GENESIS Project and Use of Sustainable Energy

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It is estimated that the world population will grow from its current 6.7 billion to 9 to 10 billion by the middle of this century. On the other hand, the world reserve-to-production ratios (RPRs) for oil, natural gas, and uranium are approximately from 40 to 85 years. Therefore, it is difficult for these energy resources to accommodate the ever-increasing population. In addition, there is a possibility that the world will face a catastrophic situation due to environmental deterioration before the energy resources are depleted. Before the Industrial Revolution, human beings had subsisted using solar energy in a natural way. In order for people in this century and the following centuries to survive, it will be necessary to go back to the pre-Industrial Revolution style of using energy originating from the sun, taking into consideration the issues of energy, resources, and the environment. At the same time, we need to accomplish the GENESIS Project, which aims at establishing a global-scale energy network to generate and supply sufficient energy in a clean and green way by making full use of technologies to harness "new energies" that have been developed by human beings.
This report explains the main features of the GENESIS Project.

Keywords: GENESIS Project, sustainable new energy, HTS DC cables, water cycle, wide-band-gap power transistor cooled with LN_2

1. The concept behind the development of the GENESIS Project

Figure 1 shows the increase in world population from the first year of the Christian era (A.D. 1) to the near future. Since the second half of the 18th century when humans gained the ability to use fossil fuel resources as energy during the Industrial Revolution, the world population began to soar dramatically. The population has risen in accordance with an explosively increasing function, as shown in **Fig. 1**, and it has already passed the point of no return. The world's population in 2008 is beyond 6.7 billion and it is estimated that it will exceed 9 billion by 2045. Resulting from the increase, energy consumption has been skyrocketing as indicated in **Fig. 2**, and it is expected to increase to 150% of its current level by 2030.

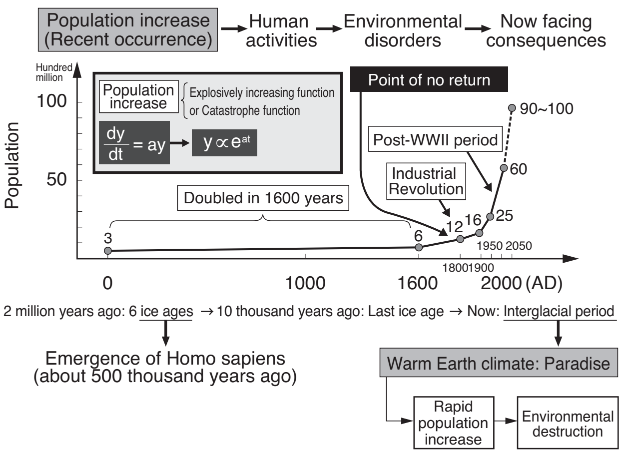


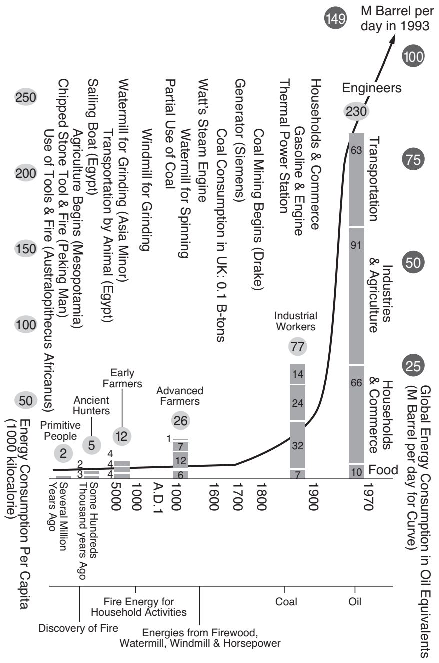
Fig. 1. Population increase and Earth's environment

We can regard "1 kW per capita," which is the level that Japan achieved during 1970s, as a steppingstone towards becoming a civilized country. When we use Japan, which has currently the world's third largest power generating capacity of 250 million kW, as a standard to compare other countries, we reach the conclusion that the number of the zones with power generation capacities that are equivalent to that of Japan (which exhibits the second largest GDP) is 27 in the world, based on the following formula: (6.7 billion people times 1 kW per capita) divided by 250 million kW ≒ 27. It can be considered that the issue of the world population will continue to be one of the largest problems for us in the future. In addition, the number of megalopolises with over one million people has increased rapidly throughout the world, as the tendency is shown in **Fig. 18**. Therefore, the reality is that we cannot support the modern civilization without maintaining the massive generation, transmission, and consumption of electricity.

The major energy resources that have been utilized to support such massive amounts of energy use are oil, natural gas, and coal (fossil fuel resources) and uranium (a non-fossil fuel resource). **Figure 3** shows the amounts of reserves of the major energy resources (as of the end of 2006). Although the reserve-to-production ratio of coal is over 150 years, those of other energy resources are limited to around 40 to 85 years. Therefore, it is important for us to recognize that they are transient resources.

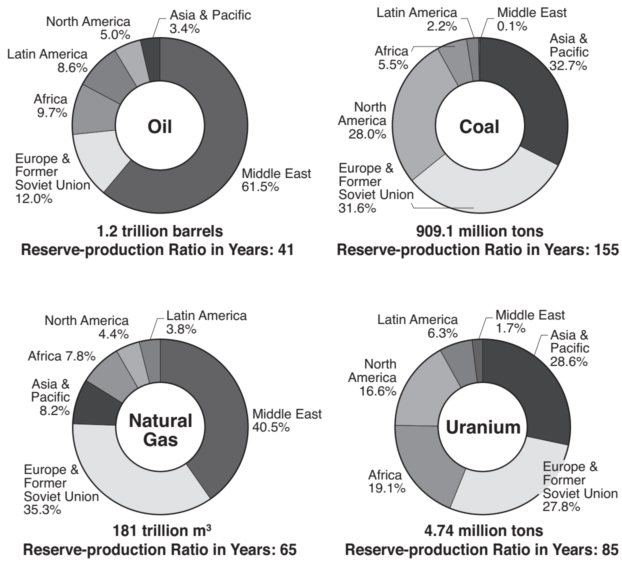
The current era is called the "age of the transition from metal to non-metal." In the field of electronics and telecommunications, the transition to non-metals has been completed by replacing metal vacuum tubes and copper wires with silicon semiconductors and fiber-optic cables, respectively. In the steel industry, the application of carbon fiber reinforced plastic (CFRP) is presently underway. I consider that from the perspective of optimal resource utilization it will become necessary to replace copper, which has been used as a main material, with non-metal alternatives in the sector of electricity infrastructure, along with wider use of ceramic-made high-temperature superconductors [(1)].

Figure 4 shows the trends in the amounts of CO_2 emissions during the past 200 years. The amounts have increased sharply, particularly since World War II, and the total amount has passed the point of no return. This situation is already causing global-scale environmental changes.



