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Green Innovations and Building of a Low-carbon Society

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Abstract

This article examines the processes through which innovation is created from the perspective of innovating towards the building of a low carbon society, what types of social change will take place due to those innovations, and finally considers how a low carbon society will be created through the analysis of case examples.

This article assumes 2 types of innovations. These are product innovation led by business, how the products (and services)created by business are supported by markets, and the social innovations that are created as those product innovations infuse throughout society. This article makes the assertion that the effective joining and linking up of these 2 types of innovation will lead to the creation of a low carbon society.

Introduction

“Low-carbon society” is a phrase often heard in recent times, and as the phrase suggests, means aiming for lower carbon use to reduce carbon dioxide emissions, a cause of global warming. However, because carbon dioxide emissions are closely related to economic activity, it is not easy for entire societies to reduce their emissions - the sluggish implementation of global warming countermeasures through the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP) due to conflicts of interest is already well known.

This article discusses the problem of building of a low-carbon society from the perspective of innovation. In short, this article aims to show how companies can play the lead in innovating green products, how those developments will induce green social innovation as key to bringing about a low-carbon society, and the processes through which these 2 types of innovation can be effectively interlocked.

First of all, this article reviews the current state of (worsening) global warming and the measures taken to date under the Kyoto Protocol, and then examines processes through which the 2 innovations have been effectively linked through case studies in the automotive industry

I. The current state of the global warming problem

1. The increasing urgency of the global warming problem

There is a growing level of seriousness to the global warming phenomenon. In today's world it can be seen that disasters caused by rising temperatures are becoming a reality.

Taking major natural disasters that have occurred since 2000 for instance, more than 1 million head of cattle have died as a result of heavy snow (Mongolia, 2000), more than 1,000 people died from flooding (China, 2002), more than 52,000 people died in the heat wave that occurred in Europe in 2003, while Australia saw a 60% drop in wheat production in 2003 due to drought. 2,000 people died in India and Bangladesh in 2004 due to heavy rain, at least 1,700 people died from the hurricane in America in 2005, while in Russia in 2010, Moscow experienced record-breaking temperatures of 37.8℃, resulting in forest fires and subsequent air-pollution, leading to the evacuation of 100,000 people. In 2011, Queensland in Australia was hit by devastating floods that covered an area greater than the size of France and Germany combined.

Although a quarter of a century has passed since the alarm was first sounded on the global warming crisis, continued ineffectiveness in implementing countermeasures will mean the world must realistically deal with the looming threat of global warming.

The mechanisms of global warming has become more well-known among ordinary people, and although they should not really need revisiting, I would like to once more outline the assumptions that are taken into any discussions on global warming.

We live on a planet that has sometimes been called “the miracle planet.” The reason for this reference is that temperatures on earth are optimized for life to survive (maintained at an average of 14℃). The temperature of the Earth is determined by the equilibrium between the solar energy that strikes the planet and the heat energy that radiates back into space. Gases such as carbon dioxide, methane and nitrous oxide in the atmosphere act to trap the heat radiated from the Earth's surface, and are therefore known as “greenhouse gases.” If these greenhouse gases did not exist in the atmosphere, almost all the heat would radiate back into space and the temperature of the earth would be -18℃ on average.

Therefore, these greenhouse gases are essential to the survival of life on Earth, thus problems can arise if their normal concentrations are exceeded. When the concentration of greenhouse gases in the atmosphere exceeds a certain level, the usual amount of heat is not re-radiated back into space and accumulates in the atmosphere leading to rising temperatures.

The concentration of atmospheric carbon dioxide in the 19th century was fairly constant at around 260~280 ppm, but since the beginning of the 20th century has been steadily rising to its current level of about 400 ppm. As a result, reports show that average global temperatures rose by about 0.74℃ over the 100 years of the 20th century.

Since the world formed 4.6 billion years ago, there have been a number of occasions when major climatic changes have threatened the survival of living organisms. Ice ages have occurred roughly once every 100,000 years over the last million years, interspersed with periods of warming, and various species have become extinct during those times.) However, current warming phenomenon is clearly not due to natural mechanisms but is man-made[i]. As stated, this man-made phenomenon is evidenced by the more than 100ppm increase in atmospheric CO_2 concentration and accompanying the 0.74℃ temperature rise during the 20th century compared to the relatively stable levels seen in the 19th century, and in terms of the Earth's history, that 100 year period is a mere the blink of the eye.

On top of that, CO_2 emissions continue to increase into the 21st-century, and temperatures are predicted to rise between 1.1 and 6.4℃ by 2090-99 compared to the 1980-99 average. If those predictions become reality, natural disasters will become even more intense and damaging, and directly threaten our very survival.

2. Issues with global warming countermeasures

The global warming problem is becoming more serious. However, what countermeasures have humans taken to date, and what have these measures achieved? It is important to note the following 2 points when considering measures to mitigate the global warming problem.

