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A 'must-go path' scenario for sustainable development and the role of nuclear energy in the 21st century

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ABSTRACT

An increase in the world population has accelerated the consumption of fossil fuels and deepened the pollution of global environment. As a result of these human activities, it is now difficult to clearly guarantee the sustainable future of humankind. An intuitional 'must-go path' scenario for the sustainable development of human civilization is proposed by extrapolating the human historical data over 30 years between 1970 and 2000. One of the most important parameters in order to realize the 'must-go path' scenario is the sustainability of energy without further pollution. In some countries an expanded use of nuclear energy is advantageous to increase sustainability, but fast reactor technology and closed fuel cycle have to be introduced to make it sustainable. In other countries, the development of cost-effective renewable energy, and the clean use of coal and oil are urgently needed to reduce pollution. The effect of fast nuclear reactor technology on sustainability as an option for near-term energy source is detailed in this paper. More cooperation between countries and worldwide collaboration coordinated by international organizations are essential to make the 'must-go path' scenario real in the upcoming 20 or 30 years.

1. Introduction

It has been a long time since Sir Isaac Newton discovered the famous law of action–reaction in Principia Mathematica (Newton, 1687), which describes the phenomena of motion related to moving objects in nature. This principle is easily extended to be applicable to a closed system like the ecosystem on our planet. Therefore, it is natural that an external or internal perturbation applied to an ecosystem induces a kind of reaction or response to accommodate the applied action.

Humankind has become highly industrialized since the Industrial Revolution in the 18th century. This industrialization has been accelerated based on the energy extracted from fossil fuels such as oil, coal, and natural gas. However, the increased use of fossil fuels has deepened the pollution of the global environment, which has resulted in the increase of greenhouse gases (GHGs) in the atmosphere and distorted the balance of the energy flow in the Earth's system (Ramanathan, 1988). This is an unintended action on the Earth's system. Now, the accumulation of GHGs is said to be responsible for global warming which has caused an abrupt climate change and has had various influences on the ecosystem. This is a kind of reaction in the Earth's system. Recent studies by the World Energy Council (WEC) and also by the Intergovernmental Panel on Climate Change (IPCC) investigated the global warming problem and intensively analyzed the predictable influences on both human life and the ecosystem (WEC, 2007a; IPCC, 2007). The conclusion of these reports requires imminent action to solve these problems.

Even though there still remains some disagreement, many scientists now are alarming that the abrupt change of the global environment due to pollution (Risbey, 2008) and the variation of natural resources could threaten the sustainability of human life on the Earth. In other words, pollution and the depletion of natural resources could limit the sustainable development of our civilization. The concept of 'sustainable development' is well defined in the famous 'Brundtland Report' (UN, 1987) from the United Nations World Commission on Environment and Development (WCED). In this report, sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their need." Actually, sustainable development of modern civilization has been a controversial topic for more than 30 years since the future of humankind was simulated by a computer model called World3 described in the Club of Rome's report entitled "The Limits to Growth" (Meadows et al., 1972). The results predicted by the World3 model gave us two pessimistic future scenarios and an optimistic one.

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More recently, Turner (2008) compared the three scenarios of 'Limits to Growth' with the true data of human history for the 30 years from 1970 to 2000. He suggested that modern civilization is on the trajectory of one of the projected pessimistic paths, which may result in a failure of sustainability in the mid-21st century. However, there is still the possibility of a successful sustainable development in the data of human locus provided by Turner (2008). Therefore, a 'must-go path' scenario is proposed which enables humankind to continue with sustainable development up to and beyond this century.

An ecosystem also seems to be governed by the law of inertia, which is another famous principle of motion described in Principia (Newton, 1687). From the viewpoint of inertia, the social system of humankind is the same as the ecosystem on earth. If the current dysfunctionality of these two systems is not changed, then the threat on the sustainable development of humankind will remain. Therefore, it is meaningful to derive some 'must-do' actions from the 'must-go path' on world population, food, pollution, natural resources, and others. The first change is expected from the pattern of energy production and consumption because the reduction of pollution may be the most urgent action. Therefore, a sustainable energy option deployable in the near-term was investigated.

