RENEWABLE HYDROGEN

COMMUNITY-DRIVEN ENERGY for a WORLDSHIFT

HARUYOSHI EBARA

The world's first Renewable Hydrogen building!

Griffith University, Australia

RH2 NETWORK

RENEWABLE HYDROGEN HARUYOSHI EBARA

RH2 NETWORK

GOODBYE

FOSSIL FUELS,

NUCLEAR POWER,

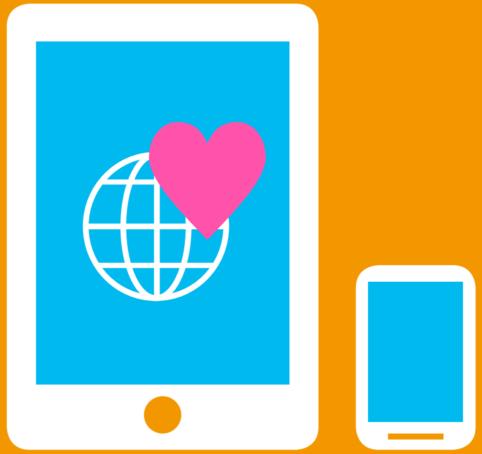
and POWER LINES

This one-of-a-kind building can run fully off-grid with Renewable Hydrogen supplying all of its energy needs. This is just the beginning of the many commercial projects around the world that can help us realize a carbon-free energy system.

A renewable hydrogen machine, Grid Free RH_2, installed by the Renewable Hydrogen Network inside a coworking space in Omotesando, Tokyo. This off-grid energy solution runs on solar power and hydrogen made from water, to power small electronic devices like laptops.

Kindle Edition

en.rh2.org/book/



Please share and recommend this book to your friends and local politicians.

Renewable Hydrogen is a sustainable form of hydrogen made by using electricity derived from sources including solar and wind power.
With Renewable Hydrogen, energy can be generated, stored, and used locally, allowing for democratic and peaceful use.

FOREWORD

A brand new building, five stories high with one basement floor, glistened beneath the bright subtropical sun. As I gazed up at the new Renewable Hydrogen building at Australia's Griffith University, I couldn't help but say, "This is it, this is what I've been looking for."

While the first words to emerge from my mouth as I witnessed what could be the beginning of a new civilization may not have been as well thought out as Neil Armstrong's words when he set foot on the moon, they were nonetheless a simple expression of joy that came from the bottom of my heart.

I have never been a scientist or engineer, and was leading a life that had nothing to do with hydrogen. Nonetheless, I understood our current climate crisis posed an existential threat to humanity. Since then, for eight years, I have committed myself to Renewable Hydrogen. During this time, I have not been advocating for unrealizable dreams, but for a reality I have seen with my own eyes. The excitement I felt in discovering this was akin to that of a time traveller upon being transported to the future.

A Renewable Hydrogen society is no longer a distant dream—it is within arm's reach. The answer to our ongoing energy crisis lies in the abundant renewable energy and water that surrounds us.

If Renewable Hydrogen permeates our society, it will become for us what wind is for birds, or water is for fish. Renewable Hydrogen will not remain obscure or feared, but instead will become the societal norm. The realization of a Renewable Hydrogen Society is dependent on the individual actions of each and every one of the citizens of our planet.

We aimed to bring together all of the knowledge regarding Renewable Hydrogen into this small book with the hope that it will become a first step towards a new civilization. I hope that once you read it, you will become a fan of renewable hydrogen yourself. And finally, I look forward to seeing all of the brave and compassionate work you do for our planet.

Haruyoshi Ebara, Chairman
Renewable Hydrogen Network, a nonprofit organization (NPO)

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Let's Shift to an RH_2 Society Together!

CHAPTER 1

What Is Renewable Hydrogen?

The Culprit Behind Many Global Problems Is Our Energy System

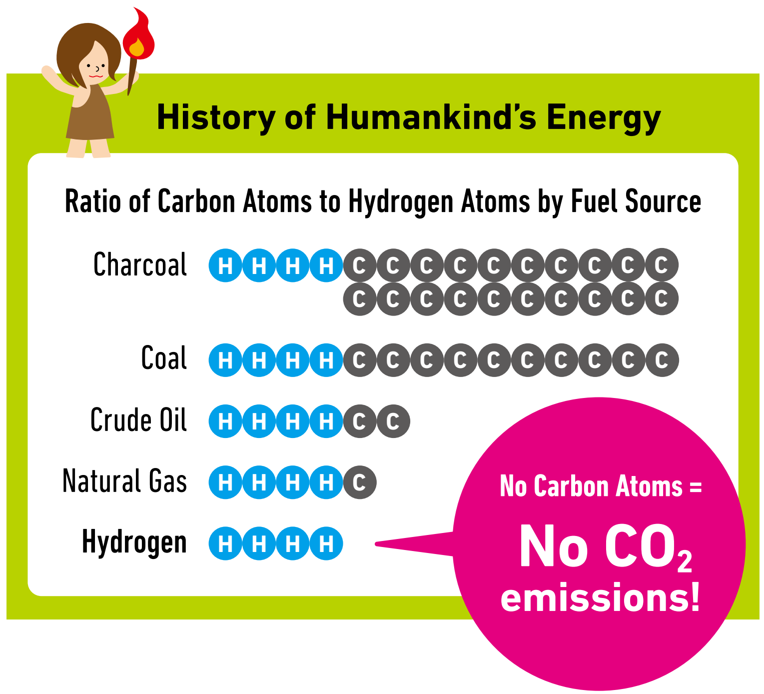
We plug our home appliances and mobile devices into wall outlets every day without thinking, knowing there will be electricity. We turn the knob on the kitchen stove expecting the gas to flow, and travel to the gas station to fill up our cars with the same assumption. But where does this energy actually come from?

In reality, the use of large amounts of energy in our daily lives has negative consequences that reach every corner of the globe. Burning large amounts of fossil fuels has resulted in a climate crisis. At this critical moment, higher temperatures, extended heat waves, drought, torrential rain, tornados, and mudslides are causing damage in communities around the world. With nuclear power plants, once an accident occurs it is difficult to return things to the way they once were. Five years after the Fukushima Daiichi crisis, many people are still unable to return to their homes, and there is no immediate solution in sight to problems including contaminated water and decommissioning the reactor.

When crude oil is extracted from areas like the Middle East, high-tech sensors are first used to locate oil, and huge well-drilling machines burrow several thousand meters into the ground before it is actually extracted. This oil then travels through pipelines several hundred kilometers long, after which it is loaded into tankers that pass through the Indian Ocean and East China Sea, traveling 10,000 km or more to transport the oil to, for example, Japan. The story doesn't end there: after arriving in Japan, the oil passes through a complicated refinement process at a refinery before it is transformed into gasoline and kerosene and delivered to local communities.

If the gas flowing into our kitchens could talk, it would tell a similar tale of having once been natural gas and crude oil, which had been lying dormant deep below the seabed in various locations around the world. Next time you turn the knob on your kitchen stove, take a moment to remember that some of that gas might have been sourced from below the North Pole, now exploitable—for your convenience—due to glacial melting resulting from global warming!

This isn't just about fossil fuels: the uranium used to fuel nuclear power plants is mined in Australia and Kazakhstan before it travels to faraway places. Wars have broken out around the world to protect strategic interests related to energy resources, as their amounts and locations are limited. Children and other innocent civilians have been caught up in the violence and even killed, fueling a depressing increase



in the number of refugees, street children, and young children forced into sex slavery. The horrific experiences documented during World War II may seem like a distant memory for many Japanese people today, but somewhere in the world a war—linked to our dependence on foreign energy—rages on. The sad reality behind the energy needed to run our society has cloaked our world in an unforgivable darkness. The reason for many of the world's problems is undeniably our current energy system.

Happily there is a simple and comprehensive solution, made possible by advanced science and technology, to many of these global problems. There are also many real-world applications we can learn from, which provide a useful framework to build a hopeful future together. Whether or not this happy trend continues and gains momentum is up to us—each global citizen bears a responsibility to take action!

Hydrogen—Our Greatest Energy Hope

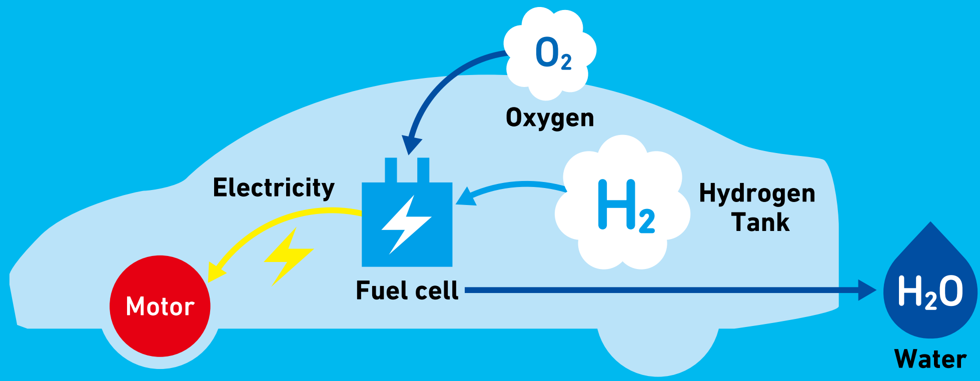
When looking at the history of human energy consumption, it's clear that we are gradually decreasing our dependence on carbon. From early energy sources like charcoal to modern-day natural gas we use at home, there has been a historical trend of new energy sources containing less carbon and more hydrogen than previous ones (reference the infographic on the previous page).

Today, 200 years after the Industrial Revolution first began, our long journey to carbon-free energy has reached its final stage: an era of Renewable Hydrogen with zero carbon dioxide (CO_2) emissions.

In 2015, car manufacturers like Toyota and Hyundai began

A solar-hydrogen station alongside a Honda FCX Clarity

The mechanism of a fuel cell car



The electricity that rotates the motor is generated when hydrogen enters the fuel cell and reacts with oxygen in the air.

mass-producing cars that run on hydrogen. Honda plans to join this eco-friendly group in 2016. A fuel cell car works in the following way: 1. Hydrogen gas is put into a hydrogen tank in the vehicle, 2. A chemical reaction that powers the car's motor occurs when the hydrogen enters the fuel cell and mixes with oxygen from the air, and 3. Pure water leaves the tailpipe instead of exhaust gas.

Fuel cells are like hydrogen generators—they are often thought of as mobile, renewable batteries (the term "battery" is actually part of the Japanese word for fuel cell). However, to assume they are similar to batteries is a mistake.

Fuel cell cars are a type of electric car that use a hydrogen tank and fuel cell as their fuel source, in contrast with most electric cars, which have a battery that needs to be recharged from an external power source.

Fuel cells are increasingly being utilized for purposes other than providing energy in cars. For example, mobility-related applications also include buses, scooters, and forklifts, while stationary applications include providing electricity for residential and commercial use. Fuel cells are also utilized as an emergency power source for cell phone base stations during emergencies, and there are even portable fuel cell products being sold for recreational outdoor use.

The International Hydrogen and Fuel Cell Expo (FC Expo[1]) has been held at the Tokyo International Exhibition Center since 2005, and showcases the latest hydrogen technology from around the world, including the United States, Germany, and Taiwan. The year 2015 was heralded as the "the genesis of a hydrogen society," and there were more than 1,500 exhibiting companies and over 70,000 visitors, making the expo a huge success.

The Japanese government is also making strides to establish a "Hydrogen Society," by making an effort to claim the world's largest share in manufacturing hydrogen-related technology. The Ministry of Economy, Trade and Industry (METI), has gone so far as to announce a three-phase roadmap to overcome persistent issues in technology, cost, regulation, and infrastructure,[2] which have prevented greater hydrogen adoption.

Renewable Hydrogen (RH_2) vs. Non-Renewable Hydrogen

What is hydrogen? Written in Chinese characters, hydrogen means "the source of water." Hydrogen was the first element created after the Big Bang, and makes up 73% of all matter in the universe. It is the lightest substance on earth, and is present in water, which covers about 70% of the Earth's surface. However, on Earth, hydrogen does not exist as a solitary element because of its low density—that is to say, on Earth hydrogen naturally bonds to different elements to form a molecule. Because hydrogen does not exist by itself, it must be extracted.

Depending on which extraction method is used, hydrogen can be classified into two general categories. The first type of extraction is called "Renewable Hydrogen" (or RH_2). It is the type we advocate for at the nonprofit Renewable Hydrogen Network. It is the sustainable energy source obtained when hydrogen is extracted from water using only renewable energy.

The second type of extraction, known as "Non-Renewable Hydrogen"

[1] The International Hydrogen & Fuel Cell Expo <http://www.fcexpo.jp/en/>

[2] Ministry of Economy, Trade, and Industry, "METI has compiled a strategic road map for hydrogen and fuel cells." <http://www.meti.go.jp/english/press/2014/0624_04.html>

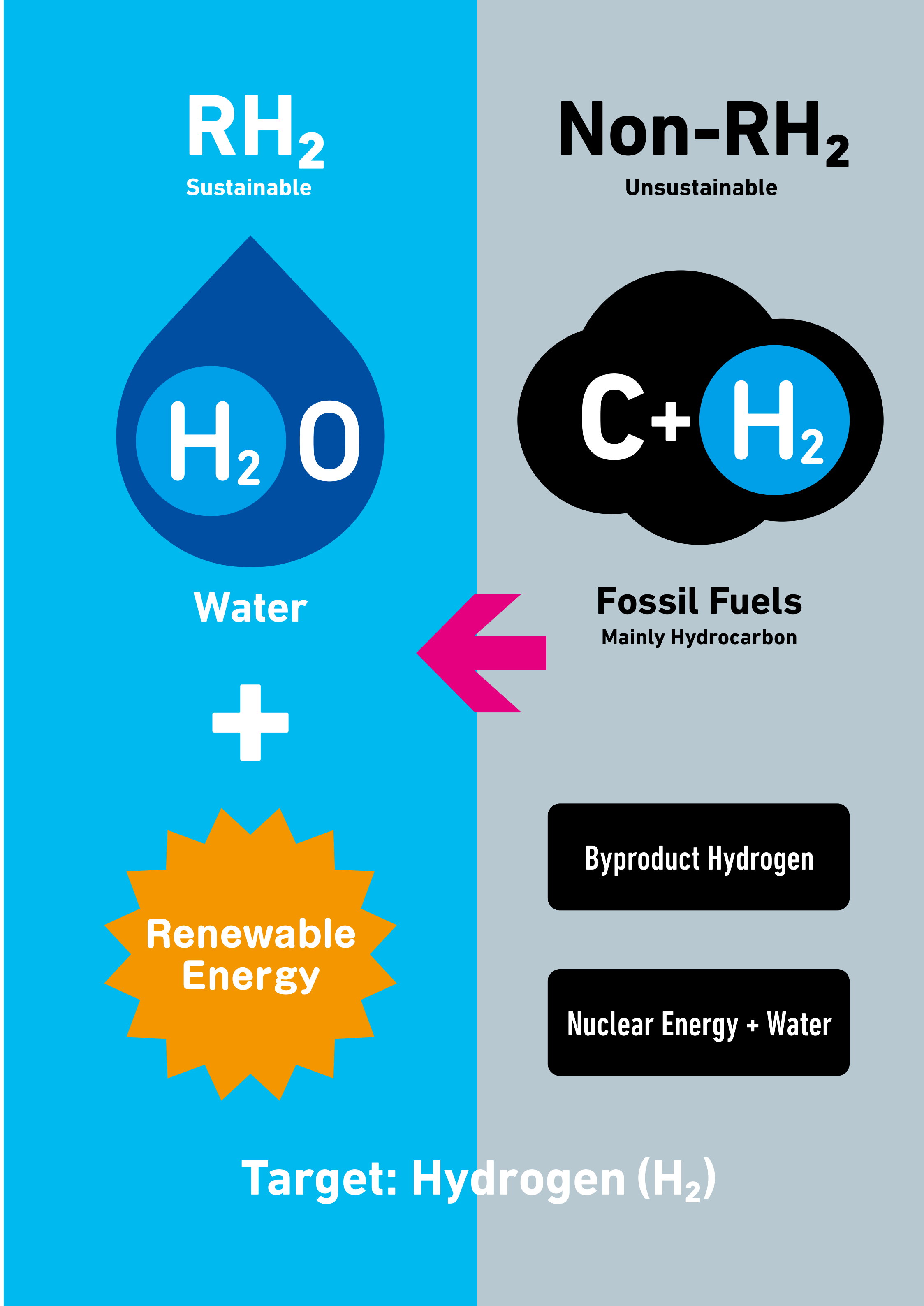
(or Non-RH_2), is the energy source and system supported by both governments and much of the private sector. It is based on hydrogen extracted using fossil fuels, or created as a byproduct in steel mills—which is why it is also known as 'byproduct hydrogen.' Current plans to extract hydrogen from water through the use of nuclear energy also fall under Non-RH_2. Hydrogen extracted from fossil fuels contributes to global warming, and is not environmentally sustainable.