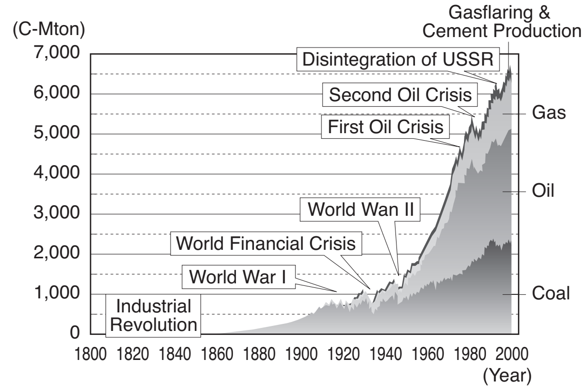
(Source: Japanese Ministry of the Environment)

Fig. 2. Historical trend of global energy consumption



Source: Oil, Natural Gas, and Coal: BP Statistics 2007(As of end of 2006)
Uranium: OECD/NEA, IAEA URANIUM2005(As of 2005)

Fig. 3. Reserves of world major energy resources



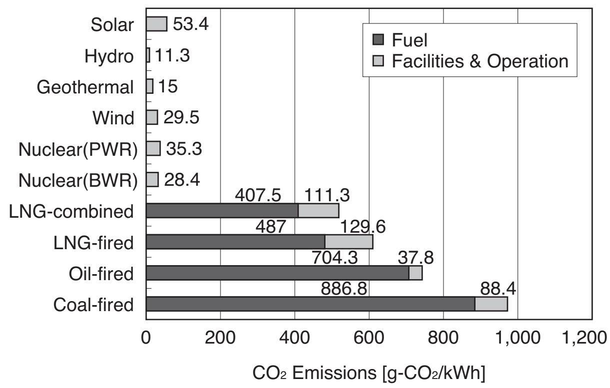
(Source: Carbon Dioxide Information Center)

Fig. 4. Changes of CO_2 emissions in past 200 years

Figure 5 shows the amounts of CO_2 emissions for each of the power generating systems that are responsible for about one third of the world's total CO_2 emissions. It is apparent that the amounts of CO_2 emissions from thermal power plants using coal, oil, and natural gas, which are the main sources of electricity, are overwhelmingly higher than those from nuclear power plants and power generation systems based on new energies originating from the sun. Therefore, in order to reduce CO_2 emissions, it is considered necessary to switch fuels from coal and oil to natural gas and further to nuclear energy and new energy resources.

The Kyoto Protocol requires Japan to curb CO_2 emissions by 6% from the level in 1990. As **Table 1** indicates, Japan's electric power industry decided to reduce CO_2 emissions per unit of electricity by 20%. A large part of the reduction was expected to be achieved by building new nuclear power plants and boosting the operating rates of existing nuclear power plants [(2)].

It is said that nuclear power is a clean energy source in terms of CO_2 emissions, so the present age is sometimes called the era of Nuclear Renaissance as it is regarded as



(Source: OHM Nov. 2004 Issue)

Fig. 5. Comparison of CO_2 emissions among various electric power generation technologies

Table 1. Self-imposed CO_2 emissions reduction target of Japan's power generation industry

CO_2 Emissions in Power Generation Industry	2002	350 M ton-CO_2/year (27%)
	2003	363 M ton-CO_2/year (32.4%)
Self-Imposed Reduction Target		20% Reduction in unit power generation 425 g-CO_2/kWh in 1990 ⇩ 340 g-CO_2/kWh in 2010
Electricity Growth Rate and CO_2 Emissions		Electricity growth rate: 37% (from 1990 to 2010) CO_2 Emissions: 1.37×0.8=1.096 (CO_2 Emissions increase by 10%)
Measures for 20% CO_2 Reduction in Unit Power Generation	(1) Newly Installed Nuclear Power Stations	5 stations ×▲3%/station=▲15% (7-8 M ton-CO_2 reduction/station/year)
	(2) Increase of Coefficient of Utilization of All Nuclear Power Stations	3% increase for each of 53 stations → ▲3%
	(3) Increase of Efficiency of Thermal Power Stations	▲1%
	(4) Adoption of Kyoto Mechanism	▲ 1% (Equivalent to reduction of 3.8 M ton-CO_2/year)

a last resort in the 21st century in which the environment is of great concern. At present, about 430 nuclear power plants are in operation, mainly in developed countries. And a number of countries plan to build new nuclear power stations, including BRIC countries that are making aggressive efforts to introduce nuclear power plants. The total number of the newly built and planned plants will be around 200. When we take 1 kW per capita as a standard, it is estimated that China will need at least over 400 nuclear power stations and the entire world will need more than 6,000 plants [(1)]. If we continue to rely on the over 400 nuclear power plants that are now in operation and on uranium, which has a reserve-to-production ratio of roughly 61 to 85 years, nuclear power cannot be the "ultimate energy resource." Also, for nuclear power, it is particularly important to ensure safety in the face of radiation hazards. And as back-end measures, disposal of radioactive waste usually requires an interim storage period of about 100 years. After that, the waste needs to be relocated deep underground and managed in final storage for somewhere between 10,000 to 20,000 years. Therefore, it is necessary to pay due attention to the imbalance between "the generations of nuclear power users and the period of use" and "the necessity for the future generations to provide long-term storage and management." In addition, there is one more important point to be considered. That is the issue of the longevity, maintenance, and renewal of nuclear power plants. The designed lifetime of the plants has been approximately 30 to 40 years, based on the "engineering capabilities." Therefore, most nuclear power plants in Japan will reach their designed lifetime during the period between 2020 and 2030. At present, the reality is that there is no solution to this problem other than extending their longevity through upgrading. As **Fig. 6** shows, however, when we extend their lifetime, we have to give extremely serious and careful examination to the

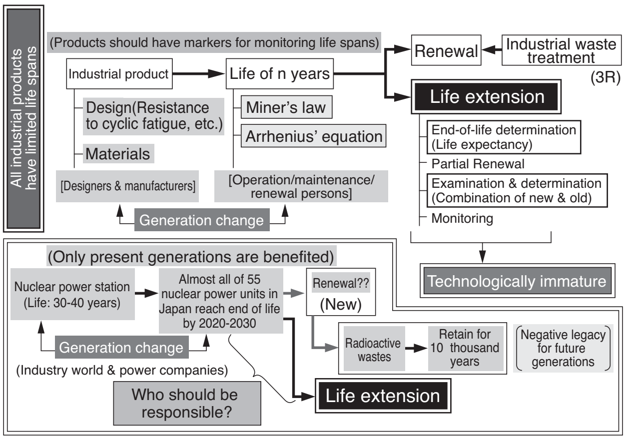


Fig. 6. Life extension measures of nuclear power plants: Importance of technology for determining life span of industrial products

following issues regarding the nuclear power plants that were built by using designs and equipment that were available 30 to 40 years ago.

1) What kinds of engineering standards and methods should be used in investigations?
2) What kinds of tests should be conducted?
3) How can we determine the feasibility of repair, lifetime extension, and upgrading or renewal or rehabilitation and how can we conduct them?
4) How can we continue to implement engineering monitoring in the future?

To put it plainly, a basic question remains unanswered: whether or not we should pursue the universalization of artificial technologies, for which renewal and final disposal technologies have not yet been established, as an ultimate solution [(1)].

The rapidly growing population and the environmental problems have aggravated the food supply situation in the world. It is reported that the world's grain inventory rate was over 35% in the 1980s but declined to 17.7% in 2005. As for water resources, the demand for water increased six-fold, which is two times the population growth, during the 100 years of the 20th century, which has been called the Oil Century. About 60 countries, mainly in Asia and Africa, cannot meet the basic requirement of 50 liters per day, which is considered essential for human survival. The Intergovernmental Panel on Climate Change (IPCC) predicts that as the global warming worsens, there will be extremely severe droughts in some areas and extremely large-scale floods will occur in other areas.

