Mankind, Civilization and Nuclear Energy

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I. Science and Technology Constructed a Civilization Based on Chemical Reaction

1. Science and Technology Supports Civilization

(1) Civilization Requests Energy, Material, Technology and Information

In my understanding, the mankind has cultivated the civilization. The civilization has its basis on the science and technology from the beginning of human history. The fundamental fields and areas in the science and technology are 4 items such as Energy, Information, Material and Technology. This feature has not changed through the history fundamentally, though we find big difference and improvement in quality and quantity. For instance, concerning technology or I should say tool, the change is so big between the boat rowed by people and the space rocket and jet airplane.

Concerning to material, age and era in the history can often be expressed by the material mainly used in that age such as: stone age, clay age and bronze or copper age though gold at the time of Mesopotamia was attempted to create by alchemy, but it failed in vain. The alchemy was realized when the Ernest Rutherford created an artificial element by a nuclear reaction around 1930 using the Cockcroft-Walton accelerator. The iron age came a few hundred years ago and initiated and supported the industrial revolution. Now, we are in the era of ceramics. Nuclear fuel of light-water reactor is also ceramic.

Concerning information, we have sensitivity on light, sound, smell, taste and feeling. On the first day of the cosmos creation but not Big Bang, God introduced light and separated day and night, as described in the Old Testament. Therefore, it clearly shows the light as the main information method. Language with literature enables us to memorize the history to the descending generations. Energy, the most important one of the four is energy. The other three should be energized before and during operation.

The main energy source for mankind changes from physical to chemical and now on the way to nuclear. The former two are originally supplied from the sun, in the form of sunshine, solar energy. What can nuclear energy play in the 21st century to supply plenty of energy and preserve environment? In other words, the recycling based civilization.

(2) The Joint Work of the Sun and Earth to Form Bio-sphere

Can nuclear energy play a central role in the sustainable development of mankind in any way?

On the earth, as far as the five senses can recognize, only chemical reactions have taken place, with the exception of the existence of solar rays. It is necessary to start from the explanation that solar rays were

essentially created by nuclear energy, and that the origin of universal energy is nuclear energy. It becomes significant how we can explain the links between nuclear energy and civilization as a whole.

If you take a moment to think, raising your eyes to the sky, you will wonder what the source of solar rays coming from the sun is, and when you realize that it is the nuclear fusion within the sun, you will, for the first time, notice the relationship between the earth and nuclear energy. Here, the sun will begin to change from something we worship to something we should study. As the result, you will realize that everything on earth takes place through the combined work of the sun and earth. The earth is open in terms of energy flow, seeking an energy source within the sun and returning the energy that it cannot use back into the space of the universe. Overwhelmingly large amounts of solar energy dominate the nature of the earth, transforming itself into phenomena such as wind, rain, and evaporation from the sea, which are seen favorably as renewable natural energies. The use of solar energy gives people a dream.
Certainly, the amount of solar energy reaching the earth is about 5×10^3 Q (1 Q = 3×10^{14} kWh), 5,000 times as much as the amount of energy consumed by mankind at present, so it offers something very attractive. George Gamov put forward the theory that solar energy is created by nuclear fusion reaction of hydrogen, and taught us for the first time that the nuclear energy has influence on the nature of the earth. It was then made clear that natural nuclear fission reactor existed on the earth, and that the energy source of the universe was basically unleashed by nuclear reactions.

(3) Bio-sphere is the Ecological Energy System on the Earth

What we have to turn our eyes to on the earth is the existence of ecological system and its energy system. Solar energy is transformed to pre-servable chemical energy by photosynthesis, even though only at a level of 0.02%, to form a bio-sphere.

Bio-sphere appeared after the joint work between the sun and the earth to enable the photo-synthesis. Bio-sphere is the important natural phenomena, especially to find out the goal of the recycling based nuclear energy system. One of the important phenomena is the formation of a biosphere, the ecological system on the earth.

