Little Green Men: The Growth of Sustainable Warfare
in the United States of America

by

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Abstract

Since the first days of President Barack Obama's administration, the U.S military has embarked on an ambitious plan to change the way its fighting forces—Army, Navy, Marine Corps and Air Force—fight and fuel wars. Since 2009, the U.S. Department of Defense has taken great strides to incorporate renewable energy technology into its infrastructure and operations. It has also made significant gains in improving the efficiency with which fossil fuels are still used. As the most technologically advanced military in the world, the armed forces of the United States are well ahead of all other nations when it comes to adopting and advancing renewable energy in warfare.

War has always driven the most important technological advances in human history. From agriculture to industry, medicine to commerce, through to the modern artificial intelligence and automation industries, technological breakthroughs are often hatched inside military research laboratories, tested on the battlefield and are later adopted for broad civilian use. Whether these technologies are developed first for the military—as in the harnessing of atomic energy, the development of the Internet, drone technology, digital photography and GPS mapping—or first in the civilian marketplace before military absorption and amplification, is not a central question of this study. That is to say that whether the military spearheads a technology's creation or is the thrust behind the spear matters little. The considerable capital, research and development, manpower and infrastructural investments that the U.S. Department of Defense affords technologies deemed useful to warfare is here the key difference-maker in a technology's

development. From successful military research and implementation follows the near certainty of wider adoption in civilian form.

And so, as the furthest along of the world's militaries in the adoption of renewable power—from using solar photovoltaic cells to electrify domestic military installations to using plant-based biofuels in stealth fighter jets and naval carrier groups—the U.S. military, the world's largest consumer of oil, is entering the throes of a renewable energy revolution that will forever change how, why and where wars are fought in the future.

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Introduction

This is not a study on how green energy will save the world. It is quite the opposite. It is not a study on how the United States military, the most advanced fighting force in human history, is rededicating itself to the protection of the environment over the exertion of American influence over all parts of the globe. Nor is it, finally, a study on “green-washing,” the process by which an institution—public, corporate or otherwise—will don a mask of social responsibility for the public relations benefit of perceived environmental stewardship. It is, rather, a study on the changing habits of fuel consumption in the United States military, away from petroleum fuels towards renewable energy sources, not for altruistic or even perceived altruistic motives, but purely for the gain of strategic and technological advantage.

As all branches of the U.S. military are fond of saying, “using energy efficiently enables us to go farther, stay longer and deliver more firepower” (Cragg, 2016). That is not to say, however, that the U.S. military does not concern itself with climate change. Indeed, a wealth of Pentagon-funded studies on the global effects of climate change have been generated over the past decade, illustrating that those in the highest ranks of U.S. military command are deeply concerned with understanding how a rise in global temperatures and sea levels increases the likelihood of military conflict worldwide.

But, again, this concern is also purely strategic; it is born from the desire to develop long-term operational scenarios in order to preserve and extend American power, and not from

motivations commonly associated with the environmental or “green” movement. This is also a study of how the changing energy consumption habits and renewable energy innovations of the U.S. military are leading a renewable energy revolution within the civilian United States as a whole.

Chapter One: A Brief History of the Role of Fuel in Military Conflict

The use of oil made it possible in every type of vessel to have more gun-power and more speed for less size or less cost. It alone made it possible to realize the high speeds in certain types which were vital to their tactical purpose. All these advantages were obtained simply by burning oil instead of coal under the boilers... But oil was not found in appreciable quantities in our islands. If we required it, we must carry it by sea in peace or war from distant countries... To commit the Navy irrevocably to oil was indeed 'to take up arms against a sea of troubles'... Yet beyond the breakers was a great hope. If we overcame the difficulties and surmounted the risks, we should be able to raise the whole power and efficiency of the Navy to a definitely higher level; better ships, better crews, higher economies, more intense forms of war power—in a word, mastery itself was the prize of the venture.

—Winston Churchill, *The World Crisis* (1923)

Early History

While the history of using crude oil as a weapon of warfare can be traced back through the 8th century B.C., as documented in Homer's *The Iliad*, through to the reign of Persian King Cyrus during a sixth-century B.C. attack on Babylon (south of modern-day Baghdad), and into the seventh-century Byzantine Empire, where it was known as *oleum incendiarum*, or "Greek fire," this chapter focuses solely on the use of petroleum as a fuel for the engines of modern war machines of the past century (Yergin, *Prize*, p. 8). In fact, oil and its usefulness in combustion were largely lost on the Roman Empire and Middle Ages Europe, only to surface in the West in the mid-1800s after its simultaneous discovery in parts of Europe, Ontario and Pennsylvania, where kerosene, oil's first distillate, would soon replace whale oil as the chief source of

manmade light. It was here, in the U.S. northeast of the late-1850s, that the burgeoning oil industry grew so quickly that, by the time the secessionist southern states fired the first shots of the Civil War on Fort Sumter, South Carolina in 1861, kerosene was already well-placed to supersede the turpentine-based lamp fuels still found in the South. Those shipments of turpentine, it's worth noting, would be cut off by the North during the war, thereby vastly expanding kerosene's market in the continental U.S. (Yergin, *Prize*, p. 30).

But it was only much later with the advent of the combustion engine that the chief market for oil production and refining would be found not in kerosene but in gasoline and diesel fuel—two previously worthless byproducts that, before the engine, were routinely dumped into rivers and streams during the kerosene refining process. It was these new petroleum fuels that would, at the beginning of the 20th century, allow not only the rapid mechanization of warfare but of the industrial societies of North America and Europe, as a whole. In 1912, Britain's First Lord of the Admiralty, Winston Churchill, established the Royal Commission on Oil Supplies, becoming the first among the world's high-ranking military leaders to see the strategic potential of petroleum in warfare.

First World War

Before coal power, the British Royal Navy was a “blue-ocean”—or long-range—fighting fleet under wind-powered sail. Relying on coal meant instead that the Navy's ships, while now faster and more maneuverable against the vagaries of the weather, had to remain permanently within reach of land-based coal supplies or risk being stranded. Ships powered by oil, however,

could be refuelled while at sea, a conversion that would restore the Royal Navy to a true blue-ocean fleet. As the head of the Royal Navy, then the world's mightiest marine fleet and the uncontested ruler of the high seas, Churchill argued passionately, and ultimately successfully, to convert the empire's coal-fired warships to oil in the lead up to the First World War. "Britain was particularly concerned since the Royal Navy was the United Kingdom's principal source of international power and the guardian of both its trade and its independence" (Bercuson and Herwig, p. 1). It was a high-risk gamble. Britain at the time had no known reserves of oil and plenty of coal in Wales, opting instead to rely on American and Persian oil assets. But the gamble ultimately paid off with the crushing Allied victory over the German Imperial Navy in the all-important sea war.

But the new petroleum fuel didn't merely deliver improved war-fighting potential at sea. With superiority in both coal and iron reserves, by early September 1914 the German forces of the Central Power axis had encircled much of France from Verdun to the Alps and were closing in on Paris, where 100,000 civilians had already been evacuated (Yergin, *Prize*, p. 152). The French capital appeared destined to fall, and with it the heart of the Allies' continental European resistance. A fierce battle between the French and German armies was raging east of the city near the river Marne, less than 50 kilometres from the centre of Paris, in what was the first major battle of the Western Front. Despite scoring some early advances, the French army was desperately short of supplies and reinforcements, which remained housed in the garrisons and armouries around Paris. Unable to move by rail due to the system's disruption, and unable to march because of the rapid urgency with which they were needed, the French reinforcements were left with no military transport option with which to replenish their front lines and halt the

German approach on the capital in what would become then the largest battle in history (Hanc, 2014). That's when General Joseph-Simon Gallieni, then the military governor of Paris, had an idea that would change the course of the battle and the war. "He was a military genius and a master of improvisation, and in the face of bleak necessity, he was the first to grasp the possibilities of yoking motor transport and the internal combustion engine to the exigencies of warfare" (Yergin, *Prize*, p. 153).

The plan was to assemble all the available taxi cabs and cab drivers of Paris, an estimated 3,000 apiece, at the Place des Invalides, where they would pick up and shuttle thousands upon thousands of soldiers to the critical point on the front line, in what became known as the Taxi Armada. The efforts of the taxi drivers "helped save Paris," Yergin writes, and, in turning back the German offensive, "had also demonstrated, under General Gallieni's improvisational tutelage, what motorized transport would mean in the future" (Yergin, *Prize*, p. 154). While some recent scholarship has downplayed the taxi armada's importance in truly turning the tide of the battle—most notably, a 2014 article in *Smithsonian* magazine which emphasizes that trains were still able to get to parts of the front line—even those articles have acknowledged the event's lasting importance on French society, then and today. "[The taxis episode] had a real effect upon the morale of the both the troops and the civilian population, as well as upon the German command," writes Arnaud Berthonnet, a historian at the Sorbonne University in Paris, as quoted in *Smithsonian*. "More marginal and psychological than operational and militaristic in importance, this 'Taxis of the Marne' epic came to symbolize French unity and solidarity."

Of course, the First World War was also an important proving ground for the utility of

the internal combustion engine in other ways. In the 1916 Battle of the Somme, the British army put into service the first petroleum-fuelled, track-mounted armoured vehicle, now known around the world by its then code name, the “tank.” When the German High Command inevitably declared in October 1918 that victory was no longer possible, the first reason it gave was the introduction of the tank and its ability to decisively break the stalemate of trench warfare (Yergin, *Prize*, p. 155).

Advancements in petroleum-fuelled combustion also brought warfare for the first time to the skies. In 1903, a decade prior to the outbreak of the Great War, the Wright brothers had made their first flight at Kitty Hawk, North Carolina. But commercial winged aviation would not take off until after its debut over the European battlefield. At the outbreak of the war in 1914, the sum total of people involved in the British aviation industry numbered just 1,000, and by January 1915, five months later, the industry had built only 250 planes—sixty of them experimental (Yergin, *Prize*, p. 155). But the British aviation trade scaled up very quickly thereafter, largely by pressing the automobile industry into service as its manufacturing base. By July 1915, every type of British airplane that had been in the air at the outbreak of the war, less than a year earlier, was now obsolete, replaced with faster, more powerful craft (Yergin, *Prize*, p. 156).

While fixed-wing aviation in warfare was first used for crude reconnaissance and battlefield observation, by 1916 planes with mounted machine guns were flying in formation and tactical bombing had been introduced to the war with devastating effects. Since then, aerial bombardment has been a military mainstay; the prime motivator for possessing war-fighting aircraft, and the preferred method with which all modern war is waged by Western countries.

During the First World War, the Allied countries of Britain, France and Italy together produced 143,000 warplanes, with the United States adding another 15,000 planes over the course of its year and a half in the conflict. Germany, on the other hand, while still favouring the slower and largely ineffective zeppelin, produced just 48,000 planes for the Central Powers, with the Ottoman and Austro-Hungarian empires producing none (Gray, Thetford, 1970; Yergin, *Prize*, p. 156). Petroleum-powered airplanes afforded greater range and speed on the battlefield, and also reduced risks to service members—especially in contrast to the sheer volume of firepower they could deliver in turn. “Since the war broke out,” writes one British aviation observer in early 1915, “the aeroplane has done such surprising things that even the least imaginative begin to realize that it affords a vital adjunct to naval and military operations, and possibly even a vehicle for ordinary use when war ceases” (Penrose, p. 9).

Due to the massive amounts of acceleration and lift that modern fixed-wing aviation requires, it remains one of the most energy intensive forms of transportation in existence, barring only perhaps the overwhelming volume of energy expelled by rocket propulsion during space exploration. It’s for that reason that aviation fuel is one of the most difficult fuels to efficiently replace with the less dense, non-liquid renewable fuels such as solar or wind energy. Though, as we’ll see later, renewable aviation fuel is an area that has made some of the most dramatic technological gains toward efficient civilian and military transport today.

For the combatant nations of the First World War, the speed at which the oil-powered combustion engine was adopted and deployed proved a decisive turning point in both the war’s outcome and in the future prosperity of their respective civilian transportation sectors, industries

and societies. “In many ways,” writes one American aerospace engineer and historian, “the First World War on the Western Front had been a contest between two technological systems, with [the Central Powers’] coal, steam, and railroads facing off against [the Alliance’s] oil, internal combustion engines, and automotive transport” (Zubrin, p. 227). By the time the Second World War began in 1939, every combatant nation had abandoned coal power for all but the lowest priority tasks of the war effort and was instead using oil as the primary fuel for both its military and its civilian sectors.

Second World War

By the time Germany invaded Poland on September 1, 1939, drawing subsequent declarations of war from both Britain and France and effectively starting the Second World War, Germany had amassed a mighty terrestrial, aerial and naval war machine, all of it powered by oil. Formidable as it was, this machine presented one big problem: Germany possessed no significant oil resources. Indeed, concerns over oil’s scarcity helped shape Hitler’s strategic approach to war, which was based on the *blitzkrieg*, or lightning war—“fierce but short battles with concentrated mechanized forces that would lead to decisive victory before petroleum supply problems could develop” (Yergin, *Prize*, p. 316).

What Germany did possess, however, were significant deposits of coal and the lower-grade combustible rock known as lignite, as well as two brilliant chemists by the names of Franz Fischer and Hans Tropsch. Together they developed the Fischer-Tropsch Process, a chemical reaction that converted coal- and lignite-derived carbon monoxide and hydrogen into synthetic

gasoline and diesel fuel. It's a process that's still in use today, most notably in the similar conversion of plant-based biomass into renewable liquid fuels. The Fischer-Tropsch coal-to-liquids program in Second World War-era Germany was the world's first large-scale synthetic fuel program. And for the success of the country's war effort, it was an absolute necessity. By the time Hitler's Fourth Panzer Division tanks were rumbling over the border into Poland, Germany was operating 14 Fischer-Tropsch synthetic fuel plants, with six more under construction, powering those tanks and producing 95 per cent of the aviation fuel used by the Luftwaffe. "Without the Fischer-Tropsch process, Hitler and Nazi Germany would have lacked the fuel resources needed to launch World War II" (Corsi, p. 4).

Meanwhile, half a world away, the leadership of the small but rapidly industrializing island nation of Japan was also threatening its neighbours with expansionism under similar rationales of cultural superiority, scarcity of resources and "living space," and the restoration of a flagging economy that had been under foreign attack through unequal treaties and currency constraints. Like Germany, Japan utterly lacked the domestic petroleum resources required to power a modern war machine in the lead-up to the Second World War—and, of course, still lacks them today. The country's Seven Year Plan of 1937 called for "the construction of 87 synthetic fuel plants using the Fischer-Tropsch process by 1944, with the goal of producing 6.3 million barrels annually each of synthetic gasoline and synthetic diesel fuel" (Corsi, p. 5). That same year, 1937, Japan invaded China, sparking the Second Sino-Japanese War. On the Japanese side, the conflict was fuelled—quite literally—with the support of the United States in providing military equipment and, most importantly, nearly all of the Japanese navy and air force's oil (Yergin, *Prize*, p. 293). But public sentiment in the U.S. turned sharply against Japan as reports

of attacks by Japanese soldiers on Chinese civilians began to mount. Another sticking point with the American public—and with Washington—was Japan's growing ties with Nazi Germany after the signing of the Anti-Comintern Pact of 1936, which, when joined later by Italy and Spain, would solidify the fascist alliance that came to be known as the Axis Powers of the Second World War.

Japan was caught in a paradox due to its fuel demands. The paradox saw it “resisting German pressure to move closer—chiefly, Tokyo explained to Berlin, because Japan's dependence on the United States and the British Empire for its indispensable raw materials, and for oil in particular, meant that it ‘was not yet in a position to come forward as an opposer of the Democracies’” (Yergin, *Prize*, p. 293). Japan's war with China only strengthened its trade and energy dependence on the United States, while at the same time its policies were putting it ever closer to a war footing with its main oil supplier. To help alleviate its energy burden, Tokyo imposed strict rationing of oil and fuel supplies for the domestic market. This included the Japanese fishing fleet, one of the main sources of Japan's food, which was ordered to give up oil and rely exclusively on wind power (Yergin, *Prize*, p. 293).

In 1940, when the Japanese invaded French Indochina—modern-day Cambodia, Laos and Vietnam—in an attempt to block American war supplies from entering China, the American strategy had shifted to full support of China. In retaliation, the United States froze Japanese assets in the U.S. and put an embargo on oil exports to Japan, which had been stockpiling American fuel in case of sanctions following its drive further into Southeast Asia. Britain followed with its own freeze on Japan, cutting off oil supplies from Borneo. The Netherlands

joined the embargo too, stopping all oil supplies to Japan from the Dutch East Indies (Yergin, *Prize*, p. 302). It was there, in modern-day Indonesia, that Japan, under pressure from its navy to cut through the tightening energy noose or else risk its warships becoming “nothing more than scarecrows,” as its then chief of the naval general staff put it, decided to attack next (Yergin, *Prize*, p. 303).

Japan had calculated that an attack on the Dutch East Indies and the seizure of its vast oil assets would immediately draw a declaration of war against it from the United States. That calculation, whether correct or not, inspired Japan’s surprise attack on the U.S. Navy’s Pacific Fleet at Pearl Harbor. The plan was not to enter a prolonged conflict with the U.S., but to knock out America’s naval presence in the Pacific and prevent a U.S. counterattack on the Japanese invasion of the East Indies:

The operation against Pearl Harbor was meant to protect the flank—to safeguard the Japanese invasion of the Indies and the rest of Southeast Asia by incapacitating the American fleet and, thereafter, to protect the sea lanes, particularly the tanker routes from Sumatra and Borneo to the home islands. The primary target of this huge campaign remained the oil fields of the East Indies.

(Yergin, *Prize*, p. 309)

The Japanese attack on Pearl Harbor was thoroughgoing enough to sink, capsize or severely damage eight American battleships, three light cruisers, three destroyers and four auxiliary craft, along with destroying hundreds of American war planes and more than 2,300 U.S. servicemen. And yet, the Japanese war planners, despite their obsession with America’s dominant position in oil, apparently failed to grasp the importance of the sheer volumes of oil the

U.S. Navy had stored on the surrounding island of O'ahu (Yergin, *Prize*, p. 310). U.S. Naval Admiral Chester Nimitz, who would become Commander in Chief of the Pacific Fleet, later mused about how a successful attack on the Navy's vulnerable oil tanks around Pearl Harbor would have paralyzed every ship in the American fleet until sufficient resupplies could arrive from California, several thousand kilometres away. "All of the oil for the Fleet was in surface tanks at the time of Pearl Harbor," Nimitz said. "We had about four and a half million barrels of oil out there and all of it was vulnerable to .50-caliber bullets. Had the Japanese destroyed the oil, it would have prolonged the war another two years" (Zimm, p. 316).

On the eve of Pearl Harbor, the United States was not only the world's dominant oil exporter, but was virtually self-sufficient in meeting its own domestic fuel needs. In 1941, the country was importing just 2.9 per cent of its oil requirements, or 140,000 barrels per day, while its daily domestic production totaled 3.8 million barrels (Bercuson and Herwig, p. 12). While that's a sharp contrast to Germany and Japan, whose necessary preoccupation with securing foreign oil assets led to ultimately disastrous wartime campaigns into Russia and Southeast Asia, respectively, the United States, due in large part to its economy's energy-hungry post-war boom, would never be so self-sufficient in oil again.

The Japanese plan of 1937 to build a significant synthetic fuel industry ultimately proved overly ambitious and too taxing on the country's dwindling supplies of steel and industrial equipment. "In the months before Pearl Harbor, some in Tokyo had championed synthetic fuels as an alternative to war" with the U.S. (Yergin, *Prize*, p. 340). One crucial mistake was the location of much of Japan's synthetic fuel industry in the seized territory of Manchuria, where by

1944 it had been rendered useless by Allied blockades (Yergin, *Prize*, p. 340).

The German synthetic fuel campaign proved successful for a time, despite the fuel's production proving to be "six times as expensive as natural crude" (Bercuson and Herwig, 2). That period of success came to a quick end, however, once the Allied bombing of the German homeland began in earnest and the synthetic fuel plants became a priority target. One such plant was I.G. Farben's synthetic fuel factory in Leuna, Germany, then the most heavily defended industrial site of the Axis Powers, complete with whole sections of decoy buildings and a perennial aerial smoke screen. A staff of thousands of anti-aircraft gunners at the Leuna plant comprised the largest single flak concentration in all of Europe, making air raids on the plant "the most dangerous and difficult assignment of the air war," in the eyes of U.S. pilots (D'Olier et al., p. 22). It was Germany's biggest synthetic fuel plant and, in May 1944, a sustained U.S. air campaign began that would see 6,552 bomber sorties drop 18,328 tonnes of bombs on and around the factory (D'Olier et al., p. 23). When Albert Speer, Germany's minister of armaments and war production, heard about the raid, he rushed by plane to Leuna to survey the damage for himself. "I shall never forget the date May 12," he later wrote. "On that day the technological war was decided" (Yergin, *Prize*, p. 329).

From that May onwards through the remainder of the war, German fuel consumption would outpace production. By December, Luftwaffe pilot training had ceased for lack of aviation fuel and entire Panzer tank divisions were immobilized and overrun in the field due to lack of gasoline (D'Olier et al., p. 23). "On May 12, 1944, the day of the Leuna raid, the Third Reich ruled an empire comprising nearly all of continental Europe, with a collective population and

industrial potential exceeding that of the United States. A year later, it did not exist.” (Zubrin, p. 244). Tellingly, on a nighttime trip to survey the status of German armaments in Italy near the end of the war, Albert Speer had “seen before him a clear vision of one of the primary reasons why the Reich that was to last for a thousand years had, in fact, only weeks to go” (Yergin, *Prize*, p. 332). The Nazi minister came upon a column of 150 German army trucks, to which were hitched four oxen each, as it was then the only way the trucks could move at all (Yergin, *Prize*, p. 332). The fuel was gone. Ironically, in those final weeks of April 1945, there *was* enough fuel left in Germany to carry out Hitler’s final order: to douse his body in gasoline and set it alight once he had committed suicide, lest it fall into the hands of the enemy.

For the Japanese, the fuel situation was no less dire. As oil imports to Japan dwindled through the war, civilian gasoline consumption in 1944 fell to just four per cent of its 1940 level (Yergin, *Prize*, p. 340). This sparked an early attempt by Japan to retrofit some petroleum-consuming sectors with rudimentary renewable fuel technology. Gasoline-driven vehicles that were considered essential to the war effort were equipped with wood-burning engines, and petroleum-derived oils for industry were made instead from soybeans, coconuts, peanuts and castor beans. Civilian supplies of foodstuffs such as potatoes, rice wine, sugar and sake were commandeered to make alcohol to power combustion engines (Yergin, *Prize*, p. 340). But it was all too little, too late. By August 1945, when American bombers set off to deliver the fatal atomic blows to Hiroshima and Nagasaki, effectively ending the Second World War, the American B-29s required no fighter escort as the Japanese air force had literally run out of gas (Zubrin, p. 243).

Post-War

The advantageous distribution of much of the world's oil deposits among the victor nations of the Second World War—notably the United States and Russia—had largely decided the fate of the conflict. But some at the time believed the end of the Second World War would mean the end of oil's reign as the modern world's fuel of choice, and that America's harnessing of wartime nuclear energy would herald the dawn of a global Atomic Age. Nuclear power would replace petroleum as oil had replaced coal, fueling not just electricity generation but transportation, too. The Ford Motor Company, in 1958, unveiled the Ford Nucleon, a concept car powered by steam generated using onboard uranium fission. It didn't catch on. But from a military standpoint, nuclear power revolutionized key areas of naval transport—take for instance, the emergence of the U.S. Navy's fleet of nuclear-powered submarines, aircraft carriers and cruisers, all of which are still in use today. Still, the notion of a nuclear-powered world—especially a civilian one—would never reach its full potential, due in large part to public fears of radiological disasters and the lingering horrors of the destructive power of the atomic bombs that ended the Second World War. Those fears were exacerbated in the post-war era as civilian nuclear mishaps, such as Three Mile Island in the U.S. and Chernobyl in the Soviet Union, became synonymous with the nightmarish potential of radiological accidents. Meanwhile, the very real threat of *intentional* global nuclear annihilation at the hands of the two American- and Soviet-aligned power blocs loomed larger still, with both sides racing to outdo one another with ever more redundantly world-destroying nuclear weapons.

Unlike oil or coal before it, nuclear energy depended less on geography than on

technological expertise. Thus, a nuclear physicist armed with a comparatively small amount of radiological material could be enough to establish a country as a nuclear power. This remains the case today. But it's no accident of history that it was within the context of the emergent nuclear age that the first sprouts of the "green energy" movement would begin to take hold in the U.S. and globally, in lockstep with the new politics of environmental conservation and nuclear non-proliferation in both its civilian and military forms.

Chapter Two: The Great Green Fleet

“If it’s good enough for the United States Marine Corps at a forward operating position, what the heck is wrong with the rest of us?”

—U.S. Navy Assistant Secretary Dennis McGinn, 2016

Biofuels at Sea

On Oct. 22, 2010, in the calm waters off Naval Station Norfolk at the south end of the Chesapeake Bay, a U.S. Navy riverine craft performed a nautical ballet for a handful of onshore onlookers. The small, armed patrol vessel designed for coastal and inland assaults plowed through the lapping waves, turned 180 degrees, reversed its engines, turned again and zig-zagged away as if chased by a swarm of bees. The maneuvers were more than just a display of technological agility. They were part of the world’s first full-power demonstration of a naval surface vessel running on biofuels, in this case derived from algae. The spectacle was also one of the first public demonstrations of the Navy’s commitment to pivoting away from its century-old reliance on fossil fuels (Moriarty, 2011).

It was the first step toward realizing the goal set out one year earlier by U.S. Navy Secretary Ray Mabus. His plan was to meet half of the Navy and Marine Corps’ total energy consumption, both ashore and afloat, with clean renewable fuels by 2020. The project was launched under the banner of the “Great Green Fleet.” That the biofuel demonstration was taking place at Norfolk, home of the U.S. Navy’s vast Atlantic division and a morning’s drive from Washington, D.C., was more than just a matter of convenience. It was also rife with symbolism: Naval Station Norfolk, the largest naval base in the world, was then, and is now, sinking. “You

know, [as the] sea level rises, Norfolk's in trouble," Secretary Mabus told an audience at New York's Columbia University in April 2015 (Mabus, 2015). Indeed, a 2012 report from the American Security Project ranked Norfolk among the five U.S. military bases most vulnerable to climate change (Foley, 2012). "It is an absolute national security issue," Mabus continued. "Climate change and the things driving climate change have the potential to be very disruptive and have the potential to draw our military into conflicts that otherwise they wouldn't be in" (Mabus, 2015).

More recently, the focus of the Navy's Great Green Fleet trials has shifted from the Atlantic Ocean to the Pacific. And instead of algae power, out on the West Coast they're using beef. On Jan. 20, 2016, the aircraft carrier strike group of the USS *John C. Stennis* set sail from San Diego, California for a seven-month tour of the Asia-Pacific region. While the *Stennis* itself is nuclear-powered, five ships in its strike group—the guided-missile destroyers *Stockdale*, *Chung Hoon* and *William P. Lawrence*, along with the cruiser *Mobile Bay* and the combat support ship *Rainier*—were running on a blend of petroleum and beef tallow, or rendered cow fat (Myers, 2016). According to the Navy, these biofuels "have been procured by DoN [Department of the Navy] at prices that are on par with conventional fuels, as required by law, and are certified as 'drop-in' replacements that require no engine modifications or changes to operational procedures" (U.S. Navy, 2016).

