Lift Off: The Rise of the Hydrogen Revolution

Book 1 – Introducing Hydrogen

A Project of the
World Business Academy

Introduction: Where We Come from, Where We Are and Where We are Headed

Look out from any spot on Earth and what do you see? Stars. Depending on how clear the night sky, you could see thousands of them with the naked eye. The entire universe is made up of stars – the originators of all light and life and literally the source of all energy. And what are stars made of? Hydrogen – every star is a giant hydrogen fusion reactor. In fact, over 75% of all the molecules in the universe are hydrogen.

The element is so abundant that to us humans, living in a hydrogen-fueled, hydrogen-powered universe, our experience is similar to that of a fish in the ocean. Just like a fish isn't aware it is swimming in something called water, most of us don't realize there is this vast ocean of hydrogen surrounding us and making our lives possible. This abundance of hydrogen makes it the most efficient and important carrier of energy and creates the potential for a,new planetary fuel system. Some have coined the term "Hydrogen Economy" to describe this revolutionary global economic system fueled by hydrogen energy.

In the pages that follow, we will articulate the benefits that could accrue to humanity through switching from a global economy based upon scarcity (a finite amount of fossil fuel resources that will rise in price as they are consumed) to an economy based upon the vast abundance of renewable energy sources.

As we will explain, hydrogen has the ability to store and transfer energy collected from renewable sources, giving our new economy the capacity to supply energy at decreasing prices as the volume and efficiency of renewable technologies improve over time. As this new reality takes hold, this transformation will inform every aspect of human society and will empower us to solve our most daunting global challenges.

It is important to note that a transition away from our fossil fuel-based economy does not require us to completely replace our existing energy infrastructure. Instead, a strategic approach to replacing key components of the electrical grid and converting existing pipelines to transport renewable hydrogen rather than fossil fuels will be explored in future installments in this World Business Academy book series.

Energy Revolutions in History

To gain perspective on how dramatic the switch to hydrogen for our planetary fuel system could be, let's look at the benefits gained from the last few times humans transitioned from one basic fuel system to another.

Harnessing and deploying nature's stored energy is a defining characteristic of our species. The first form of fuel available to humans was wood: a very bulky, heavy form of carbon used initially to cook food (allowing better metabolism of meat for protein which in turn accelerated human brain growth) and to serve as a source of heat to preserve life in

the winter. Over the years, wood was used as a material to construct housing, defense systems and tools, and ultimately as a fuel in early industrial applications. To humans of the Renaissance era, wood was the most versatile and productive source of commerce since it provided the raw material to make carts and ships to move people and goods to market and armies to battle. It would have been impossible for the people of this period to imagine how something as hard, black and filthy as coal would later revolutionize their world, but revolutionize it did.

Wood → Coal

Coal holds numerous advantages over wood as it is a much denser form of carbon that contains dramatically more power in a smaller amount of weight and space. The effect of coal was so pronounced that it became the power source driving the engines of society everywhere it was used: reshaping production, social agreements and human potential itself. As a result, the Industrial Revolution was born.

The Industrial Revolution was such a fundamental repositioning of the human species that it was impossible for anyone living prior to the 1700s to imagine what the world would look like and how the power of the Industrial Revolution would create wealth on a global scale never before dreamt of. Coal created the possibility for transformational advancements such as steel and steam engines. Living standards began to accelerate wherever the Industrial Revolution took hold – and the places where it didn't rapidly became real or de facto colonies of

industrial powers. Coal opened humanity's eyes to the potential created by using greater energy from higher density fuels. The race to create greater abundance was on.

Just as Renaissance-era humans were unable to envision the explosion of wealth to be created by a coal-powered industry, the architects of the Industrial Revolution were also unable to see the even greater explosion of economic power that would be triggered by the transition from coal to oil. Just imagine life in London during the 1870s or shortly thereafter. The air was so thick with coal dust it literally formed a cloud of soot over the city. No one even seriously questioned whether such a condition was acceptable because it was the direct result of burning coal and, as such, was thought to be a permanent, necessary evil of human progress. No one would have imagined a world without coal that was capable of both creating wealth while also leaving the air relatively clear. How could such a miracle occur? Who would even dream of suggesting that London cease its consumption of coal, even though everyone knew it was quite unhealthy to live with all the soot and ash?

Coal → Oil

Although oil was the key ingredient in asphalt dating back to Babylonian times (almost 4,000 years before the Industrial Revolution) and was used in various forms as far back as the first commercial well in China (347 A.D.), it wasn't until Edwin Drake drilled the first modern

production well in Titusville, Pennsylvania in 1857 that using oil as a fuel really took off.

Drake's humble start eventually transformed into the gargantuan Standard Oil, and the birth of the oil industry and subsequent internal combustion engines went on to create the modern society we have inherited. Along with the explosion of wealth and improvements in living conditions and life expectancy, the external cost of burning massive amounts of fossil fuel over an extended period has resulted in an acceleration of climate change which threatens to render this planet uninhabitable for its 7.3 billion (and counting) human inhabitants. Climate change is real, it is here, and it is a threat to all human, animal and plant species.

