it not for the abundant water resources of the Tennessee Valley and Columbia River.

Meanwhile, Japan did not have a nuclear program (and has limited hydroelectric resources, anyway). Germany pursued a nuclear program, but because of its limited hydroelectric resources within its borders, the country had to look northward to Norway for abundant, cheap electricity (and for heavy water, or deuterium, to serve as a moderator for nuclear chain reactions), compounding its efforts to conduct a major weapons program in a secret and nonvulnerable way.
In the end, the success of the U.S. and its allies in World War II was due to more than just abundant and reliable sources of oil and hydropower in America. However, if it had not been for these natural resources, the speed and scale of the mechanization of the U.S. military and its allies would have been significantly reduced, particularly in the early years of the conflict. The fact that these resources did exist and were already being tapped and utilized in the 1930s allowed for their rapid expansion prior to the U.S. entering the war and contributed significantly to the conduct of the war — and its ultimate outcome.

Looking forward to the prospects of looming scarcity for both of these liquids, we might ask ourselves which resources will give us the great strategic advantage that oil and water gave us in the 1940s. Perhaps sun and wind?

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