Of course, here the phrase "on par" should be considered in purely monetary terms. The factors that *ought* to be accounted for in the Navy's costing of biofuels versus petroleum fuels include the high cost of securing and deploying petroleum around the world—counted in the

lives of Marines, service members and contractors at the added expense of enriching terror-exporting petrostates—and the economic threat of climate change.

In its earliest trials, the Navy paid US\$424 per gallon for approximately 20,055 gallons of algae oil at a time when standard diesel fuel was selling for an average of under US\$3 a gallon, according to data from the U.S. Energy Information Administration. During later trials in the summer of 2012, the Navy paid roughly US\$27 per gallon for 450,000 gallons of algal biofuel that was mixed into a 50-50 petroleum blend. For the Great Green Fleet's 2016 deployment, the Navy is paying approximately US\$2.05 per gallon for its 90-10 petroleum-to-beef fat biofuel blend, due in part to a government subsidy of 15 cents per gallon on farm products (Alexander, 2016).

The 'Dismal Fact' of Diesel Fuel

That dramatic decline in the cost curve for biofuels aside, Secretary Mabus was quick to preempt any concerns about biofuels becoming a financial burden on the Navy. In his 2009 speech unveiling the Navy's Green Fleet plans, Mabus paraphrased a line from the movie *Field of Dreams* to explain his belief that the Navy's demand for new biofuels would be substantial enough on its own to create a larger market for renewable fuels, and therefore lower the market cost further, saying, "If the Navy comes, they will build it" (Mabus, 2009). In the same speech, Mabus offered a grimmer assessment of the cost of ignoring the Navy's progress on biofuels and staying the course with traditional petroleum fuels on the Afghan battlefield. "It turns out that when you factor in the cost of transportation to a coastal facility in Pakistan—or airlifting to

Kandahar—and then you add the cost of putting it in a truck, guarding it, delivering it to the battlefield, and then transferring that one gallon into a piece of equipment that needs it, in extreme cases that gallon of gasoline could cost up to \$400” (Mabus, 2009). A 2011 report from the U.S. Naval War College supports Mabus’s fuel cost assessment, estimating that each gallon of fuel the Navy uses in deployment costs between US\$100 and US\$600 depending on “whether the fuel is transported in peaceful or hostile areas and by truck, aircraft or helicopter,” adding that “delivery to a ship at sea can cost from five to fifty times the market price” (Chambers and Yetiv, 2011).

In April 2016, Assistant Secretary to the Navy for Energy, Installations and Environment, Dennis McGinn, at a panel discussion on energy security at the Washington-based think-tank, the Atlantic Council, tallied the cost to the Marines of protecting fuel convoys in Afghanistan. “The shocking, absolutely dismal fact was that there was one Marine killed or injured per every 50 convoys that we had to do,” McGinn said. “So anything we could do at the forward edge—at the forward operating bases—that would cut down on the need for diesel fuel, literally saved lives” (McGinn, 2016). For the Army, as we’ll see later, the diesel death toll was bleaker still. But taking a long-term view of the Navy’s financial expenditure on securing oil resources in the volatile Persian Gulf region, Princeton University economic geographer Roger Stern estimates that between 1976 and 2007, the U.S. military spent US\$7.3 trillion safeguarding oil chokepoints in the Gulf, with the vast majority of that burden shouldered by the Navy (Stern, 2010).

Of course, transporting liquid biofuels, like those derived from algae or beef, into a theatre of war and across resupply lines still presents some of the same logistical challenges as

moving conventional oil, or any bulk item into and around a war zone for that matter. Unlike petroleum fuels, however, agricultural biofuels can be produced almost anywhere, including in-theatre. In the case of algal biofuel, all that's really required for production is sunlight, water and some rather rudimentary laboratory equipment. Biofuels are also far more chemically stable to store and transport than refined petroleum and less prone to explode if, say, a convoy is targeted by enemy fire—a point that will be taken up in greater detail later.

The 'Prius of the Seas' and Biofuels in the Sky

Certainly liquid biofuels aren't the only alternative propulsion technology the Navy is researching and deploying. Four days after the Navy demoed its biofuelled patrol craft on Chesapeake Bay, the service's first hybrid-electric vessel was formally commissioned at Naval Air Station North Island in the waters off San Diego. Aptly dubbed the "Prius of the Seas," the USS *Makin Island* is a Wasp-class assault ship used to transport Marine expeditionary forces into hostile areas via helicopters and landing craft. It is the first ship of its class built with a hybrid propulsion system comprised of a combined diesel-electric propeller drive, instead of the traditional Wasp-class diesel-fueled steam boiler. At its launch, the Navy projected that the hybrid engine would save approximately \$250 million in fuel costs over the ship's lifetime (Navy Chief of Information, 2009).

Most modern navies are comprised of more than just boats. And since the 1920s, when it commissioned its first rigid dirigible, the United States Navy has been at the forefront of deploying its Navy to the skies. As a subset of the Department of the Navy, the United States

Marine Corps maintains a sizeable fleet of fixed-wing and rotary aircraft which are deployed from Navy vessels, including its workhorse attack aircraft, the Boeing F/A-18 Super Hornet.

On April 22, 2010, Earth Day, the Navy held the first public test flight of the “Green Hornet,” a variant of its most capable fighter jet, this time powered by a 50-50 blend of biofuel and the common kerosene-based JP-8 (“Jet Propellant 8”) fuel used across most NATO military aviation units (Chambers and Yetiv, 2011). When test pilot Lieutenant Commander Tom Weaver of the Navy’s Air Test and Evaluation Squadron eased back on the Hornet’s centre stick at Naval Air Station Patuxent River, Maryland, and rocketed out over the Chesapeake Bay at supersonic speeds, the plane’s screaming twin engines were drawing on conventional refined petroleum and a new kind of flower power. The biofuel blend that the Green Hornet was burning was made from the crushed seeds of the flowering *Camelina sativa* plant, a hardy nuisance weed known to farmers all over North America for choking out more valuable flax crops. “The aircraft flew exactly as we expected—no surprises,” Weaver said in a Navy news release following the flight. “The fuel works so well, all I needed to do was just fly the plane” (Navy Chief of Information, 2010). Mark Swierczek, the mission’s flight test engineer, called the Green Hornet’s performance on the biofuel blend “normal and as expected,” even at speeds in excess of Mach 1. “Our mission today and for the rest of the flight tests is to confirm that the fuel makes no difference in performance across the Super Hornet’s entire flight envelope, from subsonic to supersonic operations,” said the Naval Air Systems Command engineer in the same news release. “Preliminary results show there was no difference in engine ops attributable to the biofuel” (Navy Chief of Information, 2010).

As American naval aviation's largest consumer of fuel, the F/A-18 Super Hornet was a fitting test aircraft to showcase camelina's initial capabilities as a reliable and powerful energy source (Lavelle, 2010). And camelina, a highly adaptable crop that can survive seasons of frost and drought with little in the way of water or fertilizer required—even as far north as the Northwest Territories and the Yukon—is among the highest-yield biofuel crops. Camelina seeds are comprised of approximately 45 per cent oil, an unusually high ratio which puts the seed at the very top tier of those showing promise in powering American biofuelled aviation into the future. Additionally, camelina is a non-food crop which, due to its short growing season, need not compete with agricultural food crops (Fan, 2013). Rather, camelina is best grown in natural rotation with wheat crops and on non-irrigated land (Canadian Food Inspection Agency, 2012). Thus, studies have shown that camelina crops can produce 570 litres of oil per hectare annually, while posing no significant impact on agricultural land use. Additionally, a 2013 Michigan Technological University lifecycle analysis of camelina jet fuel found that its use reduces aircraft carbon emissions by 75 per cent compared to petroleum jet fuel (Fan, 2013). Sustainable Oils, the company manufacturing the U.S. Navy's camelina fuel blend, says the true lifecycle carbon reduction is closer to 80 per cent, a figure verified in an independent study conducted by aerospace engineering firm Honeywell (Sustainable Oils, 2016).

The U.S. military's camelina flight tests didn't end with the Green Hornet's 45-minute sortie around Chesapeake Bay. The demonstration was just the first of 15 aerial tests the Navy would complete by mid-June of that year, achieving a total of 23 flight hours on the camelina blend. And, on March 18, 2011, the United States Air Force followed the Navy's lead, sending one of its own considerably more technologically advanced fifth-generation fighter aircraft, the

F-22 Raptor, into the skies over southern California's Edwards Air Force Base on the same 50-50 kerosene-camelina blend. This time the fighter jet would exceed speeds reached by its Green Hornet predecessor, performing "flawlessly on the biofuel blend, citing no noticeable differences from traditional JP-8," according to Jeff Braun, director of the Alternative Fuels Certification Division, part of the Aeronautical Systems Center at Wright-Patterson Air Force Base in Ohio. "The Air Force selected the F-22 weapon system to be the biofuel blend flight-test pathfinder for all fighter aircraft," reads the Air Force news release that accompanied the successful test flight. "Testing consisted of air starts, operability, and performance at different speeds and altitude throughout the flight envelope. The F-22 Raptor performed several maneuvers including a supercruise at 40,000 ft., reaching speeds of 1.5 Mach. Supercruise is supersonic flight without using the engine's afterburner" (U.S. Air Force Public Affairs, 2011). By the time the F-22 touched down again, the U.S. Armed Forces had already signed contracts for more than 500,000 gallons of camelina-based fuels from Seattle-based supplier, Sustainable Oils.

In September, the Navy reached another biofuel milestone when its entire Blue Angels demonstration fleet of six F-18 legacy Hornets performed aerial combat maneuvers on the 50-50 camelina blend at a weekend-long Labour Day air expo. It was the first use of a biofuel blend by an entire military unit. Secretary Mabus took the opportunity to reinforce the notion that the Navy's bold push for biofuels was a move toward greater "energy security," adding that "changing the kinds of fuels we use and the way we use them is critical to assuring the Navy and Marine Corps remain the most formidable expeditionary fighting force the world has ever known" (Navy Chief of Information, 2011).

Camelina fuels are, to date, the most widely tested of the U.S. Armed Forces' aviation biofuels and have powered a variety of U.S. military aircraft, including the Air Force's F-15 Eagle, the F-16 Thunderbird, the A-10 Thunderbolt II—also known affectionately as the A-10 Warthog—the Army and Navy's Apache helicopter and the Navy's MH-60S Seahawk helicopter. Aviation biofuels derived from algae, camelina and tallow, as well as other plant and animal fat feedstocks, are officially classified as hydrotreated renewable jet fuels, or HRJs. These fuels are also now certified for unrestricted operational use across the U.S. Air Force's entire C-17 Globemaster III fleet.

'The Critics Were Wrong'

To some hardline energy reformers—and, indeed, to those opposed to any renewable energy reforms at all—the Navy's use of a half-and-half blend of biofuels and petroleum is seen as either too little too late, or an admission that biofuels alone cannot deliver the energy intensity required to push a battleship through the sea or to carry an aircraft through supersonic speeds. But the necessity of the blend actually has more to do with existing engine construction and the Navy's official demand for an immediate “drop-in” solution to its petroleum consumption problem without any engineering modifications or retrofits required.

Speaking to *National Geographic*, the U.S. Navy fuel program's civilian leader described the naval fleet's drop-in conundrum. “One of the challenges we've had is that everything we have ever used in naval aviation has been designed around petroleum-based fuel,” Rick Kamin told the magazine. “[The engine] is taking advantage of everything that a petroleum-based fuel

provides. We've had to work to break down that paradigm" (Lavelle, 2010). One example of a benefit that petroleum fuel provides an engine designed to burn exclusively petroleum is the fuel's aromatic hydrocarbon content. These aromatics cause certain engine seals to swell—something engine designers take into account—preventing fuel leaks. Camelina oil lacks such aromatics, hence the need for a traditional jet fuel blend to ensure proper engine seals. Despite the lack of aromatics in camelina oil, the biofuel derived from it is otherwise so similar to the military-grade jet fuel already in use that, not only does camelina deliver the same power and energy density as petroleum, but all other aircraft systems—including the fuel gauge—perform on camelina oil exactly as they would on traditional fuel (Lavelle, 2010). "Our goal," Kamin said, "is that these fuels have to be invisible to the operator" . To maintain that operational invisibility in the Navy's current sea and air systems, the Navy "concluded that current engine seals still need a certain amount of petroleum (Lavelle, 2010).

Precisely what the ideal biofuels-to-petroleum blend is for U.S. Navy's air and sea operations remains to be determined. But in 2012, researchers at the U.S. Naval Postgraduate School in Monterey, California, studied the question and again settled on the 50-50 blend as the most workable target for today's Navy given the age and pedigree of its current fleet, all of which was designed with only petroleum power in mind. "The question was how much biofuel can the engines handle, and 50-50 worked," says Christopher Brody, a mechanical and aerospace engineering professor at the naval school who led the algae and camelina biofuels studies. "But can you do 70-30? We don't really know the demarcation line between what fraction of biofuel you can run, but 50-50 is what the Navy has selected to date because we know it works" (Stein,

2012). Put another way, perhaps, and to paraphrase former U.S. Defense Secretary Donald Rumsfeld: You go to war with the *Navy* you have, not the *Navy* you might want.

Speaking with the Naval Postgraduate School's public affairs department, Brody cited the problem of the aromatic-activated engine seals as the key hurdle to reaching a 100-per-cent biofuel-powered Navy, especially given Secretary Mabus's demand for an immediate and invisible drop-in solution. "We know you can't go 100-per-cent biofuel because, in aviation or ground-based systems, existing seals rely on particular ingredients found in conventional petroleum fuels which causes them to swell and provide proper sealing," he said. "If you put them in biofuel, they tend to swell only a fraction of what is expected. Liquids contained within the engine are kept in by seals around a piston or a shaft, and if the seal is not expanding as expected, they leak. This has resulted in aircraft returning with significant leaks, so it's a big problem" (Stein, 2012).

But it's a problem that Mabus, the naval secretary who spearheaded the Great Green Fleet initiative, insists is in line with the long-term energy challenges that have been met time and again by the American fleet. "The critics were wrong then, and they are wrong today," Mabus wrote in the Summer 2012 issue of the Navy's energy and environment magazine, *Currents*. "Throughout the Navy's history, we have pioneered the way we fueled the fleet. In the 1850s, we moved from sail to coal. In the early 20th century, we left coal to transition to oil and we led the way to nuclear power in the 1950s. At the time of each energy transformation, there were doubters and naysayers who said trading a known source of energy for an unknown one

was too risky and too costly. But the Navy pursued innovation because it improved the capability of the fleet and made us better warfighters” (Mabus, 2012).

Beyond Biofuels

Given the U.S. Navy’s operational affinity for the sea and skies, it’s only fitting it would look to those also for new sources of energy. Wind farms, tidal energy berths—most notably the Navy’s Wave Energy Test Site that opened off Hawaii in late 2016—and solar arrays are becoming commonplace on and around U.S. Naval installations. But so, too, are smaller and seemingly insignificant energy-saving technologies. Take for instance the LED light bulb. In 2016, the Navy discovered that switching from onboard incandescent lights to LEDs on just one of its destroyers would save 20,000 gallons of petroleum fuel per ship per year (Gooding, 2016).

Since deploying to Afghanistan in support of Operation Enduring Freedom in 2011, American naval sailors and Marines from the 3rd Battalion, 5th Regiment, have been combat-testing the new ExFOB program, or Experimental Forward Operating Base, throughout the war-ravaged country. The critical platform of the ExFOB system is a simple selection of solar-powered blankets carried by sailors and Marines and used to power everything from personal communications devices to base lighting and command centre computers. One such blanket, the Solar Portable Alternative Communication Energy System, or SPACES, is a small solar blanket carried by a single Marine, used mainly for charging personal items like radio batteries. The Power Shade is a larger solar tarp that fits over a standard Marine Corps tent, providing enough energy to power the tent’s lighting system. The Ground Renewable Expeditionary Energy

System, or GREENS, is a solar blanket capable of providing enough energy to run a platoon-sized command operations centre with four computers running at a time. Lastly, the largest power source is the Zero-base Regenerator, with six flexible solar arrays fueling a single battery that can power more than 20 lighting systems, a communications network and 15 computers at a time (Price, 2011). “As a platoon commander, if I don’t have ‘comma’ [communications] with my troops and my higher-ups, I am lost,” says 1st Lt. Josef Patterson, 2nd Platoon commander with the battle group. “On the longer patrols, we pack the solar blankets and can continuously charge our radio batteries. This also allows more room to pack things like ammunition” (Price, 2011).

In late 2010, an operational assessment team with the independent Marine Corps Operational Test and Evaluation Activity authority visited Afghan ExFOB bases to collect data on the future viability of the program. Maj. Sean Sadler, the expeditionary energy liaison officer with the Navy’s Regional Command Southwest, escorted the team. “The Marines were very innovative and came up with ways to use the equipment that was not even thought of before their deployment,” Sadler told the Marine Corps public affairs department in 2011. “The Marines were frank about what worked well and what needed improvement. Many of the recommendations would have been impossible to make during the pre-deployment training program. Only through use during actual combat operations would the Marines be able to realize the capabilities of the equipment and the capabilities they would like to see” (Price, 2011).

By 2016, optimism about the Navy’s solar base program had percolated all the way up the chain of command to Navy Assistant Secretary Dennis McMinn. At the VERGE Hawaii Asia

Pacific Clean Energy Summit in Honolulu in June of that year, McMinn, who oversaw the Navy's Energy, Installations and Environment division, reinforced the idea that battle-tested military renewable energy technology will lead the future of civilian energy security, as well. McMinn told an anecdote about the Afghan Exons. "The direction from the commandant at the time, Jim Conway, was, 'Hey look, if you guys find this useful, great, go ahead and use it. If you don't, throw it in the Helmand River and just continue.' Well they did find it useful," McMinn told the panel (McMinn, June 2016). He relayed the story of one base in particular that came under a sustained rocket-propelled grenade attack. The base's solar blankets provided continuous power for base lighting and communications despite taking damage from shrapnel. "Unlike a diesel generator set getting hit by a rocket-propelled grenade, which would have blown up and probably killed or injured Marines, the solar panels took a licking and kept on ticking," McMinn said. "So, if it's good enough for the United States Marine Corps at a forward operating position, what the heck is wrong with the rest of us Americans? We've got to get out there and deploy it" (McMinn, June 2016).

Putting his words into action, on the day of the speech, McMinn signed a memorandum of understanding with Hawaii Governor David Ige, aimed at better integrating the military's renewable energy technologies—wind, solar, tidal, landfill biogas and liquid biofuel power—into the statewide grid. As a wholly energy import-dependent state with a significant military presence and some of the most ambitious renewable energy targets in the U.S., Hawaii will be a symbolic and instructive example of how the U.S. military can localize and modernize civilian energy and turn the tide of energy markets in favor of renewables and in favor of U.S. ingenuity.

Chapter Three: Post-Second World War: The Rise of Early Synthetic Fuels and the U.S. Strategy for Petroleum Disarmament

As the final battle for Berlin raged in early 1945 and Nazi Germany was in its death throes, thousands of American military intelligence officers, engineers and technicians flooded into the country not to deliver a swift and crippling blow to Nazism but to uncover exactly how this petroleum-deprived nation was able to sustain such a formidable war machine for as long as it had. The answer lay in synthetic fuels and the first-ever mobilization of a fuel synthesis program to propel a nation's war effort.

Just as modern biofuels are derived from synthesizing and speeding up—by a factor of millennia—the natural organic and geologic processes of converting decomposed plant materials into combustible liquid fuel, the German fuel synthesis program mimicked the natural underground processes by applying heat and pressure to convert abundant supplies of coal and coal-bed methane into usable liquid petroleum. In the immediate post-war era, the U.S. Office of Strategic Services, an early predecessor to the Central Intelligence Agency, began secretly bringing hundreds of former Nazi scientists and chemical engineers back to the U.S. mainland in an effort to jumpstart an American homegrown synthetic fuel program to match that of the Nazis (Kramer, 2005). The secret initiative was part of what later became known publicly as Operation Paperclip, and it involved German fuel scientists developing synthetic fuels for the U.S. Bureau of Mines, as well as German rocket scientists furthering American aviation and aerospace capabilities amidst the emerging “space race” with the Soviet Union. The transfer of German synthetic fuel technology to the U.S. was, by 1948, something other nations—including Britain, Canada and the Soviet Union—would replicate, though with limited successes due in large part

to the U.S. having first pick of the former Nazi technicians (Corsi, p. 6).

The Synthetic Liquid Fuels Act

Among the German scientists who came to the U.S. were dozens of fuel experts who were sent to work on developing synthetic fuels under the U.S. Synthetic Liquid Fuels Act. The Act, approved by the U.S. Congress on April 5, 1944, authorized US\$30 million over five years for “the construction and operation of demonstration plants to produce synthetic liquid fuels from coal, oil shale’s, agricultural and forestry products, and other substances, in order to aid the prosecution of the war, to conserve and increase the oil resources of the Nation, and for other purposes” (U.S. Department of Energy, 2017). Before the Act was signed, West Virginia Congressman Jennings Randolph even went so far as to fly from Morgantown to Washington, D.C. in a synthetic fuel-powered airplane in November 1943 to bring attention to the potential for an American synthetic fuels industry (U.S. Department of Energy, 2017).

Armed with the Act and with the information and expertise gleaned from its Technical Oil Mission to Europe, the U.S. government wanted to offer subsidies to the oil industry to build a coal-to-oil synthetic fuel demonstration plant. Convinced the technology would never be competitive with crude oil, however, the industry laughed at the offer. So the Bureau of Mines went instead to the U.S. War Department and persuaded it to transfer over the control of the Army’s wartime synthetic ammonia plant at the Missouri Ordnance Works in Louisiana, MO (U.S. Department of Energy, 2017). Helming the project was Wilburn Schroeder, the chemist who had led the Technical Oil Mission into Germany, along with a few captured German

scientists. Under his leadership, the Bureau of Mines contracted with major defence manufacturer Bechtel to convert the Missouri plant into a coal hydrogenation test facility. By 1949, the Bureau had a fully operational 200-barrel-a-day coal-to-oil synthetics plant (U.S. Department of Energy, 2017). “Optimism reigned supreme in the first year of the expanded national synthetic fuels effort,” reads the website of the modern-day Department of Energy. “In August 1949, the Bureau’s sinful experts issued a stunning assertion that they could make gasoline from coal for as little as 1.6 cents per gallon before profits and taxes” (U.S. Department of Energy, 2017).

Once again, the U.S. military was at the forefront of proving up this new fuel. From 1949 to 1953, the US\$10-million hydrogenation plant produced 1.5 million gallons of synthetic gasoline, one million of which were fleet-tested by a range of vehicles across the Armed Services (U.S. Department of Energy, 2017). This was all happening at a time when, for the first time in its history, the U.S. was importing more crude oil and oil products than it was exporting. Politicians were talking about an energy crisis, and military planners were for the first time considering the country’s reliance on energy imports as a potential national security threat.

Biomass vs. Big Oil

In March 1948, while a series of hearings were being held in Washington over the state of the country’s fuel supply, Congress amended the Synthetic Liquid Fuels Act to extend the work to eight years and double its funding to US\$60 million (U.S. Department of Energy, 2017). That same year, the *New York Times* declared that “the United States is on the threshold of a

profound chemical revolution... The next ten years will see the rise of a massive new industry which will free us from dependence on foreign sources of oil. Gasoline will be produced from coal, air and water” (Yergin, *Prize*, 410). Although the Second World War was over, the U.S. petroleum appetite was only growing as more Americans were buying cars than ever before. A second coal-to-liquids plant was built in Louisiana in 1950, this time using the German Fischer-Tropic process of chemically rearranging gasified coal molecules into liquid fuels, rather than the German Bergius process which directly turned coal into liquid fuels by treating it with hydrogen (U.S. Department of Energy, 2017).

In September 1950, the U.S. Congress continued its policy push away from traditional gasoline and approved a second amendment to the Synthetic Fuels Act, adding another three years to the project and bringing the total federal research budget to US\$87.6 million. This new outlay would earmark US\$2.6 million to fund the construction of an experimental plant in Morgantown, West Virginia, dedicated to the research and investigation of deriving liquid fuels from coal, minerals and, most importantly, peat and biomass, using the German Fischer-Tropic process (U.S. Department of Energy, 2017).

By 1952, private industry was following the government’s lead on biomass-to-liquid fuels and the first privately built and operated coal hydrogenation plant was built by the Carbide and Carbon Chemical Company—later Union Carbide—in West Virginia (U.S. Department of Energy, 2017). While not a renewable resource per se—and certainly not a “clean fuel” source by modern standards—the volume of the U.S. coal supply was at that time, and in many ways still is, a near-limitless resource. And the coal-to-oil conversion was a first crucial leap into

synthetic fuels for the U.S. government by way of attempting to manufacture energy by mimicking a natural geological process, just like the modern manufacture of biofuels from energy stored in decaying plant life.

The abundance of coal, peat and biomass on the U.S. mainland, and the possibilities they presented for the development of a thriving domestic pseudo-renewable fuels industry, rose in sharp contrast to the fortunes of the U.S. oil industry, which was then seen to be scraping the bottom of the barrel in terms of new domestic oil discoveries. According to the U.S. Department of Energy, private synthetic fuels plants like the West Virginia Carbide and Chemical operation were seen as the way out of this growing domestic fuels crisis, with the Department calling it “a symbol to many in the Eisenhower Administration and the Congress that large-scale synthetic fuels plants should now become the responsibility of the private sector” (U.S. Department of Energy, 2017). But as the U.S. government began handing over the reins of its burgeoning synthetic fuels industry to the private sector, the big oil companies were already tapping new sources of cheap foreign oil, in particular from newly business-friendly regimes in the Middle East. The simultaneous emergence of Deepwater offshore oil drilling was also opening up new U.S. petroleum plays, as in the Gulf of Mexico, and further buoying up the supply and driving down the cost of petroleum fuel for the next two decades—until the Arab oil embargo of 1973 would send the American market’s supply side crashing down.

Empires in Decline

In the postwar era, the global petroleum order was established and held by British and

American companies and backed up by their militaries. This order was nowhere more apparent than in the Arab Gulf states of the Middle East, where the U.S. was the relative newcomer, arriving with the discovery of rich oil deposits, while the British had been patrolling the Persian Gulf waterway to suppress piracy and foster business relationships among sheiks on the Arab side of the Gulf since the early 1800s. By the late 1960s and early 1970s, however, both countries were in political and economic decline internationally. After enduring years embroiled in an unpopular—and ultimately failed—war in Vietnam, the U.S. was plagued by political division and anti-imperialism at home, as well as rising anti-Americanism worldwide. In Britain, the domestic preoccupation with its economic and political decline would “make the liquidation of empire the central drama for Britain in the postwar world” (Yergin, *Prize*, p. 547).

Throughout the 1950s, the port city and British protectorate of Aden, now the southern tip of Yemen, was one of the busiest harbours in the world, second only to New York (Salisbury, 2013). The city was strategically located on the oil routes of the Persian Gulf and, before the eventual withdrawal of the British and collapse of the colony in 1967, it served as both the policeman on the corner and the market regulator for much of the world’s crude oil trade. Then in 1968, Britain abruptly announced that it would end all its previous defense commitments east of the Suez Canal and completely withdraw its military presence from the Persian Gulf by 1971, forfeiting the last major remnants of British Empire that had endured since the early 19th century. (Yergin, *Prize*, p. 547).