(1) Efforts have to be made cooperatively and internationally.

(2) There must be economic incentives to make these efforts.

Firstly, with regard to point (1), measures to mitigate global warming won't achieve much if they are only undertaken by particular countries or regions. The first Kyoto Protocol[ii] commitment period that expired in 2012 is a pertinent example of this problem. The world's greatest CO_2 emitters - countries such as China, America and India - did not commit to this international agreement, but those that did - the EU, Japan and others that reduced their emissions - only account for 1/4 of the global emissions total. For this reason, the effectiveness of past global warming countermeasures has naturally been called into question.

Aiming for 2020, there are currently negotiations underway on a framework for global warming countermeasures that include China, America and India, but whether an effective framework can be put into place remains unclear.

Although there are questions surrounding internationally binding measures under the Kyoto Protocol, certain evaluations can be made regarding point (2) above, i.e. the attachment of economic incentives to mitigation measures. - There are economic mechanisms such as emissions trading introduced under the Kyoto Protocol[iii]. These systems include the following:

1. International emissions trading schemes that enable trading of some emissions between developed countries that set CO_2 emissions frameworks.
2. Clean Development Mechanisms (CDM) that enable developed countries to add reduction results to their own targets if they supply capital and technology to developing countries to contribute to CO_2 reduction in those countries.
3. Joint implementation (JI) in which CO_2 emission reduction is jointly undertaken in developed countries, and emission reduction allowances can be assigned to investing countries by the countries that conduct emission removal projects.

Global warming countermeasures that appeal to people's conscience or sense of morality are not realistic ways to deal with the problem. Of course, one cannot deny the worthy intent of such measures or hold them in contempt - certainly the problem is essentially a moral one, however it cannot be solved with ethical or moral sentiments alone.

It is often noted that there is overall agreement about the problem of global warming, but opposition to particular approaches to dealing with it. What does this actually mean? - Nobody is advocating against the general idea that the global environment should be maintained in a healthy state – morally and ethically everybody agrees. However, when it comes to the actual details of what to do about the problem, opposing opinions are voiced one

after the other. For example, industry is unanimous against the levying of taxes such as a carbon tax to reduce carbon dioxide emissions. In other words, even if there is a general resonance of principles, many are opposed to taking specific measures if such measures are not economically desirable. This is a natural consequence of the economic character of humans (so-called “homo economics”) and the market principles that drive our societies. For those reasons, global warming countermeasures that don't include economic incentives are essentially useless. Thus as international rules, the 3 Kyoto Mechanisms defined under the Kyoto Protocol are innovative mechanisms that could substantially impact on the effectiveness of global warming countermeasures.

On the other hand, the Kyoto Protocol has also exposed the limitations of measures to mitigate global warming - as stated, with countries such as China, America and India refusing to participate, Kyoto Protocol countermeasures have only been enacted under conditions far from the ideal of international solidarity. These problems are caused by conflicts between developed and developing nations over the issues, and currently there is no organization in the world capable of resolving such conflicts. Of course, the United Nations is one organization, and many global warming countermeasures including the Kyoto Protocol are discussed under its sponsorship, but unfortunately in its current state the United Nations does not have the power to resolve conflicts of interests between developed and developing countries. Thus, the creation of an effective international framework is proving to be problematic[iv]. For example, the Intergovernmental Panel on Climate Change (IPCC) predicts that critical conditions can be avoided if the temperature does not increase more than 2℃ over the next 100 years, but this requires that global carbon dioxide emissions are reduced to 50% of 1990 levels by the year 2050. Is this really possible with the current mechanisms that are in place?

Of course to achieve these figures cooperation between developed and developing countries is crucial, but can the negotiation and conflict resolving capabilities of the United Nations really be relied upon? Unfortunately, this is highly questionable. Even achieving agreement among developed countries under the Kyoto Protocol to reduce carbon dioxide emissions by a mere 5% has been fraught with difficulty. And even if an international framework that includes countries such as China, America and India is put in place after 2020, there is ample reason to assume that there will be cases of withdrawal during its implementation, such as the case of America's past refusal to participate in the Kyoto Protocol.

Put simply, looking at the circumstances surrounding negotiations on global warming countermeasures to date, serious impediments to the formulation and implementation of effective international frameworks exist, including countries’ acceptance of numerical targets for the reduction of CO_2 emissions, while the United Nations seems unable to take the required initiatives. Instead, it would be better if it acted as a world opinion leader regarding United Nations-led global warming countermeasures - even if an effective international framework cannot be put into place, at least continued ringing of alarm bells will arouse international opinion leading to increased importance being placed on global warming countermeasures in both developed and developing countries. These kinds of developments will help induce the 2 innovations (green product innovation, green social innovation), which I believe in turn will trigger the formation of low-carbon societies.