Given this grim reality, mankind must begin to transition away from a fossil fuel economy. The critical question that we must now answer is what form of energy will we transition towards that allows us to continue developing as a global society while also providing inexpensive, clean, renewable and carbon-free energy?

Just as a Londoner in the late 1800s could never have imagined a society without coal where the economy would be far more abundant and living conditions dramatically improved, it is similarly challenging for today's citizens to imagine an economy which could be vastly larger, and yet not produce harmful environmental toxins as an external cost. This unimaginably abundant economy is achievable, but we must first

complete another transformation in the planetary fuel system: a leap to hydrogen.

Fossil Fuels → Hydrogen

Hydrogen has the potential to unlock a future economy that will make our current global economy appear, in hindsight, absolutely primitive. With the adoption of a hydrogen-based economy, our perceived limitations today will disappear so quickly and our progress as a species will accelerate so rapidly, it may even become hard to recall when we first awoke to hydrogen's vast potential.

In its simplest terms, this book is a call for the conversion from a carbon-based economy of scarcity to an abundant, literally inexhaustible hydrogen-based economy. Due to the immediacy of the climate change danger, society has no choice but to switch to this far cheaper, far safer, far more reliable and far more ubiquitous form of energy. We must work to get there as quickly as possible, as billions of lives are at stake over the next 10-50 years due to unchecked climate change threatening to devastate one community after another across the planet.

If the current trajectory remains unaltered, we could witness 90% of humanity wiped out by the severe consequences of a planet beginning to overheat past the point of survivability. However, if we act decisively, we can avoid such devastation. Based on our extensive research, the Hydrogen Economy concept is by far the most effective strategy for shifting society away from the paradigm of energy scarcity, competition

and suffering toward a future based on renewable energy, cooperation, abundance and ecological regeneration.

Hydrogen is the "Energy Carrier" of the future

A highly reactive, invisible, tasteless gas, hydrogen is essential in innumerable chemical and biological processes. Best of all, because hydrogen is an efficient carrier of energy, we can make it from renewable energy sources like wind, solar, geothermal or Ocean Thermal Energy Conversion (more on this method later). Once created, hydrogen can be transported wherever it is needed. Think of hydrogen as an energy transportation system. Just as electricity is used to transport energy across power lines from a power plant to your refrigerator or natural gas is used to transport energy from the drill site to your appliances, and just as a battery functions as a limited form of mobile energy storage, hydrogen can serve as the link between renewable power production and you – to power your home, your vehicle and even air transportation.

Hydrogen for Grid Stability and Renewable Energy Storage

Hydrogen is the simplest molecule known to humanity. It is the first element on the periodic table of elements because it contains just one neutron, one proton and one electron. And, as noted earlier, hydrogen is everywhere and is extremely easy to obtain and capture by

splitting water into its constituent parts - hydrogen and oxygen. This process is called electrolysis and occurs when a weak electrical current is applied to liquid water to break the molecular bond.

One argument against the full adoption of renewable energy resources is that they are intermittent and widely viewed as too unreliable to meet the large and constant energy needs of an industrial society (since the wind doesn't blow nor the sun shine 24 hours a day, 7 days a week[1]). Enter hydrogen. Using existing electrolyzer technology to capture renewable energy, we can indefinitely store this clean energy as hydrogen gas for later use. For example, largely unreported developments of recent years involve symbiotic projects mating renewable energy sources with hydrogen production for long-term/high-volume energy storage in salt caverns. Using hydrogen for energy storage gives us the ability to accumulate renewable energy (in the form of hydrogen gas) and deploy it when needed.

Because of the revolutionary energy storage potential of hydrogen, renewable fuel sources like wind, geothermal, ocean thermal energy conversion (OTEC) and solar can become the clean, zero-emission, affordable, stable base energy needed to power grids and vehicles around the clock, no matter the weather or time of day. Under a hydrogen

[1] Note however that both geothermal and OTEC do operate with identical efficiencies on a 24/7 basis. Geothermal currently produces electricity in the USA for the equivalent incremental cost of 6¢ per kilowatt hour, and similar efficiencies are deemed achievable with OTEC platforms by leading researchers.

energy infrastructure, the old arguments against wind and solar power can be seen for what they really are – distortions by fossil fuel companies with an enormous vested interest in maintaining a destructive status quo.

The great news is that using current technology, hydrogen gas stored at 5000 psi can be transported up to 200 miles from the place it was created and still be profitable at the equivalent cost of $3.75 per gallon of gasoline. This price point is currently less expensive than gasoline and these costs would not increase, unlike the price of finite oil and natural gas reserves, because of the abundant supply of hydrogen from unlimited renewable sources. In fact, the cost to store, transport and use hydrogen will actually come down over time as we expand the energy infrastructure and develop more efficient technology. This is key as we've seen with past renewable energy developments, the more we use it, the cheaper it becomes.[2]

In addition to the competitive price point, renewable hydrogen production and use does not release any greenhouse gas, thereby avoiding the destructive, hidden external costs that come from the use of fossil fuels.