The British withdrawal from the Persian Gulf marked the end of an energy security apparatus that had operated in the region for more than a century, and it coincided with a rise in

autocratic nationalism among the Gulf states. “Their departure marked the most fundamental change in the Gulf since World War II,” writes global energy analyst Daniel Yergin. “It left behind a dangerous power vacuum in a region that supplied 32 per cent of the free world’s petroleum and that, at the time, held 58 per cent of the proven oil reserves” (Yergin, *Prize*, p. 548).

The Soviet Union of the 1950s, meanwhile, was in dire need of hard currency and launched a massive oil-export campaign into the NATO-allied countries of Western Europe. This economic push would become known in the West as the Soviet Economic Offensive and was viewed by the U.S. as an act of political and economic aggression. The Soviets slashed prices on oil exports in what the U.S. saw as an attempt to create dependence in Western Europe, sow division within NATO and undercut the U.S. oil position in the Middle East. Allen Dulles, then director of the CIA and brother of then Secretary of State John Foster Dulles, warned President Dwight Eisenhower in 1958 that the Soviet Economic Offensive meant that “the free world faces a quite dangerous situation in the Soviet capacity to dislocate established markets” (U.S. Department of State, 2017). “Economic warfare is especially well adapted to their aims of worldwide conquest,” U.S. Senator Kenneth Keating said of the Soviet regime of the time. “Khrushchev has threatened to bury us on more than one occasion. It is now becoming increasingly evident that he would also like to drown us in a sea of oil if we let him get away with it” (Leary, p. 112). In response, the world’s Western oil companies, under pressure from the U.S. government, slashed their own prices to compete with cheap Soviet oil.

The move enraged Arab oil producers. The combination of rising autocratic rule in the

Middle East, coupled with growing anti-Western sentiment and rising resource wealth was—and still is—a deadly cocktail for the global energy market and the nations that depend on it. And it was a cocktail that Gulf state regimes in the 1960s and 1970s were eager to weaponries into a tool of war. Between 1948 and 1972, oil consumption in the U.S. tripled from 5.8 to 16.4 million barrels per day, while rising incomes and industrialization in the West increased global oil demand more than five and a half times over (Yergin, *Prize*, p. 523). In September 1960, an Arab-centric oil price-fixing cartel known as the Organization of the Petroleum Exporting Countries was founded in Baghdad and included Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. OPEC's founding intentions were to wrest control of world oil prices away from the dominant consumers in the West and regulate production quotas for member nations that could maintain high prices for the majority of the world's oil reserves in times of relative stability, as well as rapidly increase or decrease prices as it befit the most powerful Arab oil producers, in particular Saudi Arabia.

As the world's dominant oil producer, Saudi Arabia, unlike other oil-producing nations, holds millions of barrels of oil-production capacity in reserve, which is to say it keeps much of its production capacity off the market. This has allowed the kingdom to operate as OPEC's de-facto leader and “swing producer” ever since the group's inception, alternately tightening down the oil spigots to raise prices when it suits Saudi interests or opening them wide to flood the market with cheap oil in order to flush out rival producers.

The latter is what happened in the summer of 2014 when the the kingdom's market share came under threat from the American oil-fracking bonanza that came to be known as the U.S.

shale revolution. Saudi Arabia's then energy minister and OPEC leader Ali al-Naima began a sustained campaign of ramped-up oil exports that would cut the price of West Texas Intermediate crude from US\$107 per barrel in June 2014 to US\$29 a barrel just 20 months later. By 2016, U.S. oil drilling had ground to a total halt in all but a handful of the very best domestic oil plays, and the wash of energy company bankruptcies had erased hundreds of billions of dollars from the U.S. economy.

The 'Moral Equivalent of War'

The Western world's first oil crisis began in October 1973, when the members of OPEC announced an embargo on oil exports to the U.S. It was in response to the country's support of Israel in the Yom Kippur War, when a coalition of Arab states led by Syria and Egypt fought Israel over lands it had annexed and occupied since the Six-Day War in 1967. The embargo sent world oil prices skyward and sent American oil prices higher still. Long lines at the fuel pump and gasoline rationing became the norm in the U.S.

The U.S. political response to what would later be known as the "oil shocks" of the 1970s—the second would come only six years later with the 1979 Iranian Revolution—was a failed attempt to marshal the American public to wage a war on its own energy complacency. In 1972, chairman of the Atomic Energy Commission James Schlesinger argued the "then-heretical idea" that the U.S. should promote domestic energy conservation on national security grounds (Yergin, *Prize*, p. 644). In 1975, the U.S. established the world's largest strategic petroleum reserve, an emergency cache of more than 720 million barrels of crude oil buried in

underground salt caverns along the Gulf of Mexico.

By 1977, after serving two years as Defense secretary under presidents Richard Nixon and Gerald Ford, Schlesinger was named America's first Secretary of Energy under new president Jimmy Carter. As Carter later wrote in his memoirs, he and Schlesinger "deeply resented that the greatest nation on earth was being jerked around by a few desert states" (Carter, *Keeping Faith*, p. 98). Some in Washington argued for the seizure of Gulf oil fields by force, Carter wrote. Others blamed domestic oil producers, accusing them of holding back production to further squeeze the American consumer on price in a time of crisis.

Less than two weeks after his inauguration, the U.S Congress passed a law giving Carter what he admits were "extraordinary powers" to deal with the crisis (Carter, *Keeping Faith*, p. 98). He announced that within 90 days his national energy plan would be made public. And on April 18, 1977, wearing a heavy cardigan sweater and sitting beside a roaring log fire in the White House library, Carter delivered his message to the American people on the importance of energy conservation and his vision of a renewable energy-powered future. "Tonight, I want to have an unpleasant talk with you about a problem unprecedented in our history. With the exception of preventing war, this is the greatest challenge our country will face during our lifetimes," he began. "This difficult effort will be the moral equivalent of war, except that we will be uniting our efforts to build and not destroy" (Carter, *Keeping Faith*, p. 96).

Carter's first "fireside chat" was, by his own account, not well received (Carter, *Keeping Faith*, pp. 96-101). Due to its perceived tone of American weakness in confronting the all-

powerful oil companies and Middle Eastern petro-states, and its emphasis on sacrifice, moral failure and permanent scarcity, the speech would be memorialized by an acronym for the “moral equivalent of war” phrase—“Meow” (Yergin, *Quest*, p. 529).

The Early Dawn of American Solar Power

Nevertheless, solar energy generation—a brand new industry in America—was off and running by the late 1970s. The government established a new federal solar energy laboratory—the Solar Energy Research Institute—in Colorado, and also provided tax incentives, grants, a solar bank and R&D funding for industry. George Tenet, who would later become the second-longest serving director of the CIA, was then the promotions manager for the Solar Energy Industries Association. By the end of the decade, more than 1,000 companies belonged to the association, including small start-ups and global weapons manufacturers like Grumman and Boeing (Yergin, *Quest*, p. 530). By 1980, however, the Carter administration was in turmoil and the president had fired much of his cabinet. The Iranian Revolution brought new shocks to global energy markets and the White House was forced to pivot away from solar electricity towards synthetic liquid fuels, investing billions into non-traditional petroleum replacements in an effort to curb the crisis’s effects on American oil consumers just as solar was reaching its stride (Yergin, *Quest*, p. 531). American confidence in the country’s politics and energy future was wounded, however, leading Carter to criticize—in one of his final speeches as president—the “crisis of the American spirit.” By November 1980, Ronald Reagan defeated Carter for the presidency and the Democrat’s renewable energy incentives were scrapped.

Carter's end, however, was not the end of the American renewables project. The loss of corporate research grants effectively transferred the power to develop new energy technologies back to "what has over the last 70 years been the largest engine of scientific advance, and the biggest funder—the U.S. government" (Yergin, *Prize*, p. 551). With the demands of business—quarterly profit-making and shareholder return-on-investment—temporarily out of the renewable energy picture, the U.S. government was back in the driver's seat, with American energy security as its ultimate destination.

Chapter Four: The “Net Zero” Army

The Navy may have been the tip of the spear in developing new energy sources like biofuels for the U.S. military, but it was hardly alone among the Armed Services in doing so. And when it comes to reducing the use of petroleum fuel as a means of reducing casualties among American service members, it's the U.S. Army that has demonstrated the most critical need.

The Most Dangerous Mission

On Oct. 13, 2004, a group of 19 U.S. Army reservists were ordered to deliver a convoy of unarmoured and unescorted fuel trucks on an early-morning resupply mission from the Tallil Air Base in southern Iraq to a base in Taji, a small town on the front lines north of Baghdad. The troops would never complete the roughly 400-kilometre trip. Instead, all 19 were removed from their barracks and held in detention by Army authorities at Tallil for refusing to carry out an order the men deemed a “suicide mission” (Barry and Mazzetti, 2004). While the story has a decidedly better outcome than the stories of the approximately 497 American casualties taken while protecting fuel convoys in Iraq that year alone, it illustrates the same problem (AEPI, 2009). And, regardless of those 19 reservists' refusal to complete the extraordinarily dangerous resupply mission, the fuel still had to be delivered, and it fell to their fellow soldiers in the unit to take up the mission to Camp Taji that same day (Barry and Mazzetti, 2004).

After the fall of Baghdad in April 2003 and the subsequent rise of a widespread guerrilla insurgency, delivering diesel and aviation fuel in theatre became one of the most dangerous missions for service members in Iraq. Roadside bombs, rocket-propelled grenades and even small-arms fire all posed remarkable risks to the convoys and their personnel due to the volatile nature of their cargo. Between 2003 and 2007, the U.S. Army suffered 2,858 casualties on resupply convoys that were providing fuel, water and other bulk necessities to forward bases, while in Afghanistan the total convoy casualty count over the same period reached 188, according to the U.S. Army's aptly named Center for Army Lessons Learned (AEPI, 2009). The same report found that, broken down by commodity volume, approximately 20 per cent of all Army convoy casualties could be attributed to water resupply convoys, 30 per cent to various bulk commodities, and the lion's share—50 per cent—to fuel. All told, the Army estimates it was taking one casualty for every 24 fuel convoys in Iraq and Afghanistan in 2007, the last year for which the military published detailed accounts of how soldiers were injured or killed in those countries (AEPI, 2009).

A study conducted by *CNN Money* paints a darker picture still. In 2011, the network's business desk found that, between 2003 and 2007, the U.S. Army in Iraq suffered 3,000 casualties to units protecting fuel convoys. With a total U.S. Army casualty count of 22,991 during that period, the network found that one in every eight U.S. soldiers killed or wounded in Iraq were protecting petroleum supplies (Hargreaves, 2011). While American combat casualties in Afghanistan were significantly lower than in Iraq during this timeframe, the percentage of those casualties attributable to attacks on fuel convoys was markedly higher. A 2012 report from *Scientific American*, the oldest continuously published monthly magazine in the U.S., determined

that enemy attacks on petroleum resupply convoys in Afghanistan accounted for more than one-third—35 per cent—of all U.S. Army casualties in the country in 2007 (Zaffos, 2012).

The frequent and deadly attacks on petroleum resupply lines have much broader consequences for all American service members, and for the Army's operational success as a whole. In any combat effort, fuel supply lines are vital arteries which, like the vital arteries of a mammalian body, animate and sustain life to all other systems. But like the critical arteries of the body, the fuel supply lines of any war effort are often thinly guarded, highly vulnerable to attack and tremendously difficult to re-secure once severed. To use military parlance, fuel supply convoys are recognized by American battlefield commanders and by the enemy alike as "soft targets." As was demonstrated already in the chapter covering the history of military fuels in Western conflicts, a fighting force caught without fuel on the battlefield is hardly a force at all—and without other recourse or rescue, it is already defeated.

Prolonged fuel supply disruptions on the battlefield can be catastrophic to war-fighting efforts, and thus inflicting them on the enemy has been among the primary objectives of every sustained military campaign in modern history. But even the threat of a small, temporary disruption can pose a major setback to a fighting force of any size. It's for that reason the U.S. Army seeks to avoid incurring at all costs. Meeting those challenges was the vision of the Army Net Zero Initiative, announced in October 2010 by Assistant Secretary of the Army for Installations, Energy and Environment Katherine Hammack. "Net zero" refers, in this case, to the Army's goal of producing as much energy as it consumes for its electrical, thermal and transportation needs worldwide. The three ways the Army has decided to achieve this are

through conservation, co-generation (i.e.: using waste heat generated by natural gas-fuelled power plants to heat buildings) and ramping up research into renewable energy. But, in keeping with the thrust of this study, we will focus primarily on renewables.

‘Gas Lighting’

By far the bulk of the U.S. Army’s fuel bill during in-theatre deployment is not spent on powering vehicles, as one might assume, but rather on generating electricity. By 2011, the Army’s annual in-theatre fuel bill was approximately \$2 billion, of which 35 to 45 per cent was spent on fuel for mobile diesel-powered generators (Erwin, 2011). Massive on-base power generators like the six-wheeled trailer-mounted U.S. military standard MEP-012A can weigh more than 12 U.S. tons and guzzle fuel at a rate of 208 litres per hour when operating at full power (Pike, 2016). Bases in Afghanistan and Iraq regularly deploy several such generators in a single power grid configuration, running everything from base lighting to communication, radar, defenses, food prep, refrigeration and air conditioning. It’s easy to see then why energy analysts—both military and civilian—routinely refer to energy conservation—making due with fewer hours of air conditioning, for example—as one of the cheapest and most effective “renewable” energy sources available. Indeed, the U.S. Army, and the wider U.S. military as a whole, has made conservation a pillar of its fossil fuel-reduction program. However, as stated, this study will examine only those tangible renewable energy technologies and their deployment in the service of reducing and eventually *replacing* traditional fossil-fuel power.

To date, the sharpest arrow in the U.S. Army’s fossil fuel-slaying quiver is solar power.

Solar generation offers many advantages for the Army over other clean energy alternatives. Some of those advantages differ for combat deployment in theatre versus deployment on domestic or international bases, but many apply beneficially to both. From an in-theatre operations standpoint, solar generation is easily portable, highly durable, silent, self-contained and scalable to meet the electricity needs of a single soldier alone in hostile territory, or an entire infantry brigade on R&R at a main operating base. Of course, effective solar power generation requires ample sunlight, and it's perhaps no fluke of history that the U.S. military is so gung-ho about solar given that since the Cold War, and even back as far as the end of World War II, the overwhelming majority of U.S. Army interventions have occurred in hot, sunny countries on or near the Equator. That many of these countries have been, and will continue to be, the places most affected by the sociopolitical destabilization of global climate change, will be addressed in Chapter Seven: Strategic Impetus. At present, the U.S. Army has spent the better part of the last three decades—and will spend, in all likelihood, the better part of the next—deployed primarily to the vast, shadeless deserts of the Middle East.

With solar energy, “there is no supply chain vulnerability, there are no commodity costs and there's a lower chance of disruption,” Richard Kidd, the deputy assistant secretary of the Army in charge of energy security, told *Bloomberg News* in 2013. “A fuel tanker can be shot at and blown up. The sun's rays will still be there” (Goossens, 2013). And unlike harvesting solar power, procuring oil in the Middle Eastern theatre most often involves arrangements that enrich Arab Gulf states and non-state actors —either via direct transactions or through intermediaries— that are traditionally hostile to U.S. security interests. Because such arrangements speak to the larger themes of U.S. security, energy security and the use of petro-dollars to fund Western

hostility worldwide, these issues will also be addressed within Chapter Seven: Strategic Impetus.

In Theatre

The Army codified its current commitment to sending new renewable fuel technology onto the battlefield in April 2013, in accordance with the renewables-focused Operational Energy Strategy plan first set out by the Department of Defense in 2011. Additional energy-related federal government mandates—including Executive Order 13514, the Energy Policy Act of 2005, and the Energy Independence and Security Act of 2007—further informed the plan. Deploying new renewable fuels, and reducing organizational dependence on fossil fuels and the resupply vulnerabilities they create, were chief tenets of the new directive, as was establishing an “energy informed culture through education, training and awareness programs that values energy as a resource that enables enhanced capabilities (agility, endurance, flexibility, resilience) and lowers operational risk” (McHugh, 2013). What that new directive actually looks like on the battlefield is a whole lot of new military hardware.

In October 2016, the Army, in partnership with General Motors, rolled out a new hydrogen fuel cell-powered electric vehicle, cementing an important link between defense and civilian markets for renewable energy technology. What is in essence an electric tank built on a Chevy Colorado truck frame, the Chevy ZH2 is the result of a contract the Army signed with GM in November 2015 to build a fuel-cell reconnaissance vehicle fit for armed service (Adler, 2016). But besides marking the Army’s first foray into developing a fleet-ready green vehicle for the battlefield, the ZH2 is important for two other reasons.

For one, unlike its predecessor in the ubiquitous High Mobility Multipurpose Wheeled Vehicle, or “Humvee,” the similarly dimensioned ZH2 reportedly delivers near-silent mobility with minimal heat generation, which is clearly beneficial in avoiding detection in stealth situations. The electric tank also generates, as waste, exportable water and outboard electricity. Therefore, the ZH2’s potential utility in reducing the Army’s dependence on in-theatre resupply convoys is twofold; requiring no fossil fuels for mobility itself, while also acting as a miniature power plant and water source.

Secondly, the ZH2 is especially important to GM because, unlike a handful of other major automakers, GM has yet to roll out a fuel cell vehicle for the consumer market, despite working on the technology for years. The partnership between GM and the Army’s Tank Automotive Research, Development and Engineering Center (TARDEC) is intended to finally bring GM, the largest U.S. automaker, fully into the clean energy age. “This project is another example of how fuel cell propulsion can play a role in non-traditional applications,” said Charlie Freese, executive director of GM’s fuel cell activities, in an October 2016 news release. “We need to continue pursuing these opportunities along with our plans for production of a commercial fuel cell system in the 2020 timeframe” (Adler, 2016). Freese, in a separate statement upon the ZH2’s release, said that “over the next year, we expect to learn from the Army the limits of what a fuel cell propulsion system can do when really put to the test” (Adler, 2016). For its part, the Army plans to conduct combat demonstrations on the new tank platform at its Michigan proving grounds through to the end of 2017, in line with the Department of Defense’s plans to leverage commercial technologies for the Army’s net-zero energy vision.

Looking out even further along its combat procurement timeline, the U.S. Army is exploring renewables not only as a fuel source but as a weapon, as well. Directed-energy weapons such as battlefield lasers were once, until very recently, exclusively the stuff of science fiction. But today they are very much on the American military's radar. The U.S. Navy has pioneered a focused infrared Laser Weapon System (LaWS), which has been used as a defensive weapon with proven success against aerial and seaborne threats since 2014. The laser cannon uses scalable beam intensity levels that can, in Navy parlance, either “dazzle” a target—temporarily blinding its personnel and visual navigation systems—or “destroy” it—frying electrical sensors, burning out motors and detonating any explosive materials onboard in a matter of microseconds (Sheftick, 2016). The Army now views such energy weapons as a realistic replacement for some current assault weapons and for defensive armour in its next-generation vehicle fleet.

“The big advantage of electric drives is we’ll be able to supply more power to combat vehicles to support future weapons like high-intensity lasers, rail guns, or active protection systems and improved situational awareness electronics,” says John Paulson, senior director of engineering and project management for General Dynamics Land Systems, the developer of many of the U.S. Army’s current land-based combat vehicle platforms (Sheftick, 2016). His statement was released by the Army following a November 2016 forum on the future of U.S. land-based warfare systems. Paulson was speaking specifically about the remarkable adaptability of renewable fuels like hydrogen cells for powering future energy weapons. “This is not a short-term endeavor,” added Army Colonel William T. Nuckols, director of the Mounted

Requirements Division at the Maneuver Center for Excellence, at the forum. “This is a multi-decade effort to get us to the first unit equipped in 2035.” However, fielding the next-generation of combat vehicles by then requires that all major decisions on the platforms, weaponry and preferred energy sources must be made by 2025, he said, adding that the Army must therefore act now to “provide some focus for our science and technology partners,” such as General Dynamics (Sheftick, 2016).

In-Theatre Installations

With the largest portion of the Army’s fossil fuel bill during deployment going to power bases and not vehicles, tackling energy consumption at the base level is a key goal of the net-zero Army. In April 2016, the Army unveiled its prototype shelter for the remotely deployed warfighter of the future. Dubbed the Minimized Logistics Habitat Unit, or MILHUT, it’s a modular living quarters that uses energy-saving and renewable-fuel technologies to “enable warfighters to be deployed longer in remote areas without the need for resupply,” according to an official Army statement. “The MILHUT system provides habitat, hygiene and meal preparation capabilities that are not usually available with deployments to remote, austere areas,” the Army said after revealing the new technology at the United States Army Natick Soldier Research, Development and Engineering Center (NSRDEC) in Natick, Massachusetts (Benson, 2016). At the core of the MILHUT is a modular and transportable military shipping container and tent structure with in-house water recycling, flexible photovoltaic solar panels and wind-turbine connectivity to power things like temperature control, laundry facilities, refrigerators, microwaves and stovetops for meal preparation, power outlets and charging for personal

electronic devices, and hot-water shower facilities.

It's part of the Army's larger renewable deployment demonstration effort, known as the Sustainability Logistics Basing, Science and Technology Objective – Demonstration. The goal of the program is to reduce fuel, water and waste in remote expeditionary base camps. But the NSRDEC lab is also interested in how technologies developed for the remote deployment MILHUTs will help the Army “better understand the art of the possible and how they can be extended to larger systems” down the road, according to NSRDEC deputy Paul Carpenter (Benson, 2016). “The system exhibits solar energy capture, an on-board generator, a high-speed, low-flow laundry system, a waste remediating latrine, a shower with water reuse capability, and an efficient ‘kitchenette’ in a compact form factor, supporting up to 20 warfighters,” said Chris Aall, the MILHUT project officer and a mechanical engineer at NSRDEC, during the April unveiling. “These inherent benefits aim to positively contribute to the [NSRDEC] objectives in making the U.S. Army more agile and efficient,” (Benson, 2016).

When the U.S. Army transferred authority of Combat Outpost Giro to the provisional Afghan government in 2012, the remote base in Afghanistan's Ghazni province was already home to some of the Army's most cutting-edge renewable-fuel technologies. The base initially lacked enough electricity-generating capacity to meet its basic daily consumption, leaving it up to soldiers to tap their diesel-guzzling Humvees to generate power. The stop-gap measure meant that soldiers had to drive the vehicles around in the middle of the night to recharge external batteries to, literally, keep the lights on. But a new hybrid solar-diesel generator—with the additional capacity to store power for use after dark—solved that problem. Meanwhile, other

bases inside the Afghan theatre today are lit by large floodlights fitted with solar panels and built-in rechargeable batteries in place of diesel generators (Goossens, 2013).

The U.S. Army Special Forces are also enlisting the sun's power in the now 16-year-long American military campaign in Afghanistan. In November 2012, Special Forces soldiers deployed to remote outposts used 10 solar-diesel hybrid generators to produce electricity for their operations, something the Army credits with cutting fuel supply-related deaths and providing those soldiers with more time to train the Afghan forces to fight the remaining insurgency (Vergun, 2012). Because Special Forces outposts in Afghanistan are, by nature, rugged, remote and often deep within hostile territory, securing traditional fuel supplies often requires aerial fuel convoys. But while that may sound like a safer alternative to slow-moving, sitting-duck truck convoys, securing a landing zone, unloading the fuel and completing a convoy excursion back to base takes several hours and requires considerable manpower, which Special Forces outposts are necessarily short on.

Dennis Bohannon, the Army's spokesman for installations, energy and the environment, further broke down the operational benefits of those 10 solar-diesel generators. Each 28-kilowatt mobile generator, supplied by Texas-based Sundial Capital Partners, can provide enough power for 30 soldiers in Afghanistan, saving approximately 460,000 gallons of diesel per year, according to Bohannon. He estimates that's equal to pulling 185 of the Army's Afghan-deployed eight-wheeled tactical fuel trucks from the theatre each year. "In terms of cost," Bohannon said, "these systems pay for themselves in fuel savings in about two-and-a-half months" (Vergun, 2012).

In 2012, Richard Kidd IV, the Army's deputy assistant secretary for energy and sustainability, estimated that each American soldier in Afghanistan used about 20 gallons of diesel fuel per day, with more than 40 per cent of that—more than eight gallons—used to produce electricity (Vergun, 2012). “With solar power, we are cutting the supply of fuel needed in half, from 40 to 20 per cent,” Kidd told the *Army News Service* (Vergun, 2012). That not only frees up air and land assets that would otherwise be resupplying diesel fuel to Afghan outposts, but it also frees up the fuel—and the money to supply it—for use where petroleum hasn't yet been replaced.

The main objective of the net-zero policy is, of course, to reduce the *quantity* of fossil fuel energy expended by the Army. But, at the Afghan Special Forces outposts in particular, increasing energy *quality* proved to be an unintended benefit of the solar switch. High-tech electric sensors and cameras require “high-quality power to maintain consistency in hertz and frequency,” says Kidd, adding that “you don't get that when you're connected to generators, but you do when you're connected to batteries. So, operational-readiness rates of sensors and communications equipment have gone up dramatically wherever solar has been deployed” (Vergun, 2012).

The Army's standard diesel generators are also prone to breaking down more often than hybrid solar-diesel generators, putting unnecessary strain on Army mechanics. It's due to the fact that in-theatre diesel generators most often run at “wet stack” levels, meaning at the low end of their output capacity, allowing unburned fuel to be discharged through the exhaust pipe, or stack.

That causes increased wear and tear on the generator engine, but it's also necessary to produce steady and reliable output levels across a system of diesel generators powering a grid.

"Generators like to operate at 75 to 80 per cent, not the 20 to 30 per cent they often run at," Kidd told the *Army News Service* (Vergun, 2012). However, because the new split solar-diesel generators can be networked together on a "smart grid," a single generator "will service the whole load all the time," thereby running at greater capacity (Vergun, 2012).

"If more power is needed," Kidd continued, "they come on-line in a staggered manner," extending the life of the generator by allowing each to operate at its ideal capacity, while also conserving the diesel fuel that would otherwise be wasted through the exhaust (Vergun, 2012). Of course, when the sun is shining, the generator's batteries are being charged so no external fuel is needed. And when the sun is down or otherwise obscured—sandstorms are common throughout the Middle East—the batteries continue to provide stored electricity until completely expended.

In rural Afghanistan, the U.S. Army's added renewable power capacity may be helping, in small part, to win the so-called war for "hearts and minds," too. According to the Army, soldiers deployed with solar generators to Afghanistan have more than enough power-generating capacity for their own electrical needs—enough even to supply local Afghan villages. "This will help Special Forces' public engagement and village stability missions," Kidd said. "We're on the cusp of making intelligent, informed power management a feature on the battlefield" (Vergun, 2012).

Domestic Installations

On the home front, which for the United States military extends well beyond mainland America to more than 700 officially declared bases in 49 countries and territories around the world, developing and deploying renewable energy has become a mission imperative (United States Department of Defense, 2015). Deep in the New Mexico desert, the 8,300-square-kilometre White Sands Missile Range is the largest Army installation in the United States. The proving ground's pedigree in developing new modes of energy production reaches back more than 70 years to the dawn of the Atomic Age.