II. Green Product Innovation

Looking at the historical relationship between environmental problems and business activity, business has been perceived as the root cause of environmental damage, and criticism of business's sense of responsibility has been overwhelming[v]. It is undeniable that business activities have adversely impacted the earth by squandering resources and polluting the environment. It is also a certainty that business activities are the major cause of the global warming problem. However, attempting to solve the problem by criticizing business and implementing controls on those activities as has been done in the past will not be so effective. It is of course necessary to regulate business activities as one measure to control global warming, but left to regulation alone, comprehensive solutions will become more remote. What is needed now are mechanisms devised to enable companies to proactively bring forth environmentally-friendly services and products under market economies. Humans must move away from the high-carbon society of the 20th century (with its high CO_2 emissions) to the low-carbon society of the 21st-century, and its actually business that must play the lead role in creating the innovations needed to bring about such large-scale social transformation.

Just as J.A.Schumpeter pointed out, society has undergone dynamic transformations with the creation of innovations[vi] in the past, and thus we already have the experience of recreating society.

According to this concept, capitalist societies undergo 50-year economic cycles[vii] that are driven by dynamic technological innovation. In other words, in the 250 years since the beginning of the Industrial Revolution that begun in the latter half of the 18th century, society has been reformed and the behaviour patterns and values of people transfigured at each juncture when a technological innovation has emerged, such as the invention of steam locomotion, railroads, electricity, the automobile, chemical advances, atomic power and the development of information technology. Technological innovation is thus a driving force for societal change. It stimulates economies and rebuilds society at new levels, which is the basic gist of the innovation theory put forth by Schumpeter.

Economic cycles in the first half of the 21st-century are unfolding as a "fifth wave." So what technological innovations will be the key economic drivers during this period? I believe these will unmistakably be technological innovations built on the "low-carbon" keyword. This means development and dissemination of hybrid and electric vehicles, fuel cell vehicles, photovoltaic and wind power generation, low-carbon products and so forth that will propel economies in the first half of the 21st-century, thus driving social reconfiguration towards the creation of the low-carbon society - in other words, green innovation.

1. Green product innovation in automobiles

The automobile industry is one industry symbolic of global warming countermeasures. Since about 20% of the total global CO_2 emissions come from petroleum burning automobiles, they have a big impact on global warming, and as the real problem of crude oil depletion encroaches, the shift away from fossil fuel dependence has become nothing less than a matter of survival for auto industry players.

A century has passed since the birth of the automobile industry, but it stands at a major turning point. The problems it now faces are not the usual ones of cruising distance, speed,

quality and price over which automakers have traditionally competed, but the fundamental nature of automobiles - problems associated with designing and manufacturing automobiles that can run on something other than petroleum fuels. This is the type of massive transformation that would only happen once in 100 years of an industry, and accordingly has come to be called an automotive revolution[viii].

The three types of next-generation vehicles currently gaining attention, hybrid, electric and fuel cell, are described below.

(1) Hybrid vehicles

Developed by Toyota and first released in 1997, the Prius is the world's first hybrid car, and has achieved steady sales in Japan to earn its place as a full member of the automobile citizenry. Hybrids are powered by both an electric motor and an internal combustion engine, and as such are not completely "petroleum-free" vehicles. These vehicles are propelled by the electric motor in situations where petroleum combustion is inefficient, such as accelerating or driving at low speeds, but when driving at steady speeds when combustion efficiency is high, the vehicle switches over to propulsion from the petroleum engine. By switching the 2 motors according to load in this way, these vehicles are able to reduce fuel consumption and hence exhaust gases. This mechanism made it possible to reduce CO_2 emissions by up to 50% compared to older petroleum-powered vehicles.

Although conventional petroleum-powered vehicles have also undergone repeated upgrades to improve fuel efficiency and control exhaust gases[ix], the development of the hybrid vehicle is a different class of innovation, because while ordinary technological innovation has usually involved improving the existing structure of the petroleum engine, the hybrid vehicle development involved technological innovation that changed the fundamental structure of vehicles. As stated previously, hybrid vehicles most certainly have a petroleum engine in them, and they are not completely petroleum-free. Nevertheless, hybrids represent a major development in the 100-year history of petroleum-powered vehicles, because the hybrid is the first ever example of successful development and commercialization of a vehicle that uses a propulsion mechanism other than a petroleum-fuelled motor, and in that regard, the hybrid is the creation of innovation.