Let's look at one other "hidden cost" of fossil fuels over and above the creation of greenhouse gases. Aggregate direct and indirect fossil fuel subsidies far exceed those for renewable energy sources. Burdened by this huge disparity, renewable fuels are put at a distinctive price disadvantage even though renewables have none of the indirectly

[2] FOOTNOTE ON SOLAR PRICES

subsidized external costs of fossil fuels such as political instability, pollution and climate change. There is no industry in the U.S. other than the fossil fuels that is allowed to dispose of its garbage in public spaces like the air, land and water.[3] If the cost of waste disposal and environmental restoration were added to the price the public pays directly for every ounce of coal, every drop of oil, or every radioactive isotope from nuclear power, only renewables would be perceived as affordable by the public.

How does such a marketplace distortion occur? It occurs because of the egregious profits the oil industry has been allowed to take since Standard Oil first began dominating the global energy economy. These shocking after-tax profits come in the form of vast pre-tax deductions for monstrous executive salaries, outrageous lobbying and legal fees, false advertising campaigns designed to mislead the American people, fleets of private jets, and all the other accouterments of modern day royalty. These net profits are so outlandishly high that one can safely conclude the only way such wealth can occur is through an unfair manipulation of the economic playing field. That manipulation, which confers unchecked power by the oil conglomerates over our political system, has led to the obscene situation where more subsidies are

[3] The "garbage" from the fossil fuel industry includes greenhouse gases, slag from mining, the toxic chemicals from natural gas "fracking", coal ash stored in land based reservoirs that sometimes cascade downstream with horrific consequences and many more similar byproducts. The natural environment, individual communities and society as a whole pay the "cost" of this horrifying pollution.

granted to this industry which is literally cooking the planet than are provided to support the creation of renewable energy sources which have the potential to free us from energy scarcity.

Similarly, the current price of natural gas, which seems economical, also assumes that producers and consumers can pollute the atmosphere with greenhouse gases at no additional cost and can destroy thousands of acres of underground aquifers with carcinogens to get to natural gas deposits.[4] Like oil, if consumers and producers had to pay to recollect and sequester the released greenhouse gases from natural gas as well as other related environmental restorations, that fuel would be much more expensive than using hydrogen.

It's time we deployed hydrogen as the energy carrier which will power human society into the future just as it powers every star in the sky.

Why The Hydrogen Economy is Possible

A 2012 study by University of Delaware researchers Willett Kempton and Cory Budischak found that by 2030, renewable energy production and energy storage using hydrogen gas could fully power a

[4] In 2005, on instructions by then Vice President Dick Cheney (formerly President of Halliburton – a renegade oil services company so badly in disrepute that it moved its headquarters to the Middle East to avoid U.S. law) Congress banned the Environmental Protection Agency from disclosing the identity of the carcinogenic chemicals used in the fracking process. This so-called "Halliburton Loophole" is a clear example of the unmatched political power of the fossil fuel industry.

large electricity grid at costs comparable to the nonrenewable systems in use today. Utilizing a computer model for wind, solar and storage calculated to meet demand for one-tenth of the U.S. grid, their results debunk “the conventional wisdom that renewable energy is too unreliable and expensive,” says Kempton. “For example,” adds Budischak, “using hydrogen for storage, we can run an electric system that today would meet a need of 72 gigawatts, 99.9% of the time, using solar, offshore wind, and inland wind.” The Kempton-Budischak study does not factor in the vastly positive incremental effects of adding significant geothermal and OTEC resources to the energy production mix, which would greatly accelerate their proposed timeline.

Also supporting these findings is a 2014 study from a team led by Stanford University researcher Mark Jacobson, “Evaluating the Technical and Economic Feasibility of Repowering California for all Purposes with Wind, Water, and Sunlight,” which outlines the requirements, costs, benefits and policies associated with implementing a large-scale conversion for the entire state of California with its 38 million residents. The study proposes it is possible for all new energy to be “powered with wind, water and sun (WWS) by 2020, 80-85% of existing energy [to be] replaced by 2030, and 100% replaced by 2050.”

According to study guidelines, fossil fuel power generators would be replaced by “wind turbines, solar photovoltaic plants and rooftop systems, concentrated solar power plants, solar hot water heater

systems, geothermal power plants, a small amount of additional delivered hydroelectric power primarily from existing dams, and a small number of wave and tidal devices." The proposed guidelines would also replace "all fossil-fuel combustion for transportation, heating and cooling, and industrial processes with electricity, hydrogen fuel cells, and a limited amount of hydrogen combustion."

