

## Message from the Chief Guest

It is a great honor & privilege for me to send this message of felicitation on the occasion of the 5<sup>th</sup> International Symposium on Agriculture & Environment organized by Faculty of agriculture of the University of Ruhuna.

Agriculture, forestry, fisheries and aquaculture, together with the bio-based industries, are integral parts of the Sri Lankan economy and society. Relying on the use of limited natural resources, these sectors produce and process biological resources to satisfy the demand of consumers and a wide range of industries for food, feed, bio-energy and bio-based products. While they enhance Sri Lanka's self-reliance and provide jobs and business opportunities essential for rural, coastal and marine areas, these sectors are also facing significant challenges, which require solutions based on research and innovation.

The Knowledge Based Bioeconomy focuses on sustainable management, production and use of renewable biological resources, through life sciences and biotechnology and convergence with other technologies addressing the great societal challenges, to enhance the overall competitiveness and to meet high consumer demands.

So the initiative taken by the Faculty of Agriculture of the University of Ruhuna to organize a forum such as ISAE 2016 under the theme **"Towards a Knowledge-based Bioeconomy: New Challenges, Opportunities and Solutions"** is both timely and far-sighted. Therefore, I would like to take this opportunity to congratulate all officials at the Agriculture Faculty who devoted their time & energy towards this worthy endeavor. I would also like to commend all authors & scholars who will be presenting their work at this symposium for their commitment towards creating a greener and healthier world.

**Mr. B. Wijayarathna**  
Secretary, Ministry of Agriculture  
Sri Lanka

**Message from the Vice Chancellor  
University of Ruhuna**

Having successfully organized four International Symposia on Agriculture & Environment, the Faculty of Agriculture of the University of Ruhuna is now planning to congregate the 5<sup>th</sup> International Symposium (ISAE-2016) under the theme of “Towards a Knowledge-based Bioeconomy”: Challenges, Opportunities and Solutions.

ISAE-2016 will provide a good opportunity for the dissemination of new knowledge based on latest research studies done all over the world, especially Asian continent. As the Vice Chancellor of University of Ruhuna, I am happy to see that the Faculty of Agriculture is fulfilling one of the main duties of a University. I am sure this symposium would be a great opportunity to share new knowledge and experiences, and to discuss new challenges and opportunities among the scientists and academics in the fields of Agriculture and Environment.

From ancient times, agriculture is linked with the environment and the surrounding. Our ancestors protected the environment giving the highest value of their lives. They did know the value of the environment. They engaged in agriculture while protecting the environment. Unfortunately, the situation has changed and now it is worst. In modern agriculture, farmers tend to use harmful chemicals, pesticides and fertilizers. These hazardous chemicals pollute the soil, air as well the water. Gradually, the modern agriculture is moving out of the environment friendly agriculture. Contemporary agriculture is facing the critical challenge of feeding the ever increasing population while protecting the environment for future generations. If we protect the environment, environment will protect the human being by giving food and many necessary plant products. It is the law of nature. It is the prime duty of academia to take up the challenges while searching for new opportunities. I am sure this symposium will suggest better solutions to fight against the upcoming challenges in agriculture.

Faculty of agriculture always gives its highest priority to engage in research activities. On behalf of the University of Ruhuna I wish to appreciate the efforts taken by the Faculty of Agriculture to develop the research activities in the university.

I am sure this Symposium will achieve its objective through scientific deliberations to make modern agriculture more environmental friendly. It is always a big challenge to organize an International Symposium. I extend my congratulations to the Dean of the Faculty, organizing committee of the Symposium and, wish you all a very productive day.

**Prof. Gamini Senanayake**  
Vice Chancellor  
University of Ruhuna

**Message from the Dean**  
**Faculty of Agriculture, University of Ruhuna**

It is a great honor and privilege for me to send this message for the International Symposium on Agriculture and Environment-2016 organized by the Faculty of Agriculture, University of Ruhuna, Sri Lanka. The Faculty of Agriculture, University of Ruhuna is one of the leading faculties of the University of Ruhuna not only facilitating higher education but also generating new research findings to make our agriculture more competitive and environmental friendly in the global context.