The popular home energy system ENE-FARM, currently installed in over 120,000 homes in Japan, is a Non-RH_2 energy system. ENE-FARM is a fuel cell system that extracts hydrogen from propane (C_3H_8) and methane (CH_4) in order to generate electricity. According to the road map compiled by Japan's Ministry of Economy, Trade and Industry (METI), the government aims to have similar stationary fuel cells installed in 1.4 million residential homes by 2020, and 5.3 million residences by 2030.

Large multinational corporations such as Google, FedEx, and Walmart also use fuel cells, which generate energy by extracting hydrogen from natural gas. In Japan, the implementation of similar fuel cells is mainly promoted by the Softbank Corporation. These fuel cells also leverage Non-RH_2 technology.

To coincide with the release and roll out of fuel cell vehicles, 100 hydrogen stations have been planned domestically in Japan, 26 of which were up and running as of September 2015. There are over 180 of these hydrogen stations around the world, most of which rely on a hydrogen-extraction method that uses fossil fuels.

If hydrogen is truly so desirable, it would seem that our water-rich earth is a treasure trove of renewable energy resources. To make use of



this seemingly endless supply of water, we only need to shift our focus away from the hydrogen found in fossil fuels, and instead concentrate on hydrogen that is present in the water all around us! If we were to accomplish this, rivers would become nature's pipelines, and rainfall and even morning dew would become sources of energy.

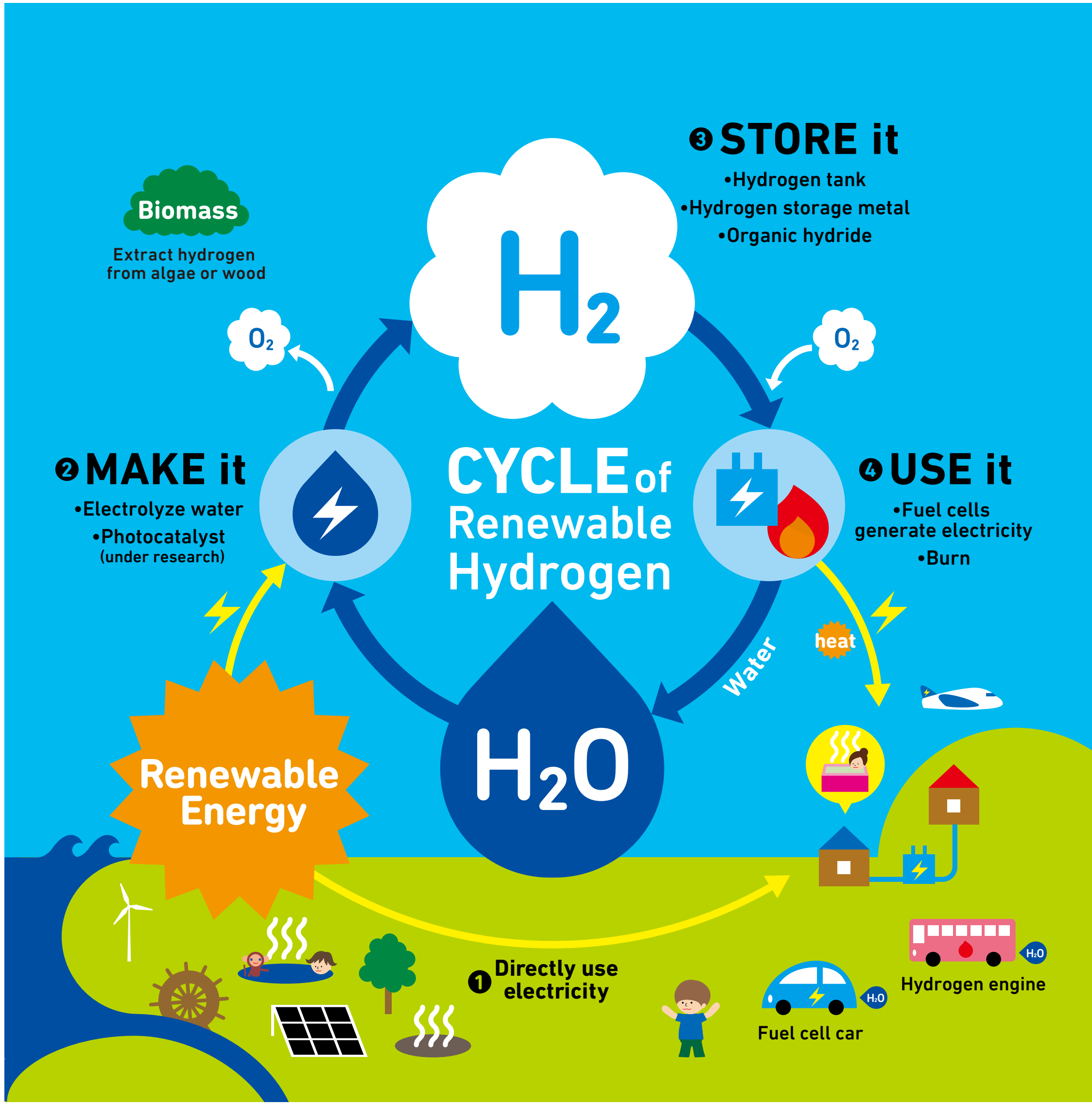
Our current urban built environment makes use of several kinds of utility lines, including electric, gas, and water. If we are able to utilize sustainable energy and the hydrogen present in water as our fuel sources for electricity generation, there may come a time when many of these utility lines will no longer be necessary.

When we consider the two extraction methods for hydrogen, there is little doubt as to which is the better option. On one hand, we have hydrogen extracted from water through the use of renewable energy sources such as the wind outside our windows, the sunlight all around us, or the waves crashing along the world's countless coastlines. On the other, we have hydrogen extracted via complex processes utilizing a limited supply of resources found in remote areas that must be transported over many miles. There is no question as to which of these methods is more sustainable.

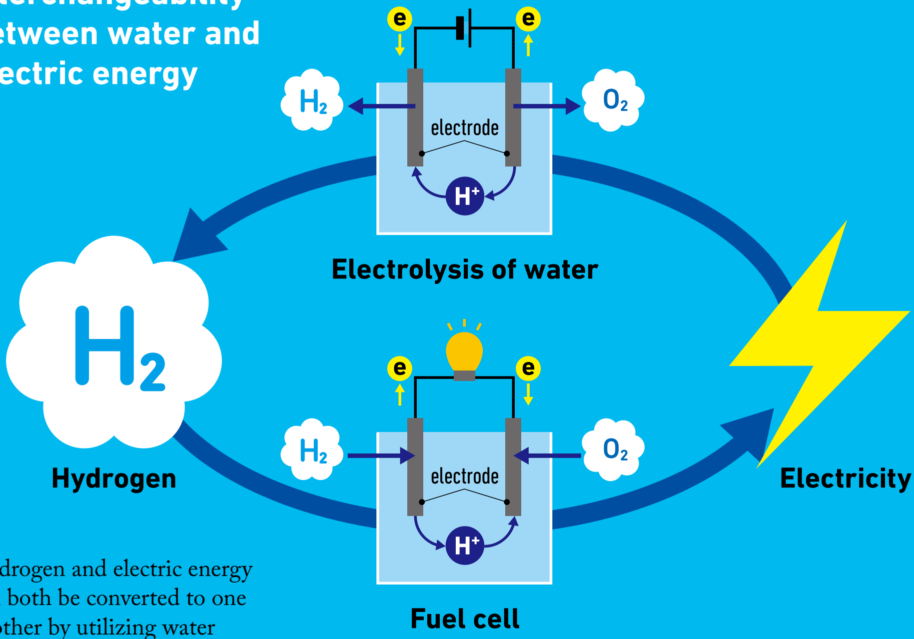
The Mechanism behind Renewable Hydrogen (RH_2)

The most common Renewable Hydrogen system consists of an electrolyzer and a fuel cell (FC). You may remember conducting experiments with electrolysis when you were in grade school!

In summary, the RH_2 paradigm is as follows:

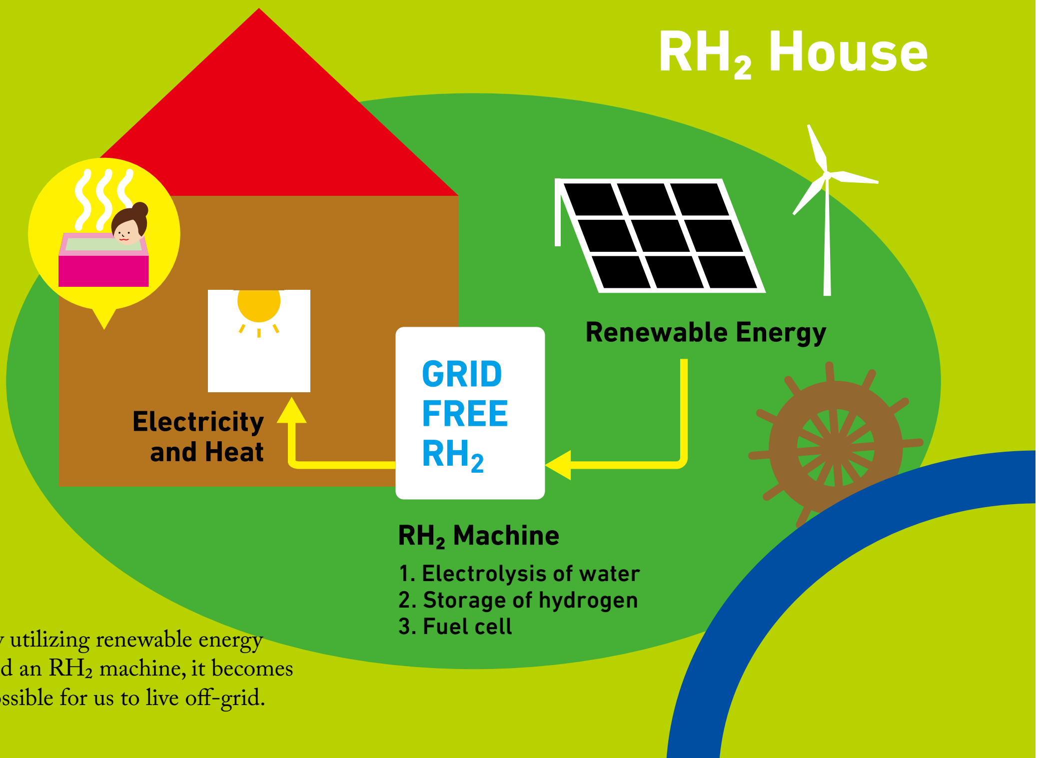


Interchangeability between water and electric energy



Hydrogen and electric energy can both be converted to one another by utilizing water electrolysis and a fuel cell.

RH_2 House



By utilizing renewable energy and an RH_2 machine, it becomes possible for us to live off-grid.

1. Create Renewable Hydrogen locally and use it locally;
2. Use local renewable energy to make hydrogen through electrolysis;
3. Store hydrogen in tanks in either a gaseous or liquid state;
4. Use a fuel cell to convert hydrogen into electricity when needed. This is accomplished through a chemical reaction between hydrogen and oxygen present in the atmosphere.

Since the electrolyzer and fuel cell cause opposite reactions, water, oxygen and hydrogen become components in a positive feedback loop. We call this the "RH_2 Cycle."

The best way to generate electricity using an RH_2 cycle is via a continuous generation system, for example utilizing low head hydropower (i.e., tidal flows or rivers with a head of 20 meters (66 ft) or less), tidal power, or leveraging hot springs or ground heat to provide energy. Using these methods, surplus energy generated overnight can be converted to hydrogen.

Let's go over the mechanisms behind both the electrolyzer and fuel cell.

In an electrolyzer, when electricity is applied to water, hydrogen and oxygen are created on the negative and positive electrodes, respectively. This phenomenon is known as electrolysis.

A fuel cell, on the other hand, causes the opposite reaction. When hydrogen and oxygen are respectively supplied to either side of an electrode, hydrogen is ionized via electron emission, and oxygen combines with electrons and hydrogen in order to generate water. Electric energy is then captured from the flow of electrons between the two electrodes. Generally, platinum (a rare metal) is used in the electrodes, but recently low-cost alternatives have been discovered.[3]

The mechanism behind this process is simple, since a fuel cell requires fewer components and has a simpler structure compared to a battery. It is also easy to scale the system downwards for personal computers, or upwards for large applications, including houses and buildings.

Electrolysis is not the only sustainable method whereby hydrogen can be generated. In addition to research being carried out on artificial photosynthesis modeled on the process performed by plants, we can also extract hydrogen from biomass, such as algae and scrap wood.

How to Store Hydrogen

Since the energy density of hydrogen is so low (in its gaseous form the hydrogen molecule has the lowest density of any molecule on earth), a lot of space is needed to store it in its natural state. Here, we will introduce three ways to store hydrogen in a more compact manner.

In the case of vehicles, because a large amount of hydrogen must be stored in a small space without significantly increasing the overall weight, a high-pressure tank (700 bar) is often used. In Japan, these tanks can only be used by people that hold a license in high-pressure gas safety; however, there is an exception for tanks installed in Fuel Cell Vehicles (FCVs), which may be used without a license.

Another storage method is the use of liquefied gas for mass transport and storage. When hydrogen is cooled to minus 253° C, its state changes to liquid, and the required volume necessary for storage shrinks to about 1/800 less than in its normal state. However, this

[3] Stanford news, "Single-catalyst water splitter from Stanford produces clean-burning hydrogen 24/7" <http://news.stanford.edu/2015/06/23/water-splitter-catalyst-062315/>

A fuel cell scooter developed in Taiwan. Hydrogen is charged by changing the metal hydride cartridges. The scooter's range with two cartridges is approximately 80 km. Each cartridge holds 45 g of hydrogen.

Hydrogen tank loading process in the FCX Clarity, Honda's fuel cell vehicle (June 2008).

cooling process requires a lot of energy.[4] In addition, there is another storage method involving a chemical reaction that requires an organic solvent such as toluene.[5] This chemical process reduces the necessary storage volume to about 1/500 of what it would be under normal atmospheric conditions. The downside is that complex infrastructure is required.

A more promising method for RH_2 is solid metal hydride storage (please refer to the top photo on the previous page). Metal hydride comes from the same material used in the Eneloop (Ni-H) battery manufactured by Panasonic, but uses smaller components and processes. This material absorbs hydrogen volumes 1,000 to 1,500 times larger than itself to change its state to hydride. It can be referred to as a hydrogen dry-cell battery—since once the hydrogen is consumed, it can be charged repeatedly up to 10,000 cycles. The limitation of this method is that metal hydride easily degrades via a chemical reaction if the hydrogen gas has impurities such as water. Therefore, the stored hydrogen needs to be pure.