It was here that the Trinity test, the world's first introduction—albeit then a secret one—to the awesome power of nuclear energy was completed. As part of the Manhattan Project, which developed and eventually deployed nuclear bombs over Japan during the Second World War, Trinity was the first ever detonation of a nuclear weapon, proving the massive dispersive energy potential of split atoms. Of course, the driving concern of the Manhattan Project was to build workable nuclear weapons, not to pioneer an age of nuclear reactors that would go on to provide electricity to power civilian infrastructure the world over. However, this example bears noting as an early instance of American military technology later driving major social and commercial forces in the energy sector.

Today, many of the same attributes that made the White Sands testing range the preferred site of the Trinity nuclear test also make it an ideal proving ground for the Army's renewable energy program. Namely, the vast southern desert is home to dependably clear skies, a large

American military base and not much else. In January 2013, the Army unveiled a US\$16.8-million solar farm at White Sands, its single biggest solar power-generating investment up to that point. According to the Army and to Siemens, one of many development partners on the project, the 4.5-megawatt power plant generates a fuel savings of US\$930,010 per year and provides on average about 10 per cent of the White Sands site's electricity needs (WSMR Public Affairs, 2013). "This solar-energy system demonstrates that the U.S. government's goals for enhancing security through energy independence can be met both economically and practically when the public and private sectors work together," said Dan Shugar, CEO of Siemens subcontractor Solaria Corporation, at the unveiling (WSMR Public Affairs, 2013).

The Army's goal of becoming a net-zero energy user requires that it install one gigawatt—1,000 megawatts—of renewable electricity infrastructure in the U.S. by 2025, and reduce its overall non-tactical fuel consumption to 70 per cent of 2005 levels by 2020. One gigawatt is roughly the production capacity of the nuclear reactors at the Palo Verde plant in Arizona, the largest nuclear power plant in the U.S (International Atomic Energy Agency, 2007; U.S. Energy Information Administration, 2016). Much of that work falls to the Army's Energy Initiatives Task Force, the central management office established in 2011 to oversee the Army's deployment of renewables across all its U.S. installations.

In August 2016, the Army reached a milestone on the road to its renewable energy installation target. Responding to a 2014 challenge from then President Barack Obama to all federal agencies to collectively achieve US\$4 billion in energy savings over the next two years, the Army alone surpassed the US\$1-billion mark well before the December 2016 deadline

(Unruh, 2014; Loveless, 2016). Since 2011, the Army has signed more than 127 private sector contracts for renewable-energy technologies at 52 installations from California to New York, Washington state to Puerto Rico, spurring more than US\$1 billion in clean energy innovation in the U.S. (Sheftick, 2016). That's not only good news for the U.S. military and the taxpayers who fund it. It's also good news for the solar, tidal, wind, biomass and waste-to-energy developers for whom a larger, more stable and more robust customer base than the U.S. military for proving up new technologies would be unimaginable.

Chapter Five: The Military-Energy Industrial Complex

The Medico Industries metal forgery in rural central Pennsylvania is a 50-year-old industrial site that lies at the nexus of the American military-energy compact. Young men in coveralls and sweat-soaked bandanas ram iron tongs into open foundries—three-thousand degree Fahrenheit pits of white fire—and pull out raw steel ingots to hammer into shape; one for a downhole well-joint for the local oil and gas fracking industry, the next for a high-fragmentation artillery shell for the United States Army. In the spring of 2016, both customers are buying product faster than it can even be delivered. It's a modern-day example of a private industry that's been pressed into the service of both the U.S. energy industry and the U.S. military with equal verve and sense of patriotic duty.

Between rows of rusted ventilation fans, the walls of Medico are lined with tri-colour banners proudly proclaiming “Powering America,” and pennants documenting the passage of multimillion-milestone markers for 155-millimeter artillery rounds delivered to the battlefields of Afghanistan and Iraq. “The military is an excellent customer because if they use it once, they have to replace it,” says Medico’s president of manufacturing, Bob Mitvalsky. “You shoot a bullet and that bullet’s gone—you have to make another bullet. With oil and gas, it’s not quite as good as that, but the swivel elbows do wear out and the tool joints do wear out” (Mitvalsky, 2016)

Medico is not unique to the region as the only joint energy-defence manufactory, either. Just a few kilometres down the highway in Williamsport, PA, lies Wire Rope Works, a century-

old factory that makes heavy steel cables for the oil and gas drilling and mining industries. But talk to any of the employees here and most will tell you that the product they're most proud to manufacture is a high-tension steel rope that's affectionately called "Tank Yank." It's a steel cable now commissioned by the U.S. Army to outfit the M88 Recovery Vehicle, known in the Army as "Hercules," or Heavy Equipment Recovery Combat Utility Lifting Extraction System. It's essentially part tank, part tow truck, and it's used primarily to pull incapacitated Army tanks off the battlefield. Most will recognize the vehicle as that which, immediately after the fall of Baghdad to American forces in April 2003, rolled into the Iraqi capital's main square and pulled down the statue of dictator Saddam Hussein. It was a moment that was broadcast live around the world and became one of the most enduring images of the U.S. invasion. The rope that did the pulling was, of course, Wire rope's own Tank Yank (Szamocki, 2015).

The energy-to-armaments industrial overlap is a natural one when considering the precise high-tensile steel machining required to make, say, a 30-foot length of pressure-resistant drill pipe, or the rifled barrel of an artillery gun. "Not a lot of people can make round, long cylindrical parts," Mitvalsky says, estimating that 80 per cent of Medico's business remains in the energy sector after first taking on military contracts in the early 1980s. "If you look at the auto industry, they're making little gears and little rocker arms, but that's all what's called closed die forging—not real flexible, and if you set a press up like that, you're going to have to adjust to make a million different parts. Well, we can make round, cylindrical parts in varying lengths, varying diameters, and we can put shape on the inside, shape on the outside, shape on the bottom, shape on the top. For the military, we just take the round cylindrical part and then we do a secondary operation where we fold the nose shut," making the sharp end of an artillery shell.

Defence-Energy Synergy

The convergence of the military and energy industries in the United States is nothing new. American defence has a longstanding partnership with the country's energy sector, dating back to the era of the Texas Railroad Commission, the "Seven Sisters" oil companies and the lead-up to the Second World War, when the state railroad body colluded with the U.S.'s largest oil firms to keep oil flowing to the Armed Forces in exchange for guaranteed access to steel for drillers. In return for their cooperation, the oil companies were allowed to essentially set national oil prices and policy (Dahl, p. 147). Prior to that, U.S. president Woodrow Wilson had established the Fuel Administration in 1917, tasked with procuring sufficient supplies of oil from U.S. companies to feed the America's military, its essential war industries, and the Allied Forces for whom the U.S. supplied 80 per cent of their wartime fuel requirements. "The needs of mobilization expanded the role of the state in the economy and created new alliances between government and private business. The United States and the American oil industry were no exception" (Yergin, *Prize*, p. 162). When the oil industry of the day protested the U.S. energy administration's request for "voluntary" domestic oil price controls due to the surging global demand for its products, the government threatened the alternative would be legislated price controls, and reminded the producers that it was the U.S. government that helped them secure the much-needed iron and steel—one-twelfth of the country's output at the time—for their drilling operations, and that it was the government that provided military draft exemptions for oilfield workers (Yergin, *Prize*, 163).

Naturally, the special relationship between energy and defence manufacturers continues today, and applies as much to the major international energy players as to the smaller domestic manufacturers and suppliers. Like the energy sector, the modern defence industry in the U.S. is by and large a free market, albeit with some special benefits and restrictions. For reasons of national security and political expediency, government defence procurement tends to favor domestic suppliers in fulfilling contracts. The Bethesda, Maryland-based Lockheed Martin, for instance, is the world's largest defence company and, in 2015, was also the U.S. government's largest single contractor, lapping second-place finisher Boeing by a margin of US\$16-billion (Mehta, 2016). Much of Lockheed's recent market dominance can be attributed to the company's pivot into the energy space, essentially double-dipping on the business end of the American defence-energy nexus. "Lockheed Martin, as it turns out, is one of those companies that's not just a defence company," says Gary Biermann, Lockheed's regional technology manager for Canada. "We also are an energy company" (Biermann, 2016).

In March 2016, Lockheed formalized its energy portfolio into the consolidated business of Lockheed Martin Energy. Newly appointed vice-president Frank Armijo told reporters at the company's 2016 Media Day that he expected 70 per cent of new energy generation in the U.S. to be driven by renewables in the years to come. "We see energy as a global security and economic imperative," Armijo said. "It's changing rapidly, the population is growing quite rapidly... The need for power is going to continue to grow" (Bach, 2016).

It's not for nothing that Lockheed Martin is affectionately known within defence circles as "Lockmart," due to its Walmart-like dominion over global defence and aerospace retail. So,

trying to be both the world's leading provider of military hardware and the fuel infrastructure that powers it makes good business sense from both an investment standpoint and an engineering standpoint, according to Biermann. "Both aerospace and the oil and gas industries work in very harsh, often unexplored or very remote environments," he says. "And they require unique technical solutions for the safety and viability of their business operations in those environments." Case in point is Lockheed's new remote-controlled freight helicopter. Unveiled in 2016, it's a pilotless helicopter built on the same airframe as Canadian oil and gas giant Cenovus Energy's SkyStrat airborne drilling rig, but for use on the battlefield. "We took it and made it remotely piloted, initially for operations in Afghanistan, where we were losing a lot of people in convoys," Biermann says. "So we found a way to fly stuff out to the front lines at night without having to risk people's lives" (Biermann, 2016).

In a word, it's about synergy. Few industries operate on the kind of mega-scale that defence and energy do, sometimes requiring dramatic feats of engineering just to get equipment to where it's needed. Building a hydroelectric dam, towing an offshore drilling rig, or erecting a line of wind turbines are each nothing short of a "military operation" as far as engineering, manpower and logistics are concerned. "Before I got involved in the energy industry a number of years ago," Biermann says, "I arrogantly thought that aerospace was the biggest-scale industry out there—until I went out and saw some processing plants in the oil fields" (Biermann, 2016).

Physical feats aside, risk is another x-factor that energy and defence companies contend with. There are, of course, inherent financial risks to any business. And there are certainly inherent physical risks to personnel when the tools of the trade are high-tension power lines,

drills designed to pierce deep into the earth's crust or weapons designed to kill people. But the sensitive nature of these trades also leaves energy and defence firms open to huge reputational risks, as well. Cyber attacks and espionage, both foreign and domestic, are routinely cited as the fastest emerging threat to companies in the energy and defence industries. And a cyber attack on a local power grid or the theft of defence software in development for the U.S. military can both have grave implications for national security.

Lastly, there's the public relations problem faced by both industries. Popular opinion is rarely on the side of those seen to be profiting—or, in the language of those opposed to either industry, “profiteering”—from the exploitation of natural resources or the global arms trade. That finds the two industries often sharing a common seat in the court of public opinion—that of the the defendant's chair. To counter these perception risks, defence firms, energy firms, and defence-energy firms such as Lockheed typically deploy sizeable public relations staffs and maintain close ties with governments through lobbying or so-called revolving-door appointments between government and industry.

The Revolving Door

In the late 1970s, when president Jimmy Carter described Hyman Rickover as “the greatest engineer of all time,” he was referring as much to the U.S Navy admiral's unprecedented 63 years of active duty—during which time he pioneered the world's first nuclear navy—as he was bringing attention to Rickover's fatherhood of the civilian nuclear power industry (Carter, p. 28) Carter himself had served on some of the Navy's earliest nuclear submarines after finishing

high school and considered Rickover one of the greatest influences on his life. After the Second World War, during which the admiral led the electrical engineering section of the Navy's Bureau of Ships, Rickover was dispatched to the secret nuclear research city at Oak Ridge, Tennessee, on orders to learn the mysteries of atomic energy and how it might be harnessed for peaceful power generation (Yergin, *Quest*, p. 365). There, Rickover realized the possibilities nuclear power could provide submarine propulsion that diesel fuel could not—namely increased range, speed, efficiency and silence. The military's nuclear power generation program reached a heightened state of urgency in 1949 with the first Soviet atomic bomb test. Rickover was soon put in charge of both the Navy's nuclear propulsion program and the newly created U.S. Atomic Energy Commission (AEC). That rare military-civilian double-duty appointment allowed the two nuclear energy programs to overcome many levels of bureaucratic oversight and implement any new technological discoveries across both of government programs. "It was said that he would write letters to himself and then answer them, ensuring instant sign-off from both the Navy and the AEC" (Yergin, *Quest*, p. 366).

As unpopular as Rickover's unusual double appointment was among the civilian and military bureaucracies of the day, his achievements spoke for themselves. The *USS Nautilus*, the world's first nuclear submarine, was commissioned in 1954, after just seven years of research and development—compared to the quarter-century that many were predicting (Yergin, *Quest*, p. 367). In 1957, the Shippingport Atomic Power Station in western Pennsylvania became the world's first full-scale nuclear power plant devoted exclusively to peacetime power generation (USNRC, 2016). It was built using Rickover's scaled-up designs for a nuclear-powered aircraft carrier, and the admiral would oversee the plant's operations for the next 25 years. By the time

Rickover retired in 1986, 40 per cent of the U.S. Navy's major combatant ships would be nuclear powered and dozens of large-scale nuclear power plants would dot the American landscape, all based on his original designs (Yergin, *Quest*, p. 367).

The Military Renewable Energy Industrial Complex

Harnessing nuclear power brought previously unimaginable energy production potential to the world, but as mentioned in the preceding chapter, it also opened the door to accidental civilian nuclear cataclysm and a global game of nuclear brinksmanship in which the stakes were, at times, the existence of all life on the planet. Unlike any civilian energy generation source before it, the proliferation of nuclear power has required the oversight of independent international regulators, whereby any suspected contravention of nuclear norms has been cited as justification for international sanctions and even war. Still other cases exist wherein nations have independently taken extrajudicial actions—including military strikes and assassinations—against states they suspected of developing covert nuclear programs.

To say that nuclear power—although otherwise clean and carbon emissions-free—is a contentious source of energy is a gross understatement. That its discovery resulted from a U.S. military plan to create a weapon of such awesome destructive force is less a condemnation of the military's ability to harness new energy—which was, after all, successful—than a recognition later of the toxicity of the energy source itself. By comparison, the U.S. military's modern renewable energy program is subject to no such scrutiny on public health grounds. Modern renewables are unique in that, unlike oil and radioactive metals, they are so far immune from

being wielded as a weapon in and of themselves, either through their deployment or restriction to combatant nations. While renewably generated electricity can propel warships and even power future battlefield weapons like tactical lasers, it is not the exposure to the fuel source itself which determines battlefield outcomes, but the access to the technology which harnesses it. For those and other reasons, the military's procurement of renewable power sources is far less socially fraught than, say, procuring oil or radioactive metals. That applies to partnerships with civilian utilities, too.

Domestic U.S. military bases are increasingly providing their excess renewable power output to local power utilities through state and municipal grids. From tidal power at Marine Corps Base Hawaii, landfill biomass at Fort Drum, New York, to a 250-acre solar array at Fort Stewart, Georgia, military renewable energy projects are partnering with local utilities to provide heightened energy security against grid failure. As new military-utility partnership projects such as these come online almost weekly in the U.S., we'll see in the following chapters that the Department of Defense is proving it's well-positioned to carry forward its renewable-energy agenda far beyond the confines of the battlefield and domestic bases to the wider commercial market.

Chapter Six: Air Force: Solar, Biofuels and Wind Beneath Their Wings

It's been said that surviving your first day in prison requires that you find the biggest, meanest inmate in the yard and fight them. That way, according to country musician Steve Earle at least, you might not win, but you've proven you're up to the challenge. A similar logic might be applied to the U.S. government's tackling of its fossil fuel bill. If Uncle Sam must prove his mettle against a heretofore spiralling fossil fuel addiction, there could be no meaner, more emblematic foe than the U.S. Air Force.

While the Pentagon is the largest institutional consumer of oil in the world, the U.S. Air Force is by far the largest single consumer of petroleum fuel within the Pentagon, and within the U.S. government as a whole. "The Navy consumes one-third of all operational energy" in the U.S. military, according to Phyllis Cuttino, the Pew Charitable Trust's foremost expert on the Department of Defense's energy policy. "The Air Force consumes half" (Cuttino, 2016). In fact, the Air Force consumes more than half—about 2.4 billion gallons of the total 4.6 billion gallons of fuel the Pentagon consumes annually, according to the Air Force's own data (Weaver-Cox, 2010).

Generating sustained lift at supersonic speeds is incredibly energy intensive. For that reason, many believe that replacing liquid jet fuels with an alternative non-combustible source is beyond the means of even near-future technology. "No matter how good the batteries get, we're not going to fly a plane on a battery or sail a ship," says Steven Martin, chief scientist with Pond Technologies, a Canadian pioneer of algae-based petroleum-fuel replacements. "We will always

have to burn stuff” (Martin, 2017). Yet, because of the prevalence of air travel in civilian life—at least compared to, say, ocean travel—the aerospace market presents a golden opportunity for renewable fuel expansion beyond the military.

In July 2016, an airplane known as the Solar Impulse 2 landed in Abu Dhabi, becoming the first aircraft to fly around the world without the use of fossil fuels. The solar-powered plane and its two pilots left that city in March 2015 and, despite its slow progress at a top speed of just 145 kilometres per hour, proved that solar-fuelled aviation is not only possible, but is also fairly reliable (Marshall, 2016).

The Solar Impulse flight was preceded by a decade of advances in solar-enabled aviation within the U.S. Air Force—albeit much of it based on the ground. In 2007, the Air Force installed the largest solar array in North America at the time, a 14-megawatt system covering thousands of acres of desert on the Nellis Air Force Base in Nevada. The Nellis solar system, which was expanded to 30 megawatts in 2015, provides both electricity for base operations, and electricity to power in-flight systems for fighter aircraft and propulsion systems for unmanned Air Force drones. “This solar project at Nellis is a first step of many toward making renewable electricity integral to the operations of the U.S. Air Force,” said then Assistant Secretary William Anderson at the plant’s opening in 2007. “As the largest consumer of energy in the federal government, the Air Force is well-positioned to promote both solar technology and new approaches to its implementation. This pioneering initiative is a good example of how a creative approach to public-private partnership can make our energy supply more sustainable, more secure and more affordable.”

With a goal to achieve 25 per cent renewable energy by 2025, the Air Force lags behind the Navy's more ambitious goal of 50 per cent renewable energy by 2020. But recent developments in unmanned aircraft technology could dramatically hasten the Air Force's progress. Over the past decade, the Air Force's rapid shift into deploying weaponized drones to carry out missions that were previously only possible with fighter jets and aerial bombers has led to a substantial drop in airborne fuel consumption. The propeller-driven, four-cylinder Predator drone, for instance, burns 300 times less fuel than a standard fighter jet on the same mission (Rise of the Drones, 2013). And whereas a fighter jet can only stay airborne for about two hours without refuelling, the Predator routinely remains airborne for more than 24 hours and flies eight kilometres off the ground in uncontested airspace (Rise of the Drones, 2013). Soon, dramatic improvements in renewable energy technology, particularly for rechargeable in-flight propulsion and guidance systems, could hasten the Air Force's reliance on battery-powered unmanned aerial drones to carry out its missions instead of petroleum-fuelled drones and piloted aircraft.

Biofuels and the Defense Production Act

Ground zero for the U.S. military's experiments in advanced aeronautics, including renewable energy-powered flight, is the Air Force Research Laboratory at Wright-Patterson Air Force Base near Dayton, Ohio. The lab controls the whole of the Air Force's science and technology research budget, which totalled US\$2.4 billion in 2006 (Petrescu and Petrescu, p. 104). It's here that the Air Force is developing a broadly sourced biofuels program for a whole range of its rotary and fixed-wing aircraft, while also working to commercialize renewable flight

fuels in the private sector. “Through government and industry partnerships and financial incentives, the little-known but extremely important program plays an essential role in assuring domestic ability to produce [aviation biofuels],” wrote the lab’s public affairs officer in August 2016 (Novobilski, 2016). “We have unique authorities through Title III [of the Defense Production Act], allowing us to enter into partnerships with commercial industry to put a manufacturing capability in place in response to a specific DoD need for technology,” says James Neely, the manager of the lab’s materials and manufacturing directorate. “Biofuels are determined as essential to national security; we are working to move the technology into the domestic industrial base, with the end goal of a consistent supply at a competitive cost” (Novobilski, 2016).

That Title III authorization came out of a 2011 decision issued by President Barack Obama which found that biofuels were vital to U.S. national security. The decision thereby triggered provisions in the Defense Production Act that are designed to provide immediate funding to new technologies that are deemed crucial to America’s war-fighting capabilities. It was the same Act invoked years before, under President George W. Bush, when there was public outcry over the insufficient quantity and quality of the armour worn by U.S. troops and plated to the sides of American Humvees in Iraq and Afghanistan. Invoking the Act at that time allowed the Pentagon to immediately guarantee a sufficient market to defense suppliers to start commercially producing high-quality armour that could be rapidly supplied to American forces in the Middle East (Lane, 2012). President Obama was applying the same rationale for building up commercial-grade biofuels for the military. “The big thing we’re trying to do is to send a clear message to industry that the Air Force wants to be in a position to purchase biofuels and to use

that operationally for our fleet,” Air Force Under Secretary Erin Conaton told Agence France Presse in 2011. “In order to do that, we need industry to be able to produce in the quantities we need at a cost-competitive price” (AFP, 2011).

The goal of the Wright-Patterson research was not only to make biofuels viable for the military and for the private aviation sector, but to eventually make biofuels the most affordable aviation option for all. (Novobilski, 2016). “The DoD uses approximately 5 billion gallons of fuel annually and represents a key market adopter for advanced biofuels technologies,” according to a March 2015 Department of Energy presentation to the Department of Defense (Haq, 2015). To that end, the Wright-Patterson lab has spearheaded and funded the retrofitting of an idle oil refinery near Los Angeles to manufacture bio-synthetic paraffinic kerosene from non-edible natural oils and farm waste. The result is a ready-to-use high-grade fuel for aircraft and other engine systems (Novobilski, 2016).

While initiated by the Pentagon, the Wright-Patterson project has since found interest from large commercial partners. They include aerospace and chemical manufacturer Honeywell, and civilian air carrier United Airlines, which, in 2016, began buying the defense lab’s leftover biofuel at a price that’s competitive with standard petroleum-based jet fuel, while at the same time achieving a reduction of more than 80 per cent in carbon dioxide emissions (United Airlines, 2016). United has since entered into a three-year contract with the Pentagon-backed refinery to buy 15 million gallons of the fuel, roughly enough to power 12,500 of its regularly scheduled flights between Los Angeles’s LAX airport and San Francisco (United Airlines, 2016). The move by United is not only good PR and good corporate social responsibility, it also

allows the airline remain low on the threshold of California's stringent carbon cap system and provides carbon credits the airline can then sell into the state's carbon market, furthering the business case for the renewable aviation fuel. Even L.A. Mayor Eric Garcetti got in on the low-carbon love-in, calling the new military-commercial biofuel project a "new standard for sustainability in aviation—an example I hope the rest of the industry will follow in the coming years" (United Airlines, 2016).

The military-funded biofuel refinery project has proved so successful that United Airlines says it intends to build its own biorefineries—five, in fact—near its main American airport hubs, estimating it could use the military technology to produce up to 180 million gallons of aviation biofuel in the coming years (United Airlines, 2016). Additionally, in September 2014, the Pentagon awarded US\$210 million under the Defense Production Act to Emerald Biofuels, Fulcrum BioEnergy and Red Rock Biofuels to build U.S. biorefineries for military fuel at a cost-competitive US\$3.50 per gallon. The refineries, once fully operational, are expected to have a combined capacity to produce 100 million gallons of military-specification jet fuel and marine diesel from rendered fats, forest products and municipal waste gases that will undergo the Fischer-Tropic process [See *Chapter One: A Brief History of the Role of Fuel in Military Conflict*] (Haq, 2015).

Of course, the demands on the military and the demands on the civilian aviation industry differ in many important ways. Airlines like United are eager to tout their green achievements to meet benchmarks of social responsibility and to draw the attention of eco-minded travellers and potential business partners. It's no fluke, after all, that United's biofuels program was piloted

between the American tree-hugging hubs of Los Angeles and San Francisco. The military, on the other hand, need not embark on such a gambit for public-relations purposes.

While both the civilian aviation industry and the United States Air Force are in the business of safely transporting passengers and crew, it remains the primary job of the U.S. Air Force to destroy targets and kill people. Fuel used for non-combat purposes such as training, transport and routine patrols undoubtedly makes up a substantial portion of the Air Force's overall fuel consumption. But, again, these are all carried out in the service of eliminating threats to American security. If biofuels can help the Air Force do so with increased efficiency, that's reason enough for the Air Force command to pursue its sustainability targets relentlessly. And if that sparks a wider adoption of biofuels within the U.S., then that's the kind of "collateral damage" that can only benefit American forces by advancing the technology, making the fuel more affordable and readily available, and denying hostile oil-exporting countries and non-state groups their oil export revenues.

As it turns out, biofuels are, in fact, demonstrably increasing the Air Force's per-plane killing power. Tests conducted at the Air Force's Wright-Patterson research laboratory have shown that American warplanes can fly faster, farther and carry larger payloads when flying on biofuels than on conventional jet fuels made from crude oil (Lane, 2012). A fully loaded and biofuelled F/A-18 Super Hornet, for instance, can carry one additional missile during military operations due to the decreased weight of biofuels versus conventional jet fuel—a difference of about seven per cent (Beidel, 2012).

At a high-level briefing in Washington following the Wright-Patterson fuel tests, Omar Mendoza, an aerospace engineer and program manager at the base, told congressional staff and departmental heads at Energy, Agriculture and the Navy that the renewable test fuels had lowered aircraft engine temperatures by 135 degrees, due to the absence of impurities found in conventional fossil fuels (Lane, 2012). The excess radiant heat from burning fossil fuels not only decreases engine efficiency but also increases metal fatigue, lowering engine reliability and shortening the lifespan of the aircraft. “At the temperatures that military jet engines perform at,” Mendoza said, “an additional 25 degrees in temperature can shorten the life of the engine by half” (Lane, 2012). He added that data showed that engine parts could last up to 10 times longer if new biofuels were used instead of conventional jet fuels (Lane, 2012). And, if new engines were designed specifically to maximize the potential of biofuels rather than simply using them as a drop-in replacement for conventional jet fuel, Mendoza said the Air Force and its partners in industry could “design engines with more capability, more speed and more range” (Beidel, 2012).

At that meeting, Matthew Seaford, then deputy director for the Defense Production Act Title III, supported invoking the Act to procure biofuels and new engine designs through commercial means, saying the decision was in line with similar situations faced by the Pentagon to secure vital materials. “We are not here to provide a subsidy,” Seaford said. “We are here to ensure that commercial production reaches levels where the military can secure the supplies it needs at prices it can afford. We come in once, and we don’t come back” (Lane, 2012). To that end, the Air Force authorized the industrial giants of aerospace engineering—Rolls Royce, General Electric, Honeywell and Pratt & Whitney—to study the Air Force’s flight-test results

and report back with cost and maintenance estimates for new biofuel engine designs (Beidel, 2012). However, subsequent years of partisan politicking within the House Armed Services Committee over the National Defense Authorization Act passed the biofuels bill out of committee in 2015.