Among other things, the study concludes that "electrification plus modest efficiency measures would reduce California's end use power demand by about 44% and stabilize grid prices since WWS fuel costs are zero." Importantly, the plan avoids the use of nuclear power, coal with carbon capture or liquid or solid biofuels and even natural gas. If the extraordinary availability and affordability of ocean thermal energy conversion (OTEC) technology were added to the production mix, the study's estimate of 15 years to accomplish energy freedom from all fossil fuels and nuclear could be reduced to 10 years or less.

The California Moonshot Project:

10 Years to 100% Renewable Power

As the studies above demonstrate, the technology to revolutionize our energy system exists today. With state regulatory approval and widespread support from political leaders, citizens, the business community and the utility companies themselves, this transition could

happen within 10 years or less. By (1) rerouting funding from nuclear power into renewable hydrogen production and deployment, (2) eliminating all subsidies to fossil fuel industries, and (3) charging a fair carbon tax for the cost of remediating fossil fuel emissions, we could completely eliminate fossil and nuclear fuel from California within 10 years at no additional cost to the consumer (net of inflation).

We call this plan The California Moonshot Project, modeled after President Kennedy's 1961 challenge to send a man to the moon and return him safely before the end of that decade.

Kennedy's specific challenge was only a part of a larger plan. The critical elements were an underlying vision and an overarching purpose that ultimately created the paradigm shift Kennedy sought. The underlying vision was to popularize and accelerate science disciplines such as chemistry, physics and mathematics to create a force of engineers and scientists who could lead a technological revolution in the post-World War II period. That catalyst came to produce the technological advancements we enjoy today like silicon chips and fuel cells. The overarching purpose was to propel the United States into a position of unrivaled economic and technological strength among the nations of the world.

Indeed, many historians consider the president's "moonshot" challenge to be the defining moment that sparked the next thirty years of economic growth, wealth creation and global dominance by the United States. The revolution that came out of the Apollo Program spread

advanced technology around the globe in just 50 years. Though the smartphone in your pocket is almost infinitely more advanced than the computers aboard the first space modules, its existence is due to the technology pioneered by NASA in the 1960s.

At the time, Kennedy didn't know how the nation would pull off this extraordinary feat of engineering and science. So he relied on his confidence in human ingenuity that it could and must be accomplished. By contrast, The California Moonshot Project is based on existing technology. We know precisely how to achieve the objectives and have all the tools at our disposal. All we lack is the collective will to make it happen. And when it does happen, as it surely must, The California Moonshot Project will create another enormous technological and economic leap forward, setting off a chain reaction from the U.S. private business sector outward to the entire planet.

Kennedy's Moonshot and The California Moonshot Project:

	Mission
President Kennedy (1961)	Land a man safely on the moon within decade.
The California Moonshot Project (2014)	Provide 100 percent of California's electricity from carbon-free and nuclear-free renewable energy sources within ten years.
	Vision
President Kennedy (1961)	Popularize and accelerate the "hard sciences" such as chemistry, physics and mathematics to build a force of engineers and scientists to lead a technological revolution in the post-World War II period. Fuel massive technology advancements such as silicon chips, advanced materials and fuel cells.
The California Moonshot Project (2014)	Introduce hydrogen as the new planetary fuel system, replacing fossil fuels as the link between sources of energy production and consumers throughout the state of California and eventually the world. In doing so, spur the massive development and deployment of hydrogen technology, as well as emerging renewable technologies such as ocean thermal energy conversion (OTEC).
	Purpose
President Kennedy (1961)	Propel the United States into a position of unrivaled economic and technological strength among the nations of the world. Historians consider Kennedy's "moonshot" the defining moment for the next thirty years of prosperity and unrivaled global dominance by the United States.
The California Moonshot Project (2014)	Disrupt the status quo of economic stagnation and resource scarcity perpetuated by reliance on fossil fuels. Introduce a new distributed renewable energy paradigm, which can spark a wave of wealth creation and inexpensively power the regeneration of our natural systems through programs to mitigate, halt and ultimately reverse climate change.

The Hydrogen Economy is Happening Now

Apart from The California Moonshot Project and current domestic programs to promote hydrogen technology, there are other countries pushing the envelope. For example, hydrogen has long played a central role in Germany's much-celebrated "Energiewende," a turnaround plan which calls for the conversion of 80% of the country's electric power production to renewables by the year 2050. First announced by Chancellor Angela Merkel in 2010, it has placed Germany at the forefront of international clean energy policy efforts. One result has been the construction of a number of "Power-to-Gas" projects where hydrogen is produced by electrolysis from solar or wind-generated electricity, then stored for later reconversion to electricity. Germany's biggest project to date, a 1 megawatt Power-to-Gas demonstration plant constructed as part of a 140 megawatt wind park, became fully operational in September 2013.

