Towards Realizing a Sustainable Society with an “Urban Vein”-type Energy Conversion and Cycling System: Initiatives of Keihanna Science City

Jiro SENDA
Department of Mechanical Engineering and Science,
Graduate School of Science and Engineering, Doshisha University

This article provides an overview of environmental and energy problems; introduces the concept of the holonic energy path, a hydrogen energy usage system in which the author was involved and whose importance will increase in the future, and initiatives being undertaken by Keihanna Science City; discusses the relationship between urban structures and energy society; and offers a summary of the above.

1. Global warming and environmental problems: Declarations of carbon neutrality

The Kyoto Protocol, which emerged from the 3rd Conference of Parties (COP-3) to the United Nations Framework Convention on Climate Change (UNFCCC) held in 1997, established targets for reducing greenhouse gases (GHGs) such as CO_2, which cause global warming, with a focus on advanced nations. (Japan’s target was a 6% reduction from 1990 levels.) Those targets precipitated an urgent global response to global warming, and in the fall of 2013, the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reiterated the significant impacts of CO_2. Also in 2013, COP-19 called on Japan to reduce CO_2 emissions 3.8% from 2005 levels by 2020. That target was equivalent to a 3% increase compared to the 1990 levels used in COP-3. At the same time, the International Energy Agency (IEA) reported in 2010 that it expected production of conventional fossil resources to decline starting around 2030, and inexpensive production of shale gas began, primarily in the U.S.

The 21st Conference of Parties (COP-21) to the UNFCCC, which was held in December 2015, saw the adoption of the Paris Agreement, which entered into effect in 2016. The agreement presented a series of initiatives to limit the rise in mean global temperature to below 2°C above pre-industrial levels and obligated Japan to cut CO_2 emissions by 80% by 2050. An IEA report published in 2019 warned that sharing of crude oil from existing conventional deposits would come to end 30 years in the future, in 2050, and that the world would enter upon a crude oil crisis. Japan’s 5th Basic Energy Plan, published in 2018, describes plans for slashing greenhouse gases by 26% relative to 2013 levels by 2030 and by 80% by 2050. Various countries subsequently issued declarations of carbon neutrality, and Japan declared its intention to achieve carbon neutrality by 2050 in October 2010. The country then formulated the “Green Growth Strategy Through Achieving Carbon Neutrality in 2050” in December 2010 (Fig. 1), emphasizing electrification, biofuel, and hydrogen fuel for the transport sector. In response, Japan's 6th Basic Energy Plan, which was published in 2021, revised the 2030 greenhouse gas reduction target to 46%.

According to certain statistics (Fig. 2), Japanese CO_2 emissions in FY2019 can be broken down as follows: 35% from the industrial sector, 19% from the transport sector, 17% from the commercial sector, and 14% from households. In this way, commercial and household use, that is, consumer use, accounts for 32% of all emissions, highlighting the urgent need to cut carbon use by radically reducing primary energy use of, and dependency on, fossil fuels by consumers, meaning in urban living spaces, in order to reduce overall carbon use.

2. Energy problems and renewable energy

Recently, society's focus in environmental and energy problems is shifting, along with the tenor of the times, from air environmental problems to the problem of global warming caused by greenhouse gases (GHGs) like CO_2, and towards the problem of sustainable energy. This warming problem is synonymous with the problem of the continued existence of a sustainable, urban, and civilized society through a shift from fossil resources to renewable energy or policies that pursue similar goals, for example to expand the percentage of electricity from nuclear power.

According to the Agency for Natural Resources and Energy, Japan's primary energy mix in generation during FY2019 was as follows: 84% from fossil resources (including 37% from oil, 25% from coal, and 22% from natural gas), 9% from renewable energy, and 3% from nuclear power, while 3% went unused. Over the last 10 or so years, observers believed that we had already reached an era of peak oil for thermal power generation using fossil resources and that we would see a shift towards compound systems and gas, including technologies such as high-efficiency gasification power generation using coal, which exists in large quantities (the integrated gasification combined cycle, IGCC, which yields a gross thermal efficiency of about 53%); the gas turbine combined cycle (GTCC, which yields a gross thermal efficiency of about 62%); and the triple combined cycle, which combines the IGCC with fuel cells (SOFC) (IGFC, which yields a gross thermal efficiency of about 65%). However, since the formulation of the Green Growth Strategy in 2020, decarbonization has moved towards the maximization of renewable energy, hydrogen power generation, thermal generation combined with carbon capture systems (CCSs), and development of next-generation nuclear reactors, while future-oriented research and development have focused on ammonia power generation.

At the same time, the percentage of power accounted for by nuclear energy in Japan has fallen since the Great East Japan Earthquake of 2011, making it important to maximize use of natural energy sources with the potential to cover declines in hydraulic-dam, thermal and nuclear power (specifically, solar, wind, micro-hydro, and biomass, none of which provides power on demand) and to resolve problems including storage of energy from those systems, development of a best mix of urban energy supplies, and optimization of supply in response to demand. Photovoltaic (PV) power generation has a head start in Japan, but wind power is the dominant technology worldwide; according to the Worldwatch Institute in the U.S., the combined equipment capacity of the world's natural energy installations exceeded the generating capacity of its nuclear power plants for the first time in 2010. Wind power accounts for more than half of that natural energy.

Concerning biomass energy, which is one source of renewable energy, we ought to be able to build a sustainable next-generation energy society based on energy-independent urban structures if we can realize cyclical use through the pollution-free and complete energy conversion of various wastes produced by cities (from urban veins).

Following is a description of the characteristics of renewable energy and natural energy:

① Generally speaking, resource quantity is low, meaning energy density (kWh) (availability) is low (unrelated to power density [kW] [equipment capacity]).

② For most types of renewable and natural energy, operation cannot be synchronized with civilized activities, and they are dependent upon natural phenomena, meaning they are not available on demand; as a result, energy storage is a must.

③ Operation is characterized by zero emissions, but there are questions about CO_2 reduction benefits in a life cycle assessment sense when plant installation and disposal processes are considered.

Renewable and natural energy includes the following:

① Use of solar energy

(1) Photovoltaic (PV) power generation: Both residential and megasolar installations are a major source of energy in Japan. Solar thermal power generation is suited to sunbelt areas and can operate in an on-demand manner.

(2) Use of solar heat: Residential hot water systems, commercial solar cooling

② Wind power generation: A major source of energy in the EU; in Japan, moving from terrestrial to marine.