There existed sea and mild environment for the birth and growth of plants. Synthesis of organic material out of carbon-dioxide and water by absorbing solar energy is the staring point of biosphere on the earth. After coming to the land from the sea the plant grew up by photo-synthesis as to be fed to animal which dissolves glucose, amino acid and protein to carbon dioxide, water and nitric acid. Here carbon, hydrogen, oxygen and nitrogen play main roles in the biosphere.

The co-existence of plant and animal has had the possibility to keep the equilibrium state between formation of organic material and the dissolution of them in the biosphere; I mean the closed system in which energy comes in and out. An open energy flow, however, materials or elements are kept inside the biosphere. It is really an energy system with closed material flow. But in reality the plant surpasses the animal in magnitude in the past, therefore the earth had a history in which carbon-dioxide contained in the air decreased. However when the mankind came into this biosphere, it reversed this trend by touching to the fossil fuel underground.

2. Sustainable Development for Mankind

(1) What Does Sustainable Development for Mankind Mean?

Since the industrial revolution, comfortable lifestyles have been underpinned by a civilization based on fossil energy, born from the development of the steam engine, an artificial power, and the introduction of electric energy, which is easy to use. Mankind will not be able to discard the many contributions created by science and technology, including this convenience, easily.

However, the world created by this civilization based on fossil energy, which can also be called a civilization based on petroleum, is reaching a turning point as problems on the discharging side lead to global warming.

To solve the contradiction of the modern age, a shift in principles from use to harmony shall be necessary. Although the ethics and social institutions required to construct a recycling-based society will of course be necessary, mankind cannot discard the comfortable life it has achieved through the progress of science and technology made up to the present.

It is hart to believe that society will accept the seemingly masochistic requests of the defenders of the environmentalist for a life ruled by nature and environment. The industrial revolution succeeded in converting a society governed by the environment to a society governed by energy in return for convenience and comfort, and was welcomed by the people.

It can be said that the achievements of the industrial revolution were artificial power by steam engine (1781) and electrical energy (electric generator 1870, Edison light 1879). It resulted in a revolutionary change to civilization, creating a social structure governed by energy.

If we hope to attain the “wholesome and cultured life”, energy is needed and resources must be secured. However, the petroleum-based civilization that made progress with mass production, consumption and disposal, regarding the use of resources as a good thing, has reached a turning point, because the discharge of carbon dioxide has created the problem of global warming. Only 200 years elapsed since the industrial revolution. As a result, environment conservation has become an issue equal to or greater in importance than the need to secure resources.

(2) The Industrial Revolution

The main energy source on the earth changes from physical to chemical and now, on the way to nuclear. The former two are originally supplied from the sun, in the form of sunshine, solar energy. What can nuclear energy play in the 21st century to supply plenty of energy and to preserve the environment? In other words, the recycling based civilization.

Science and technology have changed its quantity and quality with the times to support civilization.

Quantitative expansion to satisfy human aspirations and desires with the progress of civilization brought social reform with the industrial revolution period from agricultural society governed by environment to civil society controlled by energy consumption. In addition, this led to mass production, mass consumption and mass disposal. In particular, energy demands have expanded exponentially causing problems that are difficult to solve. This causes the situation that modern civilization supported by fossil energy cannot be continued without either reduction of energy consumption or change of energy resource.

On the other hand, the qualitative changes that were brought by high technology have shortened the time to realization of desires. At present, global communication operates at light speed and physical transport operates at the sound velocity. It takes me only 12 hours to get from Tokyo to Vienna. It took Columbus more than two months to sail from Spain to America. Of course, I also want to board the Queen Elizabeth for a relaxing world tour, but that is another story.

Qualitative change in civilization will inevitably expand energy demand. Such quantitative and qualitative changes require us to ensure environmental protection as well as resource reservation. For this reason, the relevance of energy should be first solved in relation to science and technology which supports the civilization.