At the same time, the demand for biomass fuels made from grains such as corn has increased due to efforts to reduce CO_2 emissions, resulting in a decline in the inventory rate of food. In addition, the rising production of grains for biomass fuels led to an increase in the amount of water necessary for agricultural use. It has been pointed out that the adverse effects of expanded biomass fuel production will become more widespread.

An ultimate idea as an alternative to the above-mentioned energy sources has been proposed by the academic sector. That is "nuclear fusion technology," which allows us to create a small, artificial sun on the earth. At present, it is considered that the technology will be completed in the next century or later. And nuclear fusion requires special safety measures. Therefore, some experts think that it would be better to use on the earth the nuclear fusion energy generated by the sun, remaining at a safe distance from the fusion, in the form of new energy originating from the sun [(1)].

2. What should be the ultimate energy resource?

I pointed out in the previous section that fossil fuel resources and uranium are transient sources of energy due to the limited amounts of their reserves. I also explained that it was highly likely that the unlimited increase in energy consumption would bring an unexpected and sudden catastrophe to all living organisms on the earth, including human beings due to environmental problems (before the resources are depleted). In addition, I mentioned that although nuclear power generation and nuclear fusion being developed at present are important technologies, it was difficult to embrace them as ultimate solutions, for various reasons. Then, can we, today's engineers, propose a feasible and realistic ultimate solution to save human beings, which serves as an alternative to the above-mentioned energy sources? What do **Fig.s 1, 2, 4, and 8** mean? If we learn from history, they would mean that before the Industrial Revolution, human beings lived very humbly within the limits of the amount of the energy given by the sun, as a living species on the earth that thrived in the same way as other such species. If you allow me to use modern terms, human beings have been able to survive for several million years, because they have lived depending only on "recyclable," "sustainable," and "clean and green" energies and resources. **Figure 7** provides an easy-to-understand outline of a mechanism in which it is important to rely on new recyclable and sustainable energies originating from the sun. The only question to this scenario is whether or not the resources of the new energies exist in sufficient amounts. This point will be discussed in details below, but, in theory, these resources can provide an almost inexhaustible supply of energy. **Figure 8** shows the history of energy consumption by human beings and a forecast of its future from the past (several million years ago) to the future (around 2100). As I mentioned above, it is commonly known that the production of currently effective energy resources will "peak out," and that they will become depleted. Based on the understanding of the whole situation, this fact also inevitably forces us to take the option of "using energies originating from the sun." And in order to prevent environmental problems from causing a catastrophe, we have to make active use of new energies.

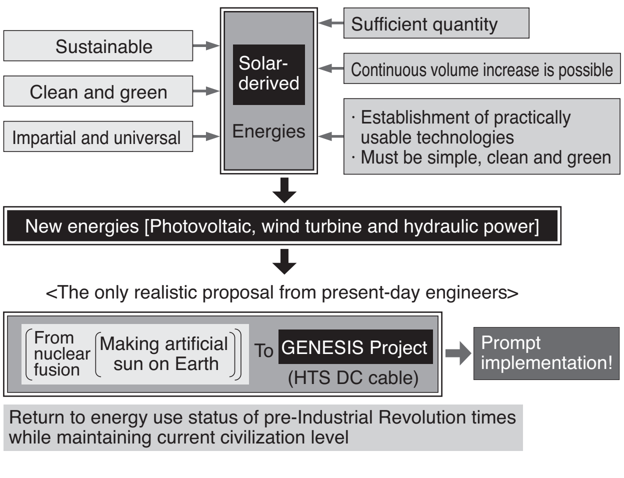


Fig. 7. Ultimate energies, or solar-derived energies, for future generations

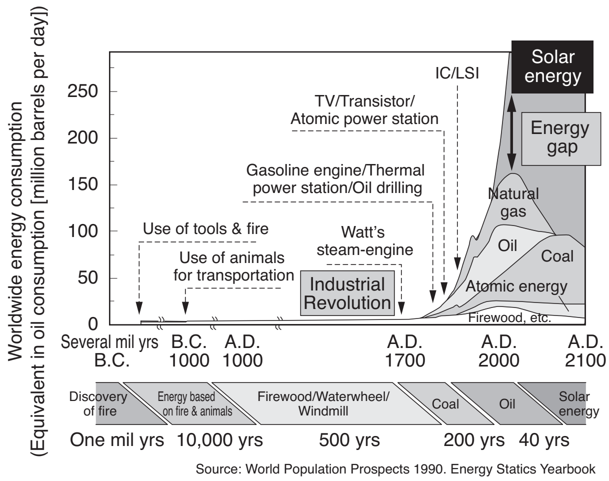
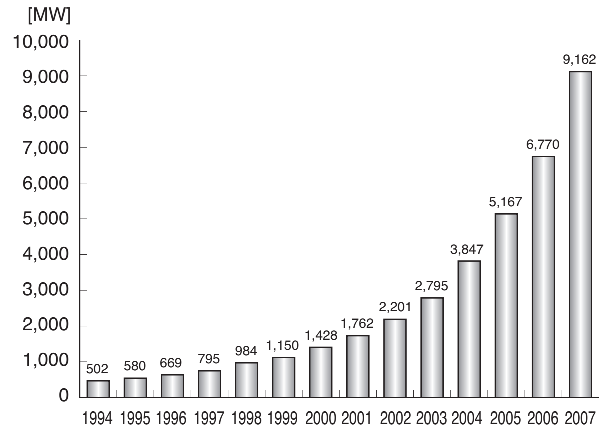


Fig. 8. History & forecast of energy consumption by mankind

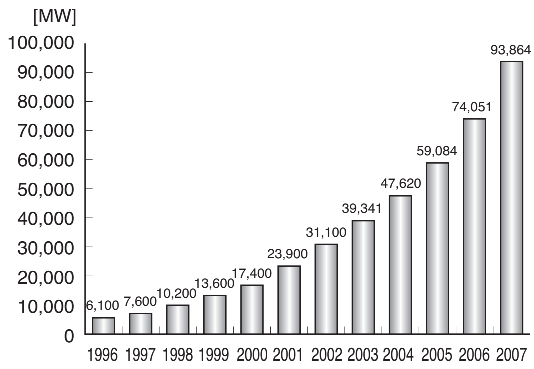
The current composition of the atmospheric constituents, including oxygen (O_2), has been developed as the earth has accumulated CO_2, which has been fixed by solar energy, and O_2 has constantly been released to the atmosphere over the unimaginably long period which could be more than 2 billion years, as **Fig. 22** shows. Based on this fact, I reached the following conclusion: When the balance of atmospheric constituents is disturbed as human beings release these fossil energies at a burst in the form of CO_2 while consuming O_2, it will take an incredibly long time to restore the balance, or it is an unavoidable necessity to study the possibility that human beings will be irreversibly headed towards a catastrophe (before the energy resources become depleted).

Photovoltaic power generation, a typical example of new energy sources, has increased by more than 50% annually, as **Fig. 9** shows. The accumulated amount of introduced solar power generation in the world was approximately 9 million kW in 2007, but its application has not expanded rapidly, because the cost of its power generation is still expensive at around 46 yen per kWh. I hope that future "eco-innovation," or technological innovation aimed at solving environmental problems, will lower the cost. And this problem is an issue to be solved, rather, by government policy based on a judgment of facts from the perspective of the future, just as with the case of the EU's introduction of the feed-in tariff system.



