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Foreword to the Roadmaps 2050*

China's modernization is viewed as a transformative revolution in the human history of modernization. As such, the Chinese Academy of Sciences (CAS) decided to give higher priority to the research on the science and technology (S&T) roadmap for priority areas in China's modernization process. What is the purpose? And why is it? Is it a must? I think those are substantial and significant questions to start things forward.

Significance of the Research on China's S&T Roadmap to 2050

We are aware that the National Mid- and Long-term S&T Plan to 2020 has already been formed after two years' hard work by a panel of over 2000 experts and scholars brought together from all over China, chaired by Premier Wen Jiabao. This clearly shows that China has already had its S&T blueprint to 2020. Then, why did CAS conduct this research on China's S&T roadmap to 2050?

In the summer of 2007 when CAS was working out its future strategic priorities for S&T development, it realized that some issues, such as energy, must be addressed with a long-term view. As a matter of fact, some strategic researches have been conducted, over the last 15 years, on energy, but mainly on how to best use of coal, how to best exploit both domestic and international oil and gas resources, and how to develop nuclear energy in a discreet way. Renewable energy was, of course, included but only as a supplementary energy. It was not yet thought as a supporting leg for future energy development. However, greenhouse gas emissions are becoming a major world concern over

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* It is adapted from a speech by President Yongxiang Lu at the first High-level Workshop on China's S&T Roadmap for Priority Areas to 2050, organized by the Chinese Academy of Sciences, in October, 2007.

the years, and how to address the global climate change has been on the agenda. In fact, what is really behind is the concern for energy structure, which makes us realize that fossil energy must be used cleanly and efficiently in order to reduce its impact on the environment. However, fossil energy is, pessimistically speaking, expected to be used up within about 100 years, or optimistically speaking, within about 200 years. Oil and gas resources may be among the first to be exhausted, and then coal resources follow. When this happens, human beings will have to refer to renewable energy as its major energy, while nuclear energy as a supplementary one. Under this situation, governments of the world are taking preparatory efforts in this regard, with Europe taking the lead and the USA shifting to take a more positive attitude, as evidenced in that: while fossil energy has been taken the best use of, renewable energy has been greatly developed, and the R&D of advanced nuclear energy has been reinforced with the objective of being eventually transformed into renewable energy. The process may last 50 to 100 years or so. Hence, many S&T problems may come around. In the field of basic research, for example, research will be conducted by physicists, chemists and biologists on the new generation of photovoltaic cell, dye-sensitized solar cells (DSC), high-efficient photochemical catalysis and storage, and efficient photosynthetic species, or high-efficient photosynthetic species produced by gene engineering which are free from land and water demands compared with food and oil crops, and can be grown on hillside, saline lands and semi-arid places, producing the energy that fits humanity. In the meantime, although the existing energy system is comparatively stable, future energy structure is likely to change into an unstable system. Presumably, dispersive energy system as well as higher-efficient direct current transmission and storage technology will be developed, so will be the safe and reliable control of network, and the capture, storage, transfer and use of CO_2, all of which involve S&T problems in almost all scientific disciplines. Therefore, it is natural that energy problems may bring out both basic and applied research, and may eventually lead to comprehensive structural changes. And this may last for 50 to 100 years or so. Taking the nuclear energy as an example, it usually takes about 20 years or more from its initial plan to key technology breakthroughs, so does the subsequent massive application and commercialization. If we lose the opportunity to make foresighted arrangements, we will be lagging far behind in the future. France has already worked out the roadmap to 2040 and 2050 respectively for the development of the 3rd and 4th generation of nuclear fission reactors, while China has not yet taken any serious actions. Under this circumstance, it is now time for CAS to take the issue seriously, for the sake of national interests, and to start conducting a foresighted research in this regard.