Hydrogen stored in metal hydride does not conflict with Japan's Fire Defense Law, and is not categorized as a hazardous object (a good example of which is spray cans). Anyone can use metal hydride storage-based systems without needing certification in high-pressure gas safety, because the storage container is kept at a pressure under 10 bars. One downside of this method is its heavy weight, so it is often installed in stationary applications like buildings.

The RH_2 building constructed at Griffith University in Australia contains a metal hydride tank to store hydrogen. The professors there regard this system as safe because the hydrogen is discharged at a slow rate. Details can be found on page 89.

As metal hydride decreases in size with technological advances, it will become easier to handle hydrogen. For instance, we can carry canisters of hydrogen charged in our homes, or exchange empty canisters for full ones at the neighborhood store.

Comparing Battery and Hydrogen Storage

Another well-known and widespread technology to store energy is a battery. Let's examine the difference between hydrogen and batteries.

1. Storage Capacity

Hydrogen and batteries both store electricity by transforming it into chemical potential energy, as electricity itself cannot be stored. One difference between these two methods is that in a hydrogen system, transformation and storage components can be separated, while in a battery they must be integrated.

It is easy to scale a hydrogen system by simply increasing the size or number of storage tanks. Hydrogen can therefore be applied to a broad array of storage scenarios—from small localized applications, to a complete substitute for societies dependent on fossil fuels. However, battery-based applications are more limited, and may include small-scale storage for an EV or single-family homes.

2. Maximum Storage Duration

The reason why the storage life of a cell phone battery gradually decreases is due to a phenomenon called degradation. Also, the natural

[4] Kawasaki Heavy Industries, "Hydrogen Road"
<http://global.kawasaki.com/en/stories/hydrogen/>

[5] Chiyoda Corporation, "Hydrogen Supply Chain"
<http://www.chiyoda-corp.com/technology/en/spera-hydrogen/spera02.html>

decrease in the amount of stored energy is due to a phenomenon called self-discharge. Because of their limited lifetime, it is difficult to use batteries in dynamic storage systems, such as in storing excess solar energy during summer months for winter use, or in storing excess energy generated by wind power during winter months for summer use.

With hydrogen, the total amount of stored energy doesn't decrease unless there is a leak in the storage tank. Therefore, in situations where renewable energy needs to be stored for long periods of time, hydrogen is more appropriate.

3. Environmental Impact

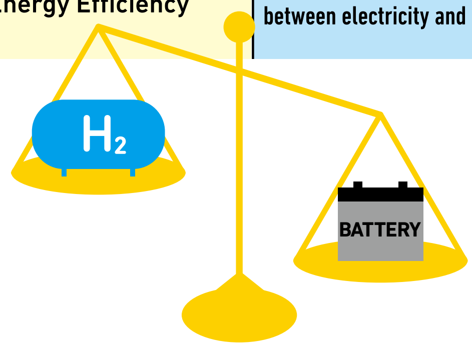
One of the problems with batteries is, despite the technical development of recycling, degraded products end up as waste. With hydrogen tanks, hydride rarely causes degradation. Fuel cells and electrolyzers degrade, but unlike in the case of batteries, there are already established recycling businesses that extract the rare metal in these products.

4. Energy to Weight Ratio

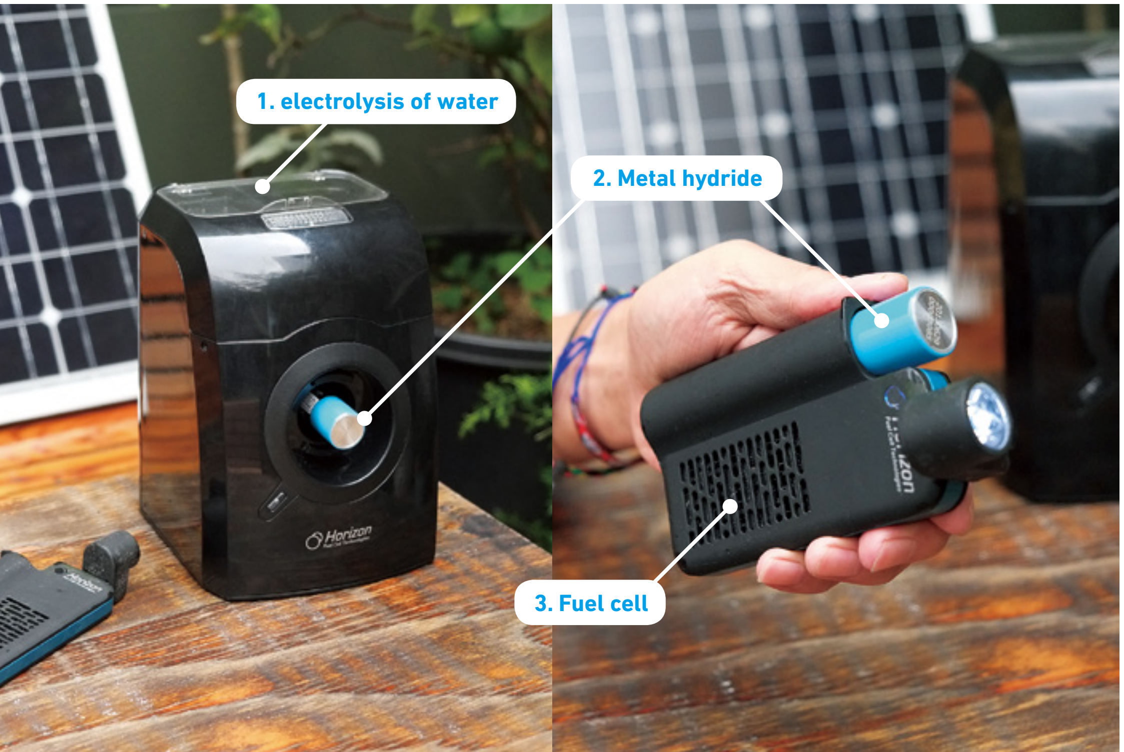
When we think of using renewable energy not only to power our homes, but also to power motors for mobility-applications, it is important to choose an energy storage system that is light, compact, and powerful. Here too, hydrogen stands a notch above batteries, as the ratios of energy density to both weight and volume is higher in high-pressure hydrogen tanks compared to lithium-ion batteries. Consider the fact that a battery in an EV is between 200 to 300 kg, which is comparable to having a gorilla in the passenger seat!

Comparison between Hydrogen and Battery Storage

Metric	Hydrogen	Battery
Storage Capacity	Small to Large	Small to Medium
Maximum Storage Duration	Long-Term	Shorter-Term due to physical degradation and self-discharge
Environmental Impact	Low; water as byproduct	Individual units degrade, then are treated as garbage
Energy to Weight Ratio	High (=Light and Powerful)	Low (=Heavy and Weak)
Charging/Filling Time	Short	Long
Intended Application	Various (e.g. electricity, chemical processing, residential heating)	Electricity only
Energy Efficiency	Loss occurs when converting between electricity and hydrogen	Gradual loss with increase in charge/discharge cycles



↑ The Iwatani hydrogen station at Shiba Park. ↓ Portable fuel cell product by Horizon, which can charge a cell phone. It's now possible to try out consumer products that allow you to produce, store and use hydrogen.



5. Charging/Filling Time

It takes about 20 minutes for an EV to reach an 80% charge when using a high-speed charger, but it takes only three minutes for a fuel cell vehicle (FCV) to reach a 100% charge of hydrogen. FCVs also have a longer drive range. In brief, these technologies are mature enough that we should honestly assess each vehicle-type on the basis of its advantages, sometimes choosing an EV and other times choosing an FVC, depending on the particular use case.

When operating a battery-powered machine with a 24 hour run-time, spare batteries must always be available. For this reason, we should gradually transition forklifts—which are frequently used in logistics centers, food delivery centers, and automotive factories in the United States—from battery to hydrogen and fuel cell technology. For these types of mobility applications, hydrogen-based technology is preferable due to the longer life span of fuel cells and their shorter charging time.

6. Usability

Hydrogen is useful not only for providing electricity, but also for various other purposes. For example, hydrogen is an ingredient in daily commodities like margarine and lipstick, and is used in the manufacturing process of industrial products, such as optical fiber and semiconductors. Also, a large quantity of hydrogen is used in the process of removing sulfur impurities from gasoline. This means the gas that powers cars is made from a combination of crude oil and hydrogen—itself taken from fossil fuels!

Hydrogen can also be used in combustion. Currently, there are over one billion registered gas-powered vehicles around the world, which poison the atmosphere every day. The technology to convert a gasoline engine to a hydrogen engine already exists. The advantage to these engines is that when hydrogen combusts, the only byproduct is water, which is formed when hydrogen reacts with oxygen in the atmosphere.

7. Energy Efficiency: The Storage-Use Cycle

Batteries have inherent inefficiencies. For example, they lose energy both when charging and during use, resulting in a decrease in their ability to hold a charge. The ratio of the amount of energy lost to the total capacity is referred to as "charging efficiency." This value varies from 80 to 90% depending on the battery type. It is also important to remember two characteristics of batteries which were previously mentioned: physical degradation and self-discharge.

Energy loss also occurs in RH_2 systems, both when producing and using hydrogen. Since the number of case studies based on real-world implementation is limited, precise data is not yet available. However, based on theoretical estimates with a 70% electrolysis efficiency and 80% fuel cell efficiency, the efficiency of the entire hydrogen manufacturing process is approximately 56%.

While RH_2 systems and batteries are different in several respects, they are nevertheless both effective methods that complement renewable energy generation by storing surplus electricity.

The more widely-used hydrogen and battery technologies become, the more we will see advances in their respective technologies. In the future, new innovative models of local storage and use of renewable energy will also be planned and implemented. At this stage, we must select the best model by not just comparing efficiency values, but by evaluating their general characteristics, which include both the amount of energy that can be stored, and the environmental impact.

Hydrogen Safety

When people hear that hydrogen can be used as an energy source, some are concerned about its overall safety. Hydrogen itself is not poisonous to humans: byproduct exhaust from the combustion of hydrogen is only steam and a small amount of nitrogen oxide, which are both harmless. The primary concern as to whether or not hydrogen is dangerous is due to the widespread misunderstanding that it can easily cause explosions.

Hydrogen combusts when its percentage by volume in the surrounding air is between 4–75%. Under these conditions, the equivalent of static electricity is needed to ignite hydrogen. But hydrogen can explode only when both of these conditions are met. Further, since the hydrogen atom is the lightest material on earth, and easily diffuses into the atmosphere, it is almost impossible to create a condition where the atmospheric concentration of hydrogen is 4% or more.

When gasoline that has leaked from a corroded tank of a gasoline-powered car is ignited, it will continuously burn due to the fact that gasoline is heavier than the surrounding air. The fire will burn straight through the tires and body of the vehicle. However, in a hydrogen vehicle, because hydrogen is much lighter than air, it quickly combines with oxygen, so as soon as there is a minor combustion, the hydrogen quickly diffuses into the atmosphere. This has a clear advantage when it comes to safety, which has been proved experimentally (see the photos on the next page).

After the Fukushima Daiichi nuclear disaster occurred in March 2011, many people thought the reactor building was damaged by a hydrogen explosion. While this is correct, the explosion—caused by a buildup of steam and hydrogen, both normal outputs from boiling light water reactors—was in fact facilitated by a reactor design implemented to mitigate risk. This prevented the reactor vessel from being destroyed, which would have resulted in an even larger amount of poisonous radioactive material being released into the atmosphere.[6]

Facilities that use hydrogen, like Fukushima Daiichi, can avoid catastrophic explosions by releasing hydrogen buildups through ventilation holes. This prevents the two conditions necessary for an explosion to occur: an ignition source and a 4–75% buildup of hydrogen gas in a closed space.

Our modern lives benefit from natural gas lines and propane gas hookups. While this energy provision is not absolutely safe, it has become widespread because its merits outweigh the risks. Similarly, as hydrogen energy becomes more widespread, certifications and laws will control various aspects of its provision, including mandatory education for engineers who handle hydrogen. Gradually people will become more accustomed to handling hydrogen, and it will become part of our daily lives.

[6] REB Research & Consulting, "Hydrogen Explosions in Nuclear Reactors and a Passive Way to Prevent Them" <http://www.rebresearch.com/REB_Hydrogen_Nuclear.html>

On the left is a hydrogen engine vehicle, and on the right is a gasoline engine vehicle. The top series depicts three seconds after ignition, and the bottom series depicts one minute after ignition. Dr. Michael R. Swain "Fuel Leak Simulation," University of Miami, 2001.

The key lies in the renewable energy and water all around us.

CHAPTER 2

Towards Regional Self-Reliance & Cyclical Renewable Hydrogen

Energy Subsidies: The Deception of Low-Cost Fossil Fuels

Most of the hydrogen used in the "Hydrogen Society" envisioned by the Government of Japan and Japanese energy companies is not the sustainable variety, but rather hydrogen sourced from fossil fuels. Conventional energy—including gasoline, kerosene, heavy oil, natural gas, and propane—is all made from fossil fuels, which is also the raw material for thermoelectric power generation.

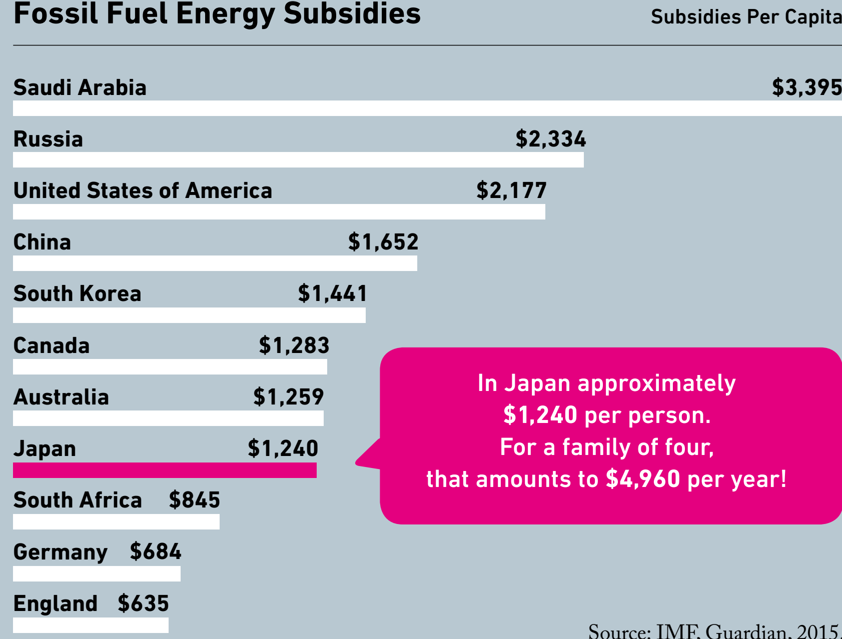
In Japan, it's not widely known that a large percentage of citizens' taxes are used to subsidize fossil fuels. In 2015, the International Monetary Fund (IMF) reported that global fossil fuel subsidies had reached an estimated $5.3tn USD a year, which is 6.5% of the world's GDP. Looking at subsidies on a country-basis, in Japan approximately ¥150,000 Japanese Yen (JPY) of each citizen's taxes is used for fossil fuel subsidies. For a family of four, that amounts to ¥600,000 JPY per year![7]

The IMF's definition of energy subsidies is the difference in price between what consumers pay for energy and the actual cost of that energy. These actual costs include the cost of energy to move and distribute fuel, but there are also several externalized costs such as global warming, air pollution, and traffic jams. The report also pointed out energy subsidies also actively suppress spending on important social infrastructure like education, health and human services (reference "Changing the Flow of Capital" on Page 73).