③ Compact hydropower: Can provide steady-state power generation.

④ Geothermal power generation: Promising as a source of on-demand power generation, but environmental assessment and other factors will take time. Japan has extensive quantities of resources, and development will expand in the future.

⑤ Use of biomass energy (with on-demand potential)

(1) Power generation using wood biomass and urban waste biomass

(2) Vehicle fuels including bioethanol and biodiesel

⑥ Use of marine energy (marine temperature difference power generation)

3. Holonic energy paths

Until now, all energy sources used in our urban society (power, natural gas, and water) have depended on large-scale, concentrated hard paths as infrastructure. By contrast, experiments that install on-site compact facilities in urban living spaces (various cogeneration systems [CGS] and natural/renewable energy such as solar and wind power) known as micro grids or smart grids in cities, buildings, and residential areas as decentralized, small-scale energy supplies (soft paths) and control them so that they operate harmoniously with the hard paths of infrastructure have recently reached the demonstration stage.

The holonic energy path is a concept that seeks to organically harmonize decentralized energy and our overall system in an effort to build a sustainable and independent society and thereby deliver the seemingly impossible trinity of a stable energy supply, environmental conservation, and economic growth. In other words, the idea is to form holonic paths (organic blends of individual components and entire systems) in order to minimize energy use by allocating hard paths that consist primarily of large-scale, concentrated systems and soft paths that consist primarily of on-site, small-scale, decentralized systems so that available technologies are used in an optimal manner. In other words, the goal is to effect a paradigm shift from the stage characterized by industrial products that have been greenified and streamlined (individual optimization) to a stage of overall optimization that seeks to further reduce carbon dependence and boost efficiency through the optimal placement of those products in living spaces.

Fig. 3 illustrates how the author proposes to map future urban transportation to an automobile/vehicle society based on the holonic-EP concept. Vehicles with a variety of power units should be optimized for specific applications that take advantage of their characteristics in a map of travel distance and user density.

Fig. 4 provides a conceptual diagram of future urban energy networks founded on the same holonic-EP concept. Reflecting the need to reduce dependency by the urban society of the future on infrastructure in the form of power networks and gas supply networks (hard energy paths) following the Great East Japan Earthquake, we need to move quickly to build compact cities with built-in compact, dispersed energy supply systems (soft energy paths) consisting of components such as various types of renewable energy and high-efficiency equipment (CHG, CGS); in other words, we need to build a sustainable, energy-independent foundation for society. The important thing here is that we work to increase energy independence by forming energy networks characterized by local generation for local consumption, meaning that energy generated on-site (in the form of electricity or heat) is consumed in the same region, instead of being sold to power companies via hard paths. We should build power systems that maximize use of renewable energy via micro-grid networks for charging of electric vehicles (BEVs) to accommodate the recent electrification of vehicles and avoid imposing losses on the hard-path electric grid.

4. Future prospects for use of hydrogen energy: Power to gas, power to liquid

This section introduces the energy-saving calculation results for a composite system consisting of photovoltaic (PV) power and solid oxide fuel cell cogeneration (SOFC) as proposed by the author in 1999. As illustrated in Fig. 5, this system utilizes power from a PV installation to manufacture hydrogen using an alkaline-type water electrolysis device and store solar energy in the form of hydrogen as an energy carrier. The hydrogen is then mixed with natural gas and supplied to an SOFC system to facilitate cogeneration in response to household demand for power and heat. When there is a sufficient volume of hydrogen, power from the PV installation can be fed back into the grid. If a polymer electrolyte fuel cell (PEFC) is used instead of the SOFC system, it can operate on pure hydrogen alone, allowing for full energy independence without relying on natural gas if enough PV and FC capacity is installed. This research combined actual hardware components and conducted a demonstration, and it also analyzed various models.

Since around 2010, the authors have also conducted research to analyze optimization models with regard to the problem of how to improve energy independence by applying hydrogen energy derived from not-on-demand renewable energy such as PV power and wind power to remote islands and cities. Fig. 6 provides an overview of that research. Although regions like remote islands that have isolated energy infrastructure have traditionally relied on diesel generators to supply power, the application of hydrogen derived from natural energy along with various cogeneration systems and heat source equipment makes possible dramatic improvements in energy independence. For the purpose of this article, I carried out an optimization analysis of primary energy consumption, CO_2 reductions, and costs (initial costs and running costs) as an objective function.

The approach of manufacturing hydrogen from not-on-demand renewable energy that is not synchronized to human beings' civilized activities, storing hydrogen gas as an energy carrier, and then using it when required, which is known as "power to gas," sparked lively discussions in the energy economy field starting in 2010. The local consumption of locally produced renewable energy via thermoelectric conversion, in which hydrogen energy is used on-site instead of transporting it through the hard path consisting of centralized thermal power plants via the feed-in tariff (FIT) mechanism is also optimal from the holonic energy path perspective.

The National Institute of Advanced Industrial Science and Technology established the Fukushima Renewable Energy Institute in April 2014 to carry out fundamental and applied research into various forms of renewable energy. The facility's programs include state-funded Strategic Innovation Programs (SIPs) involving hydrogen carrier manufacturing and utilization technologies. We're current conducting research into a power supply system that cycles natural energy, as illustrated in Fig. 7. In short, the system manufactures hydrogen from renewable energy by means of electrolysis, dissolves the hydrogen into a liquid hydrocarbon fuel known as toluene, and stores it as a liquid hydrogen carrier (methylcyclohexane, or MCH). This liquid is then heated by the exhaust gas from a diesel engine to separate the hydrogen, which is then supplied to the engine's intake. At the same time, biodiesel fuel manufactured from biomass resources is injected into the engine's combustion chamber to facilitate the efficient ignition and combustion of the hydrogen fuel. As a result, the system can supply power as well as heat recovered from the engine's exhaust energy. This approach, known as power to gas to liquid, is an example of a new thermoelectric supply network that does not depend on underground resources.