This strategic research covers over some dozens of areas with a long-term view. Taking agriculture as an example, our concern used to be limited only to the increased production of high-quality food grains and agricultural by-products. However, in the future, the main concern will definitely be given to the water-saving and ecological agriculture. As China is vast in territory,

diversified technologies in this regard are the appropriate solutions. Animal husbandry has been used by developed countries, such as Japan and Denmark, to make bioreactor and pesticide as well. Plants have been used by Japan to make bioreactors which are safer and cost-effective than that made from animals. Potato, strawberry, tomato and the like have been bred in germ-free greenhouses, and value-added products have been made through gene transplantation technology. Agriculture in China must not only address the food demands from its one billions-plus population, but also take into consideration of the value-added agriculture by-products and the high-tech development of agriculture as well. Agriculture in the future is expected to bring out some energies and fuels needed by both industry and man's livelihood as well. Some developed countries have taken an earlier start to conduct foresighted research in this regard, while we have not yet taken sufficient consideration.

Population is another problem. It will be most likely that China's population will not drop to about 1 billion until the end of this century, given that the past mistakes of China's population policy be rectified. But the subsequent problem of ageing could only be sorted out until the next century. The current population and health policies face many challenges, such as, how to ensure that the 1.3 to 1.5 billion people enjoy fair and basic public healthcare; the necessity to develop advanced and public healthcare and treatment technologies; and the change of research priority to chronic diseases from infectious diseases, as developed countries have already started research in this regard under the increasing social and environmental change. There are many such research problems yet to be sorted out by starting from the basic research, and subsequent policies within the next 50 years are in need to be worked out.

Space and oceans provide humanity with important resources for future development. In terms of space research, the well-known Manned Spacecraft Program and China's Lunar Exploration Program will last for 20 or 25 years. But what will be the whole plan for China's space technology? What is the objective? Will it just follow the suit of developed countries? It is worth doing serious study in this regard. The present spacecraft is mainly sent into space with chemical fuel propellant rocket. Will this traditional propellant still be used in future deep space exploration? Or other new technologies such as electrical propellant, nuclear energy propellant, and solar sail technologies be developed? We haven't yet done any strategic research over these issues, not even worked out any plans. The ocean is abundant in mineral resources, oil and gas, natural gas hydrate, biological resources, energy and photo-free biological evolution, which may arise our scientific interests. At present, many countries have worked out new strategic marine plans. Russia, Canada, the USA, Sweden and Norway have centered their contention upon the North Pole, an area of strategic significance. For this, however, we have only limited plans.

The national and public security develops with time, and covers both

conventional and non-conventional security. Conventional security threats only refer to foreign invasion and warfare, while, the present security threat may come out from any of the natural, man-made, external, interior, ecological, environmental, and the emerging networking (including both real and virtual) factors. The conflicts out of these must be analyzed from the perspective of human civilization, and be sorted out in a scientific manner. Efforts must be made to root out the cause of the threats, while human life must be treasured at any time.

In general, it is necessary to conduct this strategic research in view of the future development of China and mankind as well. The past 250 years' industrialization has resulted in the modernization and better-off life of less than 1 billion people, predominantly in Europe, North America, Japan and Singapore. The next 50 years' modernization drive will definitely lead to a better-off life for 2–3 billion people, including over 1 billion Chinese, doubling or tripling the economic increase over that of the past 250 years, which will, on the one hand, bring vigor and vitality to the world, and, on the other hand, inevitably challenge the limited resources and eco-environment on the earth. New development mode must be shaped so that everyone on the earth will be able to enjoy fairly the achievements of modern civilization. Achieving this requires us, in the process of China's modernization, to have a foresighted overview on the future development of world science and human civilization, and on how science and technology could serve the modernization drive. S&T roadmap for priority areas to 2050 must be worked out, and solutions to core science problems and key technology problems must be straightened out, which will eventually provide consultations for the nation's S&T decision-making.

Possibility of Working out China's S&T Roadmap to 2050

Some people held the view that science is hard to be predicted as it happens unexpectedly and mainly comes out of scientists' innovative thinking, while, technology might be predicted but at the maximum of 15 years. In my view, however, S&T foresight in some areas seems feasible. For instance, with the exhaustion of fossil energy, some smart people may think of transforming solar energy into energy-intensive biomass through improved high-efficient solar thin-film materials and devices, or even developing new substitute. As is driven by huge demands, many investments will go to this emerging area. It is, therefore, able to predict that, in the next 50 years, some breakthroughs will undoubtedly be made in the areas of renewable energy and nuclear energy as well. In terms of solar energy, for example, the improvement of photoelectric conversion efficiency and photothermal conversion efficiency will be the focus. Of course, the concrete technological solutions may be varied, for example, by changing the morphology of the surface of solar cells and through the reflection, the entire spectrum can be absorbed more efficiently; by developing multi-layer functional thin-films for transmission and absorption; or by introducing of nanotechnology and quantum control technology, etc. Quantum control research used to limit mainly to the solution to information functional materials. This is surely too narrow. In the

future, this research is expected to be extended to the energy issue or energy-based basic research in cutting-edge areas.