(Source: Solar Generation V-2008, EPIA)

Fig. 9. Cumulative amount of solar generation



(Source: Global Wind Energy Outlook 2008)

Fig. 10. Cumulative amount of wind generation

As **Fig. 10** shows, wind power generation has expanded rapidly at the rate of over 70% per year. The accumulated generation amount reached 94 million kW at the end of 2007, which is nearly equivalent to the capacity of 94 nuclear power plants. This rapid expansion became possible because the cost of wind power generation had already been lowered to the level of thermal power plants at 7 to 8 yen per kWh. It has been pointed out that if we intend to increase the wind power generation substantially in the future, it will be necessary to implement it on a larger scale and improve the strength of its facilities. However, we have to keep in mind that since wind power generation requires suitable sites, it is less unbiased than solar power generation.

Besides photovoltaic and wind power generation, hydraulic power generation is also one of the new promising energy resources. Although it is necessary to improve the level of these power generation technologies and make them more efficient and economical in the future, the fact that they can be regarded as "developed technologies" is also an important point. If these power generation technologies using new energy resources are put into practical use in combination with technologies for high-capacity, ultra-long-distance, and ultra-low-loss electric power transmission, new energy resources originating from the sun can be the "ultimate proposal for saving human beings" for the first time in the whole of human history, as discussed in greater detail below. Modern engineers have finally succeeded in developing this ultimate proposal to the stage where we can now say that it is feasible, by developing the ultimate High-Temperature Superconducting (HTS) DC power cables with no electric resistance. As a result, the Genesis Project (combination of new energies and HTS DC cables) described below has developed from an impossible dream to a possible reality, on which we can base our step-by-step efforts to make it into a concrete reality.

3. GENESIS Project and HTS DC Cables

GENESIS is an acronym standing for "Global Energy Network Equipped with Solar cells and International Superconductor grids." "Genesis" is also a section of the Old Testament of the Bible, which describes the creation of the world. Dr. Yukinori Kuwano, the former president of Sanyo Electric Co., Ltd. who first proposed the GENESIS Project, emphasized the following point: As a result of a calculation of the size of the land that will be needed to supply energy to the world exclusively through photovoltaic power generation using 10% efficiency solar cells, based on projections of future global energy consumption, a conclusion was made that a square of land approximately 800 kilometers wide and approximately 800 kilometers long would be enough to meet the energy needs of all human beings as illustrated in **Fig. 11** to understand it plainly [(1)], and this size is only 4% of the total existing desert area of the entire world [(3),(4)]. Remarkable development was achieved in the field of solar cells. For example, solar cells with over 20% total-area conversion efficiency, such as HIT solar cells, have been developed. According to a report on the cases examined by an International Energy Agency (IEA) working party, when solar cells with 15% total-area conversion efficiency are adopted taking into consideration the capabilities of currently available solar cells, an area half the size of the Gobi

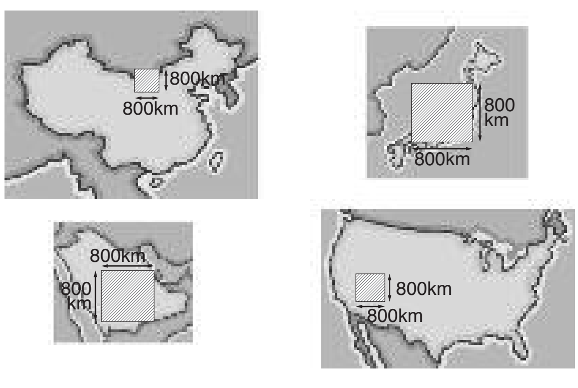


Fig. 11. Land area required for solar battery farm: 4% of world's desert area (800 km × 800 km)

Desert can meet the annual energy demands of the entire world, and we can gain an amount of energy equal to around ten times the world's entire demand from the whole area of the Sahara Desert [5]. The case of 10% efficiency solar cells requires a square of land approximately 800 kilometers wide and approximately 800 kilometers long, as described above, but when solar cells with 15% efficiency are used, a square of land 650 kilometers wide and 650 kilometers long is needed. To put it the other way around, when solar cells with 15% efficiency are used in a square of land 800 kilometers wide and 800 kilometers long, we can use about 35% of the land as working space. As **Fig. 12** shows, one of the features of the GENESIS Project is to realize a global electric power network by interconnecting and expanding new-energy power plants (mainly solar farms; supplemented by wind farms) around the world with HTS DC cables [6]. It is inevitable that DC cables that do not generate reactive power are used as ultra-long cables for power transmission in the project. **Figure 13** describes the GENESIS Project as a power generation and transmission system with necessary components. The key components include solar and wind farms, HTS DC cables, cooling stations for HTS cables (coolant: liquid nitrogen), DC/AC inverter/converter stations (equipped with inverters/converters, transformers, fault current limiter, electric current breakers, etc.)

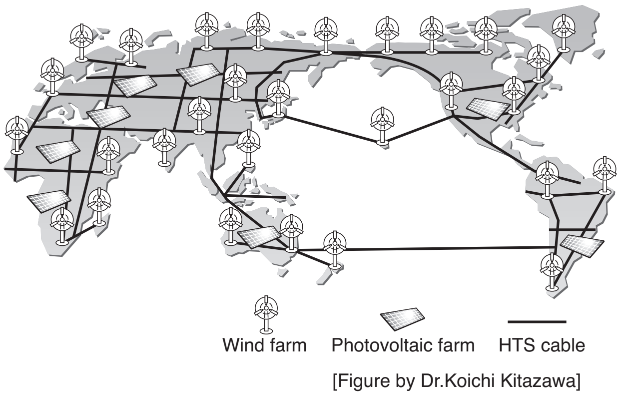


Fig. 12. Global electric power network linked by HTS cables

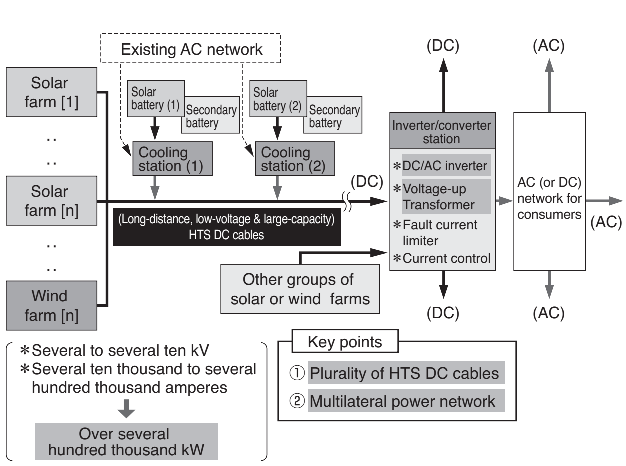


Fig. 13. GENESIS Project and HTS DC cables

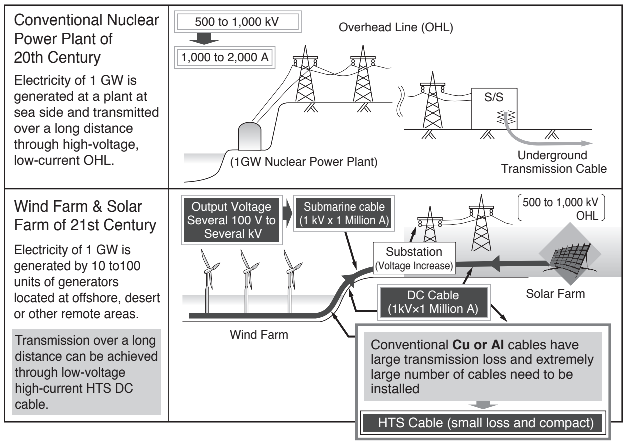


Fig. 14. Comparison of 1-GW-class low-voltage, high-current transmission system using HTS DC cable for linking wind / solar farms, and existing 1-GW-class nuclear power plant and its transmission on system