5. Initiatives of Keihanna Science City

The authors took the lead in establishing the Keihanna Environment and Energy Workshop at the Public Foundation of Kansai Research Institute (New Industry Creation and Interactive Community Center) in 2008, and the group has pursued a variety of initiatives related to urban planning founded on coexistence with the environment. Building on those initiatives, Keihanna e-Power was established in April 2011 as a general corporate judicial person to create new industries related to the environment and energy from Keihanna Science City by working with the Public Foundation of Kansai Research Institute and other partners to develop applications for technologies created at Keihanna Science City, particularly superheated steam-type gasification and carbonization systems; to conduct investigate research; to facilitate research exchanges; and to develop a network of professional connections. Later, the Keihanna Green Innovation Forum (KGI Forum) (Fig. 8) was founded in 2015 with three goals: implementing the Ubiquitous Science Plan, forming a society characterized by energy independence (autonomy), and accumulating and passing on knowledge. As part of this KGI Forum, Keihanna e-Power was dissolved to form Keihanna Green Energy Institute (Keihanna GE Institute), which continues to work towards creating demonstration projects, with the goal of realizing an energy-independent society.

The KGI Forum and Keihanna GE Institute are addressing the following topics:

①The fossil resources (coal, oil, and natural gas) that currently support our civilized activities are limited and will eventually run out.

②At the same time, CO_2 and other greenhouse gases given off by the combustion of hydrocarbons (HCs) from fossil resources are considered to be contributing to global warming. As a result, it is necessary to maximize use of energy systems that do not depend on fossil resources and renewable energy and to realize energy independence and autonomy through the use of existing green energy.

③We're considering the potential of a resource-cycling society that converts all forms of garbage, including organic waste and general industrial waste, from our neighborhoods and urban living areas along with sewage sludge, livestock manure, and other resources into fuel via a completely pollution-free process and utilizes them along with locally produced green resources from agricultural villages and forestry areas as locally produced energy to supply both heat and electricity using cogeneration technology.

The Great East Japan Earthquake of March 11, 2011, brought immense damage to the Tohoku region and triggered a crisis at one of the area's nuclear power plants. Since that time, there has been a lively discussion about the need to move quickly to build compact cities with their own compact, decentralized energy supply systems that can reduce dependence on infrastructure in the form of power networks and gas supply networks (hard energy paths) in Japan. The disaster also spurred public interest in supporting the recovery of affected areas, including processing of debris, and in using debris for energy. "Building a Low-carbon, Zero-emissions Society Through a System for Completely Converting Organic Waste into Energy" was a technology development and social system demonstration project geared toward realizing a low-carbon society that we carried out in the Keihanna Science City region from 2009 to 2010 under contract on behalf of the Ministry of Economy, Trade and Industry.

5-1. A waste biomass energy-cycling society

The demonstration project illustrated in Fig. 9 was carried out in the town of Seika in the Keihanna region in 2009 under contract on behalf of the Ministry of Economy, Trade and Industry. The system collects organic waste from households (50 kg/h), manufactures flammable biogas using a completely pollution-free process via a gasification reform system using superheated steam, and supplies it to an engine cogeneration system to supply heat and power. In short, our goal was to build a zero-emissions society that recycles waste-derived biomass. The reforming system is clean and can be miniaturized. Since FY2010, we've worked with a private-sector company to develop technology for separating and gasifying plastic and glass fiber composite waste, which is considered the most difficult component in organic waste to process, with the result that the above test system delivers decentralized power generation capability for all organic waste and can be used locally in the areas where waste is produced.

Fig. 10 generalizes this information to illustrate the urban spaces where we reside and live from the perspective of an arterial system, a venous system, and energy flows. The arterial system, embodying inputs to the city, consists of energy (power and gas), food, and water. By contrast, the venous system, which carries waste from the city, consists of various types of organic waste, including garbage; sewage sludge; livestock manure; and other waste products. If all materials carried by this urban venous system in the city's area could be converted into energy in a completely pollution-free, high-efficiency manner, and if the power and heat energy that resulted from that process could be distributed and used within the city (using urban wide-area cogeneration), which is to say, if soft energy from urban waste could be locally produced and locally consumed, it would be possible to realize a zero-waste society. The resulting improvement in energy independence would allow us to minimize hard-path energy and realize stable, low-carbon living spaces in society, which would ultimately contribute to the realization of a zero-waste society.

This system for converting urban waste into energy functions in an on-demand manner that synchronizes with our lives, making it possible to complement renewable energy on the urban grid, level out the supply of heat and power, and minimize dependence on energy from hard paths. If facilities like garbage incineration plans and sewage treatment plants, which traditionally have attracted "not in my backyard" (NIMBY) criticism, could be made completely pollution-free, they could be installed within cities or inside various buildings and in residential areas, effecting a transformation in the urban structure itself.

5-2. Smart community demonstration

Fig. 11 provides an overview of the Keihanna Eco-city Promotion Plan adopted by the Kyoto Prefectural Assembly in December 2009. The plan includes greenifying Doshisha University's Kyotanabe Campus; reducing carbon dependency in the area around the town of Seika, including Keihanna Plaza at the heart of Keihanna Science City; undertaking the demonstration of waste biomass energy cycling, described above; and building smart homes in Doshisha Yamate, an eco-town that is described below.

This section introduces a demonstration project entitled "Proposal of Environmental Coexistence in the Doshisha Yamate District" (Fig. 12) from the City of Kyotanabe, which is located next to Doshisha University's Kyotanabe Campus. The Doshisha Yamate Sustainable Urban City Council was formed in 2005 to administer the 64.5-hectare area, which upon completion will have 6,100 residents. The council, which is chaired by the author and managed by the Urban Renaissance Agency, has a membership consisting of residents, energy companies, housing manufacturers, local governments (Kyoto Prefecture and the City of Kyotanabe), the Public Foundation of Kansai Research Institute, and consulting companies. Acting on an analysis of a range of energy consumption data, in 2009 it adopted the target of reducing CO_2 emissions in the district by 50% by 2020. As illustrated in Fig. 13, it will do so through five leading projects: (1) encouraging construction of low-carbon housing, (2) building an "eco-community plaza," (3) creating smart lifestyles, (4) building a regional energy management system, and (5) building a low-carbon transportation system.

Furthermore, the Kyoto Prefecture/Keihanna area was chosen as one of several large-scale environmentally friendly urban smart city demonstration projects in four regions nationwide, a program launched by the Ministry of Economy, Trade and Industry in April 2010, launching the five-year "Kyoto Prefecture/Keihanna Eco-city Next-generation Energy and Social System Demonstration Project." The Keihanna Eco-city Promotion Council, which is chaired by Kyoto Prefecture, was formed to implement this large-scale, state-funded project, and the author participated as a member. Fig. 14 illustrates the area covered by the project, while Figs. 15 and 16 illustrate its schedule and content. The project, which was undertaken in partnership with 30 leading companies in the Kansai region, worked on all schemes to form a sustainable, low-carbon/decarbonized society, including household energy visualization, home energy management (HEMS), building energy management (BEMS), EV centers, EV charging networks, V2X, power demand response, and community energy management (CEMS). It also included research related to a feasibility study of the modal shift and conversion of lifestyle waste into energy.