Another example is South Korea. That nation has become one of the world's leaders in hydrogen fuel cell technology. Fuel cells are the critical component of a hydrogen fuel system, which combine hydrogen gas with oxygen to create electricity to power cars, homes, businesses

and factories. Think of a fuel cells as an “engine” but with no moving parts, which only releases electricity, heat and pure water (instead of greenhouse gases and other particulates like combustion engines do). Recently, Korean researchers built the world’s largest base power electrical generating station at 60 megawatts and are in the process of installing 230 megawatts of fuel cell electrical grid power across Seoul – enough to offset the need for one nuclear power plant.

Hydrogen instead of Gasoline

Hydrogen is also emerging as the eventual long-term fuel of choice for cars and buses. This emerging technology has the potential to quickly surpass electric plug-in hybrids in efficiency, range and cost. Hyundai intends to launch the first commercially produced hydrogen fuel cell vehicles in California by May, 2014, to be followed by other major carmakers including Honda and Toyota with plans to launch their hydrogen fueled cars commercially in or around 2015. Daimler (Mercedes Benz), Ford and Nissan plan to launch their commercial vehicles around 2017, and GM has yet to announce its launch date but it is believed to be in the 2016-2017 timeframe. Germany already has underway construction of a countrywide network of fueling stations to service these new automobiles, while Japan, Korea and Denmark have also announced similar operations.

In the U.S., California is at the vanguard of clean transportation with Governor Jerry Brown's Zero Emission Vehicle Action Plan announced in 2013. Under the plan, funding is in place to construct 100 publicly accessible commercial hydrogen fueling stations (in addition to the current nine public fueling stations) by no later than 2023. Since the governor's initiative was announced, seven other states (Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont) have entered into a multi-state pact to put 3.3 million zero-emission vehicles (including fuel-cell vehicles) on the roads by about 2025. All combined, the eight states entering into this agreement comprise nearly 25% of the U.S. vehicle market according to government officials. A consortium action plan is scheduled for completion in April 2014.

According to a report in the trade publication Automotive News in November 2013, a "battle is brewing" in the hydrogen fuel cell electric car sector: "As Honda and Toyota announced plans last week to move their fuel cell EV projects from the drawing board to the road, Hyundai elbowed past them with a hydrogen-powered version of its Tucson compact crossover and a free-fuel, $499-a-month lease deal to go with it, all due out in the spring [of 2014]." Technological advancements have brought about vehicle components like the fuel cell powertrain to fit right into the traditional engine compartment. Plus, driving ranges are up to about 300 miles on one tank of hydrogen gas, with only water vapor as an emission.

American Honda CEO Tetsuo Iwamura believes near-term infrastructure challenges are manageable given that, from a consumer's perspective, fuel cell vehicles operate much like gasoline-powered cars but without the emissions. "The starting [sales] number is not important at all," he said. "The question is how can we get acceptance of fuel cell technology."

On a CBS This Morning segment in November 2013, reporter Bill Whitaker spoke with then Hyundai Motor America President and CEO John Krafcik (he stepped down at the end of 2013):

> BILL WHITAKER: "For decades engineers have touted the promise of zero-emission hydrogen-fuelled cars. This week at the Los Angeles Auto Show, automakers finally are keeping that promise. Hyundai is the first major automaker to mass-produce a hydrogen-fuel cell vehicle. The Tucson SUV will be available in showrooms this spring."
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> JOHN KRAFCIK: "With the hydrogen fuel cell electric vehicle, you're actually generating your own electricity with fuel cell stacks that are fueled by hydrogen, and the only thing that comes out the tailpipe is water vapor. It's pretty cool."
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> BILL WHITAKER: "Instead of gasoline, you pump hydrogen into the tank but the process is almost identical. Three to four minutes at a fueling station and you're good to go for three hundred miles."

In a related development in October 2013, General Motors announced that one of its hydrogen-powered research vehicles reached a

milestone by surpassing 100,000 miles of real-world driving. “By using renewable hydrogen, this vehicle has saved 5,260 gallons of gasoline. At $3.50 per gallon, that's more than $18,000 in fuel cost savings,” the company announced in its press release. According to Clean Energy Patent Growth Index, GM ranked No. 1 in total fuel cell patents filed between 2002 and 2012.

In a similar vein, Germany's "H2 Mobility" initiative is in place for the current network of 15 public hydrogen filling stations to be expanded to about 400 by 2023. Of those, 100 are planned over the next 4 years.

Their companion Clean Energy Partnership welcomes these developments. One partner, Peter Blauwhoff, CEO of German Shell Holding, said: "Shell already operates a network of hydrogen filling stations based on the very latest technology in Germany and California - including the world's largest H2 filling station in Berlin. Following the foundation of the joint venture, Shell will play a significant role in the development of the future H2 retail station network in Germany. Hydrogen is an important component for the mobility of the future."

The implications of these developments for the U.S. and global car markets are barely understood. Governments in California and Germany, as well as a handful of smaller markets, are leading the way in preparing the fueling infrastructure for this new automotive technology. Once the infrastructure is built and hydrogen is mass-produced from renewable sources, consumers will literally be able to drive on sunshine and wind

alone, with pure water as the only byproduct. Subsequent publications from the World Business Academy will cover the multitude of “sunrise” opportunities in the brand new Hydrogen Economy, with a specific focus on California.