While issues with the amended biofuels portions of the bill have yet to be resolved, the Air Force is continuing to dole out development grants to private biofuel manufacturers and to research laboratories at such institutions as New Mexico State University and the University of Central Florida to further the case for biomass-fuelled aviation. And the civilian airline industry continues to follow the military's lead—and its lucrative development incentives. In the civilian industry, jet fuel accounts for 25 to 35 per cent of all operational costs, making it the largest and most unpredictable item on any airline's expense sheet (Yergin, *Quest*, 621). "Demand for petroleum will eventually outpace the supply," says Shuguang Deng, a chemical engineering professor at New Mexico State and the lead researcher on the algae-to-jet fuel project. "The use of petroleum-based jet fuel is not sustainable and negatively impacts the environment. That's a national security issue" (Bannister, 2010).

While the Pentagon consumes 4.6 billion gallons of fuel each year, Deng estimates that all airplanes globally consume approximately 80 billion gallons of fuel per year. At that level of consumption, Deng says American aviation biofuels have the potential to create far-reaching military and commercial development opportunities (Bannister, 2010). It's of little wonder then why the civilian and freight airline sectors would be so eager to allow the Pentagon—with its unmatched variety of aircraft, from the sleekest executive shuttle jets to the world's largest cargo

planes and long-haul tilt-rotor aircraft—to test the waters of the renewables market before diving in themselves once things have sufficiently warmed up. “The Department of Defense, they have a lot of resources, and if they want to do it, they will be the first one to get approval,” says Animesh Dutta, a biofuels researcher at the University of Guelph in Ontario. “Already having a user of it like Defense, you will see the supply chain will be there; you will have that supplier, and then commercial will be available right down the line” (Dutta, 2017). What it comes down to, Dutta says, is the Pentagon’s ability to absorb budgetary risk, versus that of the more risk-averse commercial airline sector, where profit margins from year to year are often razor thin. “You need someone there to welcome the risk because these are not yet mature; there are some challenges still and lots of opportunity, but if government doesn’t take the risk, no one will,” he says. “But now, in the future, biofuels will be huge for commercial airlines” (Dutta, 2017).

In many important ways that’s already happening. With an average monthly production of 535 million litres of biodiesel, the United States is now by far the largest producer of biofuels in the world (IEA, 2017). Since the Pentagon’s initial September 2014 outlay for the three biorefinery projects already mentioned, Southwest Airlines, the world’s largest low-cost carrier, has signed a fuel purchase agreement with Red Rock’s wood-waste biorefinery to purchase three million gallons of jet fuel per year, diverting 140,000 tons of forest biomass annually into the renewable fuels stream. And Cathay Pacific, Hong Kong’s official flag carrier, has become an investor in Fulcrum’s municipal solid waste biorefinery, negotiating a 10-year supply agreement for renewable jet fuel from the military-sponsored project (Haq, 2015).

Blowback: Tilting at Windmills

For all the U.S. Air Force's successes in developing, deploying and effectively demilitarizing biofuel technology into the wider aviation industry so far, the airborne armed services branch has met some resistance over its efforts to deploy another renewable energy resource, namely wind power. All branches of the U.S. Armed Services, including the Air Force, have deployed wind turbines on and around military installations over the past decade, generating reliable and efficient electrical power that's independent of local electricity grids—and independent of their potential for failure. The electricity-generating wind turbine wasn't invented by the U.S. Air Force, of course, nor is it even remotely a modern technology. The use of wind turbines to convert kinetic wind energy into electrical current is about as old as electrification itself—and the principles of the technology haven't changed much since the 1800s. What has changed, however, is the massive growth in the size of the turbines used and in the volumes of electricity they can produce. It's their size that has recently caused some problems for the Air Force.

One of the key responsibilities of the U.S. Air Force is to arm, staff and send warplanes into the skies in defence of American interests. Another is to detect, track and deter enemy aircraft that would otherwise harm the advance of those interests. It's to this second point that the suitability of wind farms near Air Force bases is intermittently debated among U.S. politicians. As with anything that dwells in the nexus of American renewable energy and national security, the discussion about wind turbines on and around Defense department property tends to veer into the purely politically partisan. But, for the purposes laid out here, it's important to stick to the

facts of the matter, wherever possible, as a question of whether wind turbines are suitable to the energy and security needs of the Air Force or not.

One of the main concerns about wind turbines has to do with the Air Force's radar systems. In early 2017, Republican state lawmakers in South Carolina asked the new administration of President Donald Trump to oppose the construction of a nearly completed wind farm over reports that the blade movement on even a handful of wind turbines could seriously hinder the ground-based radar's ability to accurately detect the trajectory of aircraft and ships hundreds of miles out over the Atlantic Ocean and in the Caribbean. The Pentagon, however, was quick to refute the claims, saying it has studied extensively the potential for interference with its so-called over-the-horizon radar systems across the state line in Virginia, and found no complications to the radar's operations or any negative implications for national security as a result of turbines near military installations (Biesecker, 2017).

Blowback II: The Drones Come Home to Roost

In early 2017, a video surfaced on a handful of social media feeds associated with the Islamic State depicting a series of drone strikes carried out inside the city of Mosul, Iraq. But unlike the hundreds of similar videos of drone strikes targeting ISIS militants which had become a hallmark of the eight years of the Obama presidency, this video was the first widespread visual evidence of a weaponized drone targeting U.S. and Iraqi security forces. The attacks depicted are admittedly low-grade and unsophisticated—consisting of little more than Soviet-era mortar rounds dropped from overhead by primarily consumer-grade remote control toys. The likely

purpose of the video, in all its CGI-enhanced glory, appears to be as a tool of propaganda more so than as an indication of shifting battlefield tactics or the introduction of a fully fledged ISIS drone program. Commenting on the video, Major General Gary Volesky, Commander of the U.S. 101st Airborne Division, referred to the Islamic State's use of drones as "a lot of commercial, off-the-shelf" technology that is "clearly not the capacity or capability that we have" (Volesky, 2016). The largest of the drones depicted in the video, however, appears to have a wingspan of between five and six feet, and bears a striking resemblance to the U.S. military's own MQ-9 Reaper drone (Adams and Campbell, 2017).

Around the time the video was posted in January 2017, Iraqi troops had just captured a drone-making facility in Mosul, where they discovered reams of drone parts and documents, including a procurement system for buying aircraft materials and procedures for altering the equipment. "On one hand, the lists show the Islamic State's efforts to acquire predictable items like a GoPro camera, memory cards, GPS units, digital video recorders, and extra propeller blades," according to a report by the Countering Terrorism Center at the U.S. Military Academy at West Point, which published some of the documents. "Yet, on the other hand, the lists also speak to the group's efforts to secure, modify, and enhance the range and performance of its drones, whether commercially procured or otherwise" (Rassler, al-'Ubaydi and Mironova, 2017).

The existence of Islamic State drones, regardless of how crude, illustrates the darker side of how the dispersal of a technology, from its invention within the United States military to its deployment by a sworn enemy on the other side of the world, has sped up dramatically in the

modern technological age. But there is perhaps no battle more doomed to failure from the outset than the fight against technological advancement or its fruits becoming ever cheaper and more sophisticated with the passage of time. But the same logic applied to renewable energy yields no such cause for concern—as does, say, the risk of oil wealth or nuclear energy falling into the wrong hands.

Solar Drones on the Horizon

For more than a decade, the U.S. Air Force’s go-to aerial drone for intelligence, surveillance and reconnaissance (ISR) missions has been the Northrop Grumman RQ-4 Global Hawk. No other drone in the U.S. arsenal can fly as high or for as long. In 2014, an Air Force Global Hawk flew for a record-setting 34 hours—the longest unrefuelled flight of any U.S. Air Force craft in operation—reaching a ceiling of 60,000 feet (United States Air Force, 2014). Although the smaller Predator drone from vehicle-maker General Atomics Aeronautical Systems is said to be now in the test phase of an update that would deliver a 40-hour flight time, the U.S. Air Force is already looking far beyond that horizon—and looking squarely at the sun to get it there.

Leapfrogging the proposed 40-hour flight time, the Pentagon, in February 2017, set about assessing the results of a solicitation for proposals from contractors to design a low-cost, ultra-long distance surveillance drone that could remain airborne without refuelling for at least one week. “The objective of this topic is to develop a low cost UAV with very long endurance, of at least seven days, that would enable the ISR mission to be accomplished with reduced manpower

and system resources—especially number of vehicles—to maintain near continuous coverage,” writes the Department of Defense in its call for submissions (SBIR-STTR, 2017). “A number of possible technologies can be considered to meet this requirement, but it is anticipated that the most likely candidates include hybrid power systems, solar power, and possibly power harvesting” from ambient sources such as wind, heat or electromagnetic radiation (SBIR-STTR, 2017).

The Pentagon has made no announcements yet on where its solicitation for a future-fuelled, ultra-endurance drone has led, but it’s clear to observers of the aviation industry that the race for a solar-powered, high-altitude, ultra-long distance aerial drone is officially on. On December 16, 2016, just two weeks after the Pentagon’s new drone procurement request was tendered, aeronautical engineers at Facebook published an update on the company’s two-year-old high-altitude solar drone project known as Aquila. In their update, the engineers specified that while Aquila’s first test flight in June had resulted in a crash after just 96 minutes of flight, the solar craft would indeed rise again and prove that it’s “designed to stay aloft for 60 to 90 days” (Maguire and Gomez, 2016).

Meanwhile, across the Atlantic, French-owned Airbus has reportedly made progress on its own solar drone prototype, the Zephyr. Described by the company as a High Altitude Pseudo-Satellite (HAPS), the solar-powered Zephyr, according to Airbus, “fills a capability gap between satellites and UAVs” and is “uniquely designed for both military and commercial purposes” with the ability to “deliver numerous payload capabilities” (Airbus, 2017). If that sounds precisely like what the Pentagon is currently looking for, it’s worth noting, too, that the Zephyr holds the

world record for the longest single unrefuelled flight of any aircraft—not just unmanned—at 14 days.

Tellingly, the website promoting the Zephyr features two illustrations of its intended applications. The first, labelled “Border Security,” depicts the Zephyr patrolling a border fence and relaying data on illegal border-crossers to a military rapid response team; while the other, titled “Communication,” depicts a so-called “special ops” military patrol moving among the adobe huts of a desert village as a Zephyr flies overhead relaying information about enemy movements to a local military base, which in turn dispatches an armoured convoy to the area (Airbus, 2017). As of this writing, Britain’s Ministry of Defence has bought three of the Zephyr solar drones. But where the U.S. eventually awards its long-range renewable drone contracts will be a far more significant indicator of which technologies will dominate the military drone space of the future, due in no small part to the U.S.’s unrivalled military spending, as well as its advances in the fields of military renewable energy and unmanned aerial warfare.

Chapter Seven: Strategic Impetus

“Each day brings further evidence that the ways we use energy strengthen our adversaries and threaten our planet.”

—U.S. President Barack Obama, 2009 Inaugural Address

The American lifestyle is oil intensive and oil is expensive—expensive to acquire and expensive to reliably transport. As previously mentioned [See *Chapter Two: The Great Green Fleet*], between 1976 and 2007 the U.S. military spent more than \$7 trillion protecting oil chokepoints in the Persian Gulf from disruption (Stern, 2010). Each day, approximately 17 million barrels of oil flow through the Strait of Hormuz at the eastern end of the Persian Gulf between Iran and the United Arab Emirates, making it the single largest potential petroleum chokepoint in the world. Less than 10 per cent of the oil that passes through the Gulf is bound for the United States, with most headed instead for China, India and Japan (U.S. Energy Information Administration, 2014). Still, it falls no less on the U.S. Navy’s Fifth Fleet to protect tanker traffic in the Gulf from sea mines and naval blockades by regional aggressors like Iran. On the other side of the Arabian Peninsula lies the Red Sea, where again the Fifth Fleet, stationed in Bahrain, stands guard over the 4.5 million barrels of oil that pass daily through Egypt’s Suez Canal to the north and the 3.3 million barrels that pass through the Mandeb Strait off Yemen to the south (U.S. Energy Information Administration, 2014). That the responsibility for protecting these sea lanes, these global energy lifelines, falls unduly on the United States Navy raises the obvious question: Why?

Oil is Power

As with any question of oil and its function in geopolitical power, the answer is complex. We have already touched upon the significance of crude oil throughout history as the world's most valuable commodity and the densest known liquid source of the energy that makes all modern economies run. Oil is, therefore, the baseline provider of not just wealth to countries, but more importantly, power. For the U.S., and particularly for its allies in foreign oil-dependent regions like Western Europe and Japan, securing access to oil is as important to preserving power as granting access is to those nations and governments that possess it. To the non-democratic oil-rich states of Africa, the Middle East and Russia, oil is absolute power. "Since 1980, the developing world has become wealthier, more democratic, and more peaceful," writes UCLA political science professor Michael L. Ross. "Yet this is only true for countries without oil. The oil states—scattered across the Middle East, Africa, Latin America, and Asia—are no wealthier, or more democratic or peaceful, than they were three decades ago. Some are worse off. From 1980 to 2006, per capita incomes fell 6 per cent in Venezuela, 45 per cent in Gabon, and 85 per cent in Iraq. Many oil producers—like Algeria, Angola, Colombia, Nigeria, Sudan, and again, Iraq—have been scarred by decades of civil war... These political and economic ailments constitute what is called the resource curse" (Ross, p. 1).

That these oil-rich states are historically hostile to the U.S.—both overtly in the case of Iran, Iraq, Libya, Syria and Russia, and covertly in the case of Saudi Arabia—is no coincidence or fluke of history. That there are longstanding cultural, ethnic political and religious sources for these grievances cannot be ignored. But in all cases, whether it be terrorist attacks targeting

Americans by adherents to the radical Saudi-funded branch of Wahhabi Islam, or Russian territorial expansionism and counter-Western policy in Syria and Iran, it has been oil money that has provided the means—or fuel for the fire—for conflict. “We are going to see our backs against the wall as Americans if we don’t change the way we get, transport and the way we use energy,” says former U.S. Navy assistant secretary Dennis McMinn. “What could this country do with an extra billion dollars a day that would stay inside the economy? What don’t you like about the fact that we can prevent future generations of men and women in uniform from having to be deployed for fossil fuel?” (The Burden, 2015).

On the battlefield, the presence and influence of oil wealth is more pronounced still. Aside from the U.S.’s vulnerability to fuel convoy attacks, as outlined in detail in previous chapters, there is anecdotal evidence that suggests the greater injury to the U.S. war effort in the Middle East arises from the military’s acquisition of petroleum in theatre through arrangements that inevitably enrich America’s adversaries. Speaking with *CNNMoney* in April 2011, Patrick Padilla, a U.S. Army combat medic and veteran of the Iraq War from 2005 to 2006, put it succinctly: “We’re essentially running small countries on diesel fuel—on the other side of the planet—that we’re buying a lot of from the bad guys,” Padilla said (Hargreaves, 2011). Of course, the U.S. military does not buy oil directly from the “bad guys” on the battlefield, per se. And, in fact, it was only when the U.S. and its allies against the Islamic State in Iraq and Syria began attacking ISIS convoys of pirated oil in 2015—denying the terrorist group “tens of millions of dollars per month”—that the war began to turn in their favour (Gordon, 2015). But the U.S. military—and the country at large—does buy large volumes of oil from Saudi Aramco, the state-owned oil asset and only major industry of the autocratic nation of Saudi Arabia, which,

as we'll see later, remains the founder and single-largest funder of extremist Islamic ideology in the Middle East and around the world (Shane, 2016). The U.S. military also buys large quantities of oil from Chevron and ExxonMobil, each of which have significant production contracts with the historically undemocratic governments of Angola, Egypt, Iraq, Kuwait, Nigeria, Qatar, Russia, Venezuela and Saudi Arabia (Chevron, 2016; ExxonMobil, 2016). BP, another major supplier of oil to the American military, operates significant oil assets in Russia (Scahill, 2010).

While the U.S. is not currently engaged in open warfare with any of these nations, their governments are at best historically hostile to Western democratic values, and are at worst—as in the case of Russia and Saudi Arabia—engaged in proxy wars against U.S. interests. “Oil is the autocrat’s power source of choice because the money is typically big, secret, unconditional, and flows even when the population is weak and divided. Oil is also highly prized by militias—for just the same reasons,” writes Leif Wenar, chair of philosophy and law at the University of Kings College:

Once petrocrats like Gaddafi [in Libya] or Saddam Hussein [in Iraq] or Bashar al-Assad [in Syria] lose control of all or part of their countries, oil then re-enters the picture. The post-Gaddafi Libyan militias quickly began fighting with each other and with the government to control the country’s oil wells and export facilities. In 2013-2014, the jihadi group ISIS seized large portions of eastern Syria and western Iraq. Oil fields in both countries were among its first targets; ISIS was soon raising up to US\$2 million a day selling crude oil (‘It’s as easy for ISIS as digging a hole and letting the oil run before siphoning it off into tankers,’ said one observer). ISIS also enriched itself through extortion and bank robbery, and with second-hand oil money sent by sympathetic Saudis, Qataris, and Kuwaitis. By mid-2014, ISIS had become the world’s richest terror group and rebranded itself as Islamic State.

(Wenar, p. 45)

The seed for modern fundamentalist Islamic terrorism was planted in 1979, when a wave of popular Islamic uprisings was threatening to topple governments in the Middle East. In Iran, most notably, fundamentalist Islamic clerics successfully overthrew the repressive pro-Western government, establishing the modern Islamic Republic of Iran that spring. In Saudi Arabia, the rule of the royal family had always depended upon the endorsement of the country's fundamentalist clerics, and now their rule seemed similarly in jeopardy:

The king's response was to outflank and co-opt the radicals. The regime had already been using its large post-1973 oil rents to bolster its reactionary religious establishment at home, and to empower that establishment to spread the faith abroad. Now it doubled down on that strategy.

The regime sprayed out petrodollars to spread Islamic fundamentalism worldwide. Mosques, schools, "study centers"—one American think tank estimates that the Saudis spent US\$70 billion in a decade-and-a-half campaign to build institutions across Asia, Africa, and Europe. Here young Muslims learned Salafism, the idea that Muslims everywhere should live according to the Islam of the seventh century, including its seventh-century laws about the punishment of crimes and the treatment of women. Young Muslims were also taught the religious duty of *jihad*...

The Saudi royals' strategy of promoting Salafism at home and worldwide worked insofar as it resolved their domestic crisis and stabilized their regime. The regime's support for this pan-Islamic ideology incited thousands of young Muslims to go off and fight the godless Soviets in Afghanistan (a fight the Saudis and Americans took on in close coordination), and it encouraged many Saudis privately to support young men prosecuting violent jihads in Afghanistan and then around the world. The Saudis were impressed by the success of their ideological campaign. Saudi-funded mosques and fighters rooted down in Pakistan, sprung up in the Caucasus, further balkanized the Balkans. Oil money empowered the Saudis to spread a medieval understanding of Islam all over the world.

(Wenar, p. 90)

Enter Osama bin Laden, whose anti-statist branch of Wahhabism would go a step further, ultimately vilifying the U.S. and Saudi Arabia for “stealing” the resource wealth of the Arabian Peninsula, the spiritual home of all sects of Islam. Relying on a strictly literal interpretation of the Koran that paints all non-adherents to Wahhabism as enemies of God, Wahhabi Islam is the dominant faith of oil-rich Saudi Arabia, reaching global notoriety as the faith of bin Laden and his al Qaeda movement, which is today carried forward in an ever-more radicalized form as the worldview of the Islamic State.

Oil is also the preferred commodity of non-religious militias and insurgent groups around the world because, unlike private businesses or banks, both the oil resource in the ground and the refinery infrastructure that produces it are static or geographically stuck. It is therefore, a relatively easy target for predation, as we have seen consistently in Iraq, Libya, Nigeria, Syria and even inside Saudi Arabia. “How much more powerful would we [the United States] be if we had sources of energy that weren’t geographically dependent?” asks U.S. Navy Captain and former special assistant for strategy to the Joint Chiefs of Staff Wayne Porter, discussing the upside to converting the U.S. economy to renewables (The Burden, 2015). Unlike other economic generators like farming or fishing, oil extraction can typically continue even as conflict rages around extraction and refinery sites. “Guerrillas extorted at least US\$140 million from foreign oil firms during Colombia’s violent 1990s,” writes Wenar. “In the midst of the second Iraq war, the U.S. government reported that armed groups were making at least US\$200 million a year through oil-related extortion and black marketeering and taxation” (Wenar, p. 49).

“Conflict Oil”

Before launching the terrorist attacks of September 11, 2001, Abdullah Ahmed Abdullah, al Qaeda’s Egyptian-born chief financial officer, travelled to Monrovia, Liberia to go diamond shopping (Farah and Schmidt, 2002). Al Qaeda was converting its vast cash reserves into so-called “blood diamonds,” the treasure from neighbouring Sierra Leone that was then propping up the brutal regime of Liberian president Charles Taylor. Al Qaeda had anticipated—correctly—that in the wake of its attacks against the U.S., its international bank accounts would be frozen. What the group likely didn’t anticipate was that this single transaction would do more to delegitimize the sale of conflict diamonds worldwide than any Leonardo DiCaprio film eventually would (see 2006’s *Blood Diamond*).

Almost overnight, blood diamonds became a U.S. national security priority. On April 25, 2003, President George W. Bush signed the Clean Diamond Trade Act, implementing into law the new Kimberley Process Certification Scheme that banned conflict diamonds from entering the mainstream diamond market through a resolution of the United Nations General Assembly (U.S. Department of State, 2003). The Kimberley Process has since become law in 81 countries, including nearly all of the world’s major diamond producers and importers (Wenar, p. 316).

Laws inspired by the Kimberley Process work by criminalizing the trade of conflict diamonds to “ensure that diamond purchases were not financing violence by rebel movements and their allies seeking to undermine legitimate governments” (Kimberley Process, 2016). If a similar process were applied to the global trade in oil, most if not all of the above mentioned oil-

producing nations—particularly in the Middle East and North Africa—would see significant overnight declines in their primary exports: oil and violence. “Since the oil price crash of 2014, undemocratic oil economies around the world have fomented strife on a global scale,” writes Wenar. “Enriched by years of high oil prices, Russia invaded Ukraine, whipped up a new domestic nationalism and threatened American-allied NATO countries on its borders. President Bashar al-Assad prosecuted a brutal suppression of a democratic uprising in Syria, drawing in American soldiers and pilots and leading to a prolonged refugee crisis in Europe, while Islamic State flexed its terrorist might outside of Iraq and Syria and into Europe for the first time. From the Middle East to Nigeria, a crescent of war and terrorist bombings rattled oil-destabilized economies. Oil markets made it all possible” (Wenar, p. 81)

It is perhaps overly ambitious, given the state of modern geopolitics, to postulate the criminalization of any trade in oil that undermines or prevents the existence of representative governments in the lands from which the oil originates, from either an international law standpoint or even an American one. As we have seen, the U.S. pours billions of dollars a year in cash and weapons into Saudi Arabia in exchange for oil—money and arms which prop up the brutal, anti-democratic rule of the Saudi royal family who preside not only over the murderous subjugation of women, homosexuals and cultural minorities, but also the export of anti-Western terrorism worldwide. To put it another way, “the world’s consumers unwittingly gave Saudi Arabia the financial backing to spread extremism for decades on a world-historical scale. The global jihadi movement that we now see would not exist without that oil money” (Wenar, p. 93). But if a legal embargo on the trade of “conflict oil,” or even anti-Western oil, is beyond the

current capacity of governments from a policy standpoint or beyond the existing will for international cooperation, then perhaps a government-incentivized market solution exists.

Market-Shift Strategy

As both the largest consumer of oil in the world and the global protector of energy access for Western nations, the U.S. military is uniquely positioned to move markets away from trading in oil that empowers groups or governments that are hostile to Western interests. Energy conservation is one weapon in the U.S. military's arsenal that can help defund anti-Western autocratic oil states while also untangling U.S. foreign policy from some of its most dubious and damaging historic alliances with states like Saudi Arabia.

Procuring and deploying renewable energy technology is another weapon that can achieve these same advantages. The U.S. military budget for fiscal year 2015 totaled US\$598.5 billion and accounted for more than 54 per cent of all federal discretionary spending (National Priorities Project, 2016). As we have already seen, energy procurement for installations and vehicles accounts for the largest portion of the military's spending, followed by the research, development and acquisition of new equipment and technology. It's in both of these areas that the U.S. military's energy procurement policies and considerable budgetary heft could wield a big stick over the future of renewable energy production and technological proliferation beyond the battlefield. "The government spends a lot of money, and if that money is geared toward innovation and technological development, then obviously that's where industry is going to go,"

says Col. Bob Charette, director of the U.S. Marine Corps expeditionary energy office. “They want the contract, that’s where they’re going to have to go” (The Burden, 2015).

Climate Change Strategy

The Pentagon characterizes climate change as a “threat multiplier” for the U.S. military, likely to demand greater U.S. humanitarian and conflict intervention in the future, while threatening military infrastructure and exacerbating threats of war and anti-Western terrorism among refugees and resource-deprived populations. That’s according to a landmark 2015 Department of Defense report to the Senate Appropriations Committee outlining how the changing global climate became a top-of-mind strategic concern for the world’s most powerful military (Department of Defense, July 2015). Within six months the Pentagon had ordered its officials to begin incorporating climate change and its mitigation into every major consideration they made, from weapons testing and maintenance to war planning and humanitarian aid.

The U.S. military relies on so-called Geographic Combatant Commands, or GCCs, which divide the globe into six American spheres of responsibility, namely the Pacific, North American, South American, European, African and Central (Middle Eastern) commands. In the Pentagon’s 2015 climate report to the Senate, all six of its separate commands reported that “in line with the Intergovernmental Panel on Climate Change (IPCC) conclusions, climate change will have the greatest impact on areas and environments already prone to instability, which aligns with DoD’s wider assessment of climate change as a threat multiplier” (Department of Defense, July 2015). However, those threats, as the military typically perceives them, are not just

to low-lying air bases on far-flung Pacific islands, or remote polar radar relay sites. Many are threats to domestic military installations, and they're already costing the military real dollars, as was made clear in the U.S. federal budget for 2016.

“The U.S. Army Corps of Engineers and the National Aeronautics and Space Administration (NASA) invested over US\$50 million in shoreline stabilization to protect almost US\$1 billion in federal and state assets located on Virginia’s eastern shore,” reads a section of the 2016 budget titled Federal Budget Exposure to Climate Risk. “The project’s costs were higher than originally estimated after Hurricane Sandy removed about 700 feet of protective raised barrier and about 20 per cent of the beach protecting Wallops Island, the location of NASA launch pads and support facilities as well as the U.S. Navy Surface Combat Systems Center” (U.S. Office of Management and Budget, 2015). The budgetary risk report continues, outlining “US\$64 million in damages due to unusual torrential downpours” at a southwestern U.S. Army base. “Within an 80 minute period, the installation experienced as much rain as typically falls over the course of a year. The flooding caused by the storm damaged 160 facilities, 8 roads, 1 bridge, and 11,000 linear feet of fencing” (U.S. Office of Management and Budget, 2015). Other branches of the military weren’t immune from climate change-related costs either, with “operational challenges due to rising seas, decreasing sea ice, and thawing permafrost” affecting “several Air Force early warning and communication installations on the Alaskan coast” (U.S. Office of Management and Budget, 2015). Additional U.S. domestic air bases have suffered coastal erosion that “damaged roads, utility infrastructure, seawalls, and runways, limiting the size of aircraft that are able to land,” with an estimated cost of US\$25

million to repair a single runway and fortify its surrounding seawall (U.S. Office of Management and Budget, 2015).