To facilitate the development of sustainable smart communities in the future, we should consider priorities such as maximizing on-site natural energy, realizing organic system control (ICT) for minimizing energy in partnership with hard energy paths, and reforming urban structures.

6. The relationship between urban structures and energy society

Through my intensive involvement to date in a range of urban planning and energy grid analysis and research, I've become acutely aware of the relationships between urban structures and energy society. The nature of optimal mobility (vehicle transport, etc.) for nations and regions and of energy networks is likely to depend ultimately on the underlying urban structures. As BRICS and other developing nations look to develop new cities and districts going forward, designing optimal structures will likely be an essential part of the drive to realize future energy savings and energy independence. In Japan, where there is an existing, and already completed, urban network, the systematic construction of micro grids and smart grids will probably prove to be extremely difficult. However, as described above, the development of systems that facilitate the mutual use of energy and resources by augmenting various forms of renewable energy with cyclical use of urban waste will be an extraordinarily important factor in the formation of the sustainable urban society of the future.

As an example, the following offers a simple comparison between Western and Japanese urban structures. Please note that this comparison is general, conceptual, and entirely based on my own personal views.

(1) West (independent, decentralized, and coordinated)

*Cities include major central cities and smaller regional cities in a decentralized, clustered arrangement.

• Power networks and gas supply lines adopt a comparatively weaker structure due to reliance on small-scale manufacturers.

• Smart meters have been installed for a large percentage of customers to prevent electricity theft (Italy).

• An energy-independent society is being built as a way to deal with frequent power outages (MG began in Silicon Valley).

• Traveling long distances on a vast inter-city road network is an everyday occurrence, so diesel vehicles provide better fuel economy than hybrid vehicles.

• That said, downtown areas have imposed restrictions on vehicles, and public transportation is being built out.

(2) Japan (central command and control)

*Cities are distributed in a continuous, sustained manner, for example along the Tokaido coast.

• Large-scale manufacturers dominate regional power networks and gas supply lines, and infrastructure is robust.

• Transmission networks and other facilities are built for strength in an advanced manner; the outage rate is extremely low, and there is no electricity theft.

• Due to the continuous distribution of cities, transportation within cities is prone to congestion, making hybrid vehicles advantageous.

• Vehicles have access to downtown areas as a matter of course.

7. Afterword

Following is a list summarizing key points for building a low-carbon urban society (with sustainable urban cities) as described above.

1. Sustainable engineering and civil engineering are necessary as part of a comprehensive, scientific approach in which the natural sciences, social sciences, and humanities all play a role.
   → Building a platform for a human resources development program
2. Consortiums must be established to facilitate the construction of sustainable urban cities.
   Developing these as special districts with a sustainable energy design
3. Building smart communities involves system integration.
   → Building business models capable of independence
   → Using subsidies to progress from the demonstration stage to general use and creating organizational systems that function as aggregators
4. We must introduce a variety of incentives to promote energy savings and the EMS streamlining.
   → Eco points, megawatts, CO_2 emissions rights trading in cities and residential areas?
   → It’s necessary to discuss the fairness of incentives (CDM, Cap & Trade).
5. It’s necessary to discuss the scale benefits of smart communities (EMS optimal solutions vary).
   → National grids, county grids, area grids, micro grids, nano grids
   (Including regional use of heat) → Increasing regional energy independence
6. Raising awareness of environmental problems through environmental education for residents and citizens

that begins during the childhood years; transforming resident and citizen awareness and lifestyles

= Helping cities grow → Fostering regional communities (local governments and residents' associations) = sustainability

→ Think globally, act locally; global social responsibility (GSR)

In closing, I'd like to note a few thoughts.

*Moving from a high tech-oriented civilization to a passive tech-oriented terrestrial resource civilization

*Increasing the energy independence (autonomy) of on-site, compact, decentralized systems in order to build a sustainable civilized society

• Completely clean energy conversion of all waste (venous system) from our civilized activities (cities and residential areas) and on-site use of the resulting heat and electricity (local production for local consumption)

*Creating new natural sciences, for example the study of coexistence with nature and the environment and the study of connections linking forests, villages, rivers, and oceans (association of all resources)

• Creating new civilized cities that don't destroy natural cycles and maximizing use of nature

• Developing science and technologies that don't leave a tab for the next generation and the generation after that

• Transforming lifestyles to accept passivity; demand response

*Creating comprehensive civil engineering as a field for the next generation in partnership with the social sciences, humanities, and other disciplines, including public policy, optimal community formation, and regulations