Because of these subsidies, a liter of gasoline is about the same price as a bottle of water. Thus, the following thinking has become pervasive:

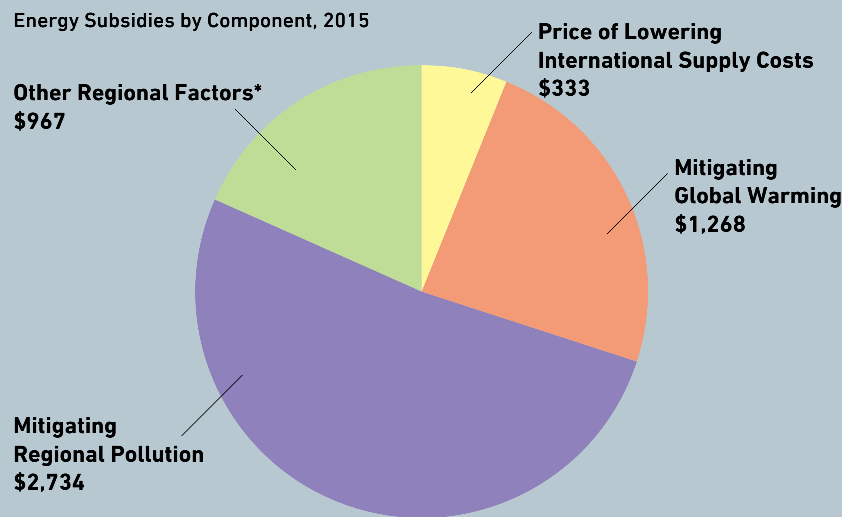
[7] The Guardian, "G20 countries pay over $1,000 per citizen in fossil fuel subsidies, says IMF." <http://bit.ly/2dSK1Pb>

Fossil Fuel Energy Subsidies



Source: IMF, Guardian, 2015.

Breakdown of Energy Subsidy Expenditure



Source: Data compiled by the International Energy Agency (IEA), Organization for Economic Co-operation and Development (OECD), and International Monetary Fund (IMF) staff statistics. Note: "Other Regional Factors" include costs related to consumer tax revenue which cannot be collected, traffic accidents, and damage to roads.

From the Film
The Economics of Happiness

Passing through roads that have been recently maintained

Building enormous power plants to produce energy

Hauling out garbage from cities without considering reuse

The phenomenon of imports and exports of the same commodity reaching the same level (e.g., in the United States imports & exports per year of potatoes, sugar, beef, and coffee)

gasoline is a cheap liquid fuel that is easy to handle, as opposed to hydrogen, which is expensive and difficult to handle in its gaseous state. Looking at thermoelectric and nuclear power generation in the same context, it becomes apparent that their low-cost is nothing but a facade.

Modern civilization is being deceived, and we are playing a risky game by wasting large amounts of our precious (and limited) natural resources. The clothing we wear and items we use every day—including gadgets like cell phones and laptops—result in spending large amounts of energy throughout an unsustainable cycle of production, shipping, garbage collection, and disposal. Society is now running on the premise that because fossil fuels are cheap, we can rely on large amounts of them to build infrastructure like buildings and roads. This is exacerbated by the fact that more than half the world's population now resides in cities dependent on large amounts of energy.[8]

Walk into a supermarket and you will realize that the food for sale comes from all over the world. Grapefruits from South Africa, oranges from the United States, kiwis from New Zealand, avocados from Mexico, bananas from Ecuador, shrimp from Indonesia, fish from Norway, Iceland and Chile. It's said that in Japan, each ton of food requires roughly 9,000 kilometers of "food mileage."

In *The Economics of Happiness*, director Helena Norberg-Hodge demonstrates how, in the United States, the levels of imports and exports of certain commodities (e.g. potatoes, sugar, beef and coffee) have become equal. In England, the same goes for milk, bread, eggs, and pork.

Thanks to low airfares, both commodities and people move freely

[8] United Nations, "World Urbanization Prospects: The 2014 Revision, Highlights." <https://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf>

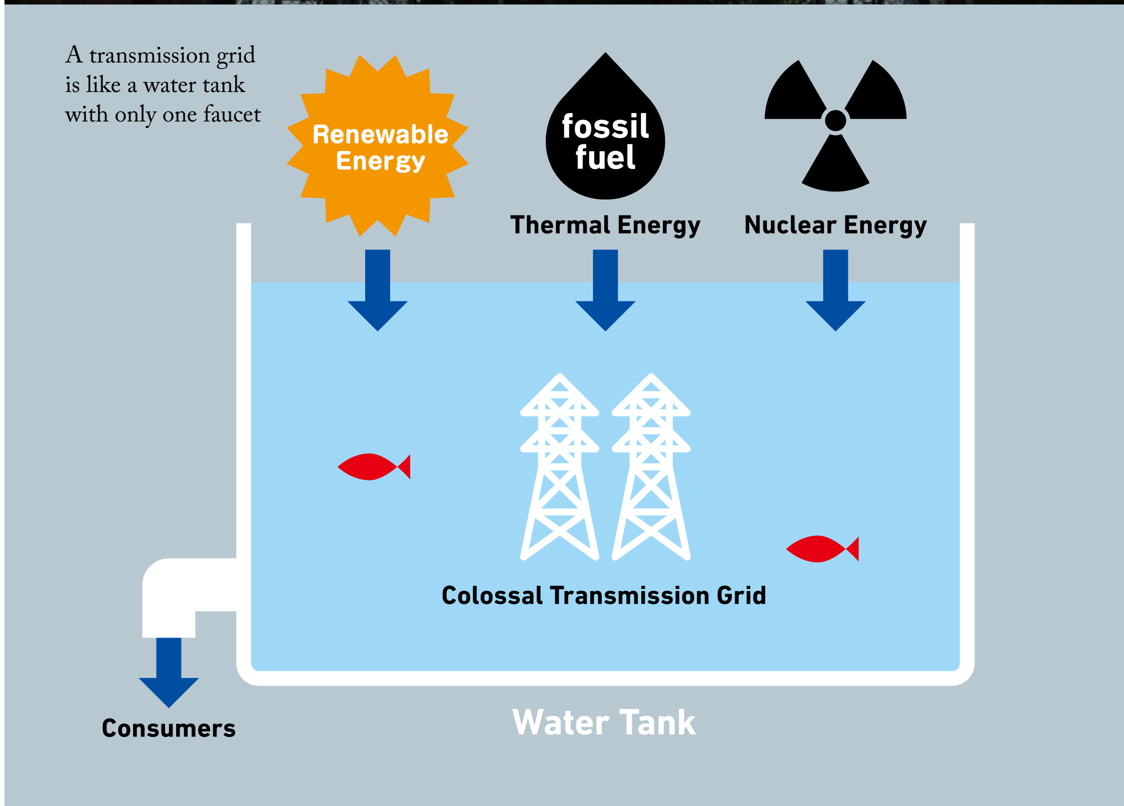
and inexpensively across the globe. The result is if a commodity is cheap in one area, a low-cost logistics company will be hired to move it across the globe. Similarly, during 2014, "the number of tourists traveling internationally grew by 4.4%, reaching a new milestone of 1.13 billion people, and capping a five-year consecutive increase since the global economic crisis of 2009." [9]

Again, the attractive glimmer of this high rate of travel is tarnished by the deceptively low cost of fuel made possible through government subsidies. The Kyoto Protocol, adopted in 1997, established an international framework for combating climate change. However, greenhouse gas emissions from international trade, i.e. international air travel and overseas shipping, are excluded from the limits established by the Protocol. Who takes responsibility for those emissions? As a result of such large quantities of non-renewable energy being consumed, the world's energy infrastructure is headed towards collapse.

Should Sustainable Energy be Dependent on the Power Grid?

Now, let's take a look at renewable energy. In 2012, a law was passed in Japan that created a Feed-In Tariff scheme for the purchase of electricity. This law stipulates that electricity generated from renewables must be sent via transmission lines to electric utilities, making community-level electricity distribution unfeasible.[10] It also guarantees a fixed purchase price for electricity, which has encouraged many companies to enter the renewable energy business. In 2016, Japan also deregulated its electricity market, allowing consumers to choose their supplier for

[9] United Nations World Tourism Organization (UNTWO), "Annual Report 2014." <http://cf.cdn.unwto.org/sites/all/files/pdf/unwto_annual_report_2014.pdf>

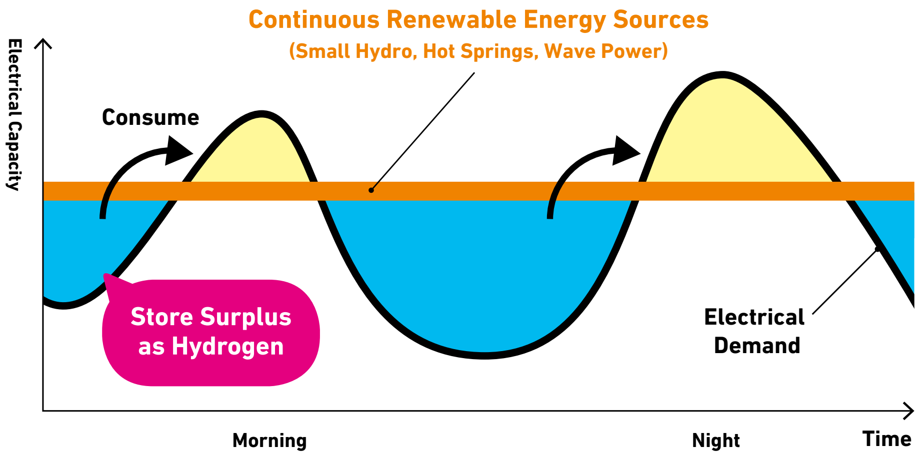


Retail Rate of Wind, Geothermal, and Hydro Energy

Energy Capacity		Retail Rate	Contract Period
Wind Power	Over 20 kW	¥22 plus tax	20 years
	Up to 20 kW	¥55 plus tax	
	Offshore Wind Power	¥36 plus tax	
Geothermal Power	Over 15,000 kW	¥26 plus tax	15 years
	Up to 15,000 kW	¥40 plus tax	
Hydro Power	1,001~30,000 kW	¥24 plus tax	20 years
	201~1000 kW	¥29 plus tax	
	Up to 200 kW	¥34 plus tax	
Small Hydro Power	1,001~30,000 kW	¥14 plus tax	20 years
	201~1000 kW	¥21 plus tax	
	Up to 200 kW	¥25 plus tax	

Ministry of Economy, Trade, and Industry "Feed-in Tariff Scheme in Japan" <http://www.meti.go.jp/english/policy/energy_environment/renewable/pdf/summary201207.pdf>

Prices during off-peak hours (e.g., nighttime) should be lowered



Stabilization of Electrical Demand Due to Hydroelectric Storage

*graph not based on existing data

the first time. However, this framework also relies on large-scale grids. In areas including Hokkaido and the Tohoku region, 300 billion yen will be spent over the course of 10 years to create a colossal transmission grid to distribute electricity generated by wind turbines.

This equates to building steel towers deep in the mountains, power lines capable of transmitting several hundred thousand volts, and hundreds of converter stations, not to mention the cost of maintaining this infrastructure. The combined total of related fixed assets for 10 electrical companies is said to be 16 trillion yen, which must be paid for, of course, by our electric bills.

In the movie *Power to the People*, Dutch filmmaker Sabine Lubbe Bakker compares a transmission grid to a water tank outfitted with only one faucet. As energy from nuclear power plants and thermal power plants is mixed with energy from renewable energy sources, consumers cannot decipher the origin of their electricity. This mingling of electricity from different sources raises doubts in their minds as to whether using renewable energy truly benefits the environment. It also undermines the responsibility and autonomy of both suppliers and consumers. The point is that the average consumer may want to purchase energy from renewable sources, as opposed to non-renewable sources, if they had an explicit choice.

Certain types of energy, such as wind, geothermal, and hydroelectric, are produced 24 hours a day. In Japan, this electricity is sold at a fixed rate, even during early morning hours when the demand for electricity is substantially lower than peak hours during the day. In Europe, however, electricity is priced according to demand: electricity sold during low-demand hours is priced lower than electricity sold during peak

[10] For more information on the Feed-In Tariff, see METI's "Present Status and Promotion Measures for the introduction of Renewable Energy in Japan." <http://www.meti.go.jp/english/policy/energy_environment/renewable/>

hours. Furthermore, because grid charges (i.e., fees incurred for using transmission lines when selling electricity) are high, selling electricity during low-demand hours results in a financial loss. This has encouraged many Europeans to consider energy storage, including hydrogen. Storing energy as hydrogen during low-demand hours allows for future sales during peak hours, preventing a deficit.

Yet in countries like Japan, where energy is purchased at a fixed rate around the clock, there is no incentive to store surplus energy as hydrogen. It follows that the first step in encouraging citizens to consider storing surplus energy as hydrogen is to lower purchase prices, even if only at night.

Sources that produce energy around the clock, such as small hydroelectric, hot springs, or waves, can produce a significant amount of hydrogen during low-demand hours. By using this hydrogen to produce electricity during peak hours, we can ensure that the balance of supply and demand is maintained.

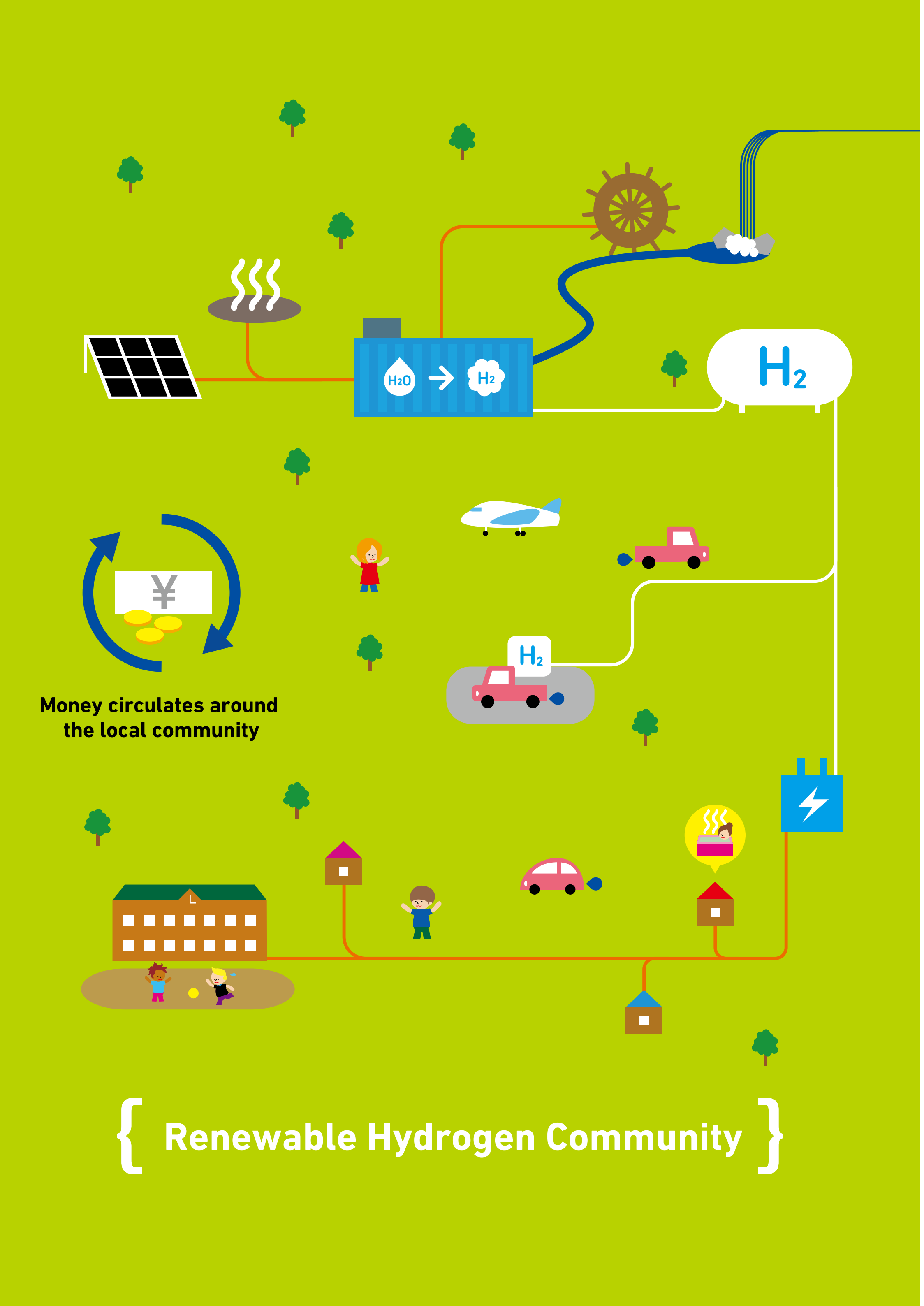
Regional Self-Reliance & Cyclical RH_2

Now, let's look at the merits of an RH_2 Cyclical Society, one based on local communities creating renewable energy and storing hydrogen to create an RH_2 "virtuous cycle," which helps make communities more independent in the process. Such a cycle allows energy to be more democratic and peaceful.