Even the U.S. Department of Energy has suffered the destructive consequences of fossil fuel emissions and their exacerbation of climate change—with grave national security implications. The 2016 budget cites “record-breaking rainfall and severe flash flooding” for overwhelming the drainage systems and causing tens of millions of dollars in damage at the department’s Texas-based Pantex Plant, which happens to be “the only nuclear weapons assembly and disassembly facility” in the country (U.S. Office of Management and Budget, 2015). The budget goes on to detail how climate change will not only intensify political instability, poverty, disease, terrorism and resource disputes around the globe, but will also intensify “the frequency, scale, and complexity of future missions and may cause the military to be called upon more frequently to support civil authorities” within the United States (U.S. Office of Management and Budget, 2015). “Cutting carbon pollution,” the budget suggests, “is essential to reducing the threat of climate change and represents one of the greatest economic opportunities of the 21st Century” (U.S. Office of Management and Budget, 2015).

To that end, renewable energy stimulus funding for federal agencies, including the Pentagon, was allocated to ensure American energy security and national security, and to spearhead a new renewable energy economy. “We could break free of oil,” says former U.S. Congressman Bob Inglis (R-SC). “We’d say to the Middle East, ‘See if you can drink that stuff’” (The Burden, 2015). It’s a domestic imperative the U.S. military has evidently seen coming for a long time. And it’s an imperative with global implications for the U.S., its allies and its enemies

alike, as securing energy from the traditional electricity grid or the fuel pump in regions affected by resource conflict and/or climate change will become increasingly difficult, if not impossible.

Chapter Eight: War in the Valley: Enlisting the U.S. Tech Industry

What New York's Wall Street is to American finance, and Washington's K Street is to the federal political lobby, Mountain View, California's North Shoreline Boulevard is to the American tech industry. Corporate tech giants such as Google, LinkedIn and Microsoft line its suburban exits. So does the Computer History Museum. And so do the headquarters of the Army's 63rd Regional Support Command, as well as a NASA aeronautics research centre and the headquarters of the Pentagon's Defense Innovation Unit Experimental (DIUx). Staffed by both civilian and military personnel, the Pentagon's Silicon Valley centre was founded in the summer of 2015 with a mission to develop, fund and integrate emerging start-up technologies into the U.S. military. Calling it "the DoD's first startup," then Secretary of Defense Ash Carter said the ultimate goal of the centre is to build bridges between the national security establishment and the American tech industry, especially in the development of advanced materials and renewable energy generation (Department of Defense, 2016). In its first 18 months of operation, DIUx partnered with more than 30 tech companies on a range of projects from autonomous wind-powered sailboats to solar satellites, in a fashion that eliminated much of the paperwork and bureaucracy typically involved in having the Pentagon as a customer (Lee, 2017).

'The World Becomes the Future'

The Defense department's foray into the world of renewable energy tech in the Silicon Valley was preceded under the Obama Administration by the founding of the Advanced Research Projects Agency-Energy, or ARPA-E, six years prior. ARPA-E is a U.S. government

agency with the mandate to fund and promote academic and commercial research and development of advanced energy technologies. While the agency is part of the Department of Energy, it is named and modeled after the Defense Advanced Research Projects Agency, or DARPA, the most secretive and most successful military science arm of the U.S. government.

Founded in 1958 in response to the Soviet launch of Sputnik-1, the world's first artificial satellite, DARPA has been responsible for nearly every technological advancement that the U.S. military has brought the world, from network-connected computers to Global Positioning Systems and stealth technology. Or, as Annie Jacobsen writes, “the world becomes the future because of DARPA” (Jacobsen, p. 6). With an annual budget of approximately US\$3 billion, DARPA is unique inside the Pentagon as it conducts no scientific research and maintains, on average, an extraordinarily small annual staff of 120 program managers on five-year tenures (Jacobsen, p. 5). “These entrepreneurial leaders, the majority of whom are accomplished scientists themselves, initiate and oversee hundreds of research projects—involving tens of thousands of scientists and engineers working inside national laboratories, military and defense contractor facilities and university laboratories—all across America and overseas” (Jacobsen, p. 5-6). Because of its massive budget, small organizational team and necessary secrecy, DARPA is able to act with speed, agility and freedom from the standard government bureaucracy and red tape (Jacobsen, p. 5).

And so DARPA was and remains the model for ARPA-E. To date, ARPA-E's fiscal year 2017 budget is approximately US\$500 million, part of a five-year, US\$1.85-billion allotment (U.S. Department of Energy, 2010). Mirroring its predecessor's ambitions to ‘own the future’ for

American progress, ARPA-E operates with the authorization of the U.S. government to carry out four key objectives:

1. To bring a freshness, excitement, and sense of mission to energy research that will attract many of the U.S.'s best and brightest minds—those of experienced scientists and engineers, and, especially, those of students and young researchers, including persons in the entrepreneurial world
2. To focus on creative “out-of-the-box” transformational energy research that industry by itself cannot or will not support due to its high risk but where success would provide dramatic benefits for the Nation
3. To utilize a DARPA-like organization that is flat, nimble, and sparse, capable of sustaining for long periods of time those projects whose promise remains real, while phasing out programs that do not prove to be as promising as anticipated
4. To create a new tool to bridge the gap between basic energy research and development/industrial innovation.

(U.S. Department of Energy, 2010)

Among ARPA-E's major military energy projects to date is the development of next-generation thermo-device and heat exchange systems. In a partnership with Georgia Tech university, ARPA-E and the Department of the Navy have put more than US\$2 million into deploying a mass-producible waste heat- and solar-powered HVAC (heating, ventilation and cooling) system that is smaller, more portable and more efficient than the diesel-powered systems currently in use by U.S. forces on the battlefield. The Navy expects the new high-efficiency system could decrease military fuel use in its air conditioning and heating systems by 50 per cent (ARPA-E, May 2017).

Another major ARPA-E military endeavour already underway is the reimagining of the electric battery. The modern soldier, sailor or pilot carries a range of high-tech devices, from secure communications systems to navigation arrays and night-vision goggles. All of them require batteries to work in the field. Battery technology has made rapid advancements in the era of smart devices, becoming smaller and more energy efficient. But batteries still add significant weight to a soldier's load and require time to recharge or replace—especially when a battery has to provide reliable battlefield power over multiple days, as is common in any remote deployment.

And so the the military has partnered, through ARPA-E, with Caltech startup SAFCCell to develop a low-cost, man-portable fuel cell battery that can power modern energy-intensive warfare systems like robotics and unmanned aerial vehicles (ARPA-E, May 2017). Unlike current rechargeable batteries like those found in cellphones, the SAFCCell-ARPA-E solid-acid battery is nearly free of precious metal catalysts. The U.S. Army Research Laboratory has already provided additional funding to the project to tailor the innovation to Army applications and the Marine Corps. has also expressed interest—both with the plan to improve troop mobility and extend in-theatre operational capabilities (ARPA-E, May 2017).

These are just two of many renewable energy technologies in development by the U.S. military with broader civilian applications and lifespans in mind. And for the companies and research laboratories ARPA-E partners with, the funding, product demand and organizational momentum the military provides has a demonstrated knock-on effect for greater investment still.

Since its founding in 2009, ARPA-E projects have attracted more than US\$1.8 billion in private follow-on funding (ARPA-E, February 2017). The funding has been allocated to 74 different ARPA-E project teams, with 56 of those projects forming new energy tech companies and 68 projects partnering with other government agencies—including all branches of the U.S. military, aerospace and defense—for further development and deployment (ARPA-E, February 2017). That private funding is in addition to the US\$1.5 billion that ARPA-E has shelled out to date across more than 580 future energy projects, according to the agency's latest figures (ARPA-E, February 2017).

Securing Energy

In late April 2016, representatives from the Air Force's energy and infrastructure department met with Silicon Valley tech companies at the Rocky Mountain Institute's eLab Accelerator boot camp on electricity innovation in Boulder, Colorado. The topic of climate change and carbon-emitting fuels' contributions to it was top of mind among presenters and attendees, including those from the Defense department. So too was the topic of energy resilience and security. But the Air Force, in particular, was here looking beyond just climate change in its assessment of threats to national energy security. Michael Wu of the office of the assistant secretary of the Air Force for installations, environment and energy was looking specifically at the threat of sabotage to electrical and fibre-optic communications grids. "The driving factor for a lot of our new initiatives has really been the determined-adversary aspect of it," Wu told a writer from the institute (Labrador, 2017).

Just as an increasingly interconnected world has heightened the demand for electricity and electrical infrastructure, it has also left the infrastructure and the systems that depend on it increasingly susceptible to sabotage. “We share a lot of energy resilience requirements with other sectors—with the financial systems sector, with cities,” Wu said. “Our missions are a little different, but the energy resilience side is actually remarkably similar... Those kinds of folks will hopefully be helping to push the technologies and the market factors in the same direction. What I think is critical is to recognize the common requirements” (Labrador, 2017). Speaking specifically about the Air Force’s integrated power requirements and susceptibility to sabotage, Wu pointed to “the expansion of our cyber mission, the expansion of our space mission, the proliferation of remotely piloted aircraft and other new platforms” as creating new vulnerabilities because they are “more networked, and that creates new interdependencies” (Labrador, 2017).

What is clear is that the relationship between the U.S. military and the American tech sector is symbiotic, with energy security and technological integration being of paramount importance to both. For the military, that counts as much for deployed energy as domestic. “Every mission expansion or shift or new technology that the Air Force has implemented in the last three decades has increased the importance and prominence of access to electricity for our installations,” Wu said. “We’re entering a new threat environment, where there’s a much greater concern over long-term, widespread power outages” (Labrador, 2017).

Seeding Supply and Demand

On the question of long-term energy security, the U.S. military has partnered with one of the world's wealthiest tech entrepreneurs to find a solution. Along the southern stretch of the New Mexican desert, where unarmed Predator drones patrol the nearby U.S. border, the U.S. Navy and Bill Gates have found common cause in the development of the world's first commercial outdoor algae biorefinery (Woody, 2012). The project is run by Sapphire Energy, a producer of both algal biofuels and agricultural feed, and was launched with nearly US\$200 million in investment split between Gates and his team of private investors and the U.S. government (Woody, 2012).

Before the project launched in 2012, U.S. Navy Vice Admiral Philip Cullom paid a visit to the 300-acre site that is expected to produce 1.5 million gallons of green crude oil per year from pond scum grown on a diet of sunlight and carbon dioxide (Woody, 2012). For the Navy, the project is about securing clean, domestically produced fuel to power its battleships, fighter jets and electric generators. For the likes of Gates and the facility's operators, the project is as much about getting in on the ground floor of American renewable energy investment as it is about proving the viability of a renewable-energy future, all the while getting to use the most sophisticated and fuel-intensive military machinery in the world as their test equipment. "No question, the military has focused the company and given us a great challenge to meet," Sapphire executive Tim Zenk told *Forbes* magazine at the plant's opening. "There's no other entity that has the capacity, the planning, the commitment and the policy drivers to make technologies real and create a market" (Woody, 2012).

While it may still be years before the U.S. military's multibillion-dollar bet on biofuels fosters a truly global industry, as it did with the Internet, nuclear power and digital photography, the Pentagon's unmatched outlay on both the supply and demand sides of the market continues to be the biggest driver for entrepreneurial startups like Sapphire, and Silicon Valley-based biofuel producers Solazyme and Dynamic Fuels, which have been powering the ships and aircraft of the Navy's Pacific Fleet. Founded in 2003 in the U.S. bioengineering hub of South San Francisco, Solazyme initially met with the Department of Defense in 2007. "At the point when you're still in test tubes and shake flasks, you're thinking to yourself, 'Ok, we need catalysts to continue to advance this technology,' Solazyme founder Jonathan Wolfson told *Forbes* in September 2012. "As a technology-driven company we needed discipline to become a production company. And there's no organization that I can think of that can drive more discipline into an organization than the DoD" (Woody, 2012).

Soon after Solazyme became an algae biofuel supplier to the Department of Defense, the Pentagon signed a major contract with the company in 2010. The company had just completed the delivery of more than 20,000 gallons of algae-derived biofuel to the Navy, marking the world's largest-ever shipment of 100-per-cent microbial-derived, non-alcohol fuel. Now the Pentagon was signing a deal with Solazyme—its third with the company that year—to develop a project to produce an additional 150,000 gallons of biofuels for ships and jets, furthering Solazyme's push towards large-scale commercial production (Business Wire, 2010).

The following year, a United Airlines 737 would fly the world's first biofuelled commercial flight on Solazyme jet fuel. "The fact that we could even make that United flight was a direct result of the work we had been doing with the Navy," Wolfson said (Woody, 2012). In 2015, a successful two-year test of Solazyme's Soladiesel was completed on Volkswagen's 2012 Passat and Jetta models, finding the fuel performed similar to standard crude-based diesel fuel while producing lower CO2 emissions (Harrison, 2015).

One Soldier's Trash...

Soldiers deployed to Iraq and Afghanistan since 2001 commonly used burn pits—essentially large, open bonfires—to dispose of everything from cafeteria waste, to medical waste to feces. But in June 2015, an investigation by Veterans Affairs discovered uncommonly high rates of lung disease and high blood pressure in soldiers who were exposed to the toxic waste-elimination pits (U.S. Department of Veterans Affairs, 2015). The Pentagon has since banned the practice at large installations in Afghanistan, opting instead to package all base waste into barrels and ship it out of theatre aboard fuel-guzzling cargo planes for incineration elsewhere. However, the Defense department newspaper *Stars and Stripes* reported that, in 2016, the pits were still in use in Iraq (Copp, 2016). But a Davis, California-based startup is working with the military on a solution that can not only eliminate waste, but create energy at the same time.

With funding from the U.S. Army's Renewable Energy Testing Center in Sacramento, California, Sierra Energy has developed a technology to gasify garbage into usable diesel fuel and electrical current. The company's primary gasification facility is fittingly located on a

mothballed Air Force base northeast of the Silicon Valley. Its business is transforming telephone booth-sized blast furnaces into portable power stations that can vaporize everyday waste like plastic bottles, aluminum cans, food scraps, toothpaste tubes and yard waste, and produce synthetic fuel and electricity in the process (Benzak, 2017). The possibility of using Sierra's technology on remote military bases has caught the attention of both the Marines and the Army, with the latter opening the company's first commercial-grade, community-scale waste-to-electricity plant at Fort Hunter Liggett in Monterey, California (Sierra Energy, 2012). As for the Marines? "The Marine Corps said, 'Make it modular so it can be delivered in the field,' and they wanted us to produce liquid fuels, so that's what we did," Sierra chief executive Michael Hart told *Forbes* (Woody, 2012). Long term, Sierra is betting that if it can capture the military market, both for liquid fuel-deprived expeditionary forces on deployment and for domestic military bases mandated with cutting their electricity costs and carbon outputs, it can eventually sell its technology to cities that are looking to generate clean electricity and green diesel for their municipal fleets while cutting landfill bills.

While these companies' partnerships with the Pentagon could be seen merely as anecdotal evidence of a good working relationship between the green fuels industry and a friendly Obama administration, it's important to note that many of these companies began their work with the Defense department during the petroleum-friendly presidency of George W. Bush. And the close ties between the Silicon Valley and the U.S. military continue to hold fast under the largely anti-environmentalist presidency of Donald Trump.

A ‘Bastion of Sanity’

On December 1, 2016, U.S. President-elect Donald Trump chose retired Marine Gen. James Mattis to lead the Pentagon as Defense secretary. The former head of the U.S. Central Command had led the Marines into Kuwait during the Persian Gulf War and the first wave of Marines into Afghanistan and Iraq again in 2001 and 2003, respectively. The latter Iraq experience, and Mattis’s battlefield observation that his mechanized Marines were hampered in the push towards Baghdad by the sluggish pace of securing fuel resupply lines, famously led Mattis to demand in a post-combat report to Congress that the government ensure that in the future the military would be “unleashed from the tether of fuel” (Douquet, 2017).

It was that pronouncement that prompted the Pentagon to investigate its in-theatre supply chain and determine that by 2009, more than 3,000 U.S. troops and civilian contractors had been killed or wounded protecting supply convoys in Afghanistan and Iraq, 80 per cent of which were transporting fuel (Wittenberg, 2016). In response, the Defense department stepped up efforts to reduce soldiers’ reliance on petroleum fuel in combat, including the development of solar blankets and flexible batteries to provide electric energy to Marines on foot patrol, and more energy-efficient generators to power forward operating bases [See *Chapter Two: The Great Green Fleet*].

While many of these energy technologies began as the pet projects of California-based tech firms and went on to garner the interest and investment of the military that was vital to bringing them fully into existence, the flow of innovation between the military and venture tech

firms clearly runs both ways. One need only look to the U.S. military's development of microchips, the Internet, the self-driving car and spy satellite technology for examples of the military's contributions to the growth of California's tech industry. And with American tech giants such as Google and Facebook looking to deliver global Internet connectivity to the most remote regions on Earth—specifically via military-style self-piloting drones powered by solar energy—the flow of innovation between the two camps continues to accelerate [See *Chapter Six: Air Force: Solar, Biofuels and Wind Beneath Their Wings*].

In May 2017, a Palo Alto-based startup called Capella Space announced US\$12 million in new funding for its synthetic aperture radar (SAR) satellites, a technology invented by the military in the 1950s and monopolized by the defence sector ever since (Vance, 2017). Smaller, cheaper and faster than its military-built equivalent, the Capella SAR satellite has thrived on contracts with the Pentagon. But its larger aim is to make hourly images of every place on Earth available to farmers, hedge funds, shipping authorities, city planners and security contractors—in essence, to commercialize the technology (Vance, 2017). It's an ethos that Silicon Valley has introduced into nearly every sector it has touched, an ethos of “move fast and break things,” as coined by Facebook. And while the Pentagon differs in a few important ways from the typically left-leaning, non-hierarchical and individualist nature of the Valley, the two worlds are closer today than ever.

Even as many leaders in California's tech sector have distanced themselves, or at very least have felt pressure to distance themselves, from the Donald Trump administration and its anti-liberal, anti-elite, anti-immigrant, anti-science rhetoric, there is a distinct divide between

how Silicon Valley tech leaders view the Department of Defense and how they view the Trump administration. “The Defense department is now viewed as the bastion of sanity and respect for law and science, versus the White House as a space of controversy,” Peter Singer, a defence expert with the New America Foundation and coauthor of the 2014 book *Cybersecurity and Cyberwar* told *Wired* magazine in February 2017 (Hsu, 2017). And as the shared security interests of the military and Silicon Valley become increasingly intertwined in dealing with 21st-century threats to American technological dominance, the two camps will have to become more reliant than ever on each other.

It’s a win for both sectors, then, that Gen. Mattis, a man who retired to the Silicon Valley when he left the military in 2013 to become an investor in Bay Area technology companies and a visiting fellow at Stanford University, is now at the centre of that defence-tech nexus. “As secretary, Mattis would have the most sway over operational energy use because many of those DoD initiatives are driven by internal department policy and executive orders,” writes Ariel Wittenberg in *E&E News*. “Those programs are likely to remain in place at least in the short term because many involve private-public partnerships and contracts lasting 20 years or longer” (Wittenberg, 2016).

Chapter Nine: The Canadian Context

For more than a decade, Canada has been shopping for a modern fighter jet to replace its aging fleet of Boeing CF-18 Hornets. From the start of that shopping trip in 2006, it seemed a foregone conclusion that Royal Canadian Air Force pilots would eventually find themselves in the cockpit of the the stealthy, single-engine Lockheed Martin F-35 Lightning II. But design delays and ballooning development costs for the airplane, coupled with political pushback on the seemingly secretive nature of the procurement process hampered the federal government's plans. On top of that there were glaring questions about the plane's suitability for Canada's defence needs; the jet is designed primarily as a first-strike stealth fighter, when the RCAF rarely engages in anything but territorial patrol and NATO air-support missions. The F-35's single-engine design also lacks the dual-engine redundancy of the CF-18 and is therefore thought by some to be too unreliable for safe patrols over Canada's frigid northern regions.

By the time the Liberal government of Prime Minister Justin Trudeau took power in November 2015 from the decidedly pro-F-35 former government of prime minister Stephen Harper, the F-35 replacement was no longer a sure bet. As part of the F-35 program, the U.S. Air Force was by this time supposed to have completed important fuel testing on the new jet to prove its afterburner performance on renewable alcohol-derived fuel, in compliance with the Air Force's long-term energy efficiency standards (Lane, 2015). To date, no such tests results have been released by either the U.S. Department of Defense or Lockheed Martin.

Boeing, on the other hand, has ramped up its lobbying efforts in Ottawa, its sales staff meeting with high-level defence procurement officials over the CF-18's replacement at least a half-dozen times between February 13 and April 5, 2017 (Office of the Commissioner of Lobbying of Canada, 2017). The Boeing CF-18's proven compatibility with biofuels versus the Lockheed Martin F-35's as yet untested track record is seen as a major selling point among Boeing executives. "Boeing's value proposition is to build the most fuel-efficient airplanes flying in the sky, as fuel represents anywhere from 20-50 percent of a carrier's operating cost. And to achieve that value proposition, 75 per cent of Boeing's commercial R&D is used to improve the environmental performance of our aircraft," says Elizabeth Wood, Boeing's regional director of environmental strategy and chair of the Sustainable Aviation Fuel Users Group. "The U.S. Navy's actual flight test platform for alternative fuels is the F/A-18, and we build the F/A-18 ... And that's really interesting because, for instance, there have been a number of instances in which biofuel has been used on Boeing defence platforms where our fuels team has been able to use its knowledge and authority to say, 'Yes, this fuel is fine—we've worked with the Air Force, we've worked with the Army to support it and we believe this fuel is fit for the purpose'" (Wood, 2017). The same test-platform sales logic Boeing employs with the F/A-18 and the U.S. Air Force, also holds true for the Boeing-built Apache helicopter and the U.S. Army, which has run numerous successful biofuels tests on the aerial workhorse. However, there is no indication as yet that any branch of the Canadian military has gotten past the request-for-proposals stage of implementing any kind of biofuel tests on its military fleet.

Keeping Up with the Joneses

The joint defence interests of the U.S. and Canada have historically been intertwined—even if, under the U.S. administration of Donald Trump and the Canadian Liberal government of Justin Trudeau, the two countries’ political paths are diverging on the threat posed by climate change. “The world will be carbon constrained regardless of one election in one country,” is how Alberta climate minister Shannon Phillips put it during a call from the United Nations climate summit in Morocco in the days after Trump’s 2016 election victory (Phillips, 2016). “We have to be focusing on CO2 because it’s not going away,” says Ian MacGregor, CEO of the North West Redwater upgrader, the only new oil refinery built in Canada in the last three decades (MacGregor, 2016). When it opens at the end of 2017, the refinery will feed its waste carbon into the Alberta Carbon Trunk Line, the world’s largest carbon capture project, designed to recycle waste carbon for industrial uses. “I don’t care if Trump says he’s not worried about [carbon],” MacGregor says. “The next guy that comes is going to be and the rest of the world is worried about it” (MacGregor, 2016).

Climate politics aside, the U.S. and Canada will inevitably continue to coordinate on defence policy, military systems and training. And the F/A-18’s renewed prominence in the U.S. military—due in no small part to the success of its biofuel trials—is a strong indication of the platform’s likely staying power north of the border, as well. The U.S. Navy put the purchase of new Boeing F/A-18 Super Hornets at the top of its unfunded priorities list in its fiscal year 2018 budget (Majumdar, 2017). The Navy intends to order at least 80 more of the Boeing planes and perhaps as many as 150 over the next five years, which will serve the fleet until at least 2040

(Majumdar, 2017). In May 2017, the U.S. government allotted US\$1.1 billion for 14 new Navy Super Hornets by 2018, after Boeing demonstrated an updated engine and airframe configuration that will cut fuel use and extend the flying time, carrying capacity and lifespan of the aircraft, all in accordance with the Navy's "Green Fleet" mandate to increase its alternative fuel consumption and halve its fossil fuel use by 2020 (CNBC, 2017; Fabey, 2017).

"Biofuel gives the aviation industry the licence to grow," Wood says of Boeing's pivot into the renewables sector in both its defence and commercial production lines. "We understand that if we don't get this right, we are not going to be able to access the [worldwide] market for 41,030 new aircraft that we anticipate will be needed over the next 20 years. We want to have the opportunity to access the US\$6.1-trillion market value that those airplanes represent. And we know that if we do not decouple the growth of our industry from the growth of carbon emissions, we're not going to be able to do that—it will impinge our licence to grow" (Wood, 2017). And what's good for Boeing's international defence sales into a country like Canada is also good for its commercial sales. "Our fuels team that has responsibility for approving the use of biofuels in our aircraft—the same team that has responsibility for the fuel going into all Boeing airplanes—is the exact same team for defence and commercial," Wood says. "Generally, when we embark upon a biofuel project or roadmap in a country, we go in with the specific purpose of furthering the goals of a commercial customer. But what really gives the project legs in the long run is to have support from that particular airline's government, stakeholder community, and NGOs—that's been our recipe for success" (Wood, 2017).

Of course, Canada's joint defence mandate with the U.S., as enshrined in formal agreements like NATO, NORAD and the Canada-U.S. Civil Assistance Plan among others, goes well beyond buying matching planes, munitions or any military hardware for that matter. Such procurement decisions are only a symptom of the deeper security interests shared by the two nations. In June 2017, the Canadian government's latest defence review indicated a continued policy of following the American defence posture towards the world, including procuring and deploying armed aerial drones and accounting for emergent national security threats like borderless terrorism, hybrid warfare and climate change (Blanchfield, 2017).

Chief among those shared North American policy interests is energy security and the assured availability of cheap, reliable fuel sources to power domestic economies and preserve Pax Americana as the dominant international order. To those ends, Canada functions—as it does in nearly all matters of cross-border relations, but especially as they pertain to war and economics—as the junior partner. “Our modus operandi is about following their trends,” says Louise Mercier, senior defence associate with Hill+Knowlton Strategies in Ottawa. “It’s about keeping up with the Joneses, and the Joneses are the Americans... They will upgrade their software every three months, but still it takes us 20 years to buy a ship.” (Mercier, 2017). That follow-the-leader ethos applies, as stated, to matters military and economic, but also to matters of energy and renewable energy technology, especially as they apply to warfare.

The global defence business, much like the energy business, does not operate in a purely free market. The market is rife with state-owned and state-supported entities and almost any purchasing agreement involves serious political calculations. For reasons of national security and

political expediency, government defence procurements tend to favor domestic suppliers when filling contracts. Canada is no different, albeit with a defence industry that's significantly smaller than its U.S. counterpart, and is thus largely made up of Canadian branch plants of large American and European parent firms. Of the top five Canadian defence companies of 2016, only one, CAE, is Canadian-owned (Canadian Defence Review, 2017). "The early adopters and investors in Canadian technology are offshore defence departments," says Mark Aruja, Canadian defence policy analyst and former commandant of the Canadian Forces Experimentation Centre in Ottawa. The homegrown defence industry in Canada is still too small and too U.S.-dependent from a technology standpoint to attract government attention away from the lavish defence bazaar south of the border. "They go down to Washington, they get their eyes watered and dazzled and they don't meet the Canadian companies in many instances because Canadian companies find it very difficult to do business with the Defence department because it's costly and there's too much uncertainty" (Aruja, 2017).