2. Strategy for sustainable development

There are many criteria affecting sustainability. These factors revolve around human civilization; population change, food and water supply, energy supply, climate, pollution, and others. Among these criteria, the world population seems to be the most influential one directly affecting the sustainability of humans. An increase in population causes an increase in the use of natural resources, energy, food and other services. This trend is a natural one because people want to improve the welfare and the quality of their lives. However, the increased population causes the depletion of available resources, which results in a reduced birth rate due to limited services for a person and an increased death rate due to a deepening pollution. Thus, the population would decrease in turn.

It is straightforward that the simplest and most direct way to continue a sustainable development is to stabilize the world population at a reasonable level. However, it is unrealistic to control directly the birth rate and death rate in every part of the world because the population change itself is also affected by other factors of human civilization. To predict the future change of these complicated parameters, a scenario approach or probability approach is a useful modeling tool (van Vuuren et al., 2008).

2.1. A scenario to sustainable development

The World3 model used by Meadows et al. (1972) to develop the 'Limits to Growth' scenarios is a typical application of a scenario approach. In this study, the future of our civilization was predicted by modeling the interactions of five subsystems: population, food production, industrial production, pollution, and non-renewable energy resources. These subsystems were modeled to be inter-related linearly or not, and the change of one system and its feedback to other systems were also described in the model. For example, the change of population is determined by several parameters: health care, annual births and deaths, education, industrial production per capita, birth control program, etc. The change of population results in the change of population, industrial production, and natural resources. Three typical categories of scenarios were identified by the World3 modeling: two might result in significant collapse of civilization and one a stabilized development followed by a relatively mild collapse.

Turner (2008) gathered observed historical data on world population, services per capita, food per capita, industrial output per capita, non-renewable resources, and pollution from various databases covering the period between 1970 and 2000. He derived normalized indices on these parameters and compared the historical data with the output of the World3 simulation. The result implied that we are chasing the trajectory of one of the pessimistic scenario. The human historical data on population increase and industrial output per capita clearly correlate with the pessimistic prediction. The observed pollution data slightly deviates from the worst scenario. The real data on services per capita, food per capita, non-renewable resources are somewhere between the optimistic and the pessimistic scenarios.

Even the data obtained by Turner closely matched the results of simulation, which predicts the global collapse around the middle of the 21st century there is still the chance to shift the pattern of life to more sustainable development. Therefore, the 30 years of human historical data was extrapolated to obtain stabilization of parameters affecting sustainability and it was named as 'must-go path' scenario, which is the projection of expectations to a sustainable development of the modern civilization. The extrapolation is performed on the basis of the following:

- stabilization of sustainability parameters after the year of 2050;
- population increase by 25% till 2050 from that of the year 2000;
- increase in pollution by up to maximum value at 2050 and a gradual decrease thereafter.

In the 'must-go path' scenario the world population is stabilized without any remarkable increase of crude birth and death rates as illustrated in Fig. 1. The population change is closely related to other factors such as services per capita, food per capita, industrial output per capita, and also natural resources. Therefore, the stabilization of world population requires the stabilization of these factors of human life. To suggest the possibility of achievement of this population scenario the prediction results by the IMAGE 2.3 model (van Vuuren et al., 2008) are also described in Fig. 1.

The IMAGE 2.3 model takes into account the impacts of biofuels and carbon plantations on the long-term dynamics of global environmental change, i.e., land-use change, climate change, emissions of GHGs and air pollutants, energy use are

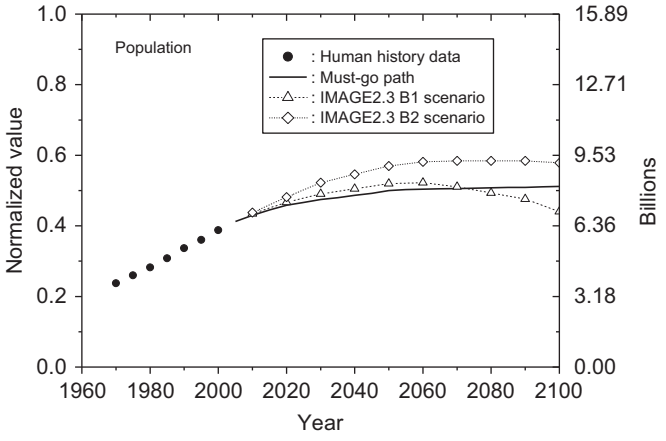

Fig. 1. Population data and its extrapolation to the 'must-go path' scenario.