For nuclear energy, it can be said that development as an energy source was an achievement of the 20th century.

Traditional civilization supported by chemical reactions and depending on fossil energy will become difficult to support a sustainable development of mankind under the threat of global warming. What is asked to us today is whether nuclear energy, which is governed by nuclear reactions rather than chemical reactions, can grow as a comprehensive science and technology to support a new recycling-based civilization or a recycle society, coexistent with or to replace traditional civilization.
To respond this question, one should probably begin by illustrating the total picture of nuclear science and technology and its long-term prospects (later discussed).

(3) UN Resolution on Sustainable Development of Mankind

The United Nations passed and later adopted "Principles of Sustainable Development" in 1992, as a resolution on the sustainable development of mankind.

It advocates maintaining the ecological system to support the earth, while presenting the ethical issue of "impartiality within a generation", the reduction of absolute poverty and also "impartiality between generations" such as "not leaving a negative legacy to the next generation". The issue of the appropriate handling of waste is by nature an issue of safety and resources, but is also an ethical issue.

The period during which fossil energy can be depended upon is 200 – 300 years at the longest, based on the currently **proved discoverable resources**. If we are talking about a period of more than 1,000 years, the only subjects for consideration are using the energy created by the nuclear reaction in the sun and received in the form of solar rays on the earth in the best way, both in terms of quality and quantity, or the nuclear energy generated on the earth. There are no ways left for mankind other than to reduce its population and return to the agricultural society of the past, or change its energy resources. This is indeed the shift from chemical energy to nuclear.

The world population was counted about 0.2 billion at the time of Christ Birth increased exponentially to reach 6 billions at the present and is estimated to reach as much as 9 billions in 2050. How can we ensure the conservation of energy and the environment in the near future? The earth is already getting smaller.

(4) Securing Resources and Conserving the Environment
Mankind will not be able to discard the many contributions created by science and technology, including this convenience easily.

However, the world created by this civilization based on fossil energy, which can also be called a civilization based on petroleum, is reaching a turning point as problems on the discharging side is leading to global warming. Nuclear energy, either within the sun or on the earth, must be depended upon as an alternative, if the problems are to be handled within the capacity that the earth has.

Waste is not necessarily generated from nuclear reactions alone. The products of chemical reactions include carbon dioxide, sulfur oxides and nitrogen oxides. The problems on the discharging side are not something particular to the use of energy; they include the problems of so-called industrial and domestic waste, such as used structures, equipment, parts and materials. How can we overcome the difficulty of making society aware of the comparison between types of waste?

It is important to compare the quantities of materials involved in the fossil energy system and the nuclear energy system. There is a difference as large as 1 million times between the energy created by chemical reaction and the energy by nuclear energy, and the latter has many advantages in supplying energy. If we consider carbon dioxide, which is not included in the category of industrial waste, the proposal of a carbon

tax has not yet been materialized. Materials such as used buildings, structures, parts, soil and concrete are industrial waste. Efforts are being made to reuse there. This is exactly what is meant by recycling.

People are beginning to look for a recycling-oriented civilization or a recycling-based society. As can be seen from the Recycling Law, limits have been set on the practice of using things and throwing them away. What is recyclable and renewable when we look at energy resources? Fossil energy is not recyclable, as it loses its resource value after a single combustion, generating waste. While efforts to prevent the generation of NOx and SOx have been made through a range of measures, the generation of carbon dioxide and water cannot be avoided, since they are the main materials generated by the chemical reaction. Fortunately, as water exists in abundance in the environment, it does not raise a problem. Carbon is a core element among organic substances and provided the basis for life to be born, and is an important element. The influence of carbon dioxide is determined by its concentration in the atmosphere, and the current situation, where its concentration is still continuing to increase, is certainly not acceptable. If it were eliminated, plants would not be able to grow, but if, on the other hand, there is too much of it, the heat balance of the earth will be adversely affected.