1. Natural Disaster Resilience through Local Energy Storage

During the March 2011 Great East Japan earthquake, harbors and

On Lolland Island, Denmark, because wind energy generated at night is priced cheaper, it is often purchased from the grid and stored as hydrogen. Later during the day, the stored hydrogen is fed into a fuel cell to generate electricity and power the local community. (Photos: visit to the demonstration project, March 2010)



coastal areas were damaged extensively by the tsunami, roads and gas stations were destroyed, and power lines were damaged. The energy infrastructure of Northeast Japan suffered incalculable damage. In order to protect ourselves from climate change, earthquakes, and increased volcanic activity resulting from rapid geological changes, it is critical to achieve sustainable energy storage on the local level. The case of Kuzumaki City, Iwaki Prefecture makes an important point: while Kuzumaki was well-known for having achieved 100% sustainable energy independence, the Great East Japan earthquake triggered a three-day blackout. Unfortunately, energy generated in Iwaki first traveled through power lines to power facilities where it was sold, with no energy being stored at the local level.

Think of this from the perspective of our food supply: if you harvest a large amount of vegetables at one time, what do you do? You can make pickles. If you haul in a lot of fish, you can make dried fish. Properly stored, rice is a non-perishable food. Preserving food helps stabilize our daily lives. Finding a way to store nature's wealth for later use is an important aspect of the wisdom that has allowed human civilization to advance.

Similarly, it's not an overstatement to say the widespread storage and later use of sustainable energy will be the next step in the evolution of human civilization!

2. Local Cyclical Economy

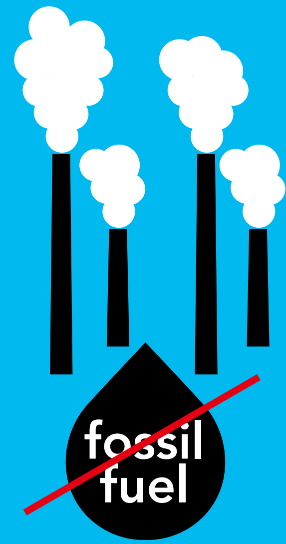
Creating energy, storing it, and then using it locally is the foundation of a local cyclical society. Energy created locally, which can be bought and used locally, translates into money being circulated locally.

In Japan, in one year each household spends approximately ¥300,000 JPY on heating, electricity, and gasoline. For a small town with 10,000 homes, household energy costs amount to three billion JPY. Looking at the town as a whole, even more energy is used. Imagine if that money circulated locally. The community wouldn't be a pawn in the global economy's money game, and complicit in the energy business—the culprit behind many of the world's problems. Keeping that money inside the community would make it a stronger, more stable, and more appealing place to live.

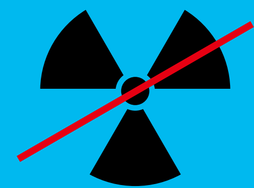
In Yamagata Prefecture, Japan, population 1.1 million, energy expenditures on electricity, gasoline, heavy oil, and kerosene—money that leaves the community—has reached ¥240 billion JPY a year. Yamagata is well-known for beautiful landscapes, which have been leveraged to grow a robust agriculture industry. While revenue from sales of agricultural products exceeds ¥200 billion JPY annually (No. 6 in Japan), it's a shame that all that wealth leaves the prefecture and the local economy as money spent on energy!

3. Revolutionary Energy Conservation

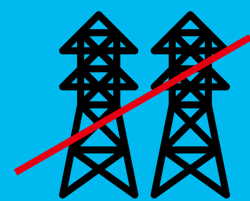
A community-based, sustainable society progressively reduces energy consumption. The global consumption of primary energy in 2010 was the crude oil equivalent of 12 billion tons. Those who forecast the future based on traditional methods of energy consumption project this number to increase to over 17 billion tons in 2030. These astronomical numbers raise the question: wouldn't it be better to reconsider our current lifestyle, which requires the long-distance transportation of energy, industrial products, and food?



No Fossil Fuels



No Nuclear Power



No Sprawling Power Grids

Even if the world were to suddenly shift to renewable energy, that shift would still be rendered pointless in a world dependent on high levels of energy consumption. If each of us switched to local products and avoided unnecessary purchases, global energy consumption would decrease by half, or even as much as two-thirds. Our reduced energy needs could then be met with renewables.

4. Ending Our Reliance on Fossil Fuels, Nuclear Energy, and Sprawling Power Grids

The RH_2 cycle is powered by easily accessible renewables and water. As opposed to fossil fuels, these "raw materials" don't need to be transported from afar at a high cost. Energy can also be saved in large quantities, allowing us to break free from fossil fuel stockpiles and fossil fuel power plants.

Furthermore, there would be no need for nuclear power plants. Considering the environmental and human rights issues surrounding uranium mining and the added risks of accidents and radioactive waste, the future clearly cannot be entrusted to nuclear energy.

Moreover, there would no longer be a need for substations, steel towers, electric power cables or large infrastructure built on unpopulated mountains to carry energy across long distances. We would also be relieved from having to spend the massive amount of money necessary to build and maintain these structures.

Journalist Naomi Klein perfectly summed up the stark contrast between global and local energy economies on *Democracy Now!*, an independent, ad-free daily news program: "Fossil fuels are the centralization of power. Enormous infrastructure is needed to mine, transport and provide fossil fuels. However, wind, solar and waves can be used endlessly and [are] ubiquitous. Anyone can become the energy provider. Fossil fuels are the possession of the wealthy 1%, but if we decentralize renewable energy, it will become the [possession] of civil society, which is the other 99%."

5. Ending Energy Poverty

There are 1.4 billion people in the world, or approximately 10 times the population of Japan, who live without electricity. Additionally, about 40% of the world's population lives on less than $2 a day. Without electricity, there is no internet. Without the internet, it is more difficult for people living in remote areas to learn about pressing issues, like the nuclear accident in Fukushima or our worsening climate crisis. The more difficult it is for citizens to obtain objective information, the more difficult it is to cultivate democracy.

In 2014, Malala Yousafzai, the youngest Nobel Peace Prize laureate in history, stated in her acceptance speech, "One child, one teacher, one book, one pen can change the world. Education is the only solution. Education first."

With the addition of energy from RH_2, the chance that a child can escape from a powerless state—both figuratively and literally—increases. With energy and education, a child can learn how to read by taking free classes on the internet. The child may even learn how to express their opinion, a far more valuable lesson, as free expression is the foundation of democracy. Resolving energy poverty would facilitate information exchange and, in turn, help develop the partnerships necessary to protect the earth.

6. The Water-Oxygen-Hydrogen Cycle

The RH_2 cycle is a process where water, oxygen and hydrogen circulate. It doesn't produce poisonous gases or pollute the water and air necessary for life. In the absence of pollutants, rain that falls from the sky will become clean, as will the earth, rivers and oceans. Food from these sources will become purified and humans will grow healthy.

CHAPTER 3

Renewable Hydrogen Projects around the Globe

Not the Year 2030—but Now!

The Japanese government and energy companies continue to repeat the story that in order to make a renewable hydrogen society a reality, we'll need to build a system that supports the expensive and large-scale production, storage, and transportation of hydrogen. They say that while Renewable Hydrogen (RH_2) is ideal, the necessary infrastructure and costs relegate its fruition to sometime in the distant future. Most media outlets report the same thing.

However, nothing could be further from the truth: realizing a renewable hydrogen society is not pie-in-the-sky, based on some future technology yet to been developed. Current technology can be leveraged to quickly make RH_2 a reality! Indeed, Renewable Hydrogen will breathe life into our shared vision of a more sustainable and equitable global culture. Luckily, things are gaining steam both in Japan and around the world.

Griffith University, Queensland, Australia: Solar & RH_2

The Sir Samuel Griffith Building of Griffith University was completed in April 2014. It is an entire building devoted to being completely off-grid and powered by RH_2. Energy generated from solar panels installed on the roof and eaves is immediately used to power the building, as well as to perform electrolysis on water to make hydrogen gas, which is stored for future use. Stored hydrogen can then be used for energy at night or when weather conditions make generating solar

Sir Samuel Griffith Centre at Griffith University

energy difficult. All the energy used in this six-story building is generated through solar and hydrogen.

Electrolysis powered by solar energy produces at most 3.6 kg of hydrogen per hour. Using metal hydride, a maximum of 132 kg of hydrogen can then be stored. This can power the building for an entire week.

For more details, please read page 83 for a full report based on onsite interviews conducted in March 2014.

Bella Coola, British Columbia, Canada: Hydroelectric & RH_2

500 kilometers north of Vancouver is the Bella Coola Valley, a network of towns with a combined population of just under 3000 people. Bella

Coola recently completed a pilot-project where hydroelectric energy generated from a waterfall, and hydrogen (primarily produced at night when energy demand is low) are managed using a smart micro-grid that provides intelligence based on current conditions. A hybrid approach using hydroelectric, fuel cells, and in some cases diesel—which the community was deeply dependent on during times of peak-demand—is now employed in the most economical way. This project was predicted to reduce Bella Coola's annual diesel consumption by an estimated 200,000 liters.

Due to Bella Coola's cold climate, hydroelectricity becomes infeasible in the winter, as the waterfall used to generate power freezes up. However, during warmer months, when hydroelectricity can be generated almost 24 hours a day, hydrogen can be extracted from water via electrolysis, and stored in tanks for winter use.

Large-Scale Nuclear Energy Company Shifts to Hydrogen

Most of you have heard about Siemens, the German multinational company with nearly 340,000 employees and 2014 revenues of approximately €71 Billion Euros. Siemens constructed all 17 of Germany's nuclear reactors and promoted nuclear power worldwide. However, on September 18, 2011, shortly after the nuclear accident in Fukushima, Siemens' then-CEO Peter Löscher announced to various media outlets that, with regard to building nuclear plants, "The chapter for us is closed," and continued, "We are no longer going to participate in taking responsibility for building nuclear power stations or financing them."[11]

[11] The New York Times, "Siemens Abandoning Nuclear Power Business." <http://www.nytimes.com/2011/09/19/business/global/19iht-siemens19.html>

This announcement came only three months after the German government's decision to phase out nuclear power by 2020.

On September 27, 2011, shortly after Löscher's announcement, Siemens unveiled a device for water electrolysis, and proposed speeding up the development of renewable energy systems where generation and storage take place in close proximity.

Saitama Prefectural Office: Solar & RH_2

In March 2013, on the grounds of the Saitama Prefectural office, Honda Motors and Iwatani Corporation installed a Renewable Hydrogen system, where hydrogen extracted from water using a solar-powered electrolyzer is used to power a fuel cell car. Filling up

takes about three minutes, and supports vehicles with a range similar to gasoline powered cars. In times of natural disaster when electricity has been cut off, the same fuel cell car can be used as a generator to meet the energy needs of an average family for six days.

A representative from Honda Motors left a strong impression when he said, "Continuing to rely on fossil fuels or uranium means continuing to depend on foreign countries for Japan's energy needs. With this project, we are realizing and developing a purely domestic energy technology, helping to begin to poke a hole in a longstanding mentality of dependence, whose very existence will only continue to lead to problems in the future."

A Hydrogen Station with a Footprint of Only 7.3 m²: Waste Incinerator & RH_2

In September 2014, a compact hydrogen station was completed at a waste management facility in Saitama City, where hydrogen is created from electricity generated from waste incineration. The simple structure, which is contained in a small box and takes only one day to install on a concrete slab, was created through a partnership between Honda Motors and Iwatani Corporation. All the station needs to produce hydrogen are hookups to running water and electricity.

The station requires 2.4 m x 3.2 m of space for installation, and takes up only 1/25th of the space needed for the previously-mentioned

hydrogen station at the Saitama Prefectural Office. Because of its small footprint and ease of installation, selecting an appropriate site is relatively easy, a fact that has created high expectations for this type of station.

Shipping Container Design RH_2 System

Kawasaki City, under the banner of creating a "Future Environmental and Industrial City," is moving forward with several initiatives based on the proactive introduction and use of hydrogen power.

In 2015, Toshiba installed a shipping container-type Renewable Hydrogen system and began a demonstration experiment. The

packaged system consists of a 30 kW solar panel, a container that holds components for water electrolysis and fuel cells, and a hydrogen tank (pressurized at eight atmospheres). The system can be used for a limited time, for example, at an evacuation center during a natural disaster to provide electricity and hot water. The system is housed in a global standard-sized shipping container, so if there's a large-scale disaster, many units can be transported by boat or truck. Individual units can also be combined to create an integrated, large-scale system.

California, U.S.A.: Supporting the Maintenance of RH_2 Stations

In California, the amount of financial support for hydrogen stations is based on the proportion of sustainably generated hydrogen (RH_2) relative to the total amount of hydrogen produced at the station. For example, a station that supplies only hydrogen produced using renewable electricity can receive up to $3,150,000 USD from the State of California.

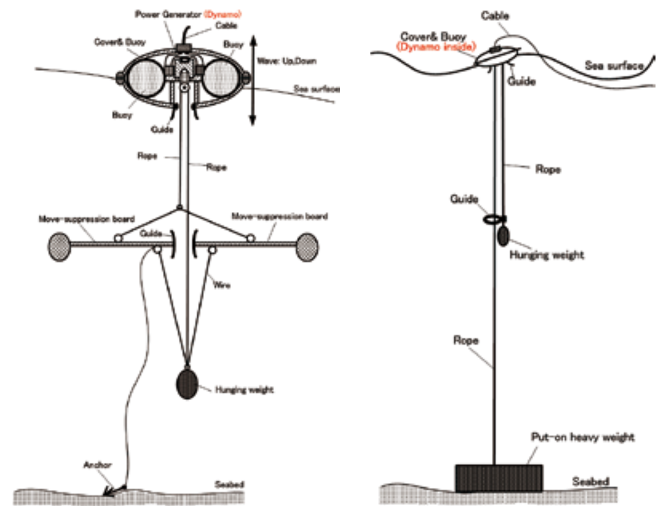
According to the late Guy Toyama, the former executive director of Friends of NELHA[12] (Natural Energy Laboratory of Hawaii Authority), "The State of California's sustainable energy policy is always the most advanced in the nation. In fact, the federal government's Department of Energy (DOE) often follows California's lead. In turn, the Government of Japan's Agency for Natural Resources and Energy, which is housed within the Ministry of Economy, Trade and Industry (METI), always keeps a close tab on the DOE's policy."

I hope the groundbreaking RH_2 policy established by California will be a catalyst for the spread of RH_2 around the world.

RH_2 System by Ocean Waves

Mitsuteru Kimura, currently Visiting Professor at Tohoku Gakuin University, has developed a simple and cost effective way to generate power by leveraging the movement of ocean waves. His patent-pending wave power system is the perfect complement to renewable hydrogen generation and storage.