This is the 5<sup>th</sup> International Symposium on Agriculture and Environment and introduces a many new features to the series. The theme of the Symposium; “Towards a Knowledge-based Bioeconomy”: Challenges, Opportunities and Solutions” will be an interesting topic for many of you. I am confident that this symposium will provide good opportunities to disseminate and share latest knowledge and new research findings among the national and international scientists and innovators in various disciplines of agriculture. I wish to extend my sincere congratulations to the organizing committee of the ISAE 2016 and wish all the success in today’s symposium organized by the Faculty of Agriculture, University of Ruhuna, Sri Lanka.

**Prof. S. Subasinghe**  
Dean/Faculty of Agriculture  
University of Ruhuna

## **Message from the Coordinator of the Symposium**

Increasing agricultural productivity and food production in a sustainable manner is a formidable challenge faced by the scientists, policy makers, planners and legislators in the face of burgeoning population, dwindling natural resources and mounting environmental consequences of agriculture. Unsustainable land use practices and indiscriminate use of agro-chemicals have posed serious social, economic, political, environmental and health issues, and if the present trend continues unabated, it will threaten the very existence of human civilization on Earth.

It is against this backdrop that the Faculty of Agriculture, University of Ruhuna organized its Fifth International Symposium on Agriculture and Environment (ISAE) on the theme "Towards a Knowledge-based Bioeconomy: Challenges, Opportunities and Solutions". Following the successful conduct of four annual international symposia by the Faculty of Agriculture, University of Ruhuna since 2011, ISAE has now become an important annual event providing a platform for the scientists at home and abroad to address issues relating to agriculture and allied fields.

Over 100 participants including eminent scientists, professionals, policy makers and planners are due to attend the fifth international symposium, comprising six plenary sessions. We are confident that the deliberations during the course of the symposium will shed light on the challenges and opportunities in producing not only food, feed and fibre, but also forest products, fish, (bio)-fuel, "pharmaceuticals"/nutraceuticals and other biomaterials and bio products from terrestrial as well as fresh water and marine systems. This will broaden the scope and face of the traditional agriculture, contributing towards emergence of a bio-economy.

The ISAE 2016 is a result of the dedication and devotion on the part of the academic staff, non-academic staff and the students of the Faculty of Agriculture who played very important roles behind the scene including raising funds for the event. Therefore I wish to take this opportunity to express my profound gratitude and deep appreciation them for their untiring efforts to make this event a reality.

I wish the ISAE 2016 a great success!

**Dr. Kumari Fonseka**  
Coordinator/ISAE2016

# Keynote Speech of the Inaugural Session

## Keynote Speech of the Inaugural Session

### Towards a Knowledge Based Bio-Economy: New Challenges, Opportunities and Solutions

CJP Siriwardana <sup>1/</sup>

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#### Abstract

The world is confronted with a range of economic, social and environmental issues, challenging the sustainable development in the future. The greatest challenge is how to maintain global food security in line with growing population producing enough nutritious food that everyone can access and doing so sustainably. This will increase the demand for agricultural, fishing, forestry and other related products, which largely depend on limited resources such as land, water and human capital. At the same time, the exploitation of ecosystems and the excessive use of non-renewable resources including fossil fuels are considered as main causal factors contributing adversely to the rapid global climate changes taking place. All these factors will contribute negatively on global sustainable development.

The bio-economy generally defined as “knowledge based production and utilization of biological resources and innovative biological process to sustainably provide goods and services across all sectors”, has gained recognition as an appropriate policy option to mitigate multi-faceted global issues while ensuring the sustainable development. The rapid improvement in life sciences including biotechnology and nano-technology, with well-coordinated policy and research environment at the national level has contributed to the significant improvement in the bio-economy in the recent past. The new strategy has been gaining its momentum gradually and firmly across the world. As a result, the first global Summit on Knowledge Based Bio-economy (KBBE) was held in 2015 in order to promote this concept considering its potential for resilience, carbon neutrality, renewability, reusability and multi-functionality. Further, the “Smart-KBBE” would help to create a World Bank recommended “Climate-Smart Agriculture System” and to achieve several United Nations (UN) targeted “Sustainable Development Goals” (SDGs) to be reached by 2030.

As Sri Lanka is not an exception to emerging challenges discussed, the bio-economy has also gained domestically. However, the potential of the bio-economy has not been fully exploited due to a lack of comprehensive approach to tap the available bio-resources. Since Sri Lanka is in the process of accelerating its growth momentum, the time has come for the country to lay its economic foundation right. In this context, the knowledge-based bio-economy would be an appropriate policy option available for sustainable development in Sri Lanka.