II. From a Civilization based on Chemical Reactions to a Civilization on Nuclear Reactions

1.What can we learn from the nature

(1) Big Bang

Here I look at the sky, not in the daytime but at night. We can have many images concerning to the nuclear science and technology. Here, I find several phenomena in the cosmos beginning from the big bang, creation of element and radiation, birth and the death of fixed stars, especially supernova. The phenomena in the sun and the earth are of course of major interest.

Big bang initiated the formation of the cosmos 14 billion years ago. George Gamov, a Russian physicist, imagined the origin of the cosmos in the fireball of atomic bomb test at Manhattan project. Big bang was an expanding ball filled with soup of radiation and particles. It is the origins of time, space, energy or mass.

We can see some high energy particles and mechanism of particle acceleration in the cosmos.

(2) Fixed Star and Supernova

In fixed stars nuclear fusion reaction occurs and releases energy and creates elementary particles. Element, not heavier than iron, were created in the fixed stars. But when a fixed star burns out its nuclear fuel, it sometimes become unstable and gravitational collapse happens to lead to supernova. In the process of supernova, gravitational energy is contained to create heavy particles like uranium and trans-uranium.

And the sun as you know makes a fusion reaction from hydrogen to helium and delivers so-dense energy into the cosmos. George Gamov also proposed and analyzed the energy source in the sun due to the nuclear fusion from hydrogen to helium.

And there are several news concerning to laser and maser phenomena observed in the Orion Nebula, Venus and Mars.

Laser as well as particle accelerator plays mainly for nuclear transmutation and change material properties. It’s also important to ask them to join for completion of nuclear fuel cycle and radiation application. I believe these facilities can open the new era of nuclear energy, science and technology in the coming civilization.

The nuclear science and technology treats the microscopic quantum world. However, as you see here in this figure the quantum world reveals its ability in the macroscopic world, that is stars in the cosmos.

Really, energy in the cosmos is supplied by the nuclear reaction occurring in the microscopic world. We find several important phenomena to apply for the nuclear science and technology, as I told already. I repeat once more that facilities which bring the microscopic quantum world to our civilization are nuclear fusion as well as nuclear fission reactor mainly for energy supply.

(3) Sun

The sun has long been both an object of faith and a subject of study. Despite of our non-stop dependence on the sun, we only succeeded in properly understanding how it generates its energy midway thorough last century. The belief that the sun burns petroleum can be immediately rejected through detailed observation, as a chemical reaction could not produce the estimated 6,000 degree C temperatures seen on the surface.

Furthermore, if chemical reactions among hydrogen, carbon, and oxygen were responsible, the sun would have burnt out within 100 million years.

It was also Gamov who declared that the sun produced its energy from nuclear fusion. In this reaction known as the hydrogen burning reaction, four hydrogen atoms come together to form helium 4. This reaction can take place in either of two ways; through a hydrogen chain reaction or a carbon-nitrogen cycle reaction.

The energy density of the fusion reaction occurring in the sun is actually quite small, around $1W/m^3$. The sun is able to sustain a nuclear fusion chain reaction namely because of its large size, which enables gravity to easily confine the nearby plasma.

(4) Natural Fission Reactor in the Earth

We have uranium in the earth. With uranium in the earth natural fission reactors became critical about two billion years ago at republic of Gabon, in the Oklo uranium mine and continued operation without a control rods for about 1 million years.

These natural fission reactors are really the light-water reactor whose enrichment of U-235 was just 3.7%. If we calculate back to 2 billion years ago, it is U-235 content in natural uranium at that time. You know that nowadays we use the enriched uranium from 3 to 5% for the light-water reactor. It is astonishing to see that the light water reactor existed about 2 billion years ago. But, I cannot find yet the existence of a fast reactor in the earth or some other planet or stars though we find fast neutron from supernova, however no chain reaction with fast neutron.

The history of natural reactor will tell us the way to treat the radioactive waste both underground disposal and annihilation of radioactivity by nuclear reaction.