In a few cases, however, Canadian defense contractors, including those subsidiaries of American firms, have a freer hand in foreign trade when it comes to certain military-grade technologies over their U.S. counterparts. Under the U.S. government's International Traffic in Arms Regulations (ITAR), Washington has a hard veto over what products and technologies companies can sell and to whom. In 2012, Lockheed bought CDL Systems, a Calgary-based software firm specializing in aerial drone technology. Today, that's where the vast majority of the operating software for Lockheed's U.S. combat drones is built, according to John Molberg, a business development manager at Lockheed and one of two trained drone pilots at the company's Calgary office. "ITAR can be very difficult for drones, because, largely, this is a defense

technology,” Molberg says. “The silver lining is, if you’re working for a company like ours where we happen to have 60 or 70 engineers who are in Calgary, everything we produce doesn’t have ITAR on it because it’s produced in Canada—and that’s significantly advantageous when it comes to trying to commercialize something” (Molberg, 2016).

As is the case with Canada’s energy industry, the country’s defence sector, including its Alberta-focused aerial drone industry, relies heavily on export markets. Defence contributes more than \$1.3 billion to the province’s economy alone—with 40 percent of those goods destined for export—and employs more than 6,000 people at 170 aerospace and defence firms (Van Vliet, 2016; Government of Alberta, 2017). Today, much of that work is dedicated to developing autonomous aerial drones equipped with renewable-power drives—technology that Canadian oil and gas companies are increasingly deploying to provide infrastructure monitoring and pipeline leak detection.

In Calgary in 2016, Gary Biermann, Lockheed Martin’s regional technology manager for Canada, introduced the country to the P-971, a hybrid helium airship that had been under development for the U.S. military for more than a decade in the company’s Skunk Works department—where the first stealth fighter and the SR-71 spy plane were born. With a top speed of 110km/hr, the P-971 is designed to efficiently carry 20 tonnes of cargo using the natural lifting power of helium coupled with steering-drive fans powered by high-efficiency, hybrid diesel-electric motors (Biermann, 2016).

The football field-sized airship, Biermann explained, was designed for battlefield resupply missions in the deserts of the Middle East. But the company is taking the technology commercial in 2018 and sees huge growth potential in deploying it to remote resource development sites in the Canadian North where little to no transportation or power infrastructure exist. “Some ice roads can cost \$20 million a year to construct,” Rob Binns, CEO of Lockheed Martin's Hybrid Enterprises, told *CNBC* (Wells, 2016). But with the airship, “you don't have to build ice roads... and wait for the environmentalists to give you permission,” added Mike Kendrick, CEO of Straightline Aviation, which signed a US\$480-million deal to buy 12 of the pre-production airships in 2016. “You can just land on ice” (Wells, 2016).

If securing Canada’s sovereignty over the North and defending the region’s natural resources is, in fact, the military priority that successive federal governments have deemed it, then securing access to new transport technologies must be a prerequisite of the mission. Communities and resource extraction sites in the Canadian North currently rely on diesel fuel and diesel-powered generators for the sum total of their energy consumption. This is in a region where, due to transport costs and seasonal impassibility, a gallon of diesel fuel can cost as much as it would on a Middle Eastern battlefield. “The amount of fuel used to drive generators in our northern and Arctic communities is staggering,” says Aruja. “The Canadian defence department has done some work on how to fuel some of their infrastructure in the Arctic, but those are national security things where you have to then address the particular issues with regard to our climatic conditions and so forth. And, those are, of course, good environmental stewardship things for the report card the defence department has to fill in. But that’s the best place for Canada to start is to reduce its domestic dependence” (Aruja, 2017).

Enlisting Academia

Much like their American counterparts, some Canadian university research labs have been recruited to help solve the question of how alternative energy can be deployed in defence applications. In 2011, Lockheed Martin Canada announced major funding for Cape Breton University's new Verschuren Centre for Sustainability in Energy and Environment, including funding for a Lockheed Martin Chair in Renewable Energy. Present for the announcement was then minister of national defence Peter MacKay, who lauded the endowment as a vote of confidence in the region where Irving Shipbuilding Inc. had just been awarded separate multibillion-dollar contracts to build a new fleet of Canadian warships, and to modernize seven of Canada's 12 existing frigates (Cape Breton University, 2011; Withers, 2016).

Fourteen months later, Defence Research and Development Canada's Atlantic research centre in Nova Scotia issued a request for proposals for a cost-benefit analysis on retrofitting Canadian warships with "existing biofuel technologies mature enough to utilize on diesel powered naval vessels" (Public Works and Government Services Canada, 2013). While the results of that study—Ottawa-based consulting firm Doyletech Corporation ultimately won the \$34,000 contract in February 2013—have never been made public, Lockheed Martin would go on to earn a half-billion-dollar slice of the initial frigate overhaul program, plus a \$170-million subcontract for systems integration on the still-forthcoming naval patrol ships (Public Works and Government Services Canada, 2013; Chronicle Herald, 2015).

At least one Canadian university has also been enlisted to develop alternative energy technology for the U.S. military. In the fall of 2017, U.S. Army soldiers and Marines will begin trials on a kinetic-powered energy generation technology conceived in a biomedical lab at British Columbia's Simon Fraser University. Developed by Max Donelan, a professor at SFU's biomedical physiology and kinesiology department, the PowerWalk Kinetic Energy Harvester is a lightweight knee brace-like device that turns the kinetic energy of simply walking into electrical energy that can generate 12 watts of electricity, or enough to charge four smartphones after an hour's walk, while still allowing the wearer a full range of motion and mobility (Meadahl, 2016).

A U.S. soldier or Marine would typically carry 16 to 20 pounds of batteries to power personal electronics and communications devices on a three-day expeditionary mission. But with an initial Department of Defense contract of US\$3.8 million to develop the PowerWalk system in 2014, plus an added US\$1.25 million outlay in 2016 to conduct the field trials, the soldiers and Marines will forgo the battery load for their three-day mission trials to test the battle readiness of the Canadian technology (Meadahl, 2016).

Writing for the U.S. Department of Defense's *Defense Systems Information Analysis Center Journal* at the end of 2016, Capt. Anthony Ripley of the Marine Corps Expeditionary Energy Office described the shifting role of the Marines and the increased energy burden that shift has placed on individual infantrymen and women. "Over the last 10 years, the Marine Corps has successfully achieved increased lethality and capability, but it has departed somewhat from its expeditionary, lightweight, fast-moving roots," Ripley said. "Today's infantry battalions

consume significantly more energy than their counterparts did a decade ago” (Ripley, p. 32). Since 2001, Ripley cites a 300-per-cent increase in electricity demand for Marine infantry computers and information technology, a 200-per-cent increase in power required for radios and a 200-per-cent increase in the number of vehicles required to move all that equipment around in theatre (Ripley, p. 32). “Consequently, for the individual Marine, the increased dependency on energy has meant an increase in overall weight carried, increased injury, and an increased dependence on resupply,” he said. “If the weight of Marines is too heavy, they either function at a reduced capacity, or they break” (Ripley, pp. 32-33).

If the PowerWalk system passes its military field trials and sees adoption by either the Marines or the Army, the contract would dwarf the Pentagon’s initial US\$5-million investment in the Canadian technology and would pave the way for wider commercial production. “My hope is that eventually we get to the point where we could start to address the needs of the developing world,” Donelan told the *Globe and Mail* in July 2016. “More than one billion people live without reliable access to electricity... They rely on cellphones for so many things, but often don’t have the infrastructure to charge those cellphones” (Hume, 2016).

Green with Envy

For many years in Canada, the only “viable” biofuels industry was corn. More specifically, the corn-based ethanol that has made up more than five per cent of the gasoline Canadians pump into their cars and trucks every day, ever since the federal government first imposed an ethanol blending quota in 2010. According to Animesh Dutta, a biofuels researcher

at the University of Guelph, the government's decision to mandate a corn quota in the gas tanks of Canadians was well-intentioned, but misguided. In short, the decision had less to do with reducing carbon emissions and more to do with subsidizing Canadian agriculture. Once again, it was a case of following the lead of the Americans. "Canada put a subsidy on corn-based fuels without putting much thought into it," Dutta says. "We were just trying to follow the U.S. without a thought about what we could have done differently" (Dutta, 2017).

But with the recent growth of so-called "biocrude" and other Canadian oil substitutes derived from alternative sources—particularly algae, agricultural and forestry waste—ethanol additives at the gas pump will become a thing of the past. "I'm optimistic that within the next decade we're going to start seeing some of the crude oil that goes into refineries that exist today in Western Canada being replaced with bio sources, or renewable sources," says Michael Rensing, director of low carbon fuels with B.C.'s Ministry of Energy and Mines. "If you look at the Chevron refinery in Burnaby, Chevron Canada does not own significant sources of crude oil—they purchase it. So they can contemplate a different model where there may be different sources of crude where those sources are renewable" (Rensing, 2017). Of course, unlike U.S. oil giant Chevron, many of the largest traditional oil refinery operators in Canada—Husky and Suncor, for instance—also own large petroleum assets, primarily in the oil sands. And so stranding some of those assets in favour of a Canadian biocrude blend is a tougher sell than for their American counterparts operating refineries and leasing oil assets in Canada. Unlike the oil sands, after all, waste biomass is cheap, uncontroversial and, more importantly, it's not especially geographically specific, though it is found in richer quantities in warmer climates such as those on the U.S. side of the border.

“I heard this funny comment at the SDTC [Sustainable Development Technology Canada] summit two years ago in Ottawa,” says Boeing’s Elizabeth Wood. “That if you can’t make it in the United States, you can’t make it in Canada” (Wood, 2017). She was talking about biofuels, not only from a resource availability standpoint, but from a defence policy one, too. “The United States is the best place in the entire world to sell biofuel. That is because of both the federal- and state-level incentives,” she says. “If the Department of Defense had not created the Defense Production Act to increase the energy security of our country through promoting sustainable alternative fuels, I do not think that we’d have the volumes that we have today. In the United States there is a rich history of the Defense department subsidizing energy technologies to move from military to civilian use. Nuclear is one of the best examples, satellites are another great example, and we as an industry have been very fortunate to benefit—and we really need it—to have the U.S. government recognize the benefit to having alternative fuels for energy security” (Wood, 2017).

‘A Step Toward Modernization’

In Canada, there is no comparable legislation to secure any portion of military fuels from sustainable or alternative sources, and no calls as yet to implement one. There is, however, a broader national mandate looming that could have all Canadian industries and institutions—the military included—rethinking fuel supply and sourcing on a cost-per-gallon basis. By January 2018, all Canadians and Canadian entities will pay a carbon tax on fossil fuels, including for gasoline, diesel and natural gas. “The Canadian defence department can’t ignore carbon pricing

because it's going to get passed down to the consumer, or in this case, the taxpayer," says Aruja. "So it's going to be perhaps those infrastructure people—like the assistant deputy minister here in Canada—who oversee infrastructure and environment and the defence department, where it seems to me the tide will turn; because ultimately when it comes to the decision table, if somebody wants to invest in a weapons system, they get the first voice" (Aruja, 2017).

From a broader policy perspective, Canada is only beginning to lean green with some of its military energy procurement. In March 2017, Enmax won the first major contract designed to fulfill a federal mandate, announced in November 2016, to run all government operations on renewable power by 2025. The five-year, \$131-million contract will see the Calgary-based electricity provider supplying renewable power to four Alberta military bases—namely, Edmonton, Cold Lake, Wainwright and Suffield—plus 11 government departments and Corrections Canada facilities within the province (Graveland, 2017). "The fact that they're talking about green programs at all is a step toward modernization," says Mercier. "Every large institutional organization is a very large animal and it takes a long time to get it moving in a certain direction, but once you get it moving in that direction it's almost impossible to stop it" (Mercier, 2017).

Perhaps if a silver lining is to be found in the Canadian defence industry's inability to match the R&D budgets of its American peer, it's that any military technology developed in Canada for the domestic military market has to find a civilian application quite quickly if it is going to survive at all. Mark Aruja cites the booming Canadian drones industry as an example. "The Defence department simply has not been in a leadership role in technology development in

Canada for years,” he says, “and that’s why the Canadian UAV industry has gone almost totally commercial” (Aruja, 2017). The downside of that rapid, and perhaps premature, commercialization of Canadian UAV technology, however, is that when Canada does eventually spend millions for its newly promised military drones, it will almost certainly be forced to buy American, even if much of the system it’s actually buying—from, for example, Lockheed Martin—was developed right here in Canada.

Conclusion: Future Tense

Sixteen years into the longest and costliest war in its history, the United States must consider what will be the military legacy of the Global War on Terror. The war's Afghan campaign—by far its longest, costliest and most intractable battle—will be, by October 2018, as old as the U.S. military's youngest recruit. Months from now, an American child born on September 11, 2001 will be eligible to enlist and fight the same petrostate-sponsored Islamist groups—whether ISIL, al-Qaeda, al-Shabaab or any number of newcomers—that have consumed the attentions and budgets of American war planners since the day of that soldier's birth.

At its outset, many were quick to criticize the War on Terror as a “war for oil.” That criticism broadened once the American war footing took a radical pivot toward Iraq. But motives aside, if not a war *for* oil, the War on Terror is undeniably a war *by* oil, in both a mechanical and transactional sense. The United States now uniquely possesses the technological capability to forgo petroleum fuel in an ever-growing proportion of its war machinery, while meeting its remaining energy demand with the domestic oil resources made recently accessible through the American innovation of hydraulic shale fracturing.

Fracking, like renewable energy, is still relatively new and still relatively expensive. But if terrorism—at very least the terrorism of September 11, 2001—were viewed in its proper historical context, it would be seen as a rearguard attack against modernity, against the future. The faces of the enemy in this context are those of adherents to a literal interpretation of an anti-modern Islamic portrayal of how the world and its people should be. But as much as the U.S. can

claim itself a victim of these adherents to history in this regard, it is also a victim, on a broader scale, of its own history—a history that has hinged on the propagation of anti-modern Mid East regimes that could afford the country cheap access to oil while posing no threat of using those petrodollars to develop competitive technologies, advanced societies or self-sustaining economies. That has been the transaction, and it's been a costly one for the United States financially, politically and militarily.

As the world witnessed in the summer of 2014, when oil is expensive enough that the U.S. can economically produce it through fracking, two things happen: Investment in increasingly cost-competitive renewable energy goes up, and the leaders of oil-dependent OPEC nations get nervous enough to undercut their own economies in order to kneecap the American energy industry and preserve their oil's market share. With the largest and most economically producible oil reserves in the world, autocratic Gulf states, namely Saudi Arabia, have traditionally set the terms of the global energy trade while forcing oil-consuming nations to not only tolerate the terror and instability the country sews in the region—and now globally—but to then turn around and ensure Saudi state security against this instability through regular arms transfers from advanced nations. It's at best an unsustainable relationship for the U.S. be in, and at worst a parasitic one.

Greater domestic oil and gas production is viewed by many as one answer to this problem. Today, it's not uncommon in the oil- and gas-rich areas of Pennsylvania and Texas to see lawn signs depicting memorials to American soldiers bearing the message: "Drill a well, bring a soldier home." But domestic petroleum production is at best a partial, temporary and

short-sighted solution to what the military already recognizes as a larger, permanent and increasingly global threat. “It would be wonderful to think we can drill our way out of this,” says former U.S. Navy assistant secretary Dennis McMinn. “But the fact of the matter is we can’t” (The Burden, 2015). And, of course, fighting oil-enriched Mid East regimes and non-state actors is not the only threat to American security with which the U.S. military is burdened. Climate change, and the decades of rapid fossil fuel-fed industrialization that continue to exacerbate it, has already been classified—and re-classified again—by the U.S. Department of Defense as a key “threat multiplier” to American national security. That’s a burden that, again, befalls the military.

The U.S. homeland’s relatively abundant supply of hydrocarbons—oil, gas and coal—has for decades kept renewables from becoming a domestic energy imperative. But these fossil fuels are, of course, entirely non-renewable. When they’re gone, they’re gone forever. Meanwhile, in an increasingly militant Middle Eastern energy market, securing petroleum-based fuels for America’s overseas military excursions will become an ever more expensive and taxing proposition. As the likelihood and duration of conflicts increases—due to not only resource scarcity but also climate instability and mass migration—this problem will again only get worse. It will necessarily be the U.S. military that is deployed to combat these crises once more. Operational advantages, cost-savings and denial of funds to hostile aggressors aside, it’s no wonder why the U.S. military is eagerly equipping itself to help lead the country out of oil’s conflict-propagating orbit.

The Non-Proliferation Rationale

In addition to climate change, resource conflict and terrorism, another area of great concern for the U.S. military—and for the world at large—is the ever-looming threat of rogue nuclear weapons proliferation. With the possible exception of North Korea and its extraordinarily brazen nuclear weapons initiative, states that seek to develop nuclear weapons always begin first under the auspices of developing a civilian nuclear electricity-generation program. Iran, a nation in possession of an enviable wealth of nuclear power alternatives, including oil, gas, solar, tidal and wind resources—all of which are currently in varying stages of development in Iran—is only the latest example of this. But the threshold that delineates a civilian nuclear power program from a weapons program is razor thin and its hallmarks are often only apparent once that threshold has been crossed. “After the United States, the Soviet Union and Britain became the first three countries with atom bombs, all the rest hid their military programs to one extent or another behind the mask of peaceful nuclear power. That includes France, China, Israel, India, South Africa and Pakistan,” according to a 2007 article in *The New York Times*. “Indeed, the most difficult part of building a bomb is not doing the secret military design work but rather the part of the process that is also crucial to civilian nuclear power—producing the fuel” (Broad, 2007).

The U.S. military’s push toward developing ever more efficient and cost-effective renewable power, if sufficiently commercialized by its domestic market partners and coerced abroad as a facet of American foreign policy, would offer significant strategic benefit in

delineating between peaceful and hostile nuclear actors in a way that is almost impossible today. “In a world of cost-effective renewables, countries will be less able to pursue ambiguously dual-use nuclear progress under the banner of electricity generation and will be more easily enticed to relinquish more dangerous ambitions,” according to *Defense One* magazine. “The Middle East, for example, where many are most concerned about nuclear developments, is perfectly positioned for solar power, and so excuses to pursue nuclear projects would be hard to come by” (Sazak, 2017). Recognizing this, the U.S., through the Nuclear Non-Proliferation Act, has already made the promotion of non-nuclear power a key feature of its foreign policy and has made it economically costly for other nations to pursue the nuclear power path. But it should go further to incorporate the promotion of its own renewable technologies abroad, bolstering the U.S. domestic renewables industry while also prioritizing the Pentagon’s stated warnings about the grave national security implications of continued global climate change.

Pulling in the Same Direction

The U.S. defence industry has a key role to play in this, as well. It’s perhaps an unfortunate reality that the U.S. military has in many ways been the face—if not the main thrust—of American interventionism abroad. That goes as much for emergency disaster relief as it does for war fighting. And, as the world’s largest exporter of heavy arms systems—accounting for fully one-third of the US\$31-billion global heavy arms trade in 2016—the U.S. defence industry, and its civilian subsidiary operations, wield the largest stick in deciding the future architecture of the world’s military and civilian-adapted military platforms. (SIPRI, 2017).

When the First World War began in the summer of 1914, traveling by horseback was still the norm all over the modern world. The petroleum-fuelled automobile had indeed been invented—and the first Ford Model T rolled out a decade before—but these were still primarily driven only by the very wealthy and those we might today call “early adopters.” The war was both a proving ground for new vehicle designs and a motivator for more efficient and more cost-effective production. The year after the war’s end, registered automobile ownership in the United States would jump sixfold since its outset and show no sign of slowing this exponential growth until the Great Depression of the 1930s (USDOT, 2017).

Much as the First World War heralded the arrival of petroleum to the battlefield, and then broadly to the consumer, the Second World War, in far more dramatic fashion, ushered in the Atomic Age. Both of these technological advents proved decisive in war fighting and later changed the landscape of geopolitics, the environment and world societies as a whole. Both technologies unleashed previously unimaginable stores of energy unto the world and both—if one is to believe climate scientists and historians of the Cold War—have at one time or another jeopardized the very continuance of entire human civilizations on Earth. But such questions of engaging in nuclear war or curbing carbon emissions to slow the effects of catastrophic climate change, while clearly the concern of military planners, are larger policy questions that are answered by politicians, not individual soldiers or even high-ranking officials inside defence departments.

Renewable energy technologies, as they exist today, pose no such global threat despite their broad military and civilian applicability. It’s at present inconceivable to imagine a future in

which nations are called upon to ratify a solar non-proliferation pact enforced by threat of sanctions or violence, or in which a cartel of wind power-producing nations hostile to democratic values could successfully launch an energy embargo tantamount to waging war against Western economies. It's in the very DNA of these technologies as decentralized, portable and non-geographically specific energy resources that makes this impossible. Renewable energy resources, such as sun and wind, are not finite commodities—and therefore, cannot be fought over—in the same way as oil. The renewable energy business is, in essence, a business without an inventory, aside from the talent and technologies that harness it. In this realm, the U.S. remains the global leader in research and development, due in no small part to the renewable energy goals set by the U.S. military. “One of the biggest roles the DoD plays in this is that they’re the world’s largest employer with three million [people], they have two billion square feet of property—three times that of Walmart,” Phyllis Cuttino, director of the Pew Charitable Trusts, told a meeting of U.S. Navy brass at the Atlantic Council in April 2016. “So when they take on these kinds of postures—when they worry about effectiveness, when they worry about conservation, when they worry about efficiency, they put advanced technologies in place and do other things—given their reputation and their heft, their ability to be an early adopter, they really send a signal to the rest of the country and you see businesses really following suit... The DoD is really providing a blueprint for the rest of the economy about how we do change and not only adapt, but mitigate” (Cuttino, 2016).

That said, the U.S. military is not a business. “It’s not in the military’s mandate to make the world’s most efficient machine,” says Doug Brown, business development manager at weapons maker General Dynamics and a veteran Canadian naval combat systems engineer. “The

military's job is to manage violence" (Brown, 2017). And managing violence on the ground—difficult as it is, as evidenced in all of the U.S.'s most recent military campaigns—is much different than managing violence on a regional or even global scale. In writing for the Center for American Progress about the military security implications of the Arab Spring and the ongoing Syrian civil war that spun out from it, authors Michael Werz and Max Hoffmann state that, "the United States, its allies, and the global community must de-emphasize traditional notions of hard security more suited to the Cold War and focus on more appropriate concepts such as human security, livelihood protection, and sustainable development" (Werrell and Femia, eds., 2013). Carrying that idea forward into the energy security realm, co-authors David Michel and Mona Yacoubian admonish the U.S. to "establish networks of renewable energy projects linking Arab countries to each other and to export markets in Europe and Africa" to lay the foundations for future green growth (Werrell and Femia, eds., 2013). But while the U.S. military and energy-defence establishments have not yet reached the full global export phase of their renewable energy initiatives, it's clear the U.S. military and its commercial partners are committed to pulling in the same direction to fight this war at home.

The War at Home

On the level of small-scale, individual contributions to military energy security, many veterans of the War on Terror are applying lessons learned on the battlefield to further the war's renewable energy legacy back home. This includes initiatives like the U.S. Department of Energy's Solar Ready Vets program, which provides civilian solar industry job training and apprenticeships for military personnel up to six months prior to their leaving military service.

Since 2010, the domestic U.S. job market in the solar power industry has grown 178 per cent, with veterans of the Afghan and Iraq wars filling many of those positions due to their already advanced technical proficiency with operating and repairing many of the same solar power and hybrid systems they deployed with on the battlefield (Office of Energy Efficiency & Renewable Energy, 2017).

Any account of the domestic green energy initiatives being carried out by the U.S. military—many of which are included in the preceding chapters—will, at this point in time, inevitably be a partial account due to the speed at which new military energy projects are coming online. According to the Pentagon’s most recently available data, the U.S. Department of Defense in 2011 operated 467 domestic renewable energy projects, which it deemed crucial to creating a more reliable and sustainable domestic energy grid (AEMR, 2016). That number had doubled by 2013, and by 2015 the number of operational green energy projects on DoD properties was 1,390 (AEMR, 2016). The same institutional urgency applies to the military’s green energy initiatives deployed in-theatre, though these are more often only documented post-deployment and with much less fanfare than, say, the ribbon-cutting on a new multi-megawatt solar microgrid system supplying green electricity to an American garrison town.

Project for a New American Renewable Energy Century

All of these developments will be part of the energy legacy of America’s War on Terror. Not because the war was, or will be, a war about ushering in a new age of renewable energy—not any more than the First World War was about replacing coal with oil, or the Second World

War a race to the nuclear age. But rather it's because, to borrow the language of the Silicon Valley, war is perhaps the greatest technology accelerator, especially in the United States, where military budgets are almost inexhaustibly elastic and the idea of achieving domestic energy security has captured the minds of military and commercial energy developers alike. In 2013, the U.S. military, along with a handful of American universities and companies including Walmart and General Motors, accounted for just five per cent of wind power contracts in the U.S., according to the American Wind Energy Association trade group. By 2016, that share had jumped to 40 per cent (Groom, 2017). Wind power costs have dropped by 66 per cent since 2009, according to the American Wind Energy Association, while the cost of solar installs has plummeted by 70 per cent, according to the Solar Energy Industries Association (Groom, 2017). Today, whole-scale industries are wading into the renewable energy pool as costs have come down dramatically and federal incentives remain in place for military energy procurement programs.

To date, the U.S. military remains by far the nation's leader in domestic solar, wind and hybrid microgrid development, accounting for fully one-third of all installed capacity expected through 2020 (Chen, 2016). According to a 2017 report from the Pew Project on National Security, Energy and Climate, the U.S. military could save hundreds of millions of dollars annually by continuing to switch its domestic bases from diesel backup generators to full renewable or renewable-hybrid microgrid generators. The move, according to the report, would not only enhance security against the threat of outages due to cyber attacks and extreme weather, but could also generate revenue for the military by opening the contracts to third-party customers, while lowering energy costs for states, companies and utilities that are willing to tie

into those localized grids (Swanson, 2017). For a current U.S. administration in Washington that has proven hostile to environmental concerns and international accords, the allure of incentivizing continued military-based renewable energy research and deployment may be non-existent. But when the same administration also promises to cut government spending, create jobs, strengthen the military and ensure domestic energy security, all under the guiding principle of “America First,” then it’s implausible to imagine the current White House—staffed as it is with an unprecedented number of retired military generals in top posts—reversing the military energy programs that are already achieving these goals. “I cannot comprehend an administration that would say, ‘Increase your costs, consume more energy and water... and be less resilient and less ready to deploy our troops,’” Katherine Hammack, assistant secretary of the Army for Installations, Energy and Environment, told a roomful of U.S. military brass at the January unveiling of the Pew report (St. John, 2017). Such a reversal would be an about-face on the course the U.S. military has been charting since the very outset of the War on Terror in 2001.

It was then-secretary of defense Donald Rumsfeld who, guided by the principles of the Project for the New American Century think tank, reorganized and re-equipped the military into a nimbler, more technologically endowed, increasingly Special Forces-dependent and “smart weapons”-oriented military. For all the faults in the way the military was so hastily realigned, and for all the failures of the missions the military was so hastily pressed into—and there were many on both accounts—those organizing principles and strategies remain by and large the same principles and strategies of the U.S. military today. Those choices and their consequences—intended and otherwise—laid the

groundwork for the modern renewable energy-reliant military, and laid the groundwork for, to repurpose the phrase, a new American *renewable energy* century.