#### 1. Introduction

The world today is confronted with many challenges. The world population surpassed 7 billion in 2011 and is projected to grow to 9 billion by 2050. The greatest challenge faced due to a growing population is maintaining global food security, producing enough nutritious food that everyone can access and doing so sustainably. The projections show that food production will have to increase by 70 percent in order to feed 9 billion populations. Moreover, the world’s middle-income population is expected to expand by another 3 billion, largely coming from developing nations such as China and India over the next two decades. This group will make a significant impact on total food demand as well as access and availability to nutritionally balanced diets.

The rising food demand driven by growing population and rising purchasing power of people will change the future allocation of physical, natural and human resources in the future. Of them, land and water resources are limited and their usage is directly linked to global food supply, climate change and depletion of natural resources. Over-exploitation of these resources will hamper the sustainability of the agriculture sector and threaten the sustainable development of the world. Therefore, development in the agriculture sector should come from sustainable improvements in the sector together with efficient use of land and water resources.

In spite of increasing demand for land and water

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<sup>1/</sup> The views expressed in this paper are those of the Author and do not necessarily represent that of the Central Bank of Sri Lanka or Central Bank’s Policy.

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from the agricultural sector, structural problems in the natural resource base are deepening, limiting the availability of usable water and arable lands. They include salinisation and pollution of water, degradation of water related ecosystems and reduction of soil quality in arable lands. Risk related to agriculture production has been rising with the rapid climate changes and global warming. Emission of green house gases, the main cause for global warming has become a serious global concern today and all countries agreed to work according to the global agenda to arrest global warming. In view of rapidly changing global climate, the main goal of the Global Climate Summit held in Paris in December 2015 was to limit the increase of global warming below 2 degrees Celsius above pre-industrial level by 2100. Since agriculture is one of major contributor to the emission of green house gases accounting for 13.5 per cent of global green house gas emission, new methodologies are required to lower its emissions while increasing production in the future.

In finding solutions to these multi-faceted global problems, a majority of the countries in the world has reached a consensus on a new concept called "Bio-Based Economy (BBE)" or "Bio-Economy (BE)" as an accepted remedy to mitigate the impact of most of these global issues. The BBE refers to the activities that make use of bio-innovations based on biological resources, materials and processes to generate sustainable economic, social and environmental development. Advantages of adopting BBE are manifold as it ensures food security, sustainable development, economic growth and the conservation of scarce natural resources. Fully operationalizing this new concept would also help to shift the world into a new paradigm called "Green Growth Paradigm".

The rapidly improving scientific knowledge in life sciences including bio technology area is the major driving force behind the growth of the BBE. The enhancement in knowledge through innovation, knowledge sharing and awareness is a necessary factor to ensure the effective contribution of BBE. After assessing performance, most of the developed countries have given a high priority to promote Knowledge Based Bio-Economy (KBBE) as a new strategy to address emerging issues.

Sri Lanka is not an exception as it faces a similar set of issues in the economy. A growing population, rising middle income people, increasing demand for foods, specially more balance and protein rich diets, fast changing

consumer habits, difficulty of excessively opening virgin lands for agriculture, issues related to water management for multiple usage, high dependence on fossil fuel for energy supply, inadequate funding for education and R & D, lack of innovations, and changing climate conditions, are significant among other issues. In addition, Sri Lanka has one of the fastest aging populations in the world and demographic forecasts indicate that Sri Lanka's old age population (over 60 years of age) will reach about 25 per cent of the total population by 2040.

Sri Lanka too needs a sustainable and comprehensive strategy to address emerging multi-faceted issues related to social, economic and climatic areas. The new economic policy framework introduced in 2015 has emphasized the necessity of investing more on education and R & D with due recognition to replace fossil fuel with renewable energy on a gradual basis. In this policy environment, the adoption of KBBE is an appropriate option as it ensures sustainable development in the country.