To make the features of the GENESIS Project clearer, **Fig. 14** compares the new system with the currently operating power generation and transmission systems ranging from several hundreds of thousands of kW to one million kW. In the case of the existing power transmission systems that use copper or aluminum conductor power cables, transmission voltage is increased to 500 kV (or 500,000 volts) at the end of a power generator (for example, the output point of a nuclear power plant of 1GW; 1GW = 1,000 MW = 1 million kW) to minimize transmission loss, which is proportional to the square of the current level. And inversely, transmission electric current is decreased below several kA. In addition, in order to reduce the limit on transmission distance for reactive power in alternating-current (AC) power transmission, power is usually transmitted over long distance to inner-city areas where it is consumed, through overhead lines that make it possible to reduce capacitance to the earth. In the GENESIS Project, on the other hand, when power is generated on the order of several hundreds of thousands kW or on a larger scale at a solar or wind farm, the (DC) voltage generated from the new-energy power sources would theoretically be low. Therefore, it is inevitable that the project's power transmission systems will be based mainly on low transmission voltage and high transmission current. In this case, since the existing metal conductor cables, which involve transmission loss, require an unimaginably large number of cables to carry high current levels and pose limits on transmission distances, the use of these cables are ultimately not considered in the GENESIS Project. (It is expected that this tendency will become stronger when large-scale installation of overhead lines becomes prohibited as they come to be regarded as visual pollution and power cables are required to be laid underground.) In short, the key components shown in **Fig. 13** and the comparison illustrated in **Fig. 14** tell us that solar and wind power generators, converters, and transformers are already fully developed technologies or have reached the level of commercial application, but one of the biggest challenges is the realization of HTS DC cables for collecting, transmitting, and distributing electricity. If we aim at ultimately establishing a superconducting global electric power network in **Fig. 12** [(6), (7)], HTS DC cables become a key component, which will be required in huge quantities and may become a bottleneck. (It will also become difficult to use a large amount of copper due to the problem of depletion of resources.) Therefore, the development of HTS DC cables made with ceramic material can open the way to the realization of the GENESIS Project.

Since the discovery of the high-temperature superconducting phenomenon in 1986, Sumitomo Electric has been consistently conducting research and development on HTS wires. As a result, the company successfully developed the Controlled Over Pressure ("CT-OP") sintering process and commercialized the first generation of high-performance bismuth-based HTS wires (under the name of "DI-BSCCO," which stands for dynamically innovative BSCCO). **Figure 15** shows the construction of a 3-core HTS AC cable that Sumitomo Electric developed using DI-BSCCO wires [(8)]. The cable was installed in an actual commercial power line in Albany, the capital of the State of New York, on a trial basis. The city started transmitting power to approximately 70,000 households in July 2006, using this HTS AC cable for the first time in human history [(9)]. It is easier to realize the use of HTS DC cables than that of HTS AC cables thanks to their insulation design [(10)]. Therefore, the success of the project of installing the HTS AC cable in Albany's commercial power line (the Albany Project) provided a foundation that convinces us for the first time that the GENESIS Project can be technically feasible or it is possible to realize the project.

Chubu University conducted the world's first test of running electricity though HTS DC cable in 2006, using the HTS DC cable with DI-BSCCO conductor manufactured by Sumitomo Electric. The test used Peltier lead between room-temperature copper conductor and ultra-low-temperature HTS conductor to control heat invasion and proved its effectiveness [(11)]. For example, if using a DI-BSCCO wire with a critical current (Ic) of 200 [A] in liquid nitrogen (LN_2) (T=77K) that is 4 mm wide and about 0.23 mm thick (cross-section area: approximately 1 mm^2), which has recently been achieved by Sumitomo Electric, makes it possible to be used in liquid hydrogen (LH) (T=20K) as a coolant, its critical current will increase 5.7 times and it becomes possible to exceed 1 kA. As a result, the use of the DI-BSCCO wire enables us to transmit the DC current at an amount 400 to 600 times greater than that of a copper wire without any loss over as long a distance as required. (There is a team that has expanded this concept and started working on a project for transmitting two energy resources [liquid hydrogen and electric power] to a remote area at the same time by placing HTS DC cables inside liquid hydrogen transport pipes in the 21st Century, which has been called the Century of Hydrogen [(12)].) Since HTS cables should keep cooled below 77 K (-196 °C) when used, it is necessary both to recool the liquid nitrogen and to reboost the coolant pressure at cooling stations placed at given intervals (15 to 20 km when currently available thermal insulation technologies are used). The amount of electricity that the cooling stations need is very small in comparison with the transmission capacity (around 0.001% of transmission capacity per km [(7)]). As **Fig. 13** shows, a cooling station will be able to supply by itself enough electricity by combining a small amount of photovoltaic cell with secondary battery installed therein. **Table 2** provides a comparison between conventional copper conductor power cables and HTS AC and DC cables in terms of compactness (transmission capacity differential), transmission loss, present reduction net value in transmission loss (including CO_2 emission right utilization), and total cost of transmission line construction. HTS cables are the cables of the future, and the superiority of the performance of HTS DC cables in comparison to other cables is quite obvious. **Figure 16** shows an example of a GENESIS Project system for installing six 1.5 kV/12 kA HTS DC cables for a transmission capacity of 100 MW (100,000 kW).

Electric conversion devices (inverters and converters), which are among the key components for the project shown in **Fig. 13**, need to be modified to be equipped with systems for reducing loss and cooling generated heat on a

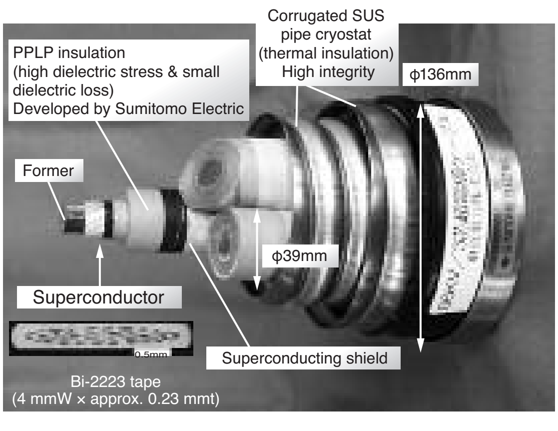
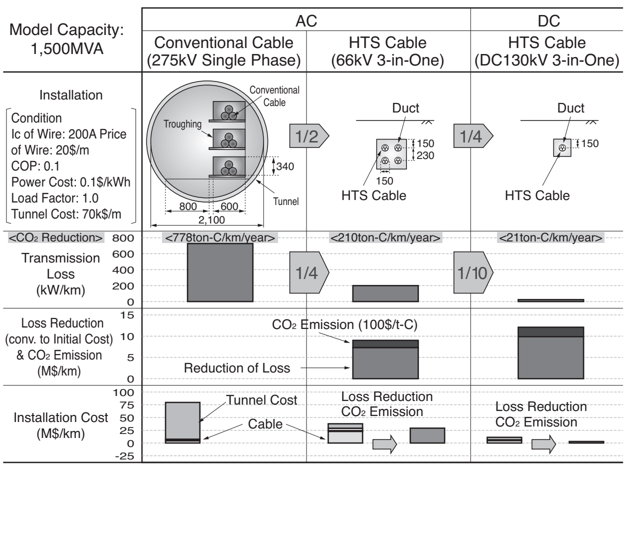