Moreover, hybrid vehicles continue to advance. Hybrid vehicles use a combination of an electric and petroleum motor, an a hybrid vehicle that is closer to a completely electric vehicle has been developed by increasing the size of the electric motor in proportion to the petroleum motor. This vehicle is the known as the "plug-in hybrid." Plug-in hybrids are different from the older style of hybrid vehicles that use a motor to supplement the petroleum engine, because they normally run on the electric motor and only use the petroleum-powered engine when battery charge is depleted or when running at high speed. The capacity of the nickel hydride or lithium ion batteries that are used in these vehicles is larger, and they offer the extra convenience of charging from ordinary domestic power outlets. Thus, plug-in hybrids have gone even further than the older hybrid versions to diminish the standing of the petroleum-powered engine. These vehicles are almost completely electric, but still use a petroleum engine to cover for the inadequacies of a purely electric vehicle to create a vehicle superior in its pragmatism, and hold great promise of reducing carbon dioxide emissions.

(2) Electric Vehicles

In contrast to the hybrid and plug-in hybrid vehicles that are not completely petroleum-free, the total absence of a petroleum engine makes electric vehicles completely different. However, vehicles that are driven by electrical energy are in no way a recent development - in fact they were developed even further back in history than the petroleum-powered vehicles[x]. There have also been a number of electric vehicle booms since the supply of crude oil became unstable in the latter half of the 20th century.

Here again, the reason that electric vehicles are in the spotlight now is that this time around technological innovations have greatly improved the battery performance of these vehicles, something that has always hindered their popularization in the past. Batteries conventionally installed and electric vehicles have mostly been lead-acid batteries - low capacity batteries that only enable only short cruising distances between charges. However, recent and remarkable technological innovations in nickel hydride and lithium ion battery developments[xi] have seen big increases to battery capacity that have advanced the practicality of electric vehicles.

The Mitsubishi-developed “i-MiEV” released in 2009 uses the latest lithium ion battery to give the vehicle a cruising distance of 160 km between charges. Best of all, these vehicles release absolutely no CO_2 into the atmosphere when they are running.

In terms of global warming countermeasures, electric vehicle development and popularization has huge potential, and there are actually new companies emerging as anticipation grows for the electric vehicle market expansion[xii], although market expansion hasn’t been as swift as expected.

With the “from petroleum to electric” sloganeering, the awareness of these innovations has grown substantially, but at the moment that awareness does not appear to have been accompanied by much movement, because there is a technological weak point that electric vehicles only have short cruising distances. Currently, electric vehicles are only able to run about half the distance between charges of the distance that a petroleum-powered vehicle can run between fills. In addition, the majority view is that it will be challenging to achieve cruising distances in the same league as petroleum vehicles even with technological innovation. Thus, the short cruising distances and the relatively long time required to charge electric vehicles are serious drawbacks compared to the convenience of petroleum powered vehicles. Thus, it's currently difficult to conceive of electric vehicles taking over from petroleum-powered vehicles in large countries like America where long distances often have to be covered. Therefore, electric vehicle demand growth has centered on demand for second cars or for short-range commuter vehicles.

(3) Fuel cell vehicles

Fuel cell vehicles work on the chemical reaction between hydrogen and oxygen to produce electricity to power the vehicle. The fuel cell is the device in the vehicle that generates electricity through this hydrogen-oxygen reaction. While these vehicles are running only clean water is emitted, and since there is absolutely no carbon dioxide emitted, these vehicles have come to be known as “the ultimate in eco-cars.”

Just like electric vehicles above, fuel cell vehicles are completely petroleum-free vehicles and thus hold great promise as global warming countermeasures, and in particular, fuel cell

vehicles win out over electric vehicles in terms of cruising distance, since they potentially have the same cruising distance as petroleum-powered vehicles[xiii]. These features have made fuel cell vehicles the favorite to become the next-generation car, but there are some high hurdles that need to be surmounted before genuine commercialization and popularization can be achieved.

The first problem is durability. Fuel cell durability and deterioration problems are technical challenges facing fuel cell vehicle development. A target of 5,000 hours has been set for fuel cell life, and research into fuel cell deterioration mechanisms is ongoing.

