



Thesis

# A Global Look into the Prospects of Bioeconomy

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### Summary

Bioeconomy is a very hot topic for discussion in recent time. However, there is a variation in how bioeconomy is defined and there is a confusion about whether bioeconomy is a new concept or an old concept. There are various topics discussed under bioeconomy. Even though many countries have already accepted bioeconomy as a significant part of their economic development and have already established various strategies, there is still the lack of global definition and strategy. The main aim of this thesis was to clarify the definition of the bioeconomy concept and history of the bioeconomy activities. Another aim was to review the bioeconomy strategies and activities from various countries and business prospects especially related with bioeconomy. The work was completed with the desk study through internet searches and analysis of data. The work was able to gather many definitions on bioeconomy provided by respected organizations and was also able to dig the course of bioeconomy development. The result shows that though there are many definitions available there are some common attributes. Bioeconomy is an old concept with the history of about 10,000 years but newer approaches are making bioeconomy take the stage for discussion. Also, bioeconomy is related with economical, environmental, political and social aspects and a lot with sustainability. Developed countries are taking bigger efforts towards the sustainable economy, environment, and living prospects through bioeconomy and many bio-based businesses.

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# 1 Introduction

Humans have always been dependent on biodiversity of the planet earth to sustain the life and survive. The biological diversity has provided the food, feed, fiber and fuel to support the life system. There has been development in agriculture, industry, and trade leading to economic activities through the utilization of bio resources. The pollution, carbon dioxide emission and climate change also followed the development. The depletion of fossil resources, increasing population, increase in demand for nutritious food, medical supplies and other goods, unemployment, and more issues are creating headlines daily. This can be taken as the base for the emerge of term bioeconomy. Sustainably produced renewable natural resources and bio-based innovative technology is the two fundamental principles which bioeconomy focuses on in order to reach the goal of sustainable and green economic growth.

The term bioeconomy is still messy and is not clear among many. Public lacks awareness on the history of bioeconomy concept and it is still in confusion whether this concept is something to believe in or this is just something that policy makers care about. It also seems that almost every country has their own view and strategies towards the concept and follow different approaches toward bioeconomy.

The main objective of this paper is to review the concept of "Bioeconomy" from the very basics and collect the information on the definitions and history of the concept, milestones, and events involved in the advancement of bioeconomy to the current global status. This paper shows the various efforts done from world leader countries to mitigate the national and international issues related with the environment, food security, energy demand and economic development with the help of bioeconomy development. Also, this paper focuses on Finland and its course to bioeconomy along with the current bioeconomy trend and innovations. So to clarify, this paper tries to answer the following questions.

1. Is there a unanimous definition of bioeconomy?
2. What is the history of bioeconomy? Can bioeconomy be classified into old or new?
3. What are the various topics bioeconomy is related with?
4. How are the world leading countries addressing bioeconomy?

5. Are there any business cases being developed specifically related to bioeconomy concept in the specific country?

## **2 Methodology**

The report was produced on the basis of the study and literature survey done on desk with reference to the publicly accessible reports, articles, documents and websites on the internet from various organizations and countries. The internet based search was done using various keywords such as "bioeconomy", "biotechnology", "bioenergy", "biofuel", "green technology", "policies for bioeconomy", "regulations for bioeconomy", "bio-based", and more for the main chapters presented in the report and the keywords for the various sub-topics presented were used respectively as well. The work was only based on the internet sources. The number of items appeared with the keywords searched in Google search was very high, for example, for the keyword "Bioeconomy" the number of hits was 583,000 and for "Bioeconomy in Finland" was 85,800 whereas the number of hits for "Biotechnology" was 80,700,000 and "Bioenergy" was 5,060,000. Similarly, in the search in the database of ScienceDirect, about 1,200 results were found under keyword "Bioeconomy" and about 435,000 results for keyword "Biotechnology". Among the results, the most relevant and original sources were used.

The search results show that there are more materials available about biotechnology and bioenergy than bioeconomy itself although both are the main aspects of bioeconomy. From the search result, it was found that there are not many papers available especially on what bioeconomy is and its history.

The sources for the information were gathered from the developed countries mainly from Europe and America. The literature related to the idea is already available in abundance specially for biotechnology and bioenergy. The information was checked with more than one source where necessary if verification was needed for example for statistical data. Since there was no primary data collection involved in the work, all the data acquired and used in the report are from the secondary sources which include reports, articles, journals, public information documents and others. Specific countries were taken for the detailed study of the bioeconomic strategies and activities for example G7 countries and Finland was taken as an example country for the bioeconomy development with specific hands-on bio-based product cases for which various news articles published online were used to gather the information.

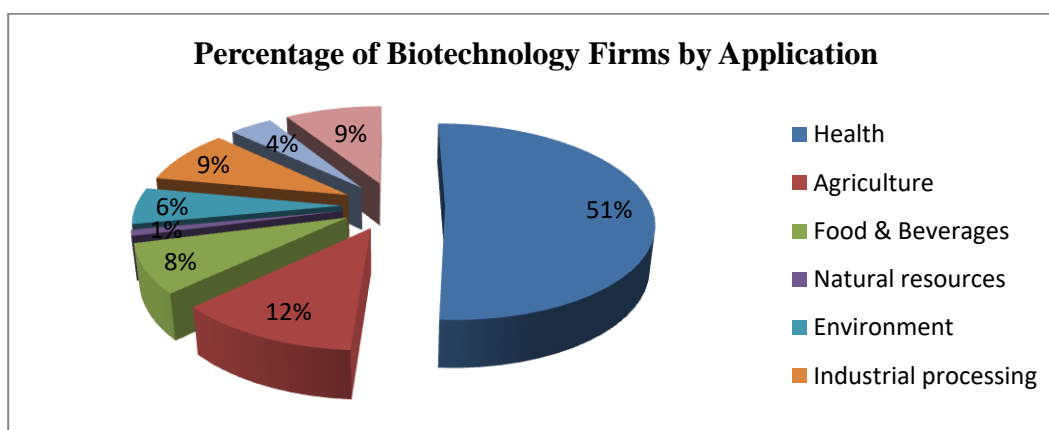
### **3 Literature Review on Bioeconomy**