Public Health Benefits of Hydrogen

The Stanford study referenced earlier, “Evaluating the Technical and Economic Feasibility of Repowering California for all Purposes with Wind, Water, and Sunlight,” discusses the cumulative public health benefits of completely transitioning away from fossil fuels. This transition “is estimated to reduce premature air pollution-related mortality in California by ~16,000 (4,800-29,600) deaths per year, including premature deaths of children. This will result in a health cost benefit of $131 ($39-$296) billion/year due to reduced air-pollution mortality, chronic bronchitis cases, heart disease cases, asthma attacks, hospitalizations, emergency-room visits, lost school days, lost work days, workman’s compensation costs; and due to improved visibility and agricultural and forest productivity. These health cost savings represent ~6.9% of California’s 2010 gross domestic product of $1.9 trillion.”

On a worldwide basis, experts like J. Jason West of the University of North Carolina at Chapel Hill and colleagues assert that cutting greenhouse gas emissions would likely save millions of people's lives by

the end of the century. “[T]he greenhouse gases created by burning fossil fuels contributes to the formation of ground-level ozone, the main component of smog,” said West. Ozone and particulate matter are believed to be root causes of heart and lung disease.[5] Further research shows that 40% of Americans live in areas with dangerous levels of air pollution. On an encouraging note, researchers at the Harvard School of Public Heath link cleaner air with longer life spans and general reductions in adverse health conditions.

With environmental activism taking hold across all segments of the population, the “National Catholic Reporter” in December 2013 released a statement from the head of the U.S. Bishops' Committee on Domestic Justice and Human Development: “It just makes good sense to want to have clean air for our children and families to breathe and for future generations. Children, inside and outside the womb, are uniquely vulnerable to environmental hazards and exposure to toxic pollutants in the environment. Their bodies, behaviors and size leave them more exposed than adults to such health hazards.”

In October 2013, The World Health Organization (WHO) classified outdoor air pollution as a carcinogen for the first time in a report issued by the International Agency for Research on Cancer. The WHO attributes

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[5] Automobiles account for a vast additional source of deadly airborne emissions, which would also be eliminated as we transition to hydrogen fuel for our transportation needs.

roughly 223,000 fatalities around the world in 2010 to air pollution related lung cancer.

Hydrogen and National Security

According to an October 2013 statement from the U.S. Department of Energy, advances in the widespread commercialization of hydrogen and fuel cell technologies are “helping to reduce the nation's reliance on gasoline and diversifying our nation's energy portfolio while reducing our dependence on foreign oil.”

With the changing threat of security risks to America and the free world, hydrogen fuel cells are in the forefront to keep our nation safe. For example, in 2013 the U.S. Navy set an unmanned flight endurance record by completing a 48-hour, 1-minute flight powered by a liquid-hydrogen-fed fuel cell. Researchers at the U. S. Navy Research Laboratory are working to make these state-of-the art unmanned weapons ready for deployment. The Navy plans to power these vehicles by extracting hydrogen from water and possibly integrating solar cells or wind turbines into the process.

According to a recent report, teams of U.S. Army scientists are working to develop portable systems to convert Jet Propellant 8 (JP-8) into hydrogen for use in hydrogen fuel cells. "There is a growing demand for portable electrical power for both commercial and military

applications," said Dr. Deryn Chu, fuel cell team leader. JP-8 is a common fuel for powering aircraft, engines of tactical ground vehicles and electrical generators. Though the logistical supply chains for distribution are burdensome, not to mention the risk of lives in protecting the convoys delivering the fuel. JP-8 is the military's most-used jet fuel and costs about $15 per gallon, but ". . . the cost multiplies to hundreds of dollars by the time you move it to and around operational locations," Chu said. “Fuel cells -- when the concept is fully developed -- may yield huge gains, potentially doubling the efficiency of diesel generators," he said.

In related news, General Motors and the U.S. Army Tank Automotive Research, Development & Engineering Center (TARDEC) are expanding their partnership in the development of hydrogen fuel cell propulsion systems. Charlie Freese, executive director of GM's global fuel cell engineering activities said, “We believe hydrogen fuel cell technology holds tremendous potential to one day help reduce our dependence on petroleum and we are committed to building on our leadership through the continued development.”

The Bright Future of Hydrogen Technology

Using current technology, renewable hydrogen can be produced at a price competitive with fossil fuels. Emerging technologies in renewable energy production, and especially in the creation of hydrogen gas, are set

to make hydrogen even less expensive in the very near future. The use of hydrogen as a replacement for transportation fuels is just the tip of the iceberg – with the right support and adoption, hydrogen could quickly become the least expensive energy carrier in the world.