## **2. Global Experiences of Knowledge Based Bio-Economy (KBBE)**

Juan Enriquez and Rodrigo Martinez at a Genomics Seminar in the 1997 American Association for the Advancement of Science (AAAS) meeting first defined the term of BBE. Then as a development strategy, this was first brought into the discussion at the International Forum i.e. The EU- Lisbon Summit in 2000 organized by the European Union (EU) countries. At this Summit, EU countries agreed to embark the KBBE by transferring knowledge into innovations in bio-economy and to be the world leading KBBEs by 2010. Since then, operations relating to KBBE were in the main agenda in EU countries that led them to organise the first KBBE Conference in 2005, under the main theme of "Transforming Life Sciences Knowledge into New Sustainable Eco-efficient and Competitive Products". At this conference, all member countries have agreed to further strengthen the KBBE operations, encompassing research and development in key areas such as agriculture, bio energy and bio technology. Meanwhile, special attention was paid, through KBBE to address famous "Jevons Paradox" which says falling resources costs as a consequence of increasing productivity lead to increasing demand for limited resources and their potential depletion. With the success of achieving performance targets, set under the first KBBE Conference, the second KBBE conference was also organized by the EU countries in 2010. The member countries have evaluated their

achievement in KBBE operations and reported that the size of KBBE in EU countries was over euro 2 trillion employing around 22 million by 2010. Accordingly, a new strategy was developed for KBBE toward 2020 with the emphasis on turning challenges into opportunities.

The concept of KBBE has gained momentum outside the EU countries too over the last decade. Most of the developed countries incorporated this new concept into their development strategies recognizing its ability to address common challenges faced by their countries. Newcomers within OECD countries included USA, Canada, Germany, Australia, Finland, Sweden, Netherland, Belgium, etc. In addition, countries in the developing world such as India, China, and South Africa have also introduced KBBE strategies into their development plans in the recent past.

Under the KBBE Strategy, most of these countries have designed and launched their National Research Strategy in line with the National Policy Strategy, as R&D is the driving force for innovation underpinning the sustainable growth of the KBBE. Further, they have promoted inter-disciplinarily and collaboration between science and industry as well as strengthening international cooperation. Intensive dialogue has been developed between policy makers and society in order to ensure responsible use of limited national resources.

With the increasing acceptance for the concept of KBBE, the first global bio economy conference i.e. Global Bio-Economy Summit-2015, was organised by German Bio-economy Council in November 2015 in Berlin. The Summit was able to attract over 500 participants from 50 countries representing policy makers, researchers, industrialists and civil society, emphasising its ability to address food security, sustainable development, economic growth and the conservation of scarce natural resources. The Summit mainly focused on the creation of sustainable bio-economy and three critical areas of action on which member countries expressed agreement. The first action was "promoting innovative as well as proven technology and measures for a sustainable bio-economy" and the second action was "establishing good governance for sustainable bio-economy". The final action was "initiating and strengthening international dialogue and cooperation". Based on this action plan, a series of new measures were identified and agreed to be implemented in order to drive the KBBE strategy across the world.

In the meantime, the United Nations (UN) has also reviewed the emerging global challenges, recommended seventeen new goals, and defined them as Sustainable Development Goals (SDGs) for member countries to be achieved by 2030. These new SDGs have replaced the UN's Millennium Development Goals (MDGs) expected to be reached by 2015. It has been recognized that the creation of a sustainable bio-economy will make an effective contribution to achieve seven SDGs. They include Food Security and Nutrition (Goal 2), Healthy Lives (Goal 3), Water and Sanitation (Goal 6), Affordable and clean energy (Goal 7), Sustainable consumption and production (Goal 12), Climate Changes (Goal 13), Ocean, seas and marine resources (Goal 14) and terrestrial eco systems, forests, desertification, land degradation and bio diversity (Goal 15).

During the last few decades, the world has given its highest attention to the changing global climate, especially global warming due to increasing emissions of greenhouse gases. Since all countries are responsible for global warming at different levels, global consensus is necessary to address this issue in a more formal manner. The last Global Climate Summit was held in December 2015 in Paris. At this Summit, it was agreed to govern climate change reduction measures from 2020. Agriculture and deforestation are recognized as one of the main Green House Gas (GHG) emission source and accounts for about 25 per cent of the global emissions of GHG significantly impacting on changes in the global climate. With the expected increase in food production, the risk of increasing the share of agriculture sector in GHG emission would be higher if the sector continues its existing agro-practices with opening of new lands for cultivation through deforestation. In this regard, the adoption of KBBE would help improve productivity through new innovations in the agriculture sector that ensure the food security while lowering its impact on future climate change. It has been proved that productivity improvement in the agriculture sector plays an important role to keep the emission rate of greenhouse gases below the rate of growth of food production. Therefore, improving productivity is important in the agriculture sector, which is one of prime objectives of the bio-economy and will help lower the negative impact of agriculture sector on the global climate change.