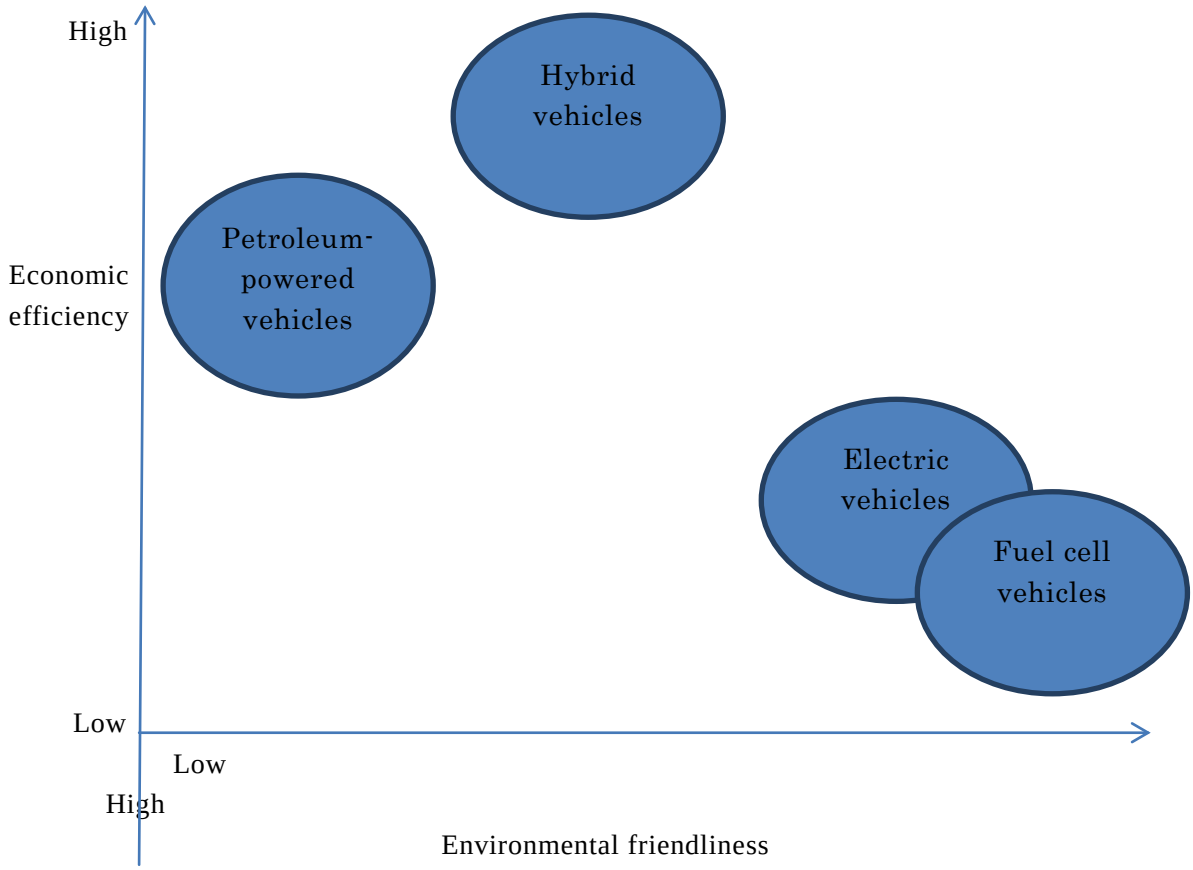
The second problem is infrastructure. For fuel cell vehicles to become widespread, hydrogen stations must be set up so that drivers can fill up their tanks. Including the problem of coordination with existing gas stations, this problem must be solved in conjunction with the popularization of fuel cell vehicles, although if these vehicles start to take off filling station construction might also spread quickly.

The third problem is cost. To date, prohibitive cost has been one of the major barriers to the spread of fuel cell vehicles. For example, fuel cell vehicles developed by Toyota and Honda in 2002 would have cost $1 million or more had they been commercialized. The high cost of these vehicles is associated with expensive platinum catalysts used in the cells, and as such, reducing the amount of platinum is a determining factor in reducing costs, and as a result of improvements, the amount of platinum used has been successfully reduced to the point where it is now possible to set a market price at half a million, meaning that prospects for commercialization have become closer to being more realistic.

One noteworthy aspect of the movements in fuel cell development is the alliances that have formed between auto makers all over the world. 2012 saw news on the agreement between BMW and Toyota for joint fuel cell vehicle development while other automakers have been going in the same direction, suggesting potential further reconfiguration of global automotive manufacturers in step with the spread of fuel cell vehicles[xiv].

The “MIRAI” developed by Toyota released in 2014 as the first fuel cell vehicles in the world.