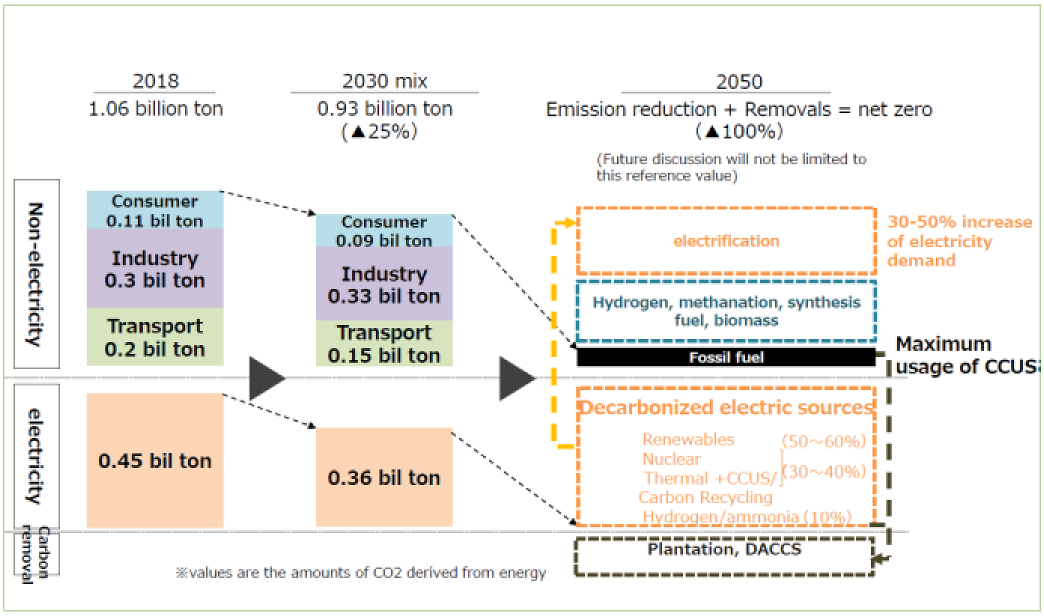

Fig.1 Energy Outlook of Carbon Neutrality in 2050 by METI

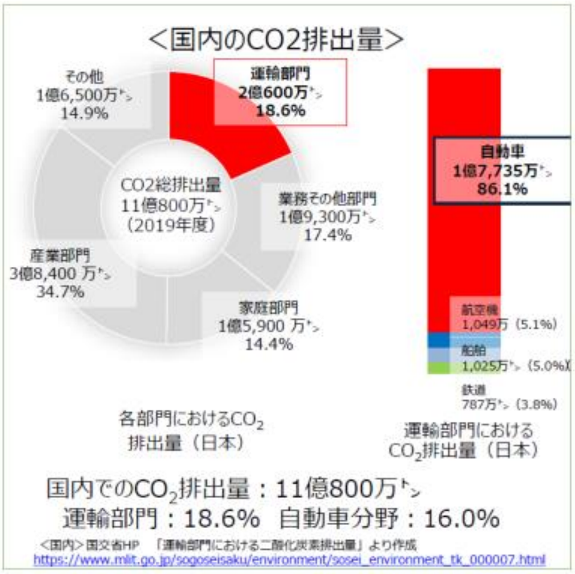

Fig.2 CO2 Emission Ration in Each Sector in 2019 - Japan

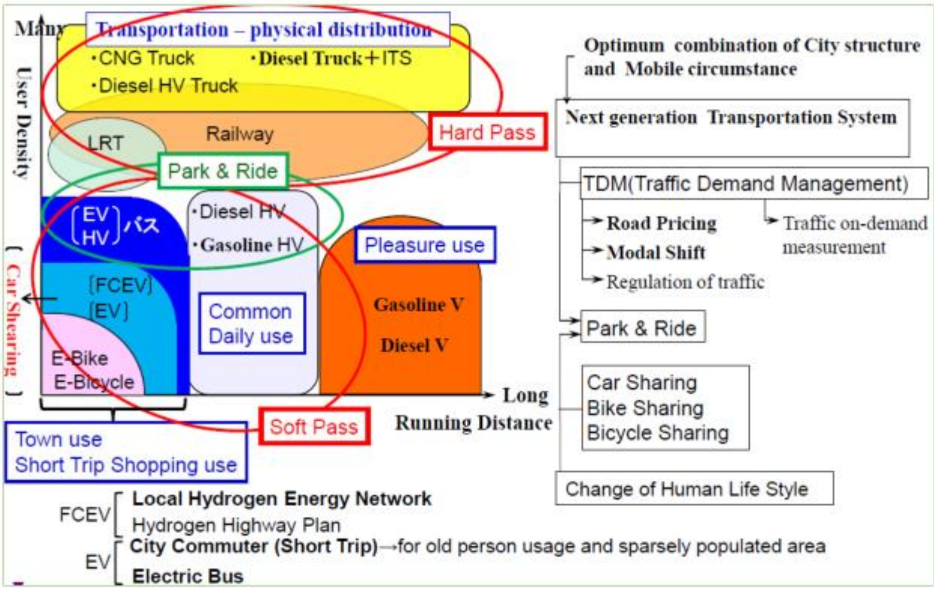

Fig.3 Future Transportation System in the City by Holonic Energy Path

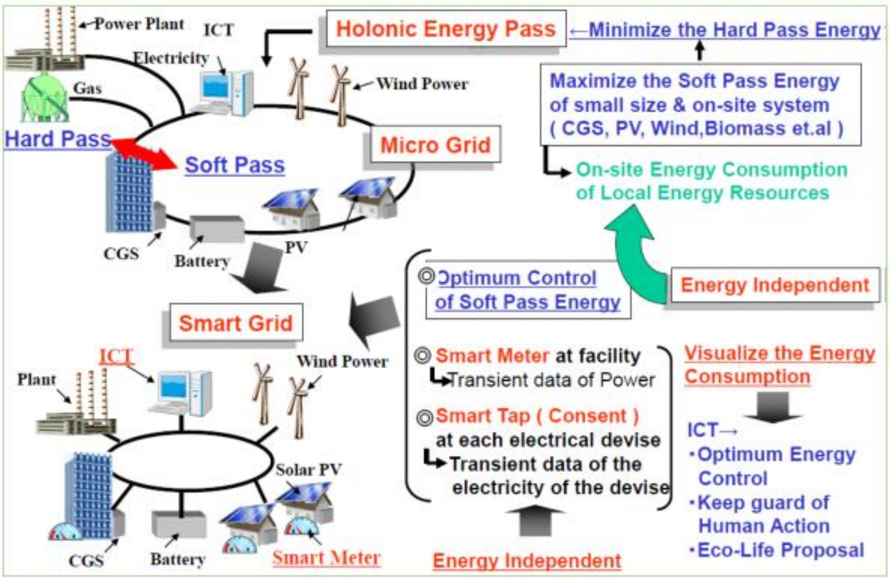

Fig.4 Holonic Energy Network in Future Urban City

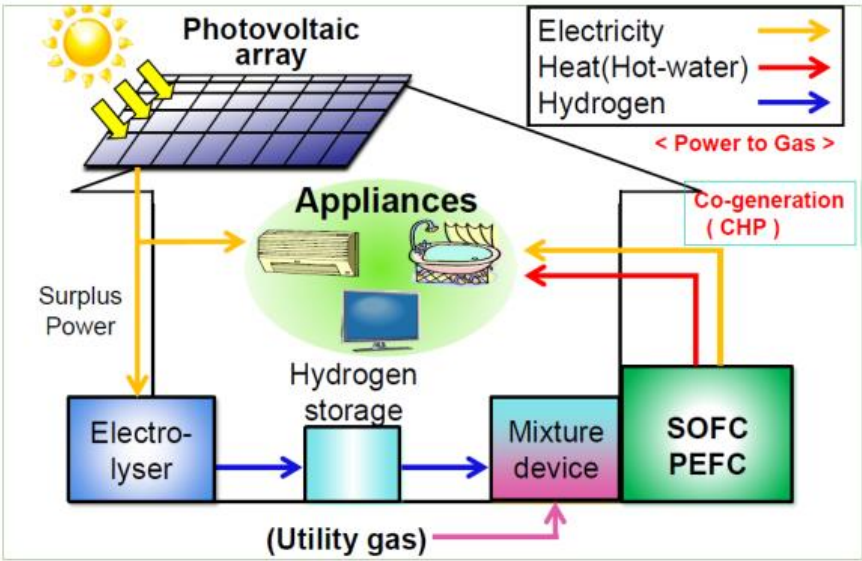