### **3. Lessons from KBBEs**

Global experience shows that the success of developing the KBBE is dependent on several key factors. The first and foremost factor is the

level of government patronage extended to drive the program. All over the world, the development of KBBE has received government assistance specially at the initial stage considering its multi-disciplinary nature and heavy investment cost involved. The second important factor is the designing of clear National Policy and National Research Policy to drive the overall operations of the KBBE. The third factor is maintaining proper coordination and cooperation between all stakeholders in the bio-economy. Finally, a visionary program is necessary to build the capacity in the bio-economy, both human and physical, for uninterrupted supply of knowledge in to the system.

The Global Bio-Economy Summit in 2015 has recommended three crucial areas of action for countries which are currently in action as well as those planning to be a member of the KBBE group for the creation of a sustainable bio-economy. They are;

- i. Promoting innovative and proven technologies and measures for a sustainable bio-economy;
- ii. Establishing good governance for sustainable bio-economy; and
- iii. Instituting and strengthening international dialogue and co-operation.

The first action requires active support from political authorities and proper policy co-ordination for the transition of the economy toward a KBBE. Under this action, several important policies are identified in order to optimize the value network of the bio-economy and minimizing waste and losses. These policies include;

- a) Investing in research to foster innovation and apply proven technologies
- b) Expanding education
- c) Increasing values and reducing structural costs
- d) Funding for innovation and capacity development
- e) Strengthening the role of businesses

Action two aims at issues related to usage of limited resources for production as it might create conflict between societal goals and stakeholder interests; recommending policies to harmonize international policies and inter governmental dialogue. These policy actions include;

- a) Addressing societal needs and market development

- b) Ensuring sustainable production and consumption of national resources
- c) Integrating bio-economy into multilateral policy process and global policy framework
- d) Assessing policy impact

Action three explains the synergy building process by establishing international dialogue and help to move forward new innovation and policies and ensure sustainable development at all levels.

Since countries are at different stages in KBBEs, a thorough review of the existing status would be useful to understand the gaps and lags in the system and for the efficient implementation of new strategies towards the bio-economy.

#### **4. Bio-economy: Current Status in Sri Lanka**

The bio-based economy in Sri Lanka has been evolving over centuries. Since independence, successive governments have played a pivotal role to develop the bio-economy by designing national policies and establishing necessary infrastructure. The necessary institutional framework including higher educational institutions, research stations, marketing framework and governance structure were also developed to facilitate the smooth operation of the bio-economy. In this process, more attention was given to build the required human capital and innovation with the ultimate goal of uplifting productivity in the bio-economy. However, the overall process was biased towards the agriculture sector as it has been playing a major role in the bio-economy.

The agriculture sector including forestry, animal husbandry, and fisheries sectors plays an important role in the Sri Lankan economy. At present, the agriculture sector accounts for about 11 per cent of Gross Domestic Production (GDP) with over 30 per cent of the labour force employed in this sector. The share of agriculture in GDP in Sri Lanka is considerably higher than the average agriculture sector share of 6 per cent in the global economy. In addition, agriculture has been used either as raw material or as finished items in the industrial and services sectors generating considerably large agro-based sector in the economy. This sector still has an enormous potential to grow. Further, the marine economy which is also highly underutilized has huge potential to develop its resources. The exclusive economic zone is about 25 times greater than that of the land area of the country. Therefore, the bio-economy has a much higher potential in Sri Lanka and innovations have wider space not only to improve food production but also to develop a wide range of

agro industries and value added products with potential application to many sectors including pharmaceuticals, energy and chemical industries, among others.