In terms of computing science, we must be confident to forecast its future development instead of simply following suit as we used to. This is a possibility rather than wild fancies. Information scientists, physicists and biologists could be engaged in the forward-looking research. In 2007, the Nobel Physics Prize was awarded to the discovery of colossal magneto-resistance, which was, however, made some 20 years ago. Today, this technology has already been applied to hard disk store. Our conclusion made, at this stage, is that: it is possible to make long-term and unconventional S&T predictions, and so is it to work out China's S&T roadmap in view of long-term strategies, for example, by 2020 as the first step, by 2030 or 2035 as the second step, and by 2050 as the maximum.

This possibility may also apply to other areas of research. The point is to emancipate the mind and respect objective laws rather than indulging in wild fancies. We attribute our success today to the guidelines of emancipating the mind and seeking the truth from the facts set by the Third Plenary Session of the 11th Central Committee of the Communist Party of China in 1979. We must break the conventional barriers and find a way of development fitting into China's reality. The history of science tells us that discoveries and breakthroughs could only be made when you open up your mind, break the conventional barriers, and make foresighted plans. Top-down guidance on research with increased financial support and involvement of a wider range of talented scientists is not in conflict with demand-driven research and free discovery of science as well.

Necessity of CAS Research on China's S&T Roadmap to 2050

Why does CAS launch this research? As is known, CAS is the nation's highest academic institution in natural sciences. It targets at making basic, forward-looking and strategic research and playing a leading role in China's science. As such, how can it achieve this if without a foresighted view on science and technology? From the perspective of CAS, it is obligatory to think, with a global view, about what to do after the 3rd Phase of the Knowledge Innovation Program (KIP). Shall we follow the way as it used to? Or shall we, with a view of national interests, present our in-depth insights into different research disciplines, and make efforts to reform the organizational structure and system, so that the innovation capability of CAS and the nation's science and technology mission will be raised to a new height? Clearly, the latter is more positive. World science and technology develops at a lightening speed. As global economy grows, we are aware that we will be lagging far behind if without making progress, and will lose the opportunity if without making foresighted plans. S&T innovation requires us to make joint efforts, break the conventional barriers and emancipate the mind. This is also what we need for further development.

The roadmap must be targeted at the national level so that the strategic research reports will form an important part of the national long-term program. CAS may not be able to fulfill all the objectives in the reports. However, it can select what is able to do and make foresighted plans, which will eventually help shape the post-2010 research priorities of CAS and the guidelines for its future reform.

Once the long-term roadmap and its objectives are identified, system mechanism, human resources, funding and allocation should be ensured for full implementation. We will make further studies to figure out: What will happen to world innovation system within the next 30 to 50 years? Will universities, research institutions and enterprises still be included in the system? Will research institutes become grid structure? When the cutting-edge research combines basic science and high-tech and the transformative research integrates the cutting-edge research with industrialization, will that be the research trend in some disciplines? What will be the changes for personnel structure, motivation mechanism and upgrading mechanism within the innovation system? Will there be any changes for the input and structure of innovation resources? If we could have a clear mind of all the questions, make foresighted plans and then dare to try out in relevant CAS institutes, we will be able to pave a way for a more competitive and smooth development.

Social changes are without limit, so are the development of science and technology, and innovation system and management as well. CAS must keep moving ahead to make foresighted plans not only for science and technology, but also for its organizational structure, human resources, management modes, and resource structures. By doing so, CAS will keep standing at the forefront of science and playing a leading role in the national innovation system, and even, frankly speaking, taking the lead in some research disciplines in the world. This is, in fact, our purpose of conducting the strategic research on China's S&T roadmap.

Prof. Dr.-Ing. Yongxiang Lu

President of the Chinese Academy of Sciences

Preface to the Roadmaps 2050

CAS is the nation's think tank for science. Its major responsibility is to provide S&T consultations for the nation's decision-makings and to take the lead in the nation's S&T development.