The system—which is currently at the proof-of-concept stage—is also notable for its high efficiency and low-environmental impact. Using underwater cables, electricity is then transmitted to the shore, where it can be used to generate hydrogen by electrolyzing either salt



Proposal of two wave power generation systems*

[12] A nonprofit, conservation education organization affiliated with the Natural Energy Laboratory Authority of Hawaii.

**Applied No. 2013-005988; PCT/JP2013/076034* or freshwater. Professor Kimura has revealed that the key to fulfilling our planet's energy needs is in the seawater all around us![13]

RH_2 Ranch in Hawaii

The Henk Ranch (called the Pu'u Wa'awa'a Ranch) is on the Big Island of Hawaii. There, Henk B. Rogers—who holds the exclusive intellectual property rights to the global best-seller video game Tetris—has created a RH_2-system powered by solar energy and water.

Rogers is currently Chairman of the nonprofit Blue Planet Foundation, an organization he helped establish, where he works tirelessly to solve environmental challenges. Rogers said, "My mission is to bring about a shift away from fossil fuel-based energy. Why? Because a host of problems has arisen because we've emitted too much CO_2 into the atmosphere. This has inspired my interest in non-traditional electricity generation and mobility. Hydrogen is truly an idea fuel: it can be created from almost anything, and when you use it combines with oxygen. So when you make electricity, the only byproduct is water! It's quite gentle."

The solar panels on the roof of his research facility are 85 kW, and the electrolyzer unit is 65% efficient. The electrolyzer uses surplus electricity for the electrolysis of water, producing between one to four kilograms of hydrogen a day. The system is capable of storing a maximum of 25 kg of hydrogen, which provides electricity to Henk's villa, guesthouse, fuel cell vehicles, and forklift. Hydrogen, which can be burned as a fuel, is used to power his air blower and cooking stove.

[13] Please email us at contact@rh2.org if you are interested in learning more or would like to be a part of the project. You can read the full text of Professor Kimura's proposal here: <http://bit.ly/2cXOft2>

The Henk Ranch in Hawaii

Hokkaido, Japan: Hydroelectric & RH_2

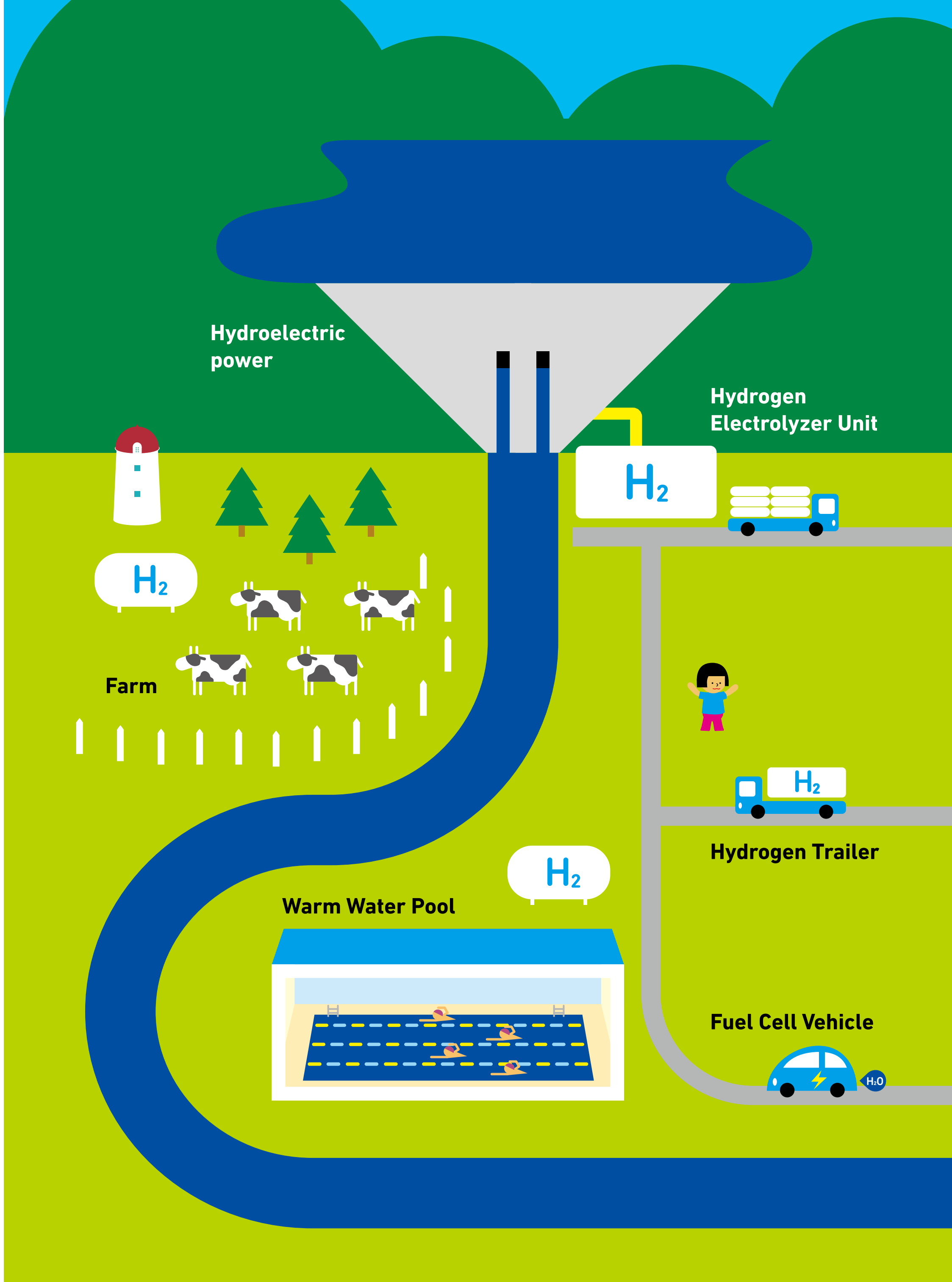
In the southeast Hokkaido, in the town of Shiranuka, planning is underway to build an RH_2-system powered by hydroelectricity. Hydrogen created onsite using electricity generated by the Shoro Dam will be stored in high pressure trailers, and distributed to the surrounding community. This hydrogen will be used in dairy farming facilities and fuel cell vehicles.

This project will reflect a new model of locally produced and used electricity, as opposed to the traditional model of building an electric grid to send renewable energy long distances to areas where it will be consumed.

Grid Free RH_2: Solar & RH_2

The Commune 245 complex, located in the Omotesando district of Tokyo, is a community space for those who think deeply about what our cities should look like. In April 2015, in the coworking space Midori So-2, which is located in Commune 245, the Renewable Hydrogen Network installed and began running a solar powered RH_2 machine, called "Grid Free RH_2."

The Grid Free RH_2 system is connected to solar panels that generate enough energy to power a laptop computer. Alternatively, excess energy can be stored as hydrogen, which is created through electrolysis. At night and other times when the solar panels cannot generate energy, fuel cells kick in to use the stored hydrogen. This off-grid energy system is made possible exclusively by sustainable energy and



hydrogen from water.

Grid Free RH_2 is a miniature version of the technology that powers Griffith University's RH_2 building. While the Grid Free RH_2 system is almost entirely a hand-assembled, original design, we can look forward to more compact designs and lower costs as the RH_2 market expands. This would allow for the advancement of similar systems that could be affordably installed in regular homes. Even though at its current stage it's a small unit that can only power a small fraction of the total energy needed for the entire coworking space, it is nonetheless a powerful showcase that demonstrates an important first step towards a new paradigm based on local, cyclical energy generation independent of a massive electrical grid!

Overview of the Grid Free RH_2 system

- Energy generated by a 1.5 kW solar panel can provide power to a laptop computer. Unused power can be used to produce hydrogen through the electrolysis of water.
- The system's electrolyzer produces hydrogen at a pressure of five bar, forcing hydrogen gas into metal hydride canisters for storage.
- Approximately 178 g (89 g x 2-tanks) of hydrogen can be stored in these metal hydride canisters.
- At night, or when there isn't enough sunlight due to inclement weather, stored hydrogen enters fuel cells where it is used to generate electricity (2 kilowatt hours x 2-tanks = 4 kilowatt hours (kWh)). This electricity can be used to power a laptop computer.
- When stored energy is nearly depleted, an alert sounds to notify the user.
- The metal hydride canisters are registered in the local fire department's database as non-hazardous materials.
- The metal hydride canisters are ISO 16111 certified, attesting to their passing rigorous safety and reliability testing.

The Grid Free RH_2 system located in the coworking space Commune 246, located in the Omotesando district of Tokyo.

On August 28, 2015, six people began the fourth Hawaii Space Exploration Analog and Simulation (HI-SEAS 4), a year-long isolation in a dome built on the Mauna Loa volcano in Hawaii in 2013.[14] Conditions simulate a space mission to Mars. Participants depend on an off-grid energy system in which RH_2 plays an important role. NASA, University of Hawaii at Mānoa, and Cornell University are partners in the project. The Henk Ranch (see page 62) also participates.

[14] Please reference: <http://www.hawaii.edu/news/2015/07/29/six-scientists-to-spend-365-days-in-isolation-for-hi-seas-simulated-mars-trip/>

CHAPTER 4

ACTION!

RH_2 Action!

Taking Energy Back into Our Own Hands

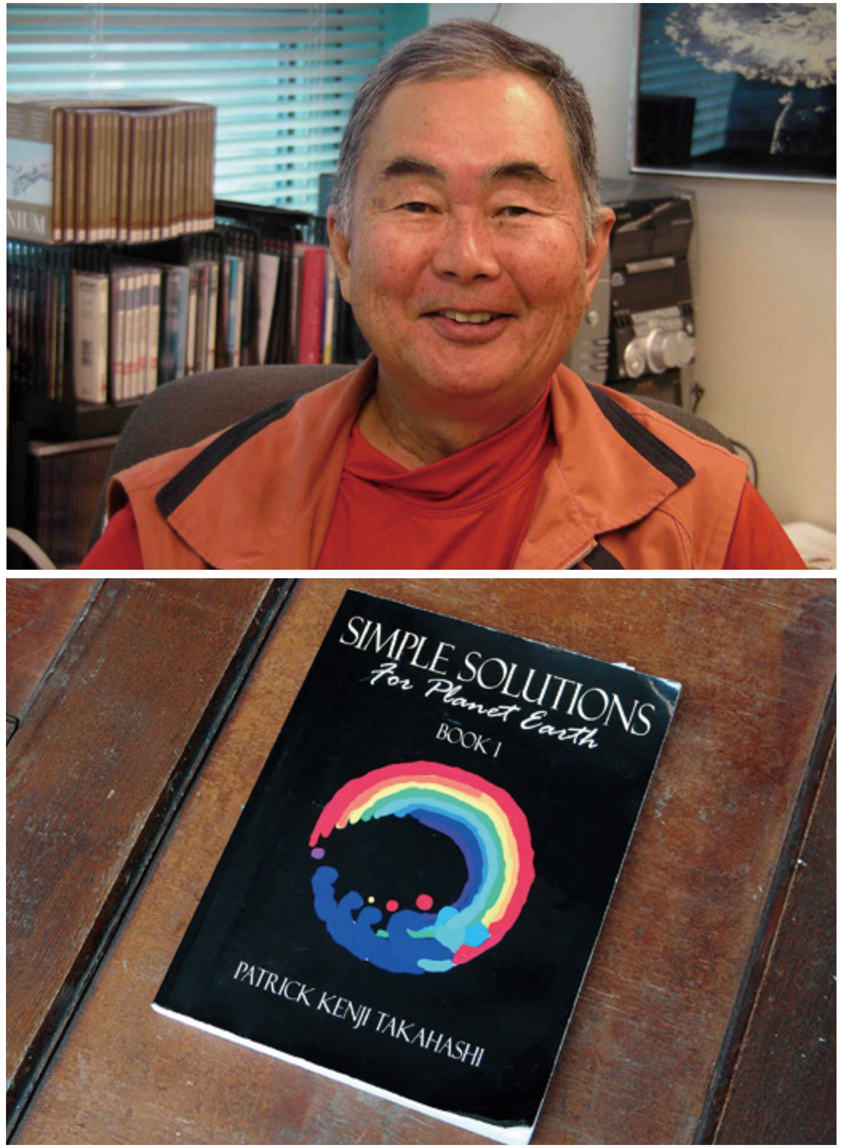
Energy and Politics

Why hasn't this type of ideal energy spread? And how can I get my hands on this type of technology? In reality, it's not just research and technology that stimulates innovation in the energy sector; Government policymaking also plays a large role in how things shake out.

The world, reeling from the oil shocks of the 1970s, decided that nuclear energy would play an important role in economic development, and nuclear plant construction ensued. Currently, there are approximately 420 nuclear power plants worldwide. How far back can we trace the history of Renewable Hydrogen (RH_2)? Electrolysis and fuel cells, which form the basis of RH_2, were invented during the Industrial Revolution. Artificial photosynthesis, which took its inspiration from photosynthesis in plants, was invented in Japan in 1972.

During the oil shocks of the 1970s, hydrogen experts gathered from around the world for an international symposium to discuss an ideal form of energy made from the sun and water. In 1982, a bill was proposed in the U.S. federal government to advance RH_2 as a key energy source. Since then, however, hydrogen has been mostly ignored. While a bill supporting hydrogen development was finally passed in 1990, a budget to support that development was not approved until 13 years later, in 2003, during the term of President George W. Bush. To add insult to injury, funding in that budget was not allocated to RH_2, but rather to hydrogen derived from fossil fuels! In the current Obama administration, the budget for hydrogen is actually decreasing.[15]

[15] For more information, check out the Renewable Hydrogen Network website: <http://en.rh2.org/rh2_info/chapter4/>



Patrick Takahashi worked with Senator Spark Matsunaga to draft and help pass the Hydrogen Research, Development, and Demonstration Act of 1990. He is Director Emeritus of the Hawaii Natural Energy Institute, and in 2007 published *Simple Solutions*, which describes the cultural zeitgeist that inspired the bill.

The Importance of Political Pressure

"The ultimate tragedy is not the oppression and cruelty by the bad people but the silence over that by the good people."

Reverend Dr. Martin Luther King Jr.

If we remain silent and wait, a Renewable Hydrogen society will never come to be. Every person, in order to protect our planet, must play a starring role in taking action to make this a reality.

In Japan, many people think talking about politics is taboo. But is that really okay? Blindly handing over responsibility to politicians and bureaucrats over how to spend our tax money is giving them carte blanche to do as they wish. Tax money being used on uranium and fossil fuels incentivizes financial institutions and corporations to make large investments, forming huge markets that speed up the destruction of the earth's environment. Citizens' indifference supports this trend, and is equivalent to destroying the earth oneself. In order to change this trend, it is not enough to simply show up to voting booths during elections.

We need to generate unprecedented interested in politics and social problems, and develop an understanding of how important it is to take responsibility and action.

Changing the Flow of Capital

Around the world, particularly among the younger generation, there is an increasing sense of crisis over climate change. This has sparked a movement that demands that universities, cities, municipalities, religious organizations, philanthropic organizations, pension funds, and financial institutions recognize the need to stop investing in the fossil fuel industry.

In 2013, when I went to the Rio Earth Summit, students were participating in a rally called "Stop Fossil Fuel Subsidies." On twitter, the hashtag #stopfossilfuelsubsidies was being used.

On September 21, 2014, 400,000 people gathered for the People's Climate March in New York City. Many young people carried placards that read "Climate Justice." Leonardo DiCaprio, who also took part in the march, gave a speech at the UN headquarters to an audience from over 120 countries, saying, "Now is our moment for action. We need to put a price tag on carbon emissions, and eliminate government subsidies for coal, gas, and oil companies."