Figure 1 Comparison of petroleum, hybrid, electric and fuel cell vehicles



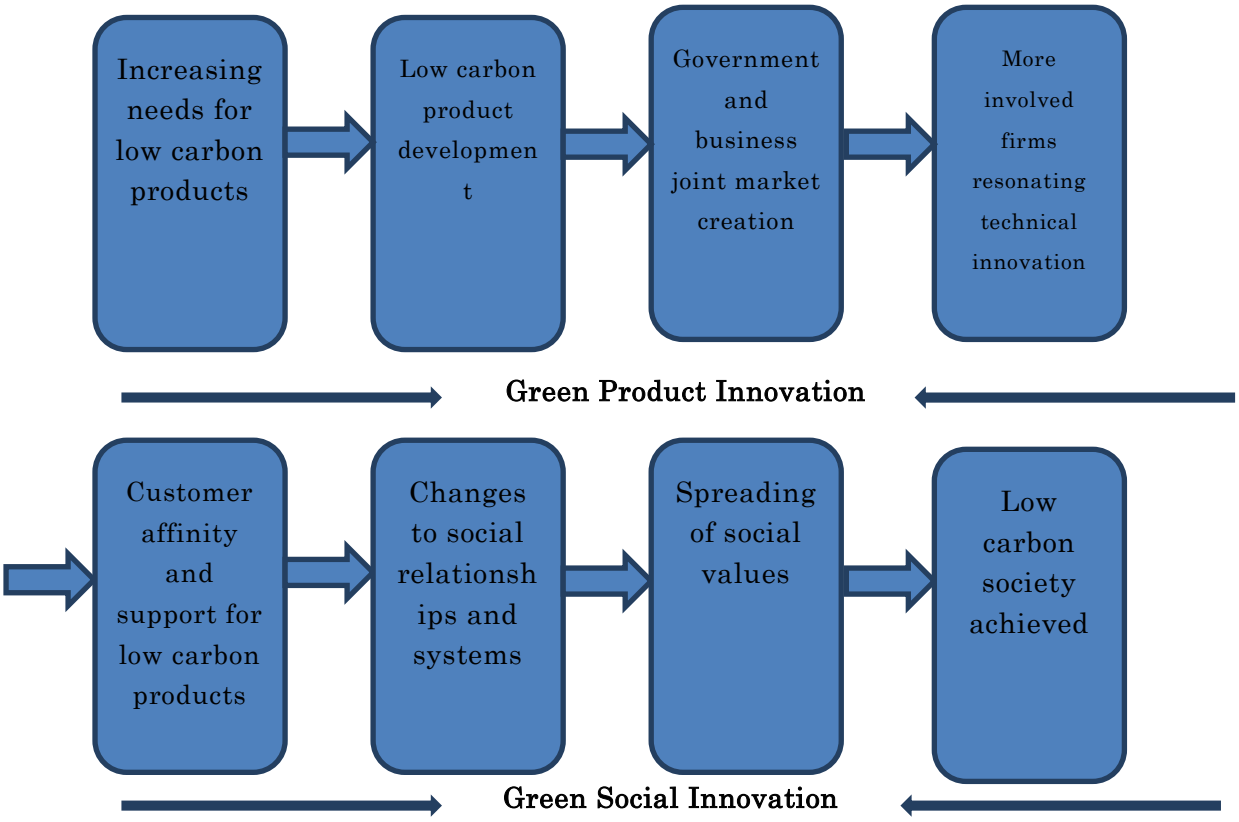
Source: Created by the author

III. Green Social Innovation

As has been pointed out, the society of the 21st century must make a clean break from the high-carbon society of the 20th century and become a low-carbon one. First of all, this means so-called “green products” must be innovated through technical developments to produce a wide range of low-carbon products, undertakings that will be led by business. The previous section provided an overview of trends in the electric vehicle and solar power fields, and similar trends can also be found in other fields [xv]. Before long, these new low-carbon products will spread and permeate throughout society, impacting on social mechanisms and people's lifestyles to bring about a new society - the low-carbon society. Trends in social systems like this are nothing other than green social innovation, and the 21st-century low-carbon society will be achieved by the effective integration of the 2 innovations - green product innovation with green social innovation.

What types of processes will bind together green product innovation with green social innovation? Figure 2 describes the process through which green product innovation will lead to green social innovation.

Figure 2 From Green Product Innovation to Green Social Innovation



Source: Created by the author

I would like to emphasize the third phase in this diagram - "Government and business joint market creation." With increasing social demands for low-carbon products, even if businesses succeed in developing them, the third phase is essential to achieve market support and therefore permeation of the products through society. If the third phase cannot be successfully implemented, it will be difficult to effectively integrate green product innovation with green social innovation. This can also be shown by analysis of the popularization of hybrid cars or solar power.

Hybrid cars have become well established in the Japanese market place, however, popularization of them was driven by support through government initiatives. To promote hybrid cars, the 2 initiatives that the government took were tax incentives and subsidies. For example if you bought a Toyota Prius, you were exempt from vehicle excise and weight tax - an amount between JPY130,000 to 140,000. The government also offered a maximum JPY 250,000 subsidy to purchasers. That meant support at the combined value of tax exemptions and subsidies at around JPY 400,000. If the government had not taken these support initiatives, the hybrid car market would not be experiencing the prosperity that it does today.

The same can also be said for solar power. Implementation of solar power is continuing in Japan at an accelerated rate, with market expansion being driven by a renewable energy feed-in tariff introduced in 2012 [xvi]. Under this system, power companies must buy up

electricity generated from renewable sources such as solar, wind and geothermal, which has spurned the increase of new market participants and rapidly expanded the market. In Japan, government subsidies were provided for residential solar panel installation from the 1990s to the early 2000s. During that time, Japan led the world in solar power deployment, but with the scrapping of the subsidies system in 2005, Germany, a country that introduced a feed-in tariff, took the lead from Japan. However, with the introduction of the feed-in tariff in Japan in 2012 and the subsequent market expansion this time around, the role of government and the importance of support measures in these areas have been reaffirmed.