Much related research comes out of The Department of Energy's Pacific Northwest National Laboratory (PNNL) as reported by States News Service throughout 2013. For instance, In February of 2013 researchers at the lab reported that they had discovered a fast and economical iron-based molecule that transforms hydrogen directly into electricity. This discovery is a movement toward affordable fuel cells being widely available. "A drawback with today's fuel cells is that the platinum they use is more than a thousand times more expensive than iron," said chemist R. Morris Bullock, who leads the research at the Department of Energy's Pacific Northwest National Laboratory Center for Molecular Electrocatalysis. The lab's discoveries are providing opportunities for new frontiers in supporting a hydrogen-fueled economy. Take food distribution chains as one commercial application. In August 2013, it was announced that grocery merchants in Texas, California and New York will have ice cream, frozen foods and fresh produce delivered by tractor trailers whose refrigeration units are powered by fuel cell devices. "This is a great application for a fuel cell," said Kriston Brooks, the researcher leading the project. "A trailer refrigeration unit traditionally is powered by a small diesel engine or electric motor that drives compressors to provide

cooling to the cargo. A fuel cell can potentially provide a clean, quiet and efficient alternative by powering the electric motor."

About 300,000 refrigerated trucks with auxiliary power units are on the road in the United States. The lab asserts that by replacing the small diesel engines with fuel cells, users will save approximately 10 gallons a day per unit. This is in addition to a reduction in air pollution.

"Accelerated fuel cell use in this application is also expected to create jobs in the energy sector, increase fuel cell manufacturing volume, decrease costs, and catalyzing a stronger domestic supplier base," said Jamie Holladay, PNNL's sector manager for fuel cell technologies.

"One of the goals is to accelerate fuel cell use in industry," said Brooks. "In spite of their higher costs now, the higher efficiency and zero emissions from fuel cells are enough to convince many companies not to wait to implement this technology. Fuel cell products are already used widely in warehouses, and this project broadens their reach." A number of facilities already use forklifts powered by hydrogen fuel cells.

In 2013, the U.S. Department of Energy launched H2USA, a new public-private partnership focused on advancing hydrogen transportation infrastructure in the U.S. Also in 2013, the U.S. Department of Energy announced spending on research involving catalysts for hydrogen fuel cells. In a companion announcement two days prior, the department said selected government funded projects “will help maintain the rapid pace of

fuel cell progress, expand the markets and applications in which fuel cells can compete, and reduce institutional and market barriers that may impede the commercialization of hydrogen fuel cell technologies."

In a 2013 report from the SUNY University at Buffalo entitled "Just Add Water," researchers discovered that super-small particles of silicon react with water to produce hydrogen almost instantaneously. "When it comes to splitting water to produce hydrogen, nanosized silicon may be better than more obvious choices that people have studied for a while, such as aluminum," said researcher Mark T. Swihart. "With further development, this technology could form the basis of a 'just add water' approach to generating hydrogen on demand," said researcher Paras Prasad. Seemingly the most practical application would be for portable energy sources.

"Perhaps instead of taking a gasoline or diesel generator and fuel tanks or large battery packs with me to the campsite (civilian or military) where water is available, I take a hydrogen fuel cell (much smaller and lighter than the generator) and some plastic cartridges of silicon nanopowder mixed with an activator," Swihart said, envisioning future applications. "Then I can power my satellite radio and telephone, GPS, laptop, lighting, etc. If I time things right, I might even be able to use excess heat generated from the reaction to warm up some water and make tea."

In a related development in September 2013, MIT researchers with support from the U.S. Department of Energy's Hydrogen Initiative Program and the Office of Naval Research discovered a new set of materials abundant in the Earth’s crust that can be used to split water into hydrogen and oxygen.

Right now, Asia is the biggest market for green technologies and governments there are pursuing renewable energy at a break-neck pace. The Asian region is the largest end user of stationary hydrogen fuel cells and their appetite for this technology is expected to continue to grow.

Partially stimulating the growth of fuel cell technology in Asia is the ongoing environmental crisis faced by China. Maclean's reported in its February 4, 2013 edition that air pollution had reached its highest levels there since the American government began monitoring it. Pollution levels in Beijing are about 44 times worse than the World Health Organization's recommended daily standards. "What do we want, breathtaking growth or taking a breath amid choking air?" questioned China's state-run news agency Xinhua. According to Maclean’s, “… behind the smog, China's environmental woes have become an unexpected boon to the global renewable energy industry. Last week's air quality emergency sent Chinese green energy stocks soaring on the hope that the political fallout will prompt the Communist party to offer up more public money for the country's burgeoning environmental

protection sector...China is also emerging as the world's biggest spender on green energy."

The International Energy Agency estimates that China will be the world's top renewable energy growth market and according to state-owned China Merchants Securities, by 2015 that market will be worth more than $470 billion and equal to about eight per cent of the country's GDP.