In July, 2007, President Yongxiang Lu made the following remarks: "In order to carry out the Scientific Outlook of Development through innovation, further strategic research should be done to lay out a S&T roadmap for the next 20–30 years and key S&T innovation disciplines. And relevant workshops should be organized with the participation of scientists both within CAS and outside to further discuss the research priorities and objectives. We should no longer confine ourselves to the free discovery of science, the quantity and quality of scientific papers, nor should we satisfy ourselves simply with the Principal Investigators system of research. Research should be conducted to address the needs of both the nation and society, in particular, the continued growth of economy and national competitiveness, the development of social harmony, and the sustainability between man and nature. "

According to the Executive Management Committee of CAS in July, 2007, CAS strategic research on S&T roadmap for future development should be conducted to orchestrate the needs of both the nation and society, and target at the three objectives: the growth of economy and national competitiveness, the development of social harmony, and the sustainability between man and nature.

In August, 2007, President Yongxiang Lu further put it: "Strategic research requires a forward-looking view over the world, China, and science & technology in 2050. Firstly, in terms of the world in 2050, we should be able to study the perspectives of economy, society, national security, eco-environment, and science & technology, specifically in such scientific disciplines as energy, resources, population, health, information, security, eco-environment, space and oceans. And we should be aware of where the opportunities and challenges lie. Secondly, in terms of China's economy and society in 2050, we should take into consideration of factors like: objectives, methods, and scientific supports needed for economic structure, social development, energy structure, population and health, eco-environment, national security and innovation capability. Thirdly, in terms of the guidance of Scientific Outlook of Development on science and technology, it emphasizes the people's interests and development, science and technology, science and economy, science and society, science and eco-

environment, science and culture, innovation and collaborative development. Fourthly, in terms of the supporting role of research in scientific development, this includes how to optimize the economic structure and boost economy, agricultural development, energy structure, resource conservation, recycling economy, knowledge-based society, harmonious coexistence between man and nature, balance of regional development, social harmony, national security, and international cooperation. Based on these, the role of CAS will be further identified."

Subsequently, CAS launched its strategic research on the roadmap for priority areas to 2050, which comes into eighteen categories including: energy, water resources, mineral resources, marine resources, oil and gas, population and health, agriculture, eco-environment, biomass resources, regional development, space, information, advanced manufacturing, advanced materials, nano-science, big science facilities, cross-disciplinary and frontier research, and national and public security. Over 300 CAS experts in science, technology, management and documentation & information, including about 60 CAS members, from over 80 CAS institutes joined this research.

Over one year's hard work, substantial progress has been made in each research group of the scientific disciplines. The strategic demands on priority areas in China's modernization drive to 2050 have been strengthened out; some core science problems and key technology problems been set forth; a relevant S&T roadmap been worked out based on China's reality; and eventually the strategic reports on China's S&T roadmap for eighteen priority areas to 2050 been formed. Under the circumstance, both the Editorial Committee and Writing Group, chaired by President Yongxiang Lu, have finalized the general report. The research reports are to be published in the form of CAS strategic research serial reports, entitled *Science and Technology Roadmap to China 2050: Strategic Reports of the Chinese Academy of Sciences*.

The unique feature of this strategic research is its use of S&T roadmap approach. S&T roadmap differs from the commonly used planning and technology foresight in that it includes science and technology needed for the future, the roadmap to reach the objectives, description of environmental changes, research needs, technology trends, and innovation and technology development. Scientific planning in the form of roadmap will have a clearer scientific objective, form closer links with the market, projects selected be more interactive and systematic, the solutions to the objective be defined, and the plan be more feasible. In addition, by drawing from both the foreign experience on roadmap research and domestic experience on strategic planning, we have formed our own ways of making S&T roadmap in priority areas as follows:

(1) Establishment of organization mechanism for strategic research on S&T roadmap for priority areas

The Editorial Committee is set up with the head of President Yongxiang Lu and

the involvement of Chunli Bai, Erwei Shi, Xin Fang, Zhigang Li, Xiaoye Cao and Jiaofeng Pan. And the Writing Group was organized to take responsibility of the research and writing of the general report. CAS Bureau of Planning and Strategy, as the executive unit, coordinates the research, selects the scholars, identifies concrete steps and task requirements, sets forth research approaches, and organizes workshops and independent peer reviews of the research, in order to ensure the smooth progress of the strategic research on the S&T roadmap for priority areas.