When the market for low-carbon goods is created jointly by government and business, the number of companies participating in the market to make a profit increases, and the resulting competition and partnering brings the beneficial effects of market mechanisms. In this process, chains of technological innovation - resonant interactions – will serve to bring about even greater product performance at even lower prices that in turn will bring about low-carbon product affinity and support from customers.

When the market supports low-carbon products, changes in social relationships and systems will occur as they become popularized through society. This corresponds to the 6th phase shown in Figure 2. The role of low-carbon products is to draw entire societies away from high-carbon to low-carbon regimes - changes that absolutely have to happen - but specifically what changes occur with social systems and relationships? It’s easy to answer this question by looking at the popularization of solar power. As stated, the popularization of solar power has been heavily reliant on feed-in tariffs. In other words, by introducing these systems, the number of solar panels on rooftops, including dwellings and ordinary households, has increased. These systems have enabled households to produce electricity themselves, and sell their unused power back to their electricity company, thus creating new social relationships.

Put differently, in the old social relationship, electric power, a linchpin infrastructure in society, was managed exclusively by power companies - electricity was generated in power stations and supplied to households through the power transmission grid, and the electric company charged the household, according to how much electricity it used. The electric power company as a supplier and the household as the power consumer were in a clearly defined relationship, with the power company having the authority to decide on how much electricity to supply and how much to charge. In contrast, the feed-in tariff has redefined this old social relationship and brought the potential for great change to the relationship between householders and power companies, meaning that the one-sided nature of power companies can no longer be replied upon. If households are able to generate their own electricity to meet their needs, surely that will influence on people's lifestyles and behaviours.

Moreover, social changes regarding electricity will move to a new level if companies other than power companies are able to participate in the business of electricity generation and transmission with the separation of generation and transmission as is currently being discussed in Japan.

Smart city experiments around the world including Japan are using IT to manage electricity supply and demand, and optimize usage by flexibly accommodating two-way power transmission and consumption within particular areas, experiments that aim to create communities that reduce energy use and hence carbon dioxide emissions. A society in which

generation and transmission are controlled with IT and in which businesses and households exchange electricity as necessary is not so far off.

Finally, I would like to discuss the 7th phase – “spreading social values.” To achieve a low-carbon society, new social values must be spread. The final steps to building a low-carbon society are changes in people's behaviours and value systems. No matter how technologies are innovated or advanced or technologies brought into being that have the potential to bring about revolutions in society, ultimately, it is human beings who learn how to use those technologies. Thus, if the way that people think and the macrocosm of social values doesn't change, there won't be any lasting change in society. Therefore, “spreading social values” must be the final phase of green social innovation.

So, to what do new social values refer? Considering the qualities of a low-carbon society obviously entails the embedded value of “environmentally friendly” - but is that enough? These social values cannot be mere abstract ideas or concepts. They must have tangible characteristics, be infused deeply into the thinking and actions of people, and be able to move communities and society to action. Ecologists and specialists involved with environmental problems have been loudly sounding the alarm about environmental threats facing the planet, and have asserted that more importance should be placed on environmental protection than on the pursuit of economic profit. Over time, these assertions have gradually gained the sympathies of people and become infused into society as environmental protection values. Now in the 21st century, it is no longer possible to engage in business activities without considering environmental conservation, and a certain proportion of consumers have become highly aware of environmental issues. However, as social values, these “environmentally friendly” sentiments are not common throughout all of society and thus cannot bring about sweeping and dynamic social change, because environmental values are not the key drivers to our socio-economic systems.

As stated, there is general agreement on environmental problems, but disagreement on the particulars - everyone agrees to the principal of environmental protection, but when it comes to the details of what to do about it, there are many conflicting economic interests involved and opposition to various protection measures. In short, it is the pursuit of economic profit that is the main driver of our socio-economic systems, and social values that neglect that fact are actually not much use. For example, the hybrid vehicles discussed in this article would most probably have spread to some degree among consumers with high environmental awareness even without government support, but that would amount to one part of society being moved to action, and would never have become a revolution involving the whole of society. In other words, this would have been a green social movement among certain environmentally-concerned consumers, but could not have qualified as genuine green social innovation.

Therefore, to trigger dynamic social revolution that encompasses all of society, social values must also appeal to consumers who do not have a high level of environmental awareness – these values must simultaneously reflect both the environmental and economic aspects. This is why offering incentives such as subsidies, tax exemptions and feed-in tariffs as motivations to purchase hybrid cars or solar panels means that people will end up being environmentally friendly by purchasing those kinds of products, regardless of their intentions. To reiterate,

social values that do not take economic value into consideration are nothing more than abstract ideas that cannot bring about real effects.