2. Comprehensive Nuclear Science and Technology

(1)Basic View of Nuclear Energy, Science and Technology

I understand the nuclear energy science and technology as the utilization of the “interaction between material and radiation based on nuclear reactions”. With this interaction, 1) energy is produced, 2) material is converted and new one is created, 3) new technology can be brought to civilization and 4) latent information and the laws of physics can be learned. As equipment to facilitate these interactions, we have 1) energy-related atomic fission and fusion reactors, and 2) non-energy-related accelerators and lasers. I think this is the essential view to broadly understand whose picture of nuclear development from the aspect of a comprehensive nuclear energy, science and technology.

Therefore, the aims of nuclear development are:

(a) Energy supply to support a resource-recycling civilization,
(b) Conversion and generation of material(nuclear fuel)
(c) Creation of knowledge opening the potential for new cutting-edge applications

Besides the conventional view of nuclear energy as a measure to investigate the physical phenomena of the big bang, stars or interstellar-molecules, I regard it as a measure to create knowledge, that is a field in which new science and technology are created.

(2). The Total Picture of Nuclear Science and Engineering

I had a chance to make a speech at the Science Technical Committee of the House of Representatives of Japan in 1996. At the committee, I explained that starting point of nuclear energy should be placed at the discoveries of X rays, radioactivity, and electros at the end of the 19th century. It is because these discoveries contributed to open science and technology to a new microscopic world, and the discovery of nuclear fission (1938) and the success of the Chicago Pile(1942) revealed its possibility as an energy resource, which triggered a scientific Big Bang in the nuclear field.

At the same time, I remarked that the present situation of practical application of nuclear electric power generation using light water reactors and the expanding use of radiation and so on is ranked around the second milestone to the mountaintop with the possibility of further expansion. The mountaintop to climb, however, is covered with snow, and might be reached only by climbing up a steep mountain trail. This is because negative aspects of nuclear energy as science and technology can be clearly expected as well as difficulty research and development.

Judging from results of research and development in 20th century, however, the mountaintop appears and disappears among the clouds, but the horizon of nuclear energy as a comprehensive science and technology is expected there. In order to arrive at the top, it is necessary to eliminate the negative image of nuclear energy and to expand its positive aspect. This will bring us public acceptance for nuclear energy to support the backbone of our civilization. I said that we should clarify the total picture of nuclear science and technology to set forth a challenge of the possibility of human dreams in the future.

At the mountain top we see a total picture of nuclear science and technology which involves total area and field to be pursued.

(3). Long-Term Prospects for Nuclear Science and Technology

I believe that the most important point for the long-term prospects of nuclear science and technology is to organize the relationship between the time required for realization of practical use and solving problems and the time units existing in civilization.

(4). Three Typical Time Spans in Nuclear R and D

Here, I introduce 3 time spans: decade, century and millennium.

Decade is a time span in which a commercialized nuclear facility can be designed, constructed and operated in the society. Century is a relatively long time span, exceeding one's life. However, nuclear energy as a gigantic technology will require a time unit of 100 years from basic research to demonstration of big technology.

Fast-reactor system as well as nuclear fusion system should spend such a time span from the start of concept, R&D and to commercialization. For example, the nuclear fusion was discussed and brought into research and development about half a century ago, when I was a student at the department of physics. Research on nuclear fusion started from those days and continues today. Some results of research and development have been publicized, but most of them need future time until reaching a practical use stage.

It's the same for the fast reactor. Firstly the concept was proposed by Enrico Fermi in his book "Nuclear Physics" in 1950s. Both needs still a few decades to the commercialization of the first generation system, not the final but first generation system.

A millennium, the word millennium became famous on the turn of the 20th century. This is a time span for nuclear science and engineering to treat the reduction of radioactive waste. Nuclear reaction with neutron has the possibility to transmute radioactive material to either short-life one or annihilate its radio-activity. We should decrease or annihilate the risk of radiation within the millennium, of which I mean the time duration of our culture or history of civilization. It lasts at least one millennium.