(2) Setting up principles for the S&T roadmap for priority areas

The framework of roadmap research should be targeted at the national level, and divided into three steps as immediate-term (by 2020), mid-term (by 2030) and long-term (by 2050). It should cover the description of job requirements, objectives, specific tasks, research approaches, and highlight core science problems and key technology problems, which must be, in general, directional, strategic and feasible.

(3) Selection of expertise for strategic research on the S&T roadmap

Scholars in science policy, management, information and documentation, and chief scientists of the middle-aged and the young should be selected to form a special research group. The head of the group should be an outstanding scientist with a strategic vision, strong sense of responsibility and coordinative capability. In order to steer the research direction, chief scientists should be selected as the core members of the group to ensure that the strategic research in priority areas be based on the cutting-edge and frontier research. Information and documentation scholars should be engaged in each research group to guarantee the efficiency and systematization of the research through data collection and analysis. Science policy scholars should focus on the strategic demands and their feasibility.

(4) Organization of regular workshops at different levels

Workshops should be held as a leverage to identify concrete research steps and ensure its smooth progress. Five workshops have been organized consecutively in the following forms:

High-level Workshop on S&T Strategies. Three workshops on S&T strategies have been organized in October, 2007, December, 2007, and June, 2008, respectively, with the participation of research group heads in eighteen priority areas, chief scholars, and relevant top CAS management members. Information has been exchanged, and consensus been reached to ensure research directions. During the workshops, President Yongxiang Lu pinpointed the significance, necessity and possibility of the roadmap research, and commented on the work of each research groups, thus pushing the research forward.

Special workshops. The Editorial Committee invited science policy

scholars to the special workshops to discuss the eight basic and strategic systems for China's socio-economic development. Perspectives on China's science-driven modernization to 2050 and characteristics and objectives of the eight systems have been outlined, and twenty-two strategic S&T problems affecting the modernization have been figured out.

Research group workshops. Each research group was further divided into different research teams based on different disciplines. Group discussions, team discussions and cross-team discussions were organized for further research, occasionally with the involvement of related scholars in special topic discussions. Research group workshops have been held some 70 times.

Cross-group workshops. Cross-group and cross-disciplinary workshops were organized, with the initiation by relative research groups and coordination by Bureau of Planning and Strategies, to coordinate the research in relative disciplines.

Professional workshops. These workshops were held to have the suggestions and advices of both domestic and international professionals over the development and strategies in related disciplines.

(5) Establishment of a peer review mechanism for the roadmap research

To ensure the quality of research reports and enhance coordination among different disciplines, a workshop on the peer review of strategic research on the S&T roadmap was organized by CAS Bureau of Planning and Strategy, in November, 2008, bringing together of about 30 peer review experts and 50 research group scholars. The review was made in four different categories, namely, resources and environment, strategic high-technology, bio-science & technology, and basic research. Experts listened to the reports of different research groups, commented on the general structure, what's new and existing problems, and presented their suggestions and advices. The outcomes were put in the written forms and returned to the research groups for further revisions.

(6) Establishment of a sustained mechanism for the roadmap research

To cope with the rapid change of world science and technology and national demands, a roadmap is, by nature, in need of sustained study, and should be revised once in every 3–5 years. Therefore, a panel of science policy scholars should be formed to keep a constant watch on the priority areas and key S&T problems for the nation's long-term benefits and make further study in this regard. And hopefully, more science policy scholars will be trained out of the research process.

The serial reports by CAS have their contents firmly based on China's reality while keeping the future in view. The work is a crystallization of the scholars' wisdom, written in a careful and scrupulous manner. Herewith, our sincere gratitude goes to all the scholars engaged in the research, consultation

and review. It is their joint efforts and hard work that help to enable the serial reports to be published for the public within only one year.

To precisely predict the future is extremely challenging. This strategic research covered a wide range of areas and time, and adopted new research approaches. As such, the serial reports may have its deficiency due to the limit in knowledge and assessment. We, therefore, welcome timely advice and enlightening remarks from a much wider circle of scholars around the world.