As a developing country in the lower middle income category, Sri Lanka needs to maintain a strong and sustainable development strategy to transform into a developed country. However, Sri Lanka's position in terms of innovation, competitiveness, knowledge and ease of doing business environment in Global Rankings is not favorable. In 2015, Sri Lanka's ranking in the Global Innovation Index was 85<sup>th</sup> position out of 143 countries, Global Competitiveness Index was 73<sup>rd</sup> position out of 144 countries, Global Knowledge Economy Index was 101<sup>st</sup> position out of 146 countries and Global Ease of Doing Business Index was 107 position out of 189 countries. Further, bio-technology and nano-technology industries are still at the primary stage, due to insufficient infrastructure and capacity resulting marginal contribution to the economy. The overall status of the economy indicated the necessity of having a novel approach for the country to take the economy forward while mitigating social and climatic issues.

The concept of KBBE is still novel for Sri Lanka, although the country has been engaging in bio-economic operations in the past. It would be an acceptable policy option for Sri Lanka to fast-track economic growth while helping to mitigate most of other issues in the country. Since the effectiveness of the KBBE is entirely dependent on innovation, the capacity building in national research and blending it with the BBE is a necessary condition to make the outcome effective, viable and sustainable.

The Economic Policy Statement explaining the medium term policy framework of Sri Lanka presented in November 2015 has clearly identified the key issues in the country and has come up with a range of recommendations to get the economic foundation right. It has recognized the building of the knowledge based economy as a priority area and states that "*The knowledge based social market economy built on social justice principles must be fostered*". It further elaborates the importance of innovation and productivity growth and states that, "*Future economic potential does not rely on labour alone. What is relevant for the development process is innovation and productivity growth.*" In line with the medium term policy framework, the Government Budget 2016 has proposed a detailed operational framework in order to move the new strategy forward. It has

recommended several new measures to build the knowledge based economy and provided necessary funding through the government budget for improving R&D, improving the quality of higher and technical education, develop the marine sector, venture capital arrangements for new inventors, and setting up of incubators to promote new investors. In addition, considerable weight has been given in the budget to promote the bio-economy and to move toward renewable energy reducing the dependency on fossil fuel with the objective of running the economy sustainably

## **5. Towards KBBE in Sri Lanka: Solutions**

The potential benefits of the KBBE are now globally accepted and more and more countries are joining the KBBE group. Sri Lanka too can access the benefits of KBBE by exploring the untapped potential of the bio-economy. A holistic approach has to be developed to get all stakeholders involved under the national policy framework with clear allocation of responsibilities among them. Further, a detailed action plan has to be developed explaining the role of government, national entities and sector specific institutions and private investors. In order to create a successful KBBE in the economy, a "To-do-List" with 10 key actions is given below:

### **5.1 Government to Play a Leading Role**

The government has to play a leading role in the creation of KBBE. Especially at the beginning, the direct involvement of the government is necessary due to the multi-disciplinary nature of KBBE and heavy funding requirements. The first task of the government is to articulate a comprehensive national policy and national research strategy to promote KBBE. The national policy should clearly spell out the scope, objectives and the guiding principles of the policy framework. Further it should provide an action plan for the government to work with and coordinate with all stakeholders and more importantly, explaining the funding plan during the process of implementation. In addition, the establishment of relevant entities such as governing bodies, research institutes, centres of excellence and development of the governance structure also need direct involvement of the government.

### **5.2 Establishment of an Apex Body**

Activities connected with the bio-economy currently fall under the purview of different public entities. Therefore, a special entity is required to be exclusively established for the purpose of policy designing, coordinating and monitoring of KBBE at national level. For this

purpose, as done in most countries, the government can set up an apex body, called a National Bio-economic Council with a clear mandate to facilitate the policy agenda.

### **5.3 Building Human Capacity**

The development of a sustainable KBBE is heavily depended upon the national research strategy focused on developing new products and commercialization of these products. The success of this process is dependent on the quality of human capital involved in the research work at universities and research institutions. It is the responsibility of education system to supply required quality of human capital in related fields. Therefore, improvement in the quality of education in line with the changing market needs and to supply the required quantity of human capital to match the demand is necessary condition. In addition, a continuous on-the-job training for researchers is also necessary to upgrade the capacity of human capital in the bio-economy.