Fig.5 PV-Fuel Cell Energy Combined System for Household;
Power to Gas (Doshisha Univ., 2009~)

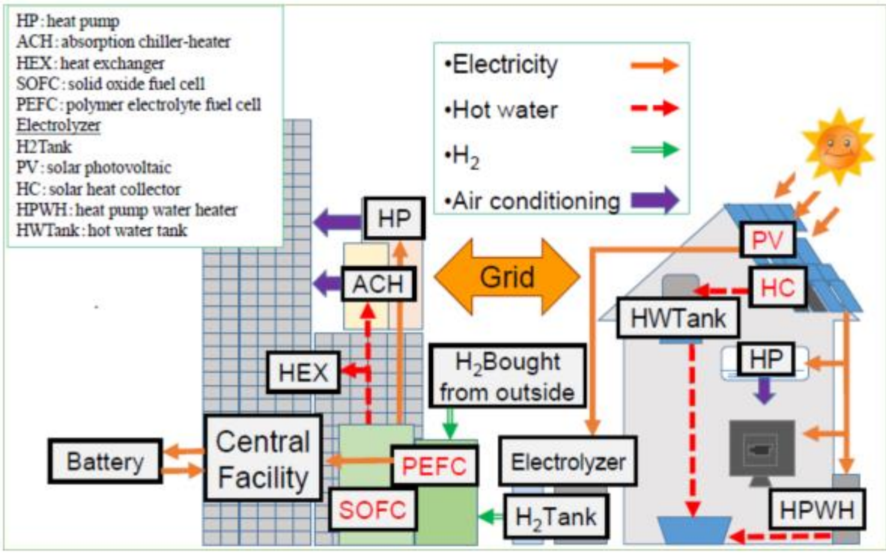

Fig.6 PV-Fuel Cell Energy Combined System for City Grid Facilities;
Power to Gas (Doshisha Univ., 2010~)

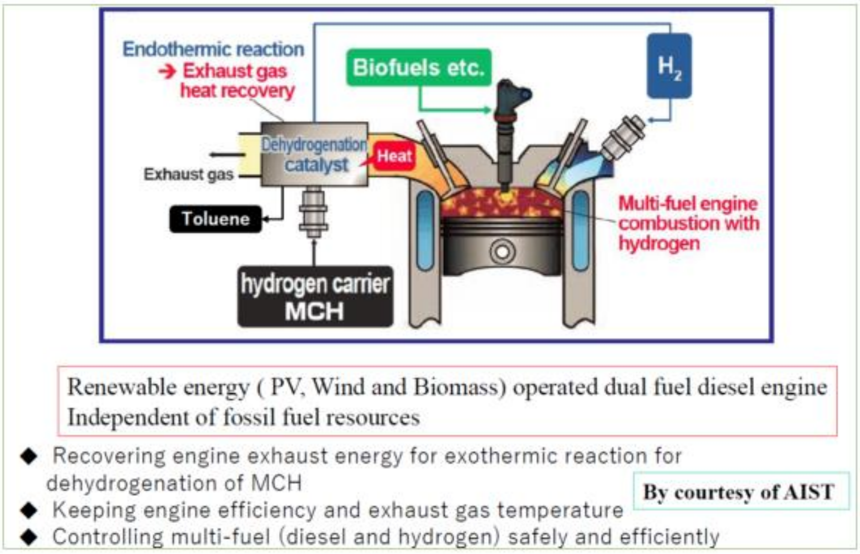

Fig.7 Co-Generation Engine System Fueling Bio-Diesel Fuel and Hydrogen Reformed from Mechylcyclohexane (MCH)

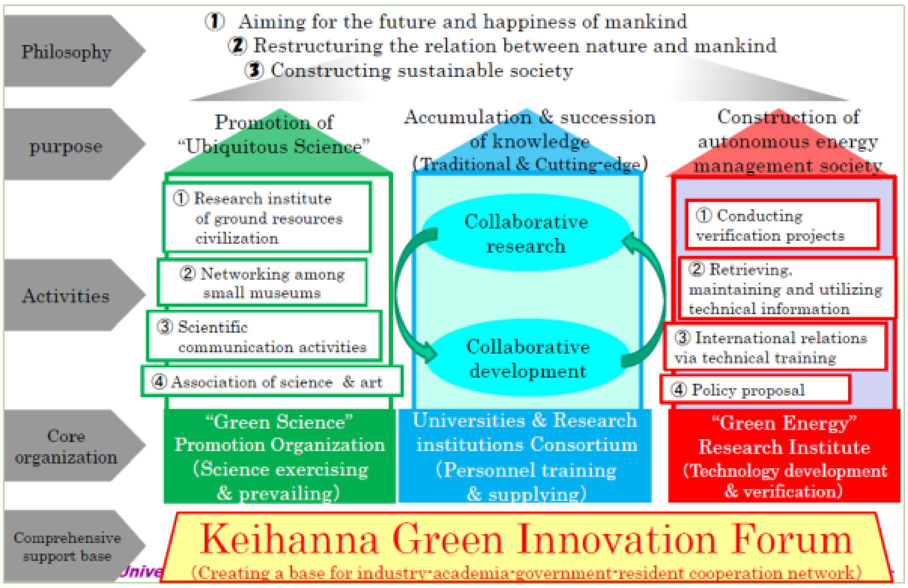

Fig.8 Keihanna Green Innovation Forum (2015~)