At Cambridge University, a group of over 40 students demanding an "end to investments to fossil fuel related companies" set up barricades in front of their school. A number of students were arrested, but the university answered the students' demands by freezing all investments to the fossil fuel industry. The Rockefeller Brothers Fund and the World Council of Churches have also divested from the fossil fuel industry.

In April 2015, following a closely watched Vatican climate change meeting at the Pontifical Academies of Sciences and Social Sciences, the attendees released a statement suggesting that a 2015 climate accord may be the last chance to keep global warming within a range deemed "safe" for the world, its people and its ecosystems.[16] The statement pointed out that "human-induced climate change is a scientific reality, and its decisive mitigation is a moral and religious imperative for humanity."

In July 2015, Prince Charles gave a speech at the Cambridge Institute for Sustainability Leadership, during which he said that in order to "rewire the economy" and build synergy between ecological, social and economic goals, there must be an "unprecedented level of cooperation and integration." He continued, "If we are to limit climate change, conserve resources and keep ecosystems functioning, while at the same time improving the health and wellbeing of billions of people...including several billion who are projected to be added to our population later this century...we will need to see profound changes."[17]

In Italy, civil action has been put forward and gained awareness that "climate change is a humanitarian problem."

Those who have realized the critical situation facing planet Earth have abandoned their conventional ways of thinking and have come forward to bravely raise their voices and take action. The current sustainability movement is simply a collective of individuals exhibiting extraordinary strength in the face of crisis.

What I have introduced here is but the tip of the iceberg. I encourage you to research the work of 350.org, which has been leading a global movement to combat the current climate crisis, and is constantly updating and sharing information.

[16] The Washington Post, "2015 the 'last effective opportunity' to safely limit warming, says Vatican conference statement." <http://wapo.st/2e408gp>
[17] To read the full speech check out: The Prince of Wales and The Duchess of Cornwall, <http://www.princeofwales.gov.uk/news-and-diary/12105/speech>

Students taking part in the "Stop Fossil Fuel Subsidies" rally at the 2013 Rio Earth Summit.

People Climate March NYC
Photo By Shadia Fayne Wood, Survival Media Agency (survivalmediaagency.com)

Forming an RH_2 Community

The next step that we at the Renewable Hydrogen Network have chosen, after showcasing the Grid Free RH_2 system in Tokyo, is to build a small community to serve as the center of an energy shift defined by freedom from three things: nuclear energy, fossil fuels, and electricity transmission lines. This community will serve as the "home base" for disseminating information regarding the merits of a cyclical, self-supporting, local resource-driven system of food, energy, and knowledge transfer.

The value of establishing and spreading a community planning model where tangible benefits circulate locally should not be understated. We prosper together when local money isn't drained away by some faceless corporation based outside of the community. I am personally interested in co-creating a community where information is shared freely among technicians, scientists, politicians, bureaucrats, companies, NGOs, and youth.

An RH_2 cycle can be established in a relatively short span without the implementation of large-scale infrastructure. It facilitates a community where people live closely with each other, with individuals holding responsibility for contributing to and invigorating the local economy. The fastest way to realizing a 100% renewable energy future is through this type of community spreading around the world, in synchronicity, like wildfire.

Think Global, Act Local

We are required to live with our roots in the local community, while always keeping in mind the larger global context. Our problems will not be solved with a mindset that, "we have enough electricity in Japan," or, "we can stop using nuclear power because we have natural gas."

Measures taken by developed nations are built on the assumption that, "we must not sacrifice our current standard of living," or, "it is impossible to change our current lifestyle." However, in our current globalized economy, we can no longer brush aside crises in overseas nations as if they are unconnected or irrelevant to us.

"Transition Towns" are currently being built and sustained around the world. This unique and creative grassroots movement arose as a response to the threats of climate change and peak oil, with the aim of using local resources to the fullest, while transitioning away from a fossil fuel-dependent way of life.

In June 2015, I attended a seminar on sustainable development held at the UN University, which was led by David Mungai of Nairobi University. In Nairobi, a severe drought had stunted the growth of grass, which people use to feed their cattle. As a result, people were forced to sell their cattle in exchange for money. With a sustainable source of income now gone, children lost the opportunity to attend school, and young girls were forced into prostitution. People now have to walk tens of kilometers in search of grass to feed their cattle. Where there is grass, cattle are often killed by wild animals competing to secure water or territory to hunt. A hopeless negative spiral has taken hold of the region, and yet its residents know nothing about climate

Mami Harada created a Japanese calligraphy piece that reads "water" for the Grid Free RH_2 machine.

The RH_2 Network is co-creating an RH_2 electric generation system with Mitsuteru Kimura, Visiting Professor at Tohoku Gakuin University. The system creates electricity using wave-power generation, at a tenth of the cost of solar energy (see page 61).

“RH₂ is the Choice of Now,” *Solar Journal*, Volume 11.


きょう世界環

クリーンで持続的

地球温暖化防止

切り札は「R」

自然エネで取り出す

集光型太陽電池 効率よく

市民有志がネットワーク

「コスト削

“R (=renewable) is the Key,” *Mainichi Shimbun*, June 5, 2015.

change.

The discussion of climate change mitigation in the developed world focuses on future generations. However, currently in Africa, over 12 million people are suffering from food shortage as a result of desertification and rivers drying up due to severe droughts. Sadly, over 250,000 people died during a 10-month period starting in July 2011—over half of whom were children. We must face these realities.

We need to put an end to our fossil fuel dependence and deforestation activities this very moment, or it may be too late. We are at a crossroads, where we may still have a chance of saving the future for our children if we act right now. If we concentrate our efforts towards cleaning up the “heart” of all problems—the problem of energy—we will be able to turn from black to white, like how whole rows of pieces on an Othello board rapidly change. We are capable of realizing a more peaceful world of stable political and economic practices. We can reverse a spiral of injustice and transform it to one of justice.

Each of us is dependent on the planet and our local societies. There are no exceptions—not even for fossil fuel companies, their workers and shareholders! No matter how powerful a celebrity, politician, or bureaucrat may be, they are nonetheless connected to something bigger than themselves. Conversely, an individual benefiting in a sustainable way leads to local and national benefits, expanding to eventually become a planetary benefit. We must take step-by-step measures to straightforwardly pursue these common benefits. Now is the time for a paradigm shift towards a value system where these common benefits are the highest priority, which is then in turn supported by laws created by politicians, policies implemented by bureaucrats, products made by companies, and promotional actions by the media and greater public.

It is imperative that we act together in solidarity now. Now is the time to change the political system by connecting separate movements around the world, like a cluster formed by disparate stars. If a policy is put in place that shows a strong will to promote RH_2, taxes will be directed towards related technology, and private investments will be made, eventually giving rise to a huge market. Necessity is the mother of invention: once spectacular innovations are made, costs will go down, and RH_2 will sweep the world. If this happens, the earth's environment—which at the moment looks bleak—will shift in a hopeful direction.

Then, further down the line, we will experience an enormous shift, to a human civilization where life is valued above all other things.

CHAPTER 5

The First RH_2 Building is Complete

On-Site Report at Griffith University

Sir Samuel Griffith Centre at Griffith University

Sir Samuel Griffith Centre—Griffith University

Using Renewable Hydrogen to power itself without relying on the grid, the Sir Samuel Griffith Centre at Griffith University is truly a world-pioneering facility. The Centre is located in Australia's third largest city, Brisbane, a city blessed with an average of 4–6 hours of direct sunlight a day and where—excluding a short winter season—you can easily pass the day in just a t-shirt.

The glass-walled corridors let in plenty of light, and because wind passes through the space in-between these glass walls, it can be hard at times to remember that you are inside. Including the basement level, the building has six floors, each of which contains 1,000 square meters of space. Despite the fact that the building is so spacious, it operates at the very low electricity level of just 60 kW, or 90 kW base load when the elevators are in use. In addition to being equipped with LED motion-detecting lighting and energy-conserving equipment, the building has no scientific laboratories. It can be very difficult to take buildings with laboratories completely off-grid, as they tend to keep their machinery running 24 hours a day. The thinking behind this Centre was to first attempt to take a building with a relatively low electricity demand entirely off the grid, before attempting to tackle a building with higher energy requirements.

The roof of the Centre is covered with 1,194 solar panels capable of generating up to 330 kW of energy. An additional 84 kW can be generated from solar panels located on the sunshades in front of the building's windows, which can be adjusted to the changing angle of the sun's rays throughout the year as the seasons change. The total solar power generating capacity of the facility fluctuates with the seasons, ranging from 1,100 kWh to 1,900 kWh per day (with a yearly average of 1,640 kWh per day). In contrast, the Centre utilizes on average only about 1,200 kWh, meaning that nearly every day, the facility is able to generate about 25% more electricity than it uses and, as a result, a certain amount of electricity is left over.

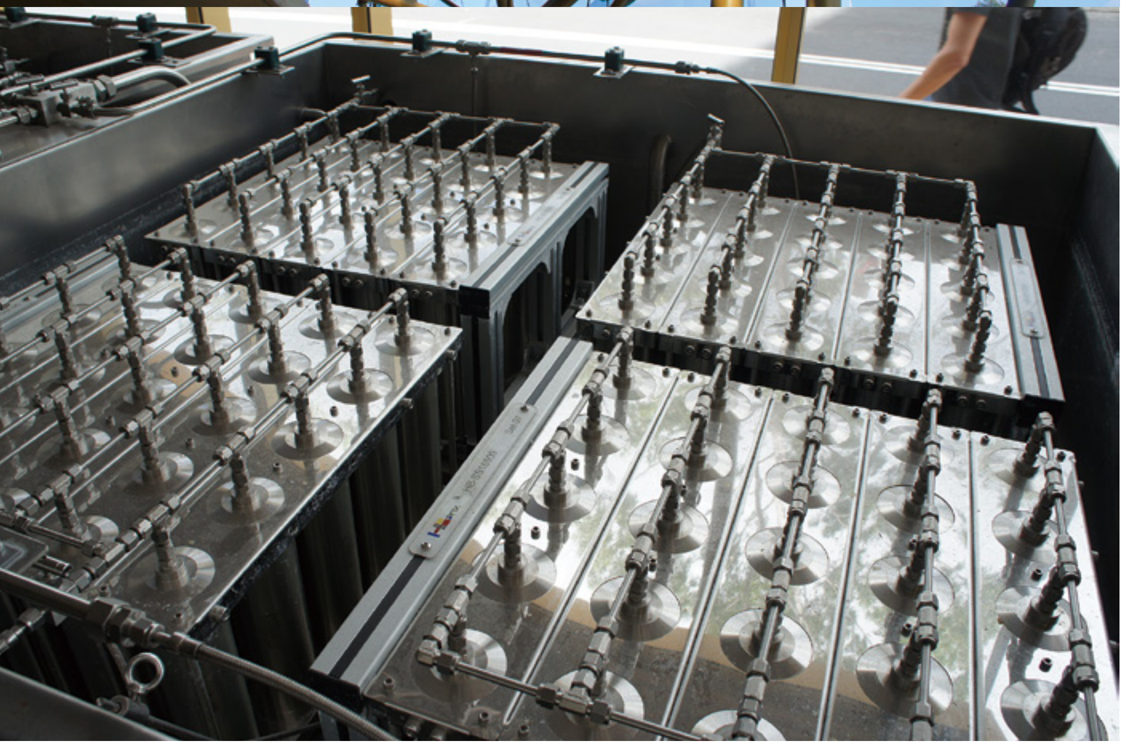
In order to counteract fluctuations in the amount of solar energy the Centre is able to generate on a given day, a certain amount of energy is stored in lithium-ion batteries, which can be used at any time. At night, the excess energy stored in these batteries is used to power a cooling machine that chills water stored in a giant tank adjoining the building. The chilled water is utilized the following day by the Centre's air conditioning system.

When I asked about the efficiency of this system, the response I received was that "regular AC systems account for about 24% of total energy usage; this system is more efficient." It is the cooling equivalent of a central heating system that distributes hot water through a building or local community in order to provide heat. This system chills water and then circulates it through the building in order to help cool the structure, helping make Brisbane's long summer endurable.

In addition, rain water gathered from the Centre's massive roof is used throughout the building in places such as toilets and the sprinkler system, which is used to water plants. In this way, it is clear that the whole building was designed ingeniously, allowing it to remain both off-grid and sustainable.

The Australian government recognizes the Centre as a "sustainable building" and, as a result, approximately half of the construction costs

Rooftop solar with 330 kW of solar panels. (Top)
On the side of the building is a tank that holds cooling water for the air conditioning system. (Bottom)



After entering the building, glass construction gives the impression of one still being outside. Hydrogen storage is accomplished through the use of metal hydride tanks.

were covered by aid from the Queensland state government and other governmental authorities.

Large-Scale RH_2 Systems

The Centre's distinguishing characteristic is its large-scale RH_2 system, whose presence is immediately made known to visitors by the visible battery array supporting the solar panels. To keep the system in good working order, water from which the hydrogen fuel is derived first passes through a purifying device. Then it undergoes electrolysis, where hydrogen and oxygen are separated. In one hour, the system can produce a maximum of 3.6 kg of hydrogen.

Hydrogen storage is accomplished using metal hydride tanks. The metal hydrides bind strongly with hydrogen, preventing leaks and degradation. This ensures that hydrogen is not lost, and that a slow, steady flow of hydrogen can be delivered, making for an extremely safe system.

Professor Evan Gray of Griffith University explains, "In many ways, hydrogen storage is safer than lithium-ion batteries. Hydrogen isn't plagued by unpredictable breakdown, fire, and even explosions. Hydrogen systems also don't rely on a large amount of toxic substances. In particular, in order to ensure the safety of our project, we've built a hydrogen storage that leverages metal hydride tanks."

When it's necessary to use electricity, stored hydrogen is sent into fuel cells, where it can generate electricity as needed. Heat released from the generation of electricity can be used by the hydrogen released from the metal alloy. During the opposite process, when the alloy absorbs hydrogen, electricity is used to cool down the alloy. This particular system is more efficient than the high pressure canister storage utilized by fuel cell vehicles.

Currently, this building is equipped with 900 kWh of battery storage. If weather doesn't permit solar power generation, the fully charged lithium-ion batteries only last four days. On the other hand, at full capacity, the 132 kg of stored hydrogen can last a full week. As of August 2015, fine-tuning of the control system was underway to better integrate the diverse array of technologies, including the metal hydride tanks (the core of the RH_2 system), solar power generation, and battery storage. For Griffith University, whose main mission is the development of RH_2, a plan is underway to gradually reduce the amount of battery storage, and eventually transition completely to hydrogen storage.

INTERVIEW

Professor Ned Pankhurst

Senior Deputy Vice Chancellor

Project Mission and Philosophy

The Sir Samuel Griffith Centre was built to provide a platform for foundational hydrogen technologies, and to provide a space to demonstrate new hydrogen technologies.

We had an internal conversation within Griffith University about how to better showcase our research activities in renewable energy but in particular hydrogen storage. Right then, Professor Evan Gray came to me with a proposal and said, "Here's what an off-grid energy storage building would look like." So I said to him, "Well, why can't we build one?" That was essentially the beginning of the project.

We call this a "demonstration project" but that doesn't mean that it's a project with an end. It's part of Griffith's built environment, and we will run this as a permanent ongoing section of our campus. For us, it's actually a living demonstration of how this technology can work.

Griffith University's interest is strongly commercial; we would like to export this technology. Because much of the activity is in the public domain, it would be possible for us to show people how the system is configured and say, "You can go and do this in another location." There's not much intellectual property unique to this building—what's unique is the way it has been put together. The thing in which we have particular expertise is the know-how, rather than intellectual property.

Energy Parameters & Hydrogen Storage

A solar powered solution was always going to be part of the discussion. The question was how to manage sustainable storage, and that was where our interest in solid state hydrogen storage originated. Solid state hydrogen storage was a potential solution not only for small power stations and off-grid locations, but also for urban locations, like where we've built.