The publication of the serial reports is a new start instead of the end of the strategic research. With this, we will further our research in this regard, duly release the research results, and have the roadmap revised every five years, in an effort to provide consultations to the state decision-makers in science, and give suggestions to science policy departments, research institutions, enterprises, and universities for their S&T policy-making. Raising the public awareness of science and technology is of great significance for China's modernization.

Writing Group of the General Report

February, 2009

Preface

Bio-hylic and biomass resources are the core component of renewable resources on earth. They are the primary source of material for human living and sustainable economic productivity and development of society, as well as the ultimate guarantee for the environment that the survival of humankind depends upon. In addition to some bio-hylic and biomass resources we have been making use of, the vast majority has a greater economic and social values we have not understood or utilized. There is still huge potential in tens of thousands of animals, plants and micro-organisms that could meet the resource needs of necessary clothing, food, housing, transportation for human's sustainable development. One of the most significant challenges in the 21st century is facing the contradiction between the increasing demand for biological resources and sustainable development. To resolve this contradiction, a principal solution is to speed up the development of revolutionary theories and new technologies for utilizing bio-hylic and biomass resources, to explore useful species, germplasm, and genes widely existing in the wildlife (animals, plants, microorganisms) resource banks, to carry out germplasm innovation, to breed new varieties, to create new technologies and techniques, and to achieve large-scale bio-industrialization in order to meet the demands of the rapid and sustainable development of Chinese society and economy.

In the 21st century, resources shortage and environmental problems have been becoming major challenges to all human societies and will impact process of social-economic development and the future of humankind:

(1) The worldwide fossil energy will be gradually exhausted. The reserves of coal, natural gas, and oil could only support us for 216, 61 and 40 years, respectively. There is a more severe situation for fossil energy in China. To gradually reduce the dependence on fossil energy and increase the use of renewable bio-energy in China's energy consumption is ultimate goal to meet the long-term sustainable development of our energy system.

(2) Biological resources are becoming rapidly disappeared. Due to the negative impact of human activities, biological species are extinct at a speed more than thousand times higher than their natural extinction rates. One third of existing 300,000 – 450,000 species of higher plants are facing extinction due to over-harvesting, exhaustive mode of intensive agricultural production, urbanization, environmental pollution, change of land-use, invasion of alien species, climate change and other factors. Two third of higher plants will even

disappear by the end of this century.

(3) Climate warming and environmental pollution are increasingly worsening. Environmental changes and global warming caused by use of fossil energy have become an indisputable reality. Polar ice shelves are melting astonishingly, and the Himalayan glaciers are shrunk obviously. In China, the problem of urban air pollution and acid rain caused by burning coal has covered more than 1/3 of national land area. Since 1990, the CO_2 emission rate of China has been increasing faster and it is now ranked the second in the world. Therefore, it is impossible to sustain on the traditional development mode at the price of over-consumption of resource and energy. Fossil energy must be utilized in a cleaner way to reduce environmental pollution. It should be encouraged to jointly cope with climate change by developing the low-carbon technologies and low-carbon economy, promoting application of the bio-energy, and significantly reducing emission of CO_2 and other greenhouse gases.

(4) The energy and resources have a profound impact on the world's economy and society, as well as China's security and long-term development. High energy price and its great fluctuation have far-reaching impacts on the global economy, especially on the economic and social development of the developing countries. Existing energy system can not guarantee energy security and sustainability. It could be expected that, in the next 50 years, there will be 2 to 3 billion people around the world to get out of poverty, achieve well-off livelihood and modernization. As a result, the new challenges for the demand of energies and resources must be faced. A new mode of production, lifestyle and a new energy system for sustainable development must be explored by the human beings. In 2006, China's import of crude oil and oil products reached 160 million tons with an external dependence rate of 47%. The energy safety and national security of China will be largely influenced by the limitation of global oil supply, increasing competition, and external dependence. To meet the energy challenge, the human society must put the sustainable use of bio-hylic and biomass resources and protection of ecological environment in the first place. Therefore, building a new system for the sustainable use of biomass resources has currently become a great concern and a major strategic focus around the world. There is no doubt that in the 21st century human society will begin to use sustainable energy to gradually replace fossil fuels.