### **5.4 Spending more on R&D**

Innovations are the cornerstones in the knowledge-based economies helping to continue the economic growth. Innovations are depending on the discoveries of researchers and scientists called as an invention. Inventing a new product is a time consuming and costly work but it does not guarantee the commercial viability of the discovered product to recover the cost involved. Further, there should be a system for making such inventions accessible to entrepreneurs to make use of it to produce commercially viable product. Then this process has to be repeated to get the maximum outcome from the invention. Even though, all inventions are not commercially viable, the flow of funding for R&D need to be maintained at an adequate level to continue the status of knowledge based economy. At present, the world accepted funding level for R&D is around 1.5 percent of GDP in order to secure the technical potential of the country.

### **5.4 Universities and Research Institutions to Play a Catalyst Role**

The success of the knowledge-based economy is entirely depending on the creation of knowledge that drives innovations in the country. Universities have to take a leading role to create knowledge for which creative capital has to be build in Universities by encouraging academic staff to get engage in research work. A better coordinated system need to be established to transfer new inventions created both by universities and research institutions into relevant industries in order to convert them into commercial products. In addition, both

universities and research institutes can provide Incubator facilities for translating research outcomes into marketable products with patent protection and licensing arrangements.

### **5.6 Promoting Entrepreneurship**

Uplifting the human capital helps to find new discoveries and then transfer of benefits of such discoveries to people and the economy through commercially viable products handled by entrepreneurs who function as investors. Therefore, a conducive environment needs to be developed through the education system, institutional arrangements and regulatory framework to develop entrepreneurial skills and an operational environment for them in the economy. In addition, building a close link between researchers (inventors) and entrepreneurs (investors) and assisting them by providing incubator facilities, capital requirements, regulatory protection and budgetary concessions would also help to develop entrepreneurs.

### **5.7 Strengthening Regional and International Co-operation**

One major drawback observed in research work in most of countries is that traditional working arrangements restricting research operations within "Research Silos" without adequately sharing their inventions with related community. Arranging more open approach for research operations and strengthening regional and international dialogue and cooperation will improve the synergy of research outcomes. This new policy needs to be incorporated in the national KBBE strategy.

### **5.8 Sustainable Use of Biodiversity**

The conservation of biodiversity is one of the global concerns and it has to be addressed in the KBBE strategy too. The impact of excessive land utilization, emission of Green House Gas and possible shift from "Black Carbon" to "Green Carbon" are key concerns raised against the concept of KBBE. Taking these issues into account, KBBE strategy needs to drive toward generating "Smart Bio-economy" for which the KBBE strategy need to be developed on biodiversity-based economy instead of Biomass-based economy.

Sri Lanka is a hot spot for Biodiversity. Therefore, KBBE strategy has to take into account the conservation of biodiversity and use it in a more sustainable and equitable manner.

### **5.9 Establish Governance Framework**

The bio-economy depends on a range of biological resources to produce a variety of bio-

based products. Since the goals of stakeholders are different to country's national goals, countries have to develop a clear and transparent governance structure for the regulation of the operations of the bio-economy. The governance structure requires focusing on all related areas including ensuring sustainable production and consumption of natural resources, addressing social needs and market development and integrating domestic bio-economy with global bio-policy framework.

### **5.10 Promote Public Awareness**

The KBBE strategy will take the country in to the new paradigm. The output of the bio-economy will be gradually shifting from traditional research based products to high-tech such as bio-technology and nano-technology based products. At the same time, bio-economy will play a key role by exploiting the total bio-resources. In this scenario, public acceptance on the new strategy as well as new products is necessary to move the KBBE strategy forward. Therefore, it is imperative to develop a national awareness campaign to educate stakeholders, policy makers, regulators and general public for the implementation of a resistant free KBBE strategy.

### **6. Conclusion**

The concept of KBBE has gained recognition in most countries during the last two decades as a better strategy to mitigate the emerging economic, social and environmental challenges. The bio-economy has its unique features and advantages including its potential for resilience, carbon neutrality, renewability, re-usability and multi functionality. Currently, more than forty countries both developed and developing actively promote bio-economy with a view to achieving sustainable development. To achieve the full benefit of the KBBE, it requires holistic and integrated policy framework operated under the government leadership with active cooperation from all stakeholders in the bio-economy. In view of emerging challenges, Sri Lanka is not an exception. So far, the bio-economy in Sri Lanka has been heavily under exploited. Therefore, adopting a KBBE strategy would help to address emerging challenges and help to maintain sustainable development in the economy.

### **Recommended sources of Information in Bio-economy**

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