Fig. 15. Three-core-in-one-cryostat HTS cable (Cold dielectric, 66 kV, 114 MVA, 1000 A)

Table 2. Economical evaluation of HTS cable



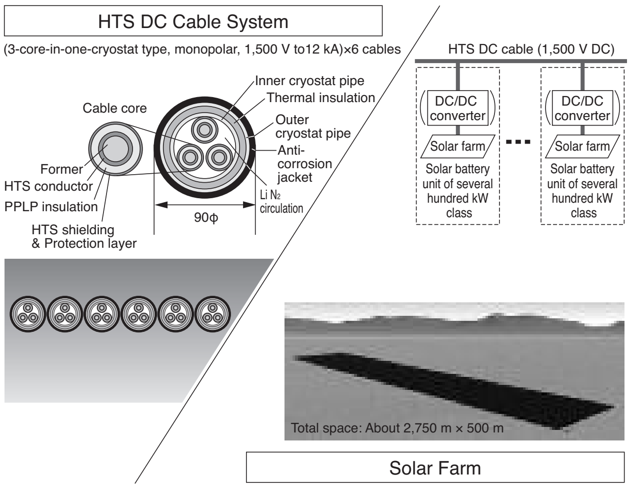


Fig. 16. 100-MW-class GENESIS System with HTS DC cable

massive scale in order to transform larger currents. When we cool these conversion devices with a coolant, it is expected that we can reduce on-resistance linearly to a certain negative temperature and that it will be easier to eliminate generated conversion loss. The concept of combining "conversion devices cooled by a coolant" with HTS DC cables offers a potential foundation for significantly advancing the efficient implementation of the GENESIS Project.

Ideas for the specific development of the GENESIS Project are explored in references [(3)-(7)]. (If a solar farm can be built at a cost of 200,000 to 400,000 yen per kW, it will be equivalent to a construction of a one-million-kW-class nuclear power plant at a cost of 200 to 400 billion yen. And, according to my calculations, if 10 trillion yen, or slightly less than 2% of Japan's GDP, is invested annually in the GENESIS Project, we will be able to build solar farms that can generate around 20 GW per year. Even with an insolation efficiency of 30%, my calculations indicate that the GENESIS Project will be able to meet the demand for all the electricity in Japan approximately in 40 years' time.) It is also suggested that only around 5% of Japan's land area is required to meet its total demand for energy [(14)].

4. For new technological development in the 21st century

The phased developmental process of the GENESIS Project is divided into four stages from Step I to Step IV, as shown in **Fig. 17** [(1)]. Step I and Step II have already been implemented in various parts of the world. It is quite easy to envision Step III. In this step, the power generated at each solar or wind farm is to be transmitted to the closest existing electric power network, and surplus power will be made available for use to neighboring areas in a sequential manner while the most nearby area is given the priority to consume as much power as it needs. As **Fig. 18** indicates, due to the ongoing migration of world population to cities, the number of mega cities each with a population of 10 million or more will increase from the current 19 to 27 in 2050. The amount of energy con-

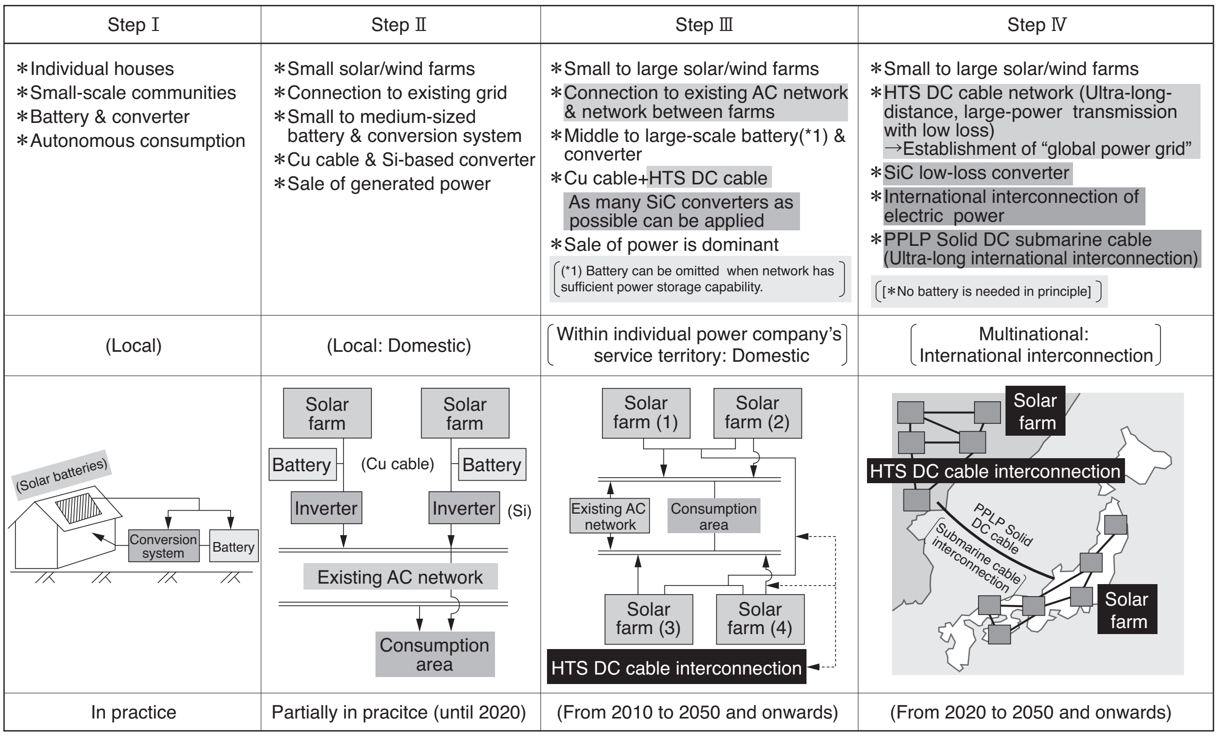


Fig. 17. Step-by-step development of "GENESIS Project"