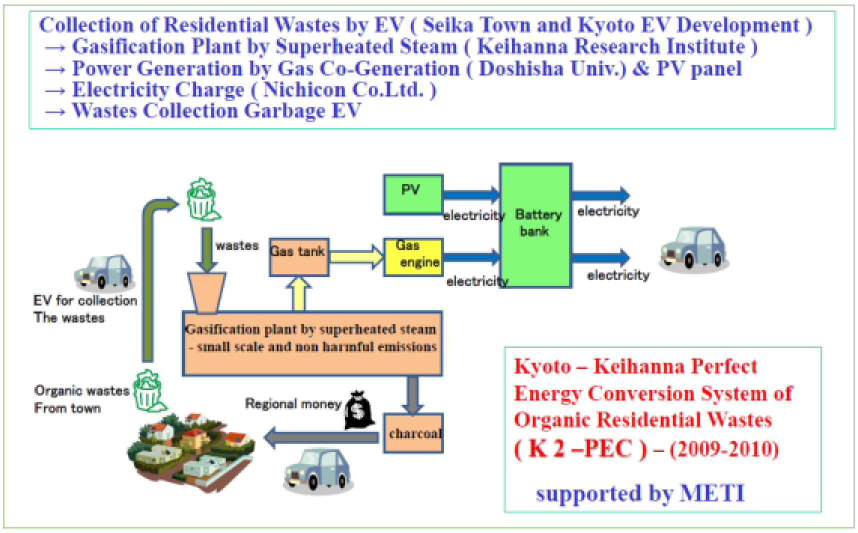

Fig.9 Ecological Circulation System of Residential Wastes
Gasification Plant (K2-PEC)-Biogas Engine Co-generation

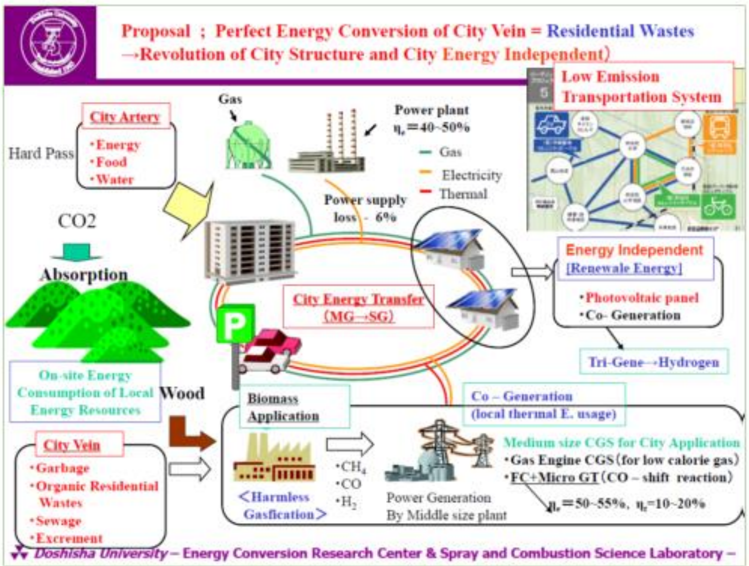

Fig.10 Proposal for Perfect Energy Conversion of City Vein

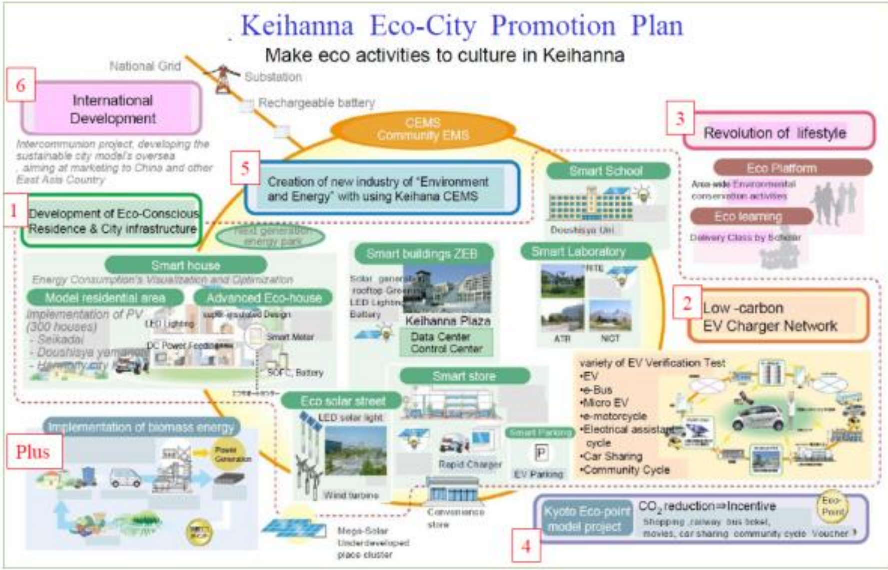

Fig.11 Keihanna Eco-City Implementation Plan Overview

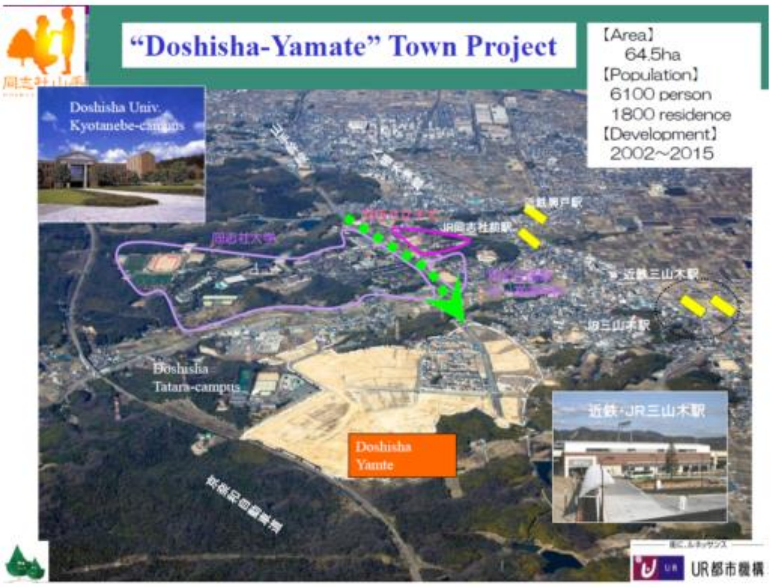

Fig.12 Sustainable Urban City Project of "Doshisha Yamate"