One very nice thing about hydrogen storage is that you can use it for any renewable energy production. You can hook it up to a wind farm or you can hook it up to wave power. We happened to choose photovoltaics (PV) because it's appropriate for the location, but essentially the storage component can operate anywhere.

Cultural Shift

The hydrogen storage system is relatively simple in engineering terms, but it is critical to understand how it is used. We had several rounds of advice and meetings, thoroughly reviewing the parameters of the project, including the people who were going to occupy the building. Part of that activity was designed to ensure that the people understood how the building would be operated. We communicated how we would need them to use the building because its use required some slightly different ways of carrying out day-to-day activities compared

Professor Ned Pankhurst, Senior Deputy Vice Chancellor

On campus view at the Sir Samuel Griffith Centre. (Top)
Of course LED technology is also used for outdoor lighting. (Bottom)

to a traditional building.

In this building, people needed to change how they operate in an office context. That's always difficult for academics. Academics have traditionally worked in their own labs, akin to their own private rooms, but in this new office, we've discarded the partitions. So we've changed the way that people work. For the most part, it has been a very good and happy experience.

There are small but significant ways we ask people to act and behave in this building that are different from what they're used to. It's necessary for people to make these changes in order to coexist in a building with a small energy footprint. After a while, people forget that they ever behaved in any different way, but it does require a cultural shift in terms of the way that the people engage with the built environment.

A Sustainable Energy Project

Renewable energy projects help describe a range of possible futures. One barrier to renewable energy is investment. Everything costs money, and the first time something is done it costs a lot more money than the next time; so in order to get to a financially sustainable level, scale is required.

One hydrogen building doesn't give you scale; ten doesn't give you scale. Only one hundred hydrogen buildings starts to give you scale. The first thing you have to do is demonstrate that it is possible. That's what this building does. The next thing that you have to do is to demonstrate that when you build the next one you can do it cheaper, and the one after that will be cheaper still. This is a balance between desirability and affordability. We will not engage in renewable energy solutions that are essentially unsustainable in financial terms.

Collaboration How-To: The Coffee Cup Principle

The intention of the design of the operational spaces in this building was to encourage people from different disciplines to engage with each other. It is integrated into things like the stairway design, where it's quite nice to stand and have a discussion. The design is deliberate. It's a space people use on a regular basis to stand and talk to each other.

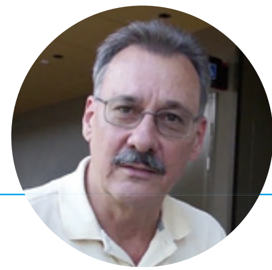
There's a theory from an ex-colleague of mine that effective collaboration only works within the distance you can carry a cup of coffee, and it's called the "coffee cup collaboration theory." It means getting people together around engagement spaces where they meet outside their laboratories or their office environment, and again, part of the building design is to encapsulate that which works exceedingly well.

A MESSAGE FROM

Physics Professor Evan Gray

Hydrogen energy is perceived by many people as something for some distant future, and has been "something for the future" for many decades. The problem with new technology becomes particularly clear when you talk about technology on a global scale; it's not just a matter of technology, but more a matter of politics and economics. So you need someone to be champion and influential who says, "This will happen," and therefore it does happen.

In the case of hydrogen energy, it really needs someone, some country, some state, to decide that they are going to do this. Things happen as much because they say that they are going to happen and because they want them to happen. It's seldom technological barriers that stop them. Most of the technological barriers to the hydrogen economy are really not technological barriers at all. The lesson of humanity is that when you have a technological barrier, you aim clever people at the barrier, and then you knock the barrier down!



EPILOGUE

Let's Shift to an RH_2 Society Together!

Last but not least, in the hope that you'll feel a closer connection to Renewable Hydrogen, I would like to share how and why I began the path I've chosen, which formed the basis of what you've just read.

To start off, I was neither a specialist in hydrogen energy, nor a business person in the energy industry. I was a complete beginner in terms of hydrogen and energy issues. I did have an interest, of course, and was aware of environmental issues, but I wasn't involved as deeply as I am now. Thinking back ten years ago, I would have never imagined I'd be involved in what I am deeply engaged in today.

*

Growing up in Osaka, I tried my hand at a couple of different jobs, and later in 1986 founded an organic cosmetics company called Kohgendo. At that time, my wife, Japanese actress Ai Saotome, mentioned to me how the oil-based foundation she applied during shoots irritated her skin. So I replied, "Well then, let's make something good for your skin!" and we started a company together.

The natural plant-based makeup we developed soon became popular among actors and actresses. Just when our brand was gaining momentum in 2002, I sold the company and moved to Washington State with my family (I was fifty years old at the time). This may sound a little dreamy, but I had always believed there must be something more meaningful in life that I still wasn't aware of. With great conviction, I chose to find an answer to the question of my life's purpose. While this was happening, the people around me kept telling me it was nonsense to give away a company I founded, and one that was still in the process of expanding.

I am sure at some point when you were a child, as you gazed up into the night sky, you pondered something that was at once vague and infinite: "For what purpose was I born?" or "Where are we headed to?" This was the feeling I had when, years later, I decided now was the time to find the answer to those questions. I trusted myself, let go, and began following my intuition.

During my time in Washington I was struck by the impacts of climate change. The ice at the North Pole was melting fast, and I learned that our planet was in such a critical state that even the term "global warming" sounded too nice! Upon this realization, I was shocked and responded, "This is terrible! This is unacceptable! I have nothing to lose!"

After this wake up call, my concern grew stronger as I continued hearing news regarding the disastrous impact of climate change. Hurricane Katrina in the U.S. was just one example of how the most vulnerable were being hit the hardest. Another was a tropical cyclone that hit Myanmar, leaving 150,000 people dead or missing.

As these shocking incidents continued unabated, I deliberately began on a different path with strong determination: from a person who was self-centered and cared about what I got out of it, to the complete opposite—someone who thought simply, and cared most about the planet as a whole. This change was a lesson to my past self, and so began the challenge of living with a completely new set of values in life.

In 2006, I was living a simple life in a camping trailer parked inside an ecovillage in the jungle of Big Island, Hawaii. Deep in the wild, this ecovillage was an extremely unique and artistic place to live. The sound from heavy tropical rain hitting my roof let me forget about myself. Wind blowing through the trees, waves continuously hitting the beach, the sound of the insects singing to each other—just listening

to these sounds soothed my soul. In addition to the sound of Mother Nature, the taste of bananas, mangos, papayas, and avocados I picked directly from neighboring trees left such a deep impression that, to this day, these sweet memories fill me with joy!

Our planet gives us these gifts without expecting anything in return. Before this experience, I held respect for our planet, but after moving to Hawaii, my determination and commitment became stronger. I fell in love with Mother Earth, and day by day my urge to take action for our planet grew stronger and stronger.

One day, I heard about an improbable sounding idea called renewable hydrogen (RH_2). At that time, there were hardly any case studies about hydrogen. Though it may have sounded a little odd, instinctually I felt RH_2 was going to become something extremely important. Again, I took the path no one else had taken, a path completely outside the scope of my imagination. Later on, as I interviewed several people working in the field of renewables and hydrogen, my initial instinct that I had found something important solidified.

I returned to Japan, and in 2008 started the online media platform greenz.jp with some good friends. Our aim was to incubate creative social movements, and share stories from around the world regarding RH_2 research and pilot projects. A year later, in 2009, we founded a nonprofit organization to create, cultivate, and accelerate a global RH_2 movement. We named it the Renewable Hydrogen Network.

*

We will never realize a Renewable Hydrogen (RH_2) society as long as we are simply sitting around, waiting for it to happen. At the end of the day, nearly all the root causes of planetary-scale tragedies, such as war and environmental destruction, lay in the selfish actions of individuals—especially the actions of politicians, bureaucrats, and the elite super-rich. These are people in a position to make big waves in the media and financial world, in pursuit of national or corporate profit.

Let's stop for a second and consider where we are living from a different point of view. Beyond just a residence where we hold certain rights, or a country where we pay certain taxes, this place we call home is, first of all, the surface of a small planet we call Earth. It therefore goes without saying that in order for us to simply stay alive, it is vital we learn how to live in harmony with the cycles and systems of earth's natural environment.

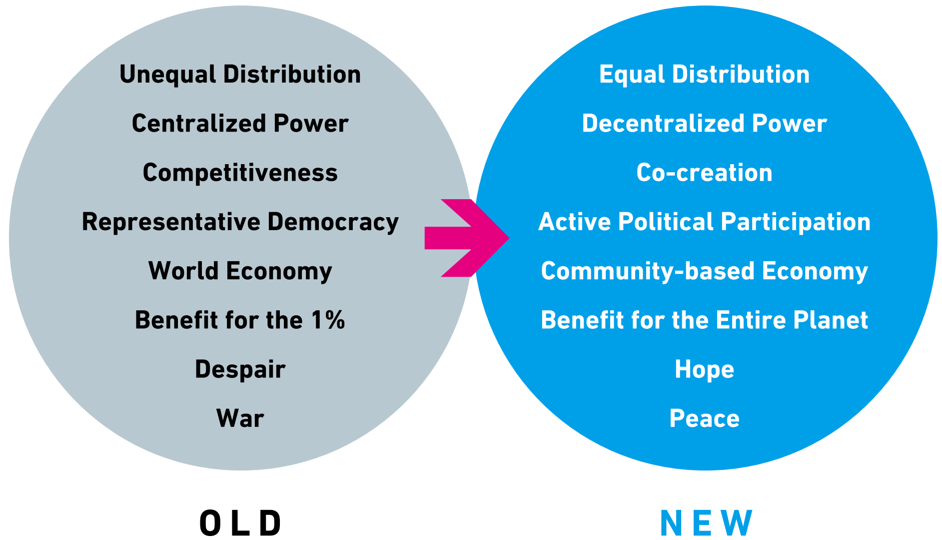
The sun, which is the source of almost all of the energy here on earth, shines its light equally everywhere, and shows no partiality or favoritism. By fully embracing this solar gift and creating an RH_2 society capable of providing energy to all people in an equitable and self-sufficient manner, we can improve lives around the world, including those who are currently suffering from harsh circumstances including poverty, hunger, or a lack of educational opportunity.

As a result, we will be able to realize the full capacity of our species' greatest shared asset—human potential. By increasing the number of individuals engaged in work of greater societal significance, we will undoubtedly start to see blessings we cannot even begin to fathom.

Political arguments and policies related to energy are often very troubling or complicated, but when we change our point of view on this matter, the solution seems utterly simple.

I believe all of you who are reading this book, or who have listened one of my presentations, already possess a strong desire to shift the world in a positive direction. It is said that in the decades to come, humanity will be unable to avoid entering into a miserable and trying

WorldShift



era as a result of the many short-sighted decisions we made in the past—including mass deforestation, and extensive water and air pollution resulting from the spread of harmful chemicals and radioactive substances. However, leaving this behind for a moment, I would like to make the argument that if we are able to firmly grasp a hopeful vision of the future, it will give us the strength to overcome this daunting problem.

History has much to say on the matter. The way of thinking that originally gave birth to such movements as the Renaissance or the Industrial Revolution, was at first possessed by only a very small number of thinkers, scientists, and artists. However, these movements later went on to influence a massive number of people, and change the course of history. And so, while I cannot say with certainty that it will happen in the blink of an eye, it is more than plausible that in this internet-enabled era where we can communicate with someone on the other side of the planet in an instant, we can effectively realize a world shift in a very short amount of time if we were to join forces for the sake of the planet.

The Renewable Hydrogen Network will continue its mission of realizing a "Renewable Hydrogen Society" as soon as humanly possible. We welcome the participation and cooperation of anyone who is willing to join us in our pursuit of this vision.

ACTION!

Here are ways you can help:

- **Recommend this book to politicians or friends**
- **Link to the "Goodies" section of our website (http://en.rh2.org/goodies/) via social networking sites**
- **Conduct study groups or workshops on Renewable Hydrogen (RH_2)**
- **Start Renewable Hydrogen projects at your company or any group you're affiliated with**
- **Recommend RH_2 to your local government representative**
- **Recommend RH_2 as a power source for music and outdoor events**
- **Submit your opinion to diverse media outlets**
- **Convey the RH_2 message to key industry leaders through personal letters**

The ideas above are only a few examples of action you can take.
Let's work together to take action on as many fronts as possible!

RENEWABLE HYDROGEN NETWORK

The Renewable Hydrogen Network is a nonprofit organization that educates and advocates for the realization of a sustainable energy society based on a cycle of local renewable energy and hydrogen. Here is a sample of our activities.

1. Education and Awareness Campaigns
We cultivate social engagement by providing information on RH_2, in simple to understand terms, to the media and general citizens.

2. Research and Consulting
We support innovation by accumulating technical knowledge, and creating networks with companies and academic institutions working with RH_2. All profits made from business and partnerships made with for-profit companies and academic institutions are used to accelerate the energy shift movement.

3. Political Statements
We help expand the market for RH_2 by cooperating with citizen organizations, such as other NPOs and non-government organizations (NGO). Together, we advocate for increased research and development to improve RH_2 technology, and encourage politicians to pass laws to deregulate and subsidize RH_2.

To foster and accelerate a movement to realize a Renewable Hydrogen society, we need your support! Please share what you read and learned from this book with the people around you. Alternately, show your support through donations or volunteering your knowledge and skills with the Renewable Hydrogen Team. Check out our website for more information on how you can help (http://en.rh2.org).

The Renewable Hydrogen Network logo is comprised of three water droplets, which express the three R's central to our mission: Renewable, Respect, and Responsibility.

AUTHOR

Haruyoshi Ebara (Chooneui Ham)

Chairman of the Renewable Hydrogen Network

1986: Establishes the natural skin care company KohGenDo Co., Ltd. with his wife, Japanese film actress Ai Saotome. KohGenDo's products grow to become a preferred choice among actresses and actors.

2002: Haruyoshi leaves his position as Chairman and CEO of KohGenDo Co., Ltd., to move to the United States with his family, where he learns of the increasing impact of climate change. Later on, in Hawaii, he learns about a form of clean energy known as Renewable Hydrogen.

2008: Haruyoshi moves back to Japan and establishes greenz.jp with his fellow colleagues. Greenz.jp is a creative internet media source in Japan dedicated to selecting innovative and socially good ideas from around the world to promote a sustainable society based on Renewable Hydrogen.

2009: Establishes the nonprofit Renewable Hydrogen Network, based in Tokyo, Japan.

SUPERVISOR

Tomoyo Nonaka

Chair and Founder of GAIA Initiative, formed in 2007 as a nonprofit organization. Full member of The Club of Rome. Formerly served as Chairman and CEO of Sanyo Electric Co. Ltd., in addition to serving as a director and advisor at various large Japanese corporations.

TECHNICAL SUPERVISOR

Professor Kimitaka Yamane

Head of the Yamane Hydrogen Energy Research Centre. He holds a Ph.D. in Engineering, and is Councilor and Editor at Hydrogen Energy Systems Society of Japan (HESS). Also, Chairman of Global Business Society, and Assistant Professor at the Hydrogen in Energy Research Centre at Tokyo City University (*formerly*, Musashi Institute of Technology) until March 2013. Since the 1970s, known as a pioneer in the research of hydrogen engines.

Professor Bruno G. Pollet

An international research leader in Electrochemical Engineering, Electrochemical Energy Conversion, Energy Materials, and Sono-electrochemistry. He is currently Chief Technology Officer at KP2M Ltd. (UK) and Visiting Professor at the Universities of Ulster (UK) & Yamanashi (Japan). He was a full Professor of Energy Materials & Systems at the University of the Western Cape (South Africa), and an Associate Director of the Birmingham Centre for Hydrogen & Fuel Cell Research (UK).

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Translation Team	Adam Lobel, Rina Ariizumi, Ian Shimizu, Kaori Ishii, Stephen Johnson, Marie Tanao, and Tatsuya Inoue
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