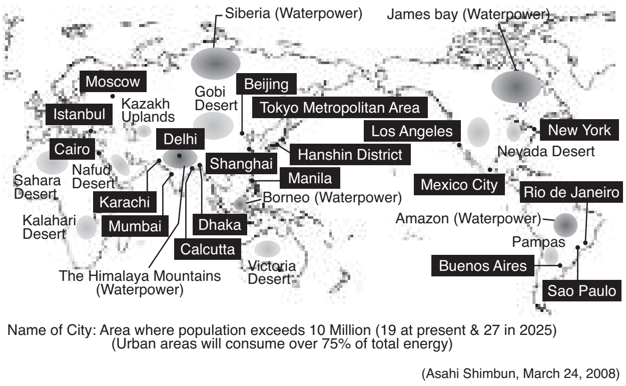


Fig. 18. Megacities and GENESIS Projects

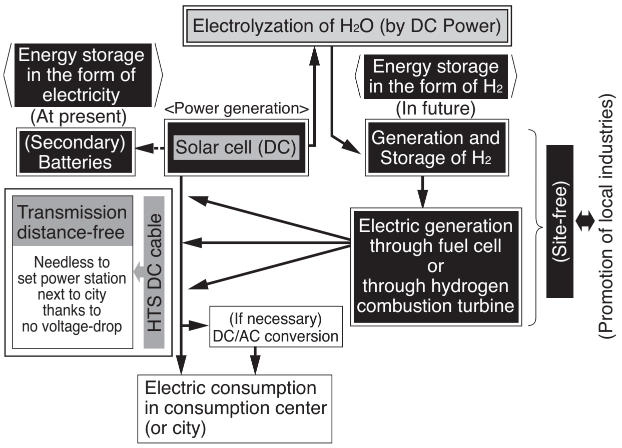


Fig. 19. Transformation of solar electricity into H_2 and storage in the form of H_2 – From secondary battery system to system of H_2 generation & storage and regeneration of electricity using H_2 –

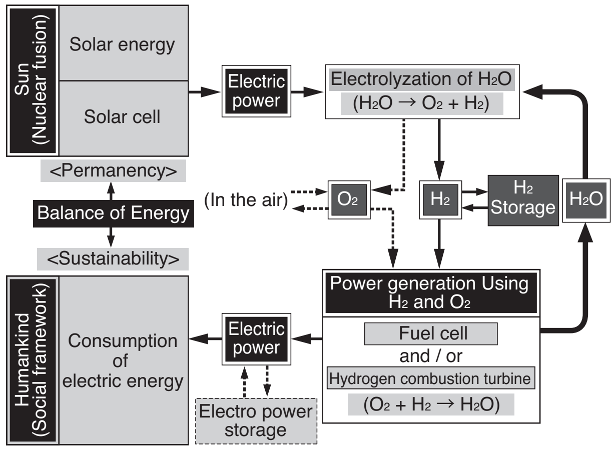


Fig. 20. Acquirement of solar energy through "water cycle" – Permanent balance of energy –

sumed by the 27 mega cities is expected to exceed 75% of the world's total energy consumption. Fortunately, extensive spaces such as huge deserts, vast plains, and large water sources, which can be used for the GENESIS Project, still exist in the neighboring areas of these cities. If we expand Step III of the GENESIS Project and apply it to these mega cities, it is highly possible that we can find solutions to the problems of energy, resources, and the environment in our near future. Step IV is the final phase that leads to the realization of the global superconducting electrical power network portrayed in **Fig. 12**. In this stage, it will become unnecessary to store electric power by charging a secondary battery system according to a predetermined time-based schedule, based on the same concept as "surface integral" that will be explained in **Fig. 22**, because day and night as well as summer and winter come in regular alternation. And it is expected to be possible to match the supply with the demand by applying "surface averaging." Even if we are in the stage in which the system of "surface averaging based on interconnected grids" has not yet been fully developed, it becomes possible to avoid the use of unfeasible (ultra) large electric power storage based on a secondary battery system if we adopt the concept of replacing the surplus electricity generated by solar farms with the generation and storage of hydrogen (H_2), as shown in **Fig. 19**. If the demand for electricity increases, a fuel cell or a hydrogen combustion turbine power generation system will be used to generate new electricity. When electricity is transmitted through HTS DC cables, it is no longer necessary to install power generation sites or H_2 storage sites in areas near big cities, as shown in **Fig. 19**, because the cables have no resistance.

Without the need for power generation sites near areas in which electricity is consumed (which implies freedom from power transmission distance), it becomes easier to implement more realistic power generation. If we can generate electric power, generate and store H_2, and regenerate electric power using the stored H_2 in a huge desert, we will be able to solve both the problems of space and security. Moreover, these advancements will also lead to the development of industries in remote areas with weak economic bases (a solution to one of the contradictions of the current Kyoto Protocol), which in turn will help alleviate large urban population concentrations. The unbiased aspect of solar energy shown in **Fig.s 7, 18, 20, and 22** improves reliability and security in ensuring the supply of energy and eliminates the seeds of large-scale strife among human beings.

There is a revolutionary idea of "transmission cables that have the function of storing electric power," in which HTS DC cables are equipped with an electricity storage function ($W=1/2L \cdot I^2$) using the ultra-long length of HTS DC cables to increase their inductance (L) and through the application of large currents (I) [13]. It becomes possible to realize this dream technology only with the GENESIS Project, because the project is based on HTS DC cables. I hope that the technology will be established soon.

The 21st century is the century of "energy, resources, and the environment." As the world's population and energy consumption continue to increase, human beings today need to make every effort to preserve energy, resources, and the environment while clearing up the negative legacies of the 20th century. It is also necessary for us to have strong determination to contribute to the wel-