IV. Conclusions and Implications

The low-carbon society will be created by the effective linking of 2 types of innovation - green product innovation led by business, and the green social innovation created as low-carbon products that result from green product innovation are infused through society, and key to tying these 2 types of innovation together are the economic support initiatives taken by governments. This conclusion can be drawn from looking at the processes of developing and popularizing hybrid cars , and thus it’s probable that similar processes will be followed with the popularization of next-generation vehicles such as electric and fuel cell vehicles.

As has been pointed out, capitalist society has already survived and prospered through the destruction of old systems and subsequent social reconfiguration brought about by major technological revolutions, and now businesses are now advancing with green product innovation towards the colossal challenge of transforming a high-carbon society into a low-carbon one. The hybrid vehicles mentioned in this article are past examples of effective linking of the 2 types of innovation described, and can now be seen as being at the social level innovation stage.

As future issues, focus should be on how the low-carbon products that come about can be combined effectively to achieve a low-carbon society - however much individual products follow low-carbon design, disparate use of them is meaningless as it will not bring about a low-carbon regime for the whole of society - optimizing the parts is optimizing the whole, as it were.

Already, trials in overall optimization with smart houses, smart buildings and smart cities are being conducted, and the key to speeding up these movements is once again, government support.

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Notes

[i] The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report on Climate Change announced in 2007 concluded that the current change in climate has been caused by increasing human economic activity.
[ii] An international treaty on greenhouse gas reduction adopted at the Third Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3), held in Kyoto in December 1997. Numerical targets for the reduction were introduced for the first time at this convention. Targets of EU 8%, United States 7% and Japan 6% were established, but the United States later withdrew from the treaty.
[iii] These systems are referred to as Kyoto Mechanisms.
[iv] Lead by the United Nations, the Conference of the Parties to the Framework Convention on Climate Change (COP) has been held every year since 1995, but has become a place where conflicts of interest occur between developed and developing countries. Other than the first commitment period that ended in 2012, the convention has failed to establish any international frameworks.
[v] After Rachel Carson's 1962 book "Silent Spring" alerted the world to the problem of environmental pollution from mainly agricultural chemicals, culpability of chemical manufacturers in the United States was pursued. Furthermore, studies questioning corporate responsibility regarding the pollution problem were carried out in Japan during the 60's and 70's when the problem became a social one.
[vi] Innovation does not just mean technical transformation. As the driving force of economic development, Schumpeter defined innovation as combinations of the five elements of "new product developments", "new production methods," "development of new markets," "development of new raw materials" and "building a new organizations."
[vii] "Kondratieff wave" is named after the Russian (former Soviet) economist Nikolai Kondratieff who put forth this business cycle theory.
[viii] The automotive industry has an extremely broad base that includes parts manufacturers and related industries (including service industries), and as such can have major effects on entire economies. The problem of shifting away from petroleum-powered vehicles is not only a problem confronting automobile manufacturers, but one that can potentially bring about fundamental shifts in related industries and cause major changes to the way industries are structured.
[ix] For example, the CVCC engine developed by Honda ahead of other global manufacturers in 1973 was famed for having passed the 1/10th air pollutant reduction (CO, HC, NOx etc) in exhaust gasses required by the Clean Air Act in the United States.
[x] Electric vehicles were developed in the United Kingdom and France during the emergence of the automotive industry in the late 19th century.
[xi] Nickel hydride and lithium ion battery developments have advanced as the demand for high capacity, compact and lightweight batteries that can be installed in personal computers and mobile phones has increased. Notably, both of these battery types were developed by Japanese companies.
[xii] For example, some companies, such as Tesla Motors of America or BYD of China did not have experience in automobile manufacture, but embarked on the production of electric vehicles regardless.
[xiii] For example, the Honda "FCX Clarity" fuel cell vehicle developed in 2007 achieved a cruising distance of 570 Km on one hydrogen filling. Similarly in 2007, Toyota also successfully ran their "Toyota FCHV" from Tokyo to Osaka on a single tank of hydrogen filled to 700 atmospheres.
[xiv] GM and Honda, Daimler and Renault-Nissan also have also formed partnerships respectively for the joint development of fuel cell vehicles. These partnerships have

been formed as a way of tackling the problem of the massive cost of fuel cell vehicle development. So far, the investments made by automobile manufacturers have been said to be upwards of JPY 200 billion. Such financial undertakings by sole companies can put serious pressure on their management.

[xv] Green product innovation is not limited to manufacturing. For example, new types of financial instruments called “environmental finance” have rapidly appeared in the field of finance since 2000. Typical examples include investment fund-type “eco-fund” financial products.

[xvi] Germany was the first country to introduce feed-in tariffs. Since introduction of the system in Germany in 2004, deployment of solar power has progressed in leaps and bounds. However, because power companies are forced to cover the feed-in tariff by raising charges and thus increase the overall price of electricity, there is growing pressure to review the system. Similar things are happening in Spain.