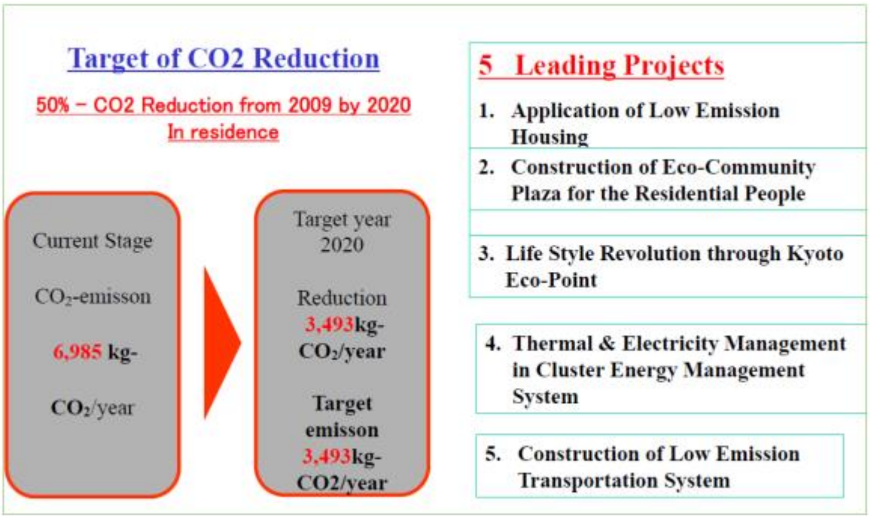

Fig.13 Five Leading Project in "Doshisha Yamate"

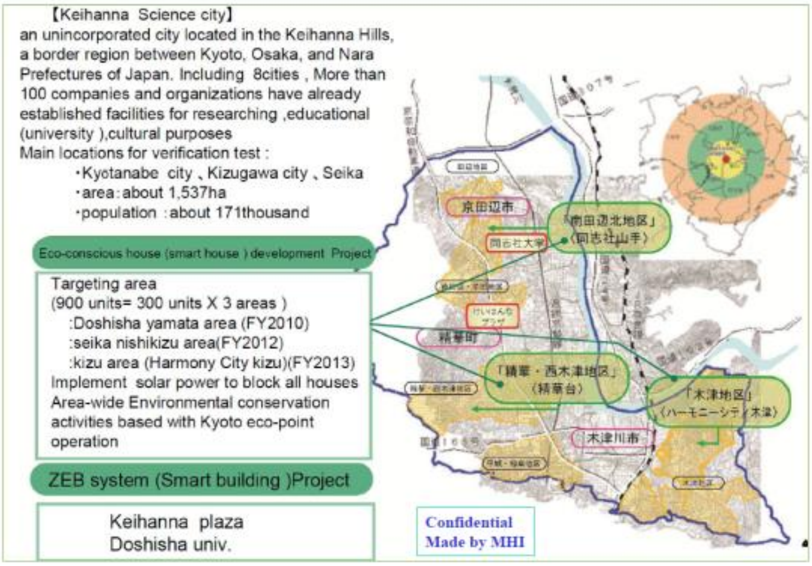

Fig.14 Kiehanna Verification Test Area for METI Next Generation Energy and Social System Demonstration Program

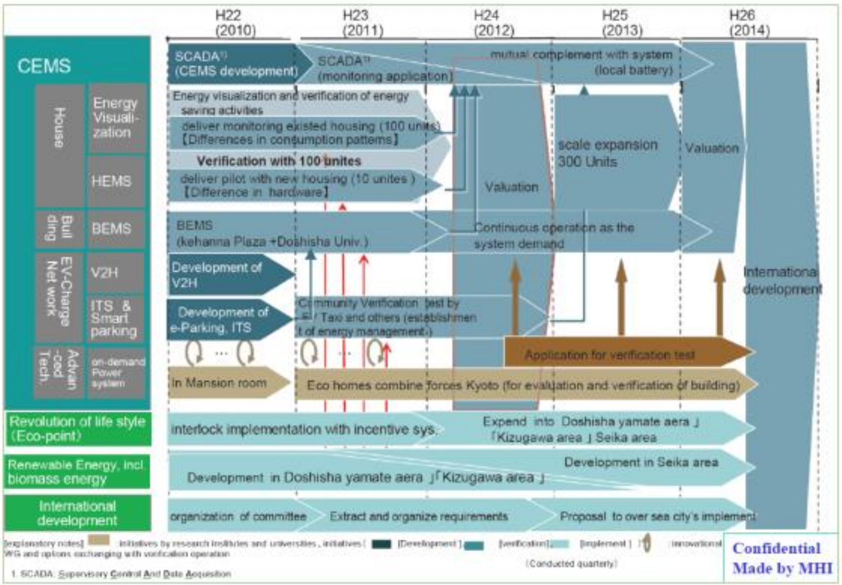

Fig.15 Overall Schedule of Kiehanna Verification Test

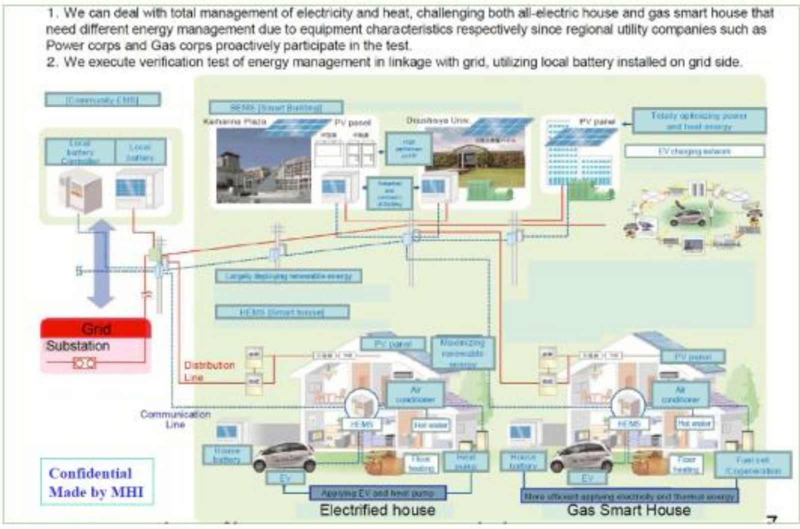

Fig.16 Feature of Kiehanna Verification Test

- Local Utility Proactively Participate and Utilizing Local Battery Interfacing to Grid -