With a commitment on economic, clean, and efficient use of fossil fuels, we will simultaneously develop the advanced renewable energies, increase the proportion of renewable energy, and develop advanced, safe, reliable, clean nuclear energy and other alternative energy sources.

Bio-hylic and biomass resources are the basis of the sustainable development of economy and society and national competitiveness. Building a sustainable system for developing bio-hylic and biomass resources is essential and urgent for fulfilling the third-phase strategic goal of China's modernization. According to China's national conditions, it is of great significance facing the

future to make a strategic planning of China's bio-hylic and biomass resources in the next 30–50 years in thoughtful considerations of the demands, resources, environment, technology, economy and other factors.

The Guideline and Framework of Compilation and Research

The general idea of compilation and research of the roadmap for bio-hylic and biomass science and technology development are: to systematically understand biological material resources, bio-functional resources, gene resources and bio-intelligent resources; to strategically implement a demand-driven research on collective coverage from bio-community population - individual - tissue - cell - genes, through the basic deployment of research goals including creation, evolution, metabolic regulation and other mechanisms of bio-hylic and biomass resources; in forward-vision to build systematic biology theories and applied technologies of life science, and to develop the new approaches of exploring and utilizing bio-hylic and biomass resources at both levels of macro-biological resources and micro molecular biology in order to provide a sound scientific support for sustainable developments in new energy and materials, agriculture and food, nutrition and health care, ecological and environmental fields in the future.

Under the premise of highlighting bio-energy in the near future, the roadmap for development of science and technology of bio-hylic and biomass resources will focus on the following six aspects of important bio-hylic and biomass resources by defining boundary from roadmaps of "human population and health care" and "modern agriculture".

(1) The mechanism of photosynthesis, and exploration and use of high photosynthetic efficiency and high-biomass production of bioresources: It is fundamental important to reveal the mechanism of photosynthesis and breakthrough applied technology; based on native bio-hylic and biomass resources, it is crucial to build China's sustainable energy system and achieve large-scale application and commercialization of renewable energy technologies by strengthening the theoretical and technical research on screening, selection and evaluation of bioresources, development and application of new theory and technology by breaking bottlenecks in theory and core technology on genetic improvement, genetic engineering, scalable cultivation and industrial production.

1) Mechanism of photosynthesis;

2) Exploration and improvement of energy trees, grass and algae species with high photosynthetic efficiency;

3) Increasing photosynthetic efficiency and fatty acid content of the oil plants;

4) Scientific base and industrialization of algal photosynthetic hydrogen;

5) Bionic research on photosynthesis, R & D of solar cell.

(2) Biomass energy: It is urgently needed to screen high-quality energy plant resources and establish national breeding and production bases for energy

plants in different geographical areas; to explore biological mechanisms of high-efficient energy conversion and storage, whereas it is equally critical to emphasis on germplasm innovations, large-scale planting optimization, production and process system of energy plants; To establish a sound theory and technology integration of biomass energy conversion and application to improve the grade of biomass energy, and thus achieve a large-scale commercial application of biomass energy.

1) To establish germplasm resource repositories, information databases and an exploration system of energy plants (including micro-organisms), and improve the breeding and production bases of energy plants in different regions, and to optimize cultivation, processing, and production systems;

2) To study biological mechanisms of high efficient energy conversion and storage in energy plants and improve or produce new germplasm and varieties of energy plants with high conversion efficiency, resistance, adaptability and wide distribution through the means of modern biotechnology;

3) To establish an economic and rational system of biomass energy technology and optimize production system of the vaporization and liquefaction of biomass, fuel ethanol, bio-diesel and etc;

4) To improve theory and technology integration of biomass energy conversion and application and improve the grade of biomass energy, and achieve large-scale commercial application of biomass energy.

(3) Exploitation and utilization of microbial resources. Microbial resources are the fundamental important to human existence, development and biotechnology innovation. The research of life sciences, preventive medicine, the research and development of biotechnology and its industrialization as well as food science are all built on the basis of microbial resources. Considering the current biotechnology development and utilization of microbial resources, the focus should be on the development of cellulosic ethanol production, bio-photolytic hydrogen production, environmental remediation, carbon cycling and carbon sequestration, high-efficient physical-/bio-chemical conversion of agricultural wastes, process of biomass raw material as the alternative chemical raw materials, recycling and industry chain system to upgrade China's competitiveness in biological industry.