In the 20th century, nuclear development succeeded in production of electric power, but demonstration of the nuclear fuel cycle was carried over to the 21st century. Natural reactors proved that the environmental effects of radioactive wastes could be eliminated by deep geological disposal. This can be feasible technically by vitrification with very long durability compared with recorded history, but it is difficult to obtain social acceptance because radiation risks can possibly remain permanently. Radioactive waste risks should be eliminated within the time span of a millennium as a unit of civilization extension.

Plutonium has a half-life 24,000 years so it is difficult to dispose of it directly. Does this fit into our understanding of the meaning of the word "retrievable"?

3. Challenge to What the Nuclear Energy System should be

(1) Ultimate Nuclear Energy System-SCNES

In order to contribute to civilization, the most important point we should first consider is to supply high quality energy system. So, I spoke about "What is an ultimate nuclear energy system?"

A nuclear energy system has four roles such as Energy, Fuel, Safety and Environment (SCNES: Self-Consistent Nuclear Energy System). Any nuclear energy system so far has satisfied these roles partially or even insufficiently. Light water reactor has played a role in generating electric power with a safety record that is almost perfect. However, production of new nuclear fuel (plutonium) can meet only half of the consumption demand at present, and deactivation of radioactive waste has not been realized.

Study of an ultimate system (SCNES) aims to show the scientifically possible extent to which the assets of nuclear fission can achieve these four roles. The assets in this case mean about three neutrons produced at nuclear fission and about 200 MeV of energy released.

As you already know, the nuclear system consists of a power generating reactor and a nuclear fuel cycle for fuel preparation and treatment. Neutrons are used for many nuclear reactions including nuclear fission in a reactor. Energy generated in the reactor is transferred outside the reactor and part of it is used for material mainly fuel preparation.

I explained that both requirements for a self-supporting energy supply (fuel production) (100% use) and deactivation by nuclear transmutation of radioactive materials (100%) in 1997 at Japan-US Santa Fe energy seminar.

The requirements cannot be realized in principle by light water reactors or high temperature gas-cooled reactors using thermal neutrons but are only feasible theoretically by employing fast neutron nuclear systems. This is just the scientific possibility for effective use of resources and zero-release of radioactive waste as a real vision of nuclear energy. At the Santa Fe seminar, I said perfect recycling of resources and zero-release, but someone revised it to not zero-release but zero-emission. Therefore, my summary report was changed to zero-release-emission.

A participant, Mr. Richard Rhodes, Pulitzer Prize recipient as the writer of *The Making of the Atomic Bomb*, agreed to my presentation, and at a luncheon speech he remarked that it would be best if plutonium burned in a nuclear reaction as Fujiie pointed out. On the other hand, someone has called this idea a "plutonium utopia".

I understand that this difference in a evaluation derives from different attitudes toward science and technology. At the present, science and technology is likely to be considered as one field, but I believe that science is the science of possibility and technology is the science of efficiency. This means that anything scientifically possible should be challenged, but that achievement depends on applied technologies and methods. An idealized scientific version is not always realized 100% perfectly, but it may be acceptable as an expression comparing the essences of fossil energy and nuclear energy.

Fossil energy can convert 100% of resources to energy, but its reaction product of carbon dioxide is fully delivered to the atmosphere. On the contrary, nuclear energy only uses 1% of resources in a once-through operation in a light water reactor, but radioactive wastes are isolated from the environment by geological disposal. Nuclear energy is called comfortable to the environment because of zero emission of carbon dioxide, but I don't think that a limitation of nuclear energy exists there from the viewpoint of its essence. The theme of my speech was to offer a presentation on whether the use of 100% of resources and deactivation of 100% of reaction are scientifically feasible.

(2) SCNES System with Non-Proliferation Objectives

Nuclear non-proliferation is not a simple characteristic of nuclear energy utilization, it has to be treated by both intrinsic and extrinsic way.