"All the key players are going to China these days," says Changhua Wu, Greater China director of the Climate Group, a London-based agency that promotes green energy investment. "Everyone is trying to figure out what the potential for opportunity is, partly because everyone recognizes that China could potentially be the largest market for clean tech in the world."

Maclean's goes on to report: "China's current five-year plan, which runs through 2015, includes an economic development blueprint that will see more than $1.5 trillion invested in seven industries, all of them related in some way to environmental protection and renewable energy technology."

Hydrogen History and Historical Inevitability

Renewable, zero carbon hydrogen is the ultimate chemical fuel. The shift from carbon dense fuels like coal and wood toward zero carbon

fuels is a trend first detected by Italian scientist, Cesare Marchetti, in the 1970s. Marchetti, then one of Europe's leading hydrogen proponents and a researcher at the Euratom Research Center in Ispra, Italy, described a gradual shift over centuries from hydrocarbon fuels with high carbon and low hydrogen content (coal) to fuels with increasingly less carbon and more hydrogen (natural gas). He foresaw the culmination of this trend as using pure hydrogen as the principal energy carrier of an advanced industrial society. This view was further supported by Nebojša Nakicenovic of the International Institute for Systems Analysis. In a 1996 essay entitled "Freeing Energy from Carbon," Nakicenovic wrote about how the carbon intensity of the world's energy consumption, expressed in tons of carbon per ton of oil equivalent energy, dropped from just below 1.1 in 1860 to 0.7 in the early 1990s—a decline of about 0.3 percent per year. "The ratio has decreased because high-carbon fuels, such as wood and coal, have been continuously replaced by those with lower carbon content, such as gas […]"

Igniting an Energy Revolution

Now the question is: HOW? How do we convince political and business leaders, the American people and people around the world to

adopt hydrogen technologies to speed their development and implementation?

In the United States, California has historically led previous revolutions in consciousness, technology and behavior. It would seem that the time is ideal to launch The California Moonshot Project to eliminate all fossil and nuclear fuels within 10 years at no additional cost to ratepayers. In the assessment of the World Business Academy, California is ready to take this progressive leap and fire the "shot heard around the world" in the emerging renewable energy industry.

Given the unmatched potential of hydrogen to replace the current planetary fuel system, Californians may be ready to lead again by adopting this approach to halting climate change. According to a recent Yale University report, Californians are ready for action on climate change. The report found that 79% of Californians believe global warming is happening. 60% want more action taken by governments, 73% want more action taken by businesses, and importantly, 70% want more action taken by citizens themselves.

Just like the creation and commercialization of the silicon chip, the hydrogen economy can become the revolution that begins in California and spreads to the rest of the country, then, along with support from Germany, South Korea, Canada and other visionary nations, to the rest of the globe.

Conclusion

In the early 19th century, scientists and science-fiction writers began discussing the unique properties of hydrogen. Probably the most famous among the well known in the world's hydrogen community was Jules Verne. His uncannily prescient description in one of his last books spoke of hydrogen becoming the world's chief fuel. "The Mysterious Island" was written in 1874, just about 100 years before research into hydrogen energy began in earnest. In one remarkable passage, Verne described the discussions of five Civil War era, Northerners who were marooned on a mysterious island 7,000 miles away from their starting point of Richmond, Virginia after a storm tossed their hot air balloon adrift. One of them, the reporter named Gideon Spillett, raises a question about what would happen to commerce and industry once coal supplies run out: "Without coal there would be no machinery, and without machinery there would be no railways, no steamers, no manufactories, nothing of that which is indispensable to modern civilization!"

"But what will they find?" asked the soldier Pencroft. "Can you guess, captain?"

"Nearly, my friend."

"And what will they burn instead of coal?"

"Water," replied Captain Harding.

“Water!” cried Pencroft, “water as fuel for steamers and engines! Water to heat water!”

“Yes, but water decomposed into its primitive elements,” replied the captain, “and decomposed doubtless, by electricity, which will then have become a powerful and manageable force, for all great discoveries, by some inexplicable laws, appear to agree and become complete at the same time. Yes, my friends, I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. Some day the coalrooms of steamers and the tenders of locomotives will, instead of coal, be stored with these two condensed gases, which will burn in the furnaces with enormous calorific power. There is, therefore, nothing to fear. As long as the earth is inhabited it will supply the wants of its inhabitants, and there will be no want of either light or heat as long as the productions of the vegetable, mineral or animal kingdoms do not fail us. I believe, then, that when the deposits of coal are exhausted we shall heat and warm ourselves with water. Water will be the coal of the future.”

We are on the ground floor in creating the evolving hydrogen economy with massive economic growth and phenomenal societal benefits just waiting to be unleashed. Although the challenges before us are great, the opposing forces, now brittle and overweight, are less formidable. Now is the time to challenge them. Now is the time to take

control of our future and move beyond scarcity into a paradigm of abundant, almost limitless energy utilizing hydrogen to harness the potential power of the sun, the wind, the oceans, and the Earth's core.