1) Cellulosic ethanol production;

2) Bio-photolytic hydrogen production;

3) Environmental remediation;

4) Carbon cycling and sequestration;

5) High-efficient physico-/bio-chemical transformation of agricultural wastes;

6) Technological process of biomass-based raw materials to replace chemical raw materials;

7) Recycling and industry chain system.

(4) Innovative system for exploration and sustainable use of strategic biological resources. Biological resources are the most important renewable

resource on earth as well as one of national important strategic resources. It is of very importance to strengthen scientific research on national unique strategic biological resource and halt species extinction, to emphasize conservation and utilization of our strategic biological resources, to rationally develop bio-industry in China's vast non-farming marginal land, to safeguard sustainability of our nation's social-economically dependable and original biological resources for bio-energy, agriculture and forestry, ecological environment and health care.

1) Centurial inventory, natural reserve assessment and innovative capacity building of biological resources;

2) Genomic conservation, discovery of functional genes, and genetic improvement of important strategic biological resources;

3) Mechanisms of biodiversity formation, evolutionary changes and maintenance, and bioresources exploration and germplasm innovation;

4) Evolutionary genomics of several major life science issues and sustainable use of biological resources;

5) Coevolution and maintaining mechanism of biodiversity and sustainable use of biological resources.

(5) Gene and genome resources: Considering the development trend of genomics and gene technology in the 21st century and China's national conditions, the efforts should focus on exploration of genome resources, bio-fuel molecular development, understanding and improvement of molecular machines. Also, the efforts should be put forward to revealing the molecular machines of life-support systems, understand regulatory mechanism of molecular machines, and establish the theory and applied technology of systems biology based on databases and informatics of the genome, gene expression, and protein expression and gene assembly, and to explore new bio-hylic resources at the micro level of -molecular biology.

1) Exploration and use of natural genetic resources;

2) Mechanism and technology integration of molecular machines;

3) Bio-fuel molecular design;

4) Theory and applied technology of systems biology.

(6) Biomimetic and Bioinspired Sciences & Technologies: The naturally bio-hylic world is rich in intelligent resources. The natural world with "natural selection" is a knowledge treasure and origin of technological innovation, which also is an intelligence resource pool scarcely touched by human. To learn from nature and draw inspiration from nature and give full play to the unique role of bionic technologies should provide us new principles, new methods and new approaches for design and construction of novel technical equipments. Thus, more reliable, more flexible, more efficient, more economical, and more environment friendly and biosystems-based devices will be invented for mankind.

1) To promote integration of nano-technology, life sciences, informatics science, brain and cognitive sciences, and upgrade the knowledge structure of future scientists and engineers;

2) To establish a platform of biological complexity research and discovery based on bionics research-oriented system, and infrastructure a number of bionic science and technology laboratories at the international standard;

3) Major breakthroughs in basic research, applied research and industrialization of bionic materials, bionic energy and environmental technologies, bionic sensing technology, process bionic technology and bionic information, and other related fields will be emphasized to meet the great demands of national needs in the fields of materials, energy, environment, population and health, information and security;

4) Development of bionic technology has been changing the design and manufacturing concepts of the engineering and technology field. The similarity degree determined between engineering technology and equipment's features including reliability, flexibility, economy, performance and environmental friendliness and those of the biological system serves as an important measure of the quality of technology and equipments.

Compilation Format and Framework

(1) Background information
1) Strategic plans around the world;
2) Status quo of China;
3) Bottlenecks of existing theories and applied technologies;
4) Needs of economical and social development.

(2) Feasibility analysis and prospects of theoretical and technical breakthroughs
1) Bottlenecks of existing theory and technology;
2) Development trends of science and technology;
3) Prospects of new science and technology;
4) Potential impact on national economy and society.

(3) Key scientific and technological issues, strategic paths, S & T developmental strategies of the Roadmap
1) S & T connotation;
2) Key S &T issues and technical paths;
3) Developmental strategies;

(4) Expected timeframe of the roadmap

Research Group on Bio-hylic and Biomass Resources of
the Chinese Academy of Sciences

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