From the scientific view, non-proliferation problem can be categorized to 2 aspects, one is the space allocation of the nuclear material, and the other is the characteristic of the nuclear material itself, the adaptability to a nuclear explosion or a nuclear weapon. Given the place of fuel material usage, it's better to deal with this problem by the material composition of nuclear fuel.

In SCNES concept, since all the actinides are treated altogether as fuel material, nuclear reprocessing with co-extraction of Trans-uranium would be desired. To enhance the proliferation resistance by the change of material characteristic, the most important physical point in SCNES is the "Neutron Balance", since the multi-recycled TRU fuel burning and the isotopic denaturing of plutonium requires more neutrons in addition to fission, fuel production, and waste transmutation. In order to reconsider the neutron balance in SCNES with the non-proliferation sense, neutrons required for the denaturing of plutonium by even-mass-number plutonium isotopes are reevaluated. The results shows that in the fuel cycle stream within SCNES, Plutonium fissile is always together with eve-mass-number plutonium isotopes and plutonium isotopes composition always satisfy the level of reactor grade plutonium. With isotope separation of fission products, there is a clear perspective of neutron balance with Oxide and Metal fuel fast reactors with multi-recycling of TRU.

A multi region core concept is examined without blanket zone for non-proliferation objectives. Core concepts with blanket have been typical for FBRs in the past. Along with TRU-recycling without separation of TRU elements from discharged fuels, fast spectra cores provide low fractions for Pu-239

with converging into such fractions; Pu:MA=96%:4%. Fast spectra cores are provided the largest potential to utilize those TRU fuels with depleted and recovered uranium avoiding excessive minor actinide accumulation along with sustaining energy supply and fuel self sufficiency.

The conclusion in this section is that the scientific approach to non-proliferation can be treated within SCNES framework.

What kind of energy system can we use if we aim to construct a recycling-oriented society? The entrance is natural uranium and the exit is stabilized FP. Put simply, this would mean producing nuclear energy using a nuclear energy system incorporating uranium-238, and as a result only releasing stable fission products outside the system.

Is there a nuclear energy system that can succeed in completely recycling the nuclear fuel, which is suitable for a recycling-oriented civilization and releases zero radioactive materials at the same time? In a scientific sense, the ultimate target is to construct this within the confines of the assets of nuclear fission reactions. The scientific pursuit is to provide that this is possible using the assets SCNES shows that this is possible, at least in the sense of scientific feasibility. The concept of SCNES that I presented in 1992 had this purpose, namely, discussing whether it would be scientifically possible to make the full use of resources and discharge no radioactive materials. In other words, it presented the question of whether it would be possible to achieve recycling and zero release (zero emission).

(3) New Era Has Come for Nuclear Development

Development of nuclear energy seems to have moved into a new era, where the future of nuclear energy is openly discussed all around the world.

The 50th anniversary of President Eisenhower's historic "Atoms for Peace" address to the United Nations General Assembly on December 8, 1953 has also provided a great opportunity to talk about the contributions that nuclear energy has made to society so far, as well as its promising future developments. International cooperation such as GEN-4 is also gaining more and more momentum in many respects to sustain the sustainable development of man kind.

Nuclear energy, which is a technology that constitutes a fundamental pillar supporting human civilization, has the potential to make significant contributions to society in terms of energy, technology, materials and information. For example, the aim of the development of nuclear energy is to establish nuclear fuel cycles and thereby achieve a system that secures both energy supply and environmental protection at the same time. On the other hand, the public are now becoming aware that steady progress is being made, not only in the field of nuclear energy, but also with regard to the beneficial applications of radiation. Particularly, medical applications of radiation are increasingly familiar to the general public today. It is not unreasonable, therefore, to presume that in the future it will become more and more difficult to find any area, whether in high technology or in industries, that is completely free from the influence of radiation or nuclear energy.