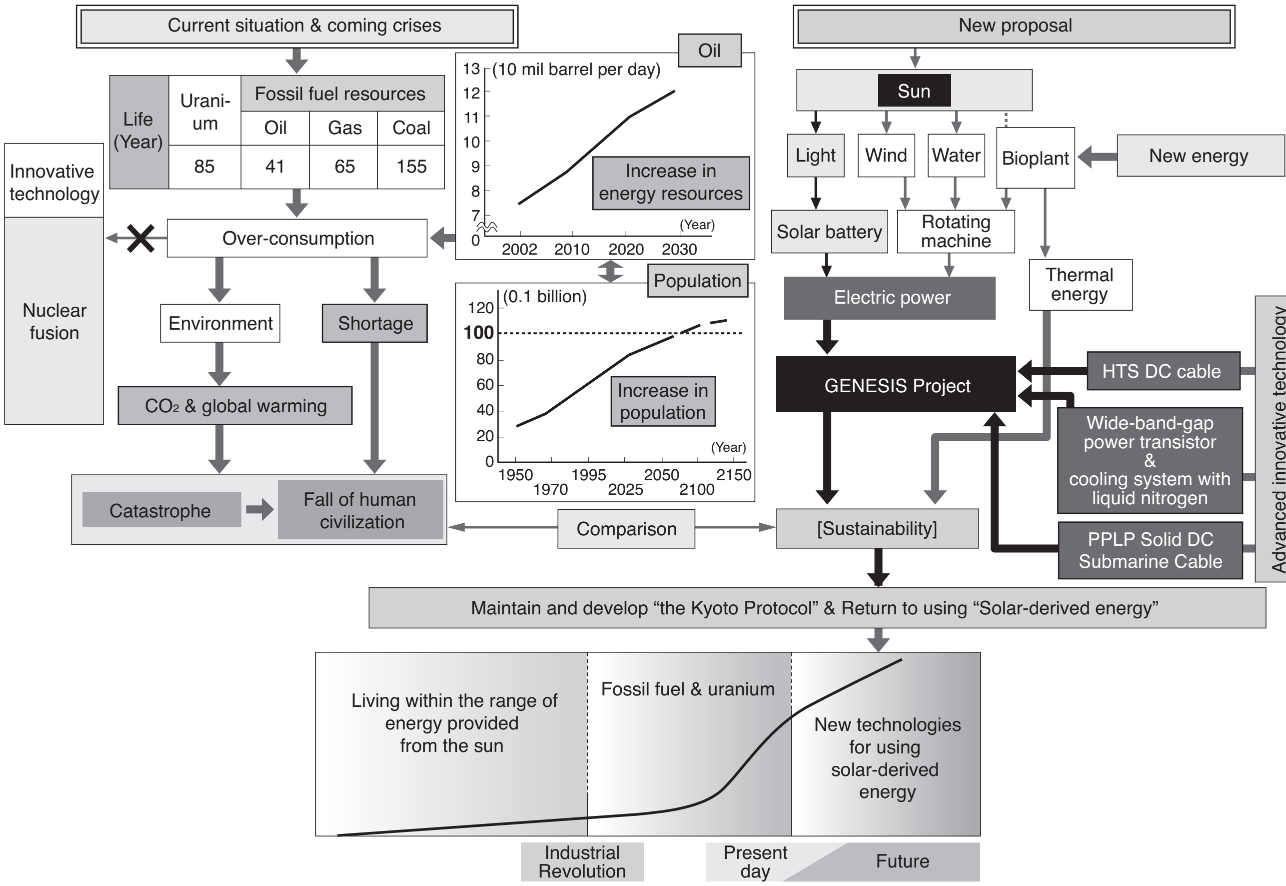


Fig. 21. Energy, resources and environment for 21st Century and future

fare of all living beings on the earth, including future generations of human beings. Given that population growth is inevitable, we must make comprehensive plans for development of new technologies based on new ideas and act aggressively to implement them to preserve our energy, resources, and the environment. As described above, the "water cycle" driven by solar energy was the source for the maintenance of energy, resources, and the environment before the Industrial Revolution. It is important to understand that in the "GENESIS Project and plus α," which I present to you in this paper, the "water cycle" based on decomposition of water by solar energy and man-controlled synthesis of water is the very foundation for new sustainable technologies invented by human beings, as **Fig. 20** shows. In view of the exponential increase in energy consumption and degradation of the environment, we have no more important duty than to introduce new systems based on these new technologies into human society sufficiently before it reaches the point of no return and to bring the systems to maturity. When we look into the future based on the lessons of past history, it becomes apparent that as shown in **Fig.s 7 and 21**, the "GENESIS Project plus α" is the only feasible solution, which combines HTS DC cables, with both new energies originating from the sun (photovoltaic, wind and hydraulic power), and power conversion devices cooled by a coolant. When we view the "GENESIS Project plus α" from the standpoint of today ("In-Out" perspective from the present to the future), it may seem like a mere casual idea that will face very high hurdles. However, when we look at the project from the standpoint of the future ("Out-In" perspective from the future to the present), its inevitability is apparent [(1)].

Finally, the essence of this entire paper is illustrated in **Fig. 21**. When we compare the "current situation" on the left side with the "new proposal" on the right side, the proper path that human beings should follow is obvious.

I firmly believe that now is the time for each of us to understand the true meaning of sustainability, to ask all people which path we should follow, and rise up and take action to open a path to the future by making strenuous efforts with wisdom, vision, a sense of mission, and courage.

[NOTE] Fossil fuel resources that human beings are now using are, as shown in **Fig. 22**, mainly composed of carbon that has been fixed (and released oxygen) and accumulated for 4.6 billion years since the birth of the earth through a solar-driven carbon dioxide assimilation process (photosynthesis). Therefore, the generated energy was spread widely and sparsely at certain times in the past, and it has been accumulated and condensed over a very long period of time. When we use fossil fuels by oxidizing them at once, an enormous amount of transient energy is released along with CO_2.

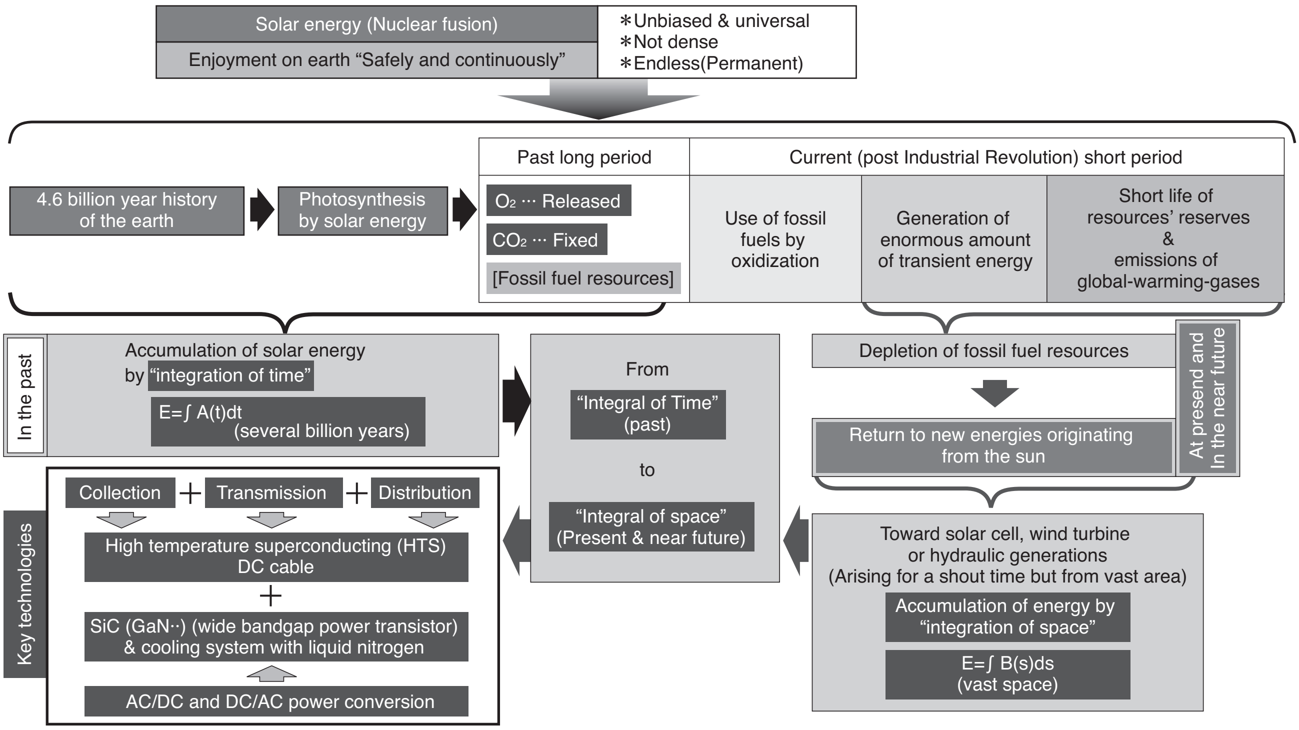


Fig. 22. From integral of time to integral of space

In contrast to the case of fossil fuel resources, new energies are based on solar energy, which is emitted almost instantly in a diffuse, widespread manner. In order to capture and use meaningful quantities of such new energies—that is to say, to make use of them as energy resources—it is necessary to concentrate energy resources that are scattered over enormous areas. This means that the integral of time needs to be replaced by the integral of space, as shown in **Fig. 22**. Therefore, key technologies to make the best use of new energies are the technologies for "collection, transmission, and distribution of electric power," which will be supplemented by those for "electric power storage" in a temporal manner.

Now we have to answer the question of whether or not those of us who are living after the Industrial Revolution can accomplish the "switch from time to space" in terms of energy resources by achieving the development of leading-edge and innovative technologies based on the "water cycle" within a very limited period of time [1].

* "CT-OP", "DI-BSCCO", "PPLP" and "3-in-One" are trademarks or registered trademarks of Sumitomo Electric Industries, Ltd.

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