In a world still rife with conflict and plagued by depleting conventional energy resources, the U.S. military will continue to drive technological advancements across all sectors of American society—but the energy sector in particular. The U.S. is, and will remain for the foreseeable future, at the cutting edge of deploying clean energy tech in its war-fighting and commercial enterprises, especially as renewable energy becomes ever more efficient, adaptable and inexpensive. That rapidly declining cost curve and the pervasion of American technological know-how will have a democratizing effect on these technologies worldwide. We are not yet beyond the era of aspirational nations warring for control over, or in defense of, increasingly scarce energy resources. But it's clear that those nations which have to rely on such conflicts for their survival will soon be relegated to the dustbins—or rather, coal bins—of history. That is how history has played out for all warring societies that were either insufficiently resourced in energy or otherwise outclassed in energy technology. Likewise, in a future where fossil fuel depletion is likely to breed greater conflict, greater fuel acquisition costs and greater displacement of peoples to more sufficiently resourced regions, without the continued development of alternative energy to fuel modern warfighters and the institutions and economies they fight for, what is the alternative? Victims of history, indeed.

Works Cited

- Adler, Alan. "October Reveal for Chevrolet Colorado-Based Fuel Cell Vehicle." GM Advanced Technology Communications. 30 August 2016. Web. 22 September 2016.
- . "Mission-Ready Chevrolet Colorado ZH₂ Fuel Cell Vehicle Breaks Cover at U.S. Army Show." GM Advanced Technology Communications. 3 October 2016. Web. 4 October 2016.
- Adams, Sam and Scott Campbell. "ISIS propaganda footage shows young terrorists using drones to drop bombs on battlefield as children celebrate destruction." *The Daily Mirror*. 24 January 2017. Web. 1 February 2017.
- AEMR. *Department of Defense Annual Energy Management Report, Fiscal Year 2015*. Washington, DC: Office of the Assistant Secretary of Defense - Energy, Installations and Environment. U.S. September 2014. Web. 8 June 2016.
- AEPI. *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys: Final Technical Report*. Army Environmental Policy Institute: Arlington, Virginia. September 2009. Web. 14 May 2016.
- AFP. "US Air Force ready for biofuels when costs drop: official." *The China Post*. 21 July 2011. Web. 16 January 2017.
- Airbus. *Zephyr, the High-Altitude Pseudo-Satellite*. Toulouse: Airbus Defence and Space. 2017. Web. 22 February 2017.
- Alexander, David. "Great Green Fleet using biofuels deployed by U.S. Navy." *Reuters*. 20 January 2016. Web. May 10, 2016.

ARPA-E. “Celebrating Armed Forces Day: A Look at ARPA-E Technologies with Potential Military Applications.” ARPA-E Press & Public Affairs. 22 May 2017. Web. 29 May 2017.

---. “ARPA-E Projects Receive More than \$1.8 Billion in Private Follow-On Funding for Transformational Energy Technologies.” ARPA-E Press & Public Affairs. 27 February 2017. Web. 12 June 2017.

Aruja, Mark. Personal interview. conducted by telephone 12 May 2017.

Bach, James. “Lockheed Martin launches new energy business.” *Washington Business Journal*. 16 March 2016. Web. Accessed 10 July 2017.

Bannister, Justin. “NMSU wins more than \$2.3 million to study algae-based jet fuel for the Air Force.” *NMSU News*. 22 November 2010. Web. 21 January 2017.

Barry, Ellen and Mark Mazzetti. “Army Reserve Unit Reportedly Balked at Risky Mission in Iraq.” *Los Angeles Times*. 16 October 2004. Web. 15 August 2016.

Beidel, Eric. “Biofuels Industry Has Fight On Its Hands As Senators Take Up Budget Debate.” *National Defense Magazine*. 21 May 2012. Web. 16 January 2017.

Benson, Jane. “Minimized Logistics Habitat Unit saves energy, preserves quality of life.” Natick, MA: United States Army Soldier Research, Development and Engineering Center. 15 April 2016. Web. 1 October 2016.

Benzak, Jeff. “Sierra Energy: Transforming Waste into Clean Fuel.” *Fueling Growth*. Web. 6 June 2017.

Bercuson, David J. and Holger H. Herwig. *Long Night of the Tankers: Hitler’s War Against Caribbean Oil*. Calgary: University of Calgary Press. 2014. Print.

Biermann, Gary. Personal interview. 11 February 2016.

Biesecker, Michael. "Navy: Wind Farm Opposed by GOP Lawmakers Won't Harm Radar." *Military.com*. 20 January 2017. Web. 28 January 2017.

Blanchfield, Mike. "Canada to use armed drones, cyber attacks to respond to global security threats." *The Canadian Press*. 7 June 2017. Web. 1 July 2017.

Board, William J. "The Thin Line Between Civilian and Military Nuclear Programs." *The New York Times*. 5 December 2007. Web. 4 August 2017.

Brown, Doug. Personal interview. 30 March 2017.

Business Wire. "Solazyme Completes World's Largest Microbial Advanced Biofuel Delivery to U.S. Military." *Business Wire, Inc.* 15 September 2010. Web. 2 June 2017.

Canadian Defence Review. "Canada's 2016 Top 50 Defence Companies." *Canadian Defence Review*. 2017. Web. 8 May 2017.

Canadian Food Inspection Agency. "The biology of *Camelina sativa* (L.) Crantz (Camelina)." CFIA Plant and Biotechnology Risk Assessment Unit. 2012. Web. 15 June 2016.

Cape Breton University. "CBU Creates Global Legacy with Opening of Verschuren Centre for Sustainability in Energy and the Environment." Cape Breton, NS: Cape Breton University News & Events. 7 November 2011. Web. 4 July 2017.

Carter, Jimmy. *White House Diary*. New York: Farrar, Straus and Giroux. 2010. Print.

Chatterjee, Pratap. *Halliburton's Army*. New York: Nation Books. 2009. Print.

Chambers, Alaina M., and Steve A. Yetiv. "The Great Green Fleet: The U.S. Navy

and Fossil Fuel Alternatives.” *Naval War College Review, Summer 2011, Vol. 64, No. 3*. June 2011. Web. 19 February 2016.

Chen, Olivia. “US Installed Microgrid Capacity to Grow 115% and reach 4.3GW Over the Next 5 Years.” *Greentech Media*. 29 August 2016. Web. 5 August 2017.

Chevron. “Chevron Worldwide.” Chevron Corporation. 2016. Web. 19 November 2016.

Chronicle Herald. “Lockheed, Irving ink \$170M patrol ship deal.” *Chronicle Herald*. 8 April 2015. Web. 8 July 2017.

CNBC. “Under Trump, Super Hornet Gets a Boost: Production Set to Double.” *CNBC Defense*. 8 May 2017. Web. 4 July 2017.

Copp, Tara. “Despite concerns, military continues use of burn pits in Iraq.” *Stars and Stripes*. 4 January 2016. Web. 17 June 2017.

Corsi, Jerome R. *The Great Oil Conspiracy*. New York: Skyhorse. 2012. Print.

Cragg, Jennifer. “NECC’s Fuel Reporting Tool Indicates 78 Percent Reduction in Fuel Usage Since 2008.” United States Navy. 13 October 2016. Web. 20 October 2016.

Cuttino, Phyllis. “The US Navy & Cutting Edge Energy Innovation in the Defense Sector.” The Atlantic Council. 12 April 2016. Speech.

Dahl, Carol Ann. *International Energy Markets: Understanding Pricing, Policies, and Profits*. Tulsa: PennWell. 2004. Print.

- D'Olier, Franklin and Henry Alexander, George Ball, Harry Bowman, John Galbraith, Rensis Likert, Frank McNamee, Paul Nitze, Robert Russell, Fred Searls, Theodore Wright, Charles Cabot. *The United States Strategic Bombing Survey Summary Report – European War – September 30, 1945*. The United States Air Force: Air University Press. 1945. Web. 22 October 2016.
- Douquet, Greg. “Unleash Us From the Tether of Fuel: Innovation in energy can be a force multiplier on the battlefield.” *The Atlantic Council Blogs*. 11 January 2017. Web. 7 June 2017.
- Dutta, Animesh. Personal interview. 11 January 2017.
- Dyer, Gwynn. *Climate Wars*. Toronto: Vintage Canada. 2009. Print.
- Erwin, Sandra. “Army’s Energy Battle Plan: Attack Fuel Demand.” *National Defense Magazine*. May 2011. Web. 12 September 2016.
- ExxonMobil. “Oil.” Exxon Mobil Corporation. 2016. Web. 19 November 2016.
- Fabey, Mike. “The U.S. Military’s Strategy to Dominate the Air: Have the F-35 and F/A-18 Join Forces.” *The National Interest: The Buzz*. 29 March 2017. Web. 4 July 2017.
- Fan, Jiqing. (2013). *Sustainable Energy Production in the United States: Life Cycle Assessment of Biofuels and Bioenergy*. Houghton, MI: Michigan Technological University. 2013. 24 July 2016. Dissertation.
- Farah, Douglas and Susan Schmidt. “Al Qaeda’s New Leaders.” *The Washington Post*. 29 October 2002. Web. 21 November 2016.
- Foley, Catherine. “Military Basing and Climate Change.” American Security Project. Washington, D.C. 2012. Web. 14 May 2016

- Gooding, Mike. "Navy, State, Dominion join forces at Oceana." *WVEC-13 News Now*. Norfolk, VA. 2 August 2016. Web. 10 October 2016.
- Goossens, Ehren. "Exploding Fuel Tankers Driving U.S. Army to Solar Power." *Bloomberg News*. 1 October 2013. Web. 9 September 2016.
- Gordon, Michael R. "U.S. Warplanes Strike ISIS Oil Trucks in Syria." *The New York Times*. 16 November 2015. Web. 17 November 2016.
- Government of Alberta. "Aerospace and Defence Industry Profile." Government of Alberta. 2017. Web. 17 June 2017.
- Graveland, Bill. "Going green: Enmax wins federal contract for renewable energy in Alberta." *The Canadian Press*. 18 March 2017. Web. 17 July 2017.
- Gray, Peter and Owen Thetford. *German Aircraft of the First World War* (Second ed.). London: Putnam. 1970. Print.
- Groom, Nichola. "America's hungriest wind and solar power users: big companies." *Reuters*. 20 June 2017. Web. 4 August 2017.
- Hanc, John. "A Fleet of Taxis Did Not Really Save Paris From The Germans During World War I." *Smithsonian*. Web. 24 July 2014. 24 July 2017.
- Haq, Zia. *Energy Efficiency and Renewable Energy: Biofuels in Defense, Aviation and Marine*. Washington, DC: U.S. Department of Energy Bioenergy Technologies Office. 24 March 2015. Web. 22 January 2017.
- Hargreaves, Steve. "Iraq War made me switch to solar." *CNN Money*. 14 April 2011. Web. 19 July 2016.

---. "For the military clean energy saves lives." *CNN Money*. 17 August 2011. Web. 12 July 2016.

Harrison, Darryll. "Volkswagen Completes Successful Renewable Fuel Evaluation with Solazyme and Amyris." Volkswagen U.S. Media. 29 June 2015. Web. 2 June 2017.

Hsu, Jeremy. "Despite Trump, Silicon Valley's Pentagon Ties Stay Strong." *Wired*. 10 February 2017. Web. 16 June 2017.

Hume, Mark. "US military takes SFU power-generating project for a test walk." *The Globe and Mail*. 13 July 2016. Web. 1 August 2017.

International Atomic Energy Agency. *IAEA Issues Report on Kashiwazaki-Kariwa Nuclear Plant*. Vienna: International Atomic Energy Agency. 17 August 2007. Web. 1 November 2016.

Jacobsen, Annie. *The Pentagon's Brain: An Uncensored History of DARPA, America's Top Secret Military Research Agency*. New York City: Little, Brown and Company. 2015. Print.

Kashi, David and Kevin Wang. "Major U.S. military operations/actions to protect oil." Medill National Security Journalism Initiative. Evanston, IL: Northwestern University. 2015. Web. 14 November 2016.

Kimberley Process. "KP Basics: Kimberley Process: About." 2016. Web. 22 November 2016.

Krammer, Arnold. "Technology Transfer as War Booty: The U.S. Technical Oil Mission to Europe, 1945." *Technology and Culture*. Vol. 22, No. 1. Baltimore, MD: Johns Hopkins University Press. January 1981. Web. 3 Apr. 2017.

Labrador, David. "Why the U.S. Air Force wants to fly on renewable energy." *GreenBiz*. 17 January 2017. Web. 19 January 2017.

- Lane, Jim. "US warplanes can fly faster, carry additional weapons load using advanced fuels and biofuels: new data." *Biofuels Digest*. 21 May 2012. Web. 16 January 2017.
- . "US Navy, DOE, USDA award \$210M for 3 biorefineries and mil-spec fuels." *Biofuels Digest*. 19 September 2014. Web. 18 January 2017.
- . "'High confidence level' as alcohol-to-jet fuel closes in on historic ASTM approval." *Biofuels Digest*. 16 December 2015. Web. 12 June 2017.
- Lavelle, Marianne. "First Green Supersonic Jet Launches on Earth Day." *National Geographic*. 20 April 2010. Web. 28 May 2016.
- Leary, Raymond J. *Over A Barrel: Breaking Oil's Grip on our Future*. New York City: Encounter Books. 2007. Print.
- Lee, Elizabeth. "US military taps into innovations in startup tech world." *VOA News*. 16 May 2017. Web. 2 June 2017.
- Mabus, Ray. "Seeking Alternative Energy Sources Key to Navy Mission." *Currents*. Summer 2012 Issue. June 2012. Web. 14 August 2016.
- . "Remarks by the Honorable Ray Mabus Secretary of the Navy Naval Energy Forum." Naval Energy Forum. McLean, Virginia. 14 October 2009. Speech.
- . "Remarks by the Honorable Ray Mabus Secretary of the Navy Energy Innovation and National Security: A Conversation Introduction and Moderator: David Sandalow to Columbia University, New York." New York City. 21 April 2015. Speech.
- . "Remarks by U.S. Navy Secretary Mabus to the Commonwealth Club of California." San Francisco. 6 January 2016. Speech.

MacGregor, Ian. Personal interview. 8 December 2016.

Maguire, Yael and Martin Luis Gomez. "Reviewing Aquila's first full-scale test flight."

Facebook Code. 16 December 2016. Web. 22 February 2017.

Majumdar, Dave. "The Future is Looking Bright for the U.S. Navy's Super Hornet." *War is*

Boring. 24 June 2017. Web. 24 June 2017.

Martin, Steven. Personal interview. 6 January 2017.

Marshall, Aarian. "Solar Impulse Just Completed Its Momentous Flight Around the World."

Wired. 25 July 2016. Web. 18 December 2016.

McGinn, Dennis. "The US Navy & Cutting Edge Energy Innovation in the Defense Sector."

The Atlantic Council. Washington, DC. 12 April 2016. Speech.

---. "Accelerating Energy Resilience and Security: Lessons from the Front Lines." The Verge Hawaii

Asia Pacific Clean Energy Summit. Honolulu. 21 June 2016. Speech.

McHugh, John. *Army Operational Energy Policy*. Washington, DC: Office of the Secretary of the

Army. 30 April 2013. Web. 21 September 2016.

Meadahl, Marianne. "Bionic Power Strides into new field trials with U.S. Army." *SFU News*.

Burnaby, BC: Simon Fraser University. 13 July 2016. Web. 4 July 2017.

Mehta, Aaron. "Lockheed Martin Biggest US Government Contractor in 2015." *DefenseNews*

15 May 2016. Web. 5 December 2016.

Mercier, Louise. Personal interview. 11 May 2017.

Mitvalsky, Bob. Personal interview. 13 February 2015.

Molberg, John. Personal interview. 11 February 2016.

Moriarty, Tracey. "Navy Fuels Great Green Fleet Vision." *Currents: The Navy's Energy and Environmental Magazine, Winter 2011 Issue*. 2011. Web. 9 December 2016.

Myers, Meghann. "Navy deploys first biofuel-powered Great Green Fleet to Asia-Pacific." *Navy Times*. 21 January 2016. Web. 12 May 2016.

National Priorities Project. "Military Spending in the United States." Northampton, MA: National Priorities Project. 2016. Web. 27 November 2016.

Navy Chief of Information. "Green Ship USS Makin Island Brought to Life in San Diego." U.S. Department of the Navy. 26 October 2009. Web. 1 June 2016.

---. "Navy Tests Biofuel-powered 'Green Hornet.'" U.S. Department of the Navy. 22 April 2010. Web. 6 June 2016.

---. "Blue Angels to Soar on Biofuel During Labor Day Weekend Air Show." U.S. Department of the Navy. 1 September 2011. Web. 24 July 2016.

Noguchi, Yuki. "As Sea Levels Rise, Norfolk is Sinking and Planning." *NPR*. 14 July 2014. Web. 28 July 2016.

Novobilski, Marisa. "Fueling the future: Air Force Title III program working to 'home-grow' biofuels for DOD, industry." Wright-Patterson Air Force Base Air Force Research Laboratory. 29 August 2016. Web. 10 January 2017.

- Office of the Commissioner of Lobbying of Canada. "12-month Lobbying Summary: Boeing Global Sales Corporation, Tracey Hubley, Consultant; Boeing Operations International, Incorporated: James Zrust, President." Ottawa: Office of the Commissioner of Lobbying of Canada. Web. 19 June 2017.
- Office of Energy Efficiency & Renewable Energy. "Solar Ready Vets." Washington, DC: United States Department of Energy. Web. 4 August 2017.
- Olah, George. *Beyond Oil and Gas: The Methanol Economy* (2nd Edition). Weinheim, Germany: Wiley-VCH. 2009. Print.
- Penrose, Harald. *British Aviation: The Great War and Armistice 1915-1919*. London: Bodley Head Ltd. 1969. Print.
- Phillips, Shannon. Personal interview. 14 November 2016.
- Pike, John E. "Military Standard Generators." *GlobalSecurity.org*. 2016. Web. 12 September 2016.
- Price, William. "Renewable energy vital to Marines success in Afghanistan." United States Marine Corps: 1st Marine Division. 12 January 2011. Web. 13 December 2016.
- Public Works and Government Services Canada. "Determination of costs associated with the introduction of biofuel technologies onto diesel powered vessels (W7707-135625/A)." Procurement Data: Tenders. Ottawa: Public Works and Government Services Canada Published 14 January 2013. Amended 30 March 2013. Web. 21 January 2016.
- Rassler, Don, Muhammad al-'Ubaydi and Vera Mironova. *CTC Perspectives: The Islamic State's Drone Documents: Management, Acquisitions, and DIY Tradecraft*. West Point, NY: Combating Terrorism Center at West Point. 31 January 2017. Web. 20 February 2017.

- Ripley, Anthony. "Lightening the Load for the Modern Marine." *DSIAC Journal*, Winter 2016. Vol. 3, No. 1. Arlington, VA: Defense Systems Information Analysis Center. 2016. Web. 14 February 2017.
- "Rise of the Drones." *Nova*. PBS. WGBH, Boston. 23 January 2013. Television.
- Ross, Michael L. *The Oil Curse: How Petroleum Wealth Shapes the Development of Nations*. Princeton, NJ: Princeton University Press. 2012. Web. 3 September 2016.
- Salisbury, Peter. "Sad decline of Aden's once-thriving port." *Financial Times*. 6 March 2013. Web. 1 May 2017.
- Sazak, Selim C. "How Green Energy Will Help Slow Nuclear Proliferation." *Defense One*. 5 August 2017. Web. 8 August 2017.
- SBIR-STTR. *Ultra-Endurance UAV*. Funding Topic Details: Small Business Innovation Research: U.S. Small Business Administration: United States Government. Web. 22 February 2017.
- Scahill, Jeremy. "Fueling War: Pentagon Still Buying Most of Its Oil and Gas from BP." *The Nation*. 9 June 2010. Web. 19 November 2016.
- Schaefer, Paul. "Largest Solar Array in North America: Nellis AFB." *Environmental News Network*. 17 December 2007. Web. 21 December 2016.
- Shane, Scott. "Saudis and Extremism: 'Both the Arsonists and the Firefighters.'" *The New York Times*. 25 August 2016. Web. 19 November 2016.
- Sheftick, Gary. "Army reaches \$1 billion in energy-saving projects." *Army News Service*. Office of the Secretary of the Army. 11 August 2016. Web. 6 November 2016.

---. "The next-generation combat vehicle could have lasers, run on hybrid power." *Army News Service*. Office of the Secretary of the Army. 3 November 2016. Web. 6 November 2016.

Sierra Energy. "U.S. Department of Defense Selects Sierra Energy for 2013 Installation." Sierra Energy Media. 15 November 2012. Web. 14 June 2017.

SIPRI. "Increase in arms transfers driven by demand in the Middle East and Asia." Solna, Sweden: Stockholm International Peace Research Institute, Arms Transfer Database. 20 February 2017. Web. 12 August 2017.

St. John, Jeff. "How Military Microgrids Could Save the Country—on Energy Costs." *Greentech Media*. 17 January 2017. Web. 11 August 2017.

Stein, Amanda D. "NPS Researchers Evaluate Biofuels For Powering the Fleet." Office of the U.S. Navy Chief of Information. 31 August 2012. Web. 14 August 2016.

Stern, Roger J. "United States cost of military force projection in the Persian Gulf, 1976–2007." *Energy Policy*. Princeton, NJ: Princeton University Press. 7 January 2010. Web. 23 July 2016.

Sustainable Oils. "Aviation Opportunities." Global Clean Energy Holdings, Inc. 2016. Web. 10 January 2016.

Swanson, Tom. "U.S. Military Could Save Over \$1 Billion and Boost Energy Security, New Research Finds." Pew Project on National Security, Energy and Climate Research and Analysis. The Pew Charitable Trusts. 12 January 2017. Web. 8 August 2017.

Szamocki, Norm. Personal interview. 12 February 2015

Taylor, Henry. "Who is the world's biggest employer? The answer might not be what you expect." World Economic Forum. 17 June 2015. Web. 8 December 2016.

“The Burden.” Roger Sorkin. Sorkin Productions. 2015. Film.

United Airlines. “United Airlines Makes History with Launch of Regularly Scheduled Flights Using Sustainable Biofuel.” United Airlines Worldwide Media Relations. 11 March 2016. Web. 13 January 2017.

United States Air Force. “RQ-4 Global Hawk.” United States Air Force: About Us: Fact Sheets. 27 October 2014. Web. 22 February 2017.

United States Air Force 88th Air Base Public Affairs. “F-22 Raptor flown on synthetic biofuel.” United States Air Force – Publications. 23 March 2011. Web. 21 July 2016.

United States Department of Defense. *Base Structure Report – Fiscal Year 2015 Baseline*. United States Department of Defense – Publications. 2014. Web. 16 October 2016.

---. *National Security Implications of Climate-Related Risks and a Changing Climate*. United States Department of Defense – Publications. 23 July 2015. Web. 28 November 2016.

---. *The “X” is for Experimental*. United States Department of Defense – Publications. 11 May 2016. Web. 15 May 2017.

U.S. Department of Energy. *Early Days of Coal Research*. Office of Fossil Energy. Web. 2 April 2017.

---. *FY 2011 Congressional Budget Request*. Office Chief Financial Officer. February 2010. Web. 28 May 2017.

United States Department of State. *Clean Diamond Trade Act*. Washington, DC: U.S. Bureau of Economic and Business Affairs. 25 April 2003. Web. 17 November 2016.

---. *Foreign Relations of the United States, 1958-1960, Foreign Economic Policy, Volume IV*. U.S. Department of State. Office of the Historian. Web. 4 May 2017.

United States Department of Veterans Affairs. *Report on Data from the Airborne Hazards and Open Burn Pit Registry*. Veterans Health Administration Office of Public Health, U.S. Department of Veterans Affairs. June 2015. Web. 18 June 2017.

United States Energy Information Administration. *Arizona State Profile and Energy Estimates*. EIA: Independent Statistics and Analysis. 2016. Web. 1 November 2016.

---. *Monthly Biofuel Production Report: November 2016*. EIA: Independent Statistics and Analysis. 17 January 2017. Web. 3 February 2017.

---. *World Oil Transit Chokepoints*. EIA: Independent Statistics and Analysis. 10 November 2014. Web. 14 November 2016.

United States Navy. "Great Green Fleet." United States Navy: Energy, Environment and Climate Change. 2016. Web. 16 September 2016.

United States Office of Management and Budget. *Budget of the United States Government: Fiscal Year 2016*. Washington, DC: Government Printing Office. 2015. Web. 16 October 2016.

Unruh, Timothy. "Federal Energy-Saving Program Keeps Federal Government on Pace to \$4 Billion Investment." Washington, DC: United States Department of Energy. 19 December 2014. Web. 4 November 2016.

USNRC. "Related Documents and Other Resources: History." The United States Nuclear Regulatory Commission. 30 March 2016. Web. 12 December 2016.

Van Vliet, Kimberley. Personal interview. 12 February 2016.

Vance, Ashlee. "Satellite Pics for Cheap!!!" *Bloomberg Businessweek*. 15 May - 21 May 2017. Print.

Volesky, Gary. "Department of Defense Press Briefing by Army Maj. Gen. Gary J. Volesky via teleconference from Baghdad, Iraq." Press Operations: U.S. Department of Defense. 19 October 2016. Web. 1 February 2017. Transcript.

Vergun, David. "Soldiers using sunlight to improve combat capability." *Army News Service*. 14 November 2012. Web. 9 October 2016.

Weaver-Cox, Karen. "Air Force takes step toward cleaner fuels." *The Wright-Patterson Air Force Base Skywriter*. 8 April 2010. Web. 18 January 2017.

Wells, Jane. "Lockheed has liftoff: Sells new airships in \$480M deal." *CNBC*. 30 March 2016. Web. 14 May 2017.

Wenar, Leif. *Blood Oil: Tyrants, Violence, and the Rules that Run the World*. Oxford, UK: Oxford University Press. 2014. Print.

Werrell, Caitlin E. and Francesco Femia, eds. "The Arab Spring and Climate Change." Washington, DC: The Center for American Progress Center for Climate and Security. February 2013. Web. 20 August 2017.

Withers, Paul. "'On time and under budget:' Navy marks end of \$4.3B frigate modernization." *CBC News*. 29 November 2016. Web. 2 July 2017.

Wittenberg, Ariel. "Trump pick helped spur Pentagon renewables." *E&E News*. 12 December 2016. Web. 4 March 2017.

Wood, Elizabeth. Personal interview. 27 April 2017.

Woody, Todd. "The U.S. Military's Great Green Gamble Spurs Biofuel Startups." *Forbes*. 24 September 2012. Web. 12 May 2017.

WSMR Public Affairs. "White Sands home to Army's largest solar power system." White Sands Missile Range Public Affairs. 17 January 2013. Web. 22 October 2016.

Yergin, Daniel. *The Prize: The Epic Quest for Oil, Money & Power*. New York City: Free Press. 2009. Print.

---. *The Quest: Energy, Security, and the Remaking of the Modern World*. New York City: Penguin Press. 2011. Print.

Zaffos, Joshua. "U.S. Military Forges Ahead with Plans to Combat Climate Change." *Scientific American*. 2 April 2012. Web. 3 September 2016.

Zimm, Alan. *Attack on Pearl Harbor: Strategy, Combat, Myths, Deceptions*. Philadelphia: Casemate Publishers. 2011. Print.

Zubrin, Robert. *Energy Victory*. Amherst, NY: Prometheus Books. 2007. Print.