This part introduces biotechnology and bioenergy as two distinct disciplines of bioeconomy. This section can be considered as the theoretical part of the report and will help the readers understand the main aspects of bioeconomy. The information will be relevant to understand the various parts in the result section.

#### **3.1 Biotechnology**

The Convention on Biological Diversity (CBD) defines biotechnology as: "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products for specific use". [1]

Biotechnology refers to the utilization of the biological resources from nature for consumption through industrial and other processes and also with genetic applications for the development of better technologies and products to improve human lives and health of the planet [2]. Technologies applied for the production of the products for practical purposes with the use of biological resources from living organisms to the substances extracted from living organisms are known as biotechnology. Since biotechnology deals with all classes of bio-organisms from viruses, bacteria and micro-organisms to plants and animals, it has been used in various sectors (see figure 1) such as agriculture, medicine, and industry and also in genetic modification. Some applications such as fermentation, brewing, production of antibiotics, use of yeast in food production, plant breeding, producing genetically modified seeds, pest controlling, strengthening the nutritional value in the food products, diagnosing the diseases in plants and animals has been in practice for quite a long time. Farmers and people involved in the agriculture and animal farming have been using biotechnology for producing superior nutritional crops and animals and advancing the animal feeds and feeding practices with the reduction of agricultural and animal waste. [1]



**Figure 1 Applications of Biotechnology [3]**

The research in the genetic structure and genetic properties have already made a significant breakthrough in agricultural biotechnology. Genetics explore the functions and compositions of the single genes whereas there is genomics also which addresses all the genes and their interrelationships to study the connection and influence on the growth and development of the organisms. Genetic engineering helps in understanding the value, characterizing and managing genetic resources in crops, livestock, fisheries, and forestry. Also, the practices of diagnostics and epidemiology are part of biotechnology. It has been difficult to identify and monitor the diseases in plants and animals previously until the development of biotechnology. It has been made possible to study the plants and animals in molecular level and analyze to characterize viruses, bacteria, parasites and fungi which have made valuable development in improving the health and disease control. Production of disease control products and vaccinations have been made possible because of biotechnology. Also, various innovative technologies have been introduced through biotechnology to aid the production of nutritious food and with gene-based technology new ways to improve the animal and aquaculture productivity has been employed either by modifying the feed or through modifying the metabolic system of animals. [1, 4]

Biotechnology proposes various tools and technologies for advancing traditional and modern agricultural research and improving the understanding of the genetic level of the plants and animals. New ideas are being produced through biotechnology to increase the quality production of both food crops and cash crops and uplifting the economy of agriculture and making agriculture-related jobs efficient and effective and hence uplifting the bioeconomy.



### 3.2 Bioenergy

All kinds of solid, liquid and gaseous form of fuels that can be acquired directly from organic matters produced from plants and animals or indirectly from the industrial or domestic waste are biofuels. Biofuels are the source for any form of bioenergy. Today about 10% of energy demand is fulfilled through bioenergy [5]. From the traditional firewood to the refined ethanol or biodiesel, biofuel has been a part of the human state of living. Ethanol and biodiesel are the two most popular form of biofuel used today as replacement of fossil fuels. It has been estimated that about 80% of bioenergy consumption is for homes or domestic use, about 18% for industrial use and about 2% for liquid fuel for vehicles. The technologies used for converting biomass to energy are thermo-chemical or biological. [5]

Biofuel has gained its importance because of many factors such as finite fossil fuel sources, fuel price, energy crisis, carbon footprint, energy safety, the need of cleaner and sustainable fuel source, lower emissions and economic value. Though biofuels are not new there are also some issues that are preventing the development of biofuels. The competition of fuel crops and food crops for land and investment usage, difference in the fuel price, lack of biorefineries and infrastructure for producing biofuels, the market for fuel blend, lack of easy access to the technologies using biofuel and lack of investment in commercialization are some of them.

**Biomass** is the easiest and **primary** form of biofuel which can be directly burned for energy on its own or by mixing with other combustible fuel. Energy from plants can be considered a form of solar energy because plants capture sun's energy with the help of chlorophyll through photosynthesis. Carbon dioxide from air and water from the ground are converted into complex compounds of carbon, hydrogen, and oxygen known as carbohydrates. When these carbohydrates are burned, the components break down again into carbon dioxide and water releasing the energy. [6]

**Ethanol** is a type of alcohol which is formed by **fermentation** and a type of **secondary** biofuel. Organic matters with high sugar or starch content such as sugarcane, sugar beet, maize, wheat are fermented and distilled to produce bioethanol. Brazil and USA are the largest producers of bioethanol. Ethanol is used either in its pure form or by mixing with petrol in new types of vehicles which are compatible of using biofuel. [5]

**Biodiesel** is also another type of **secondary** biofuel and produced through a chemical process by combining vegetable oil or animal fat with an alcohol and a catalyst. The process is known as **transesterification**. Oil crops such as rapeseed, soybean, palm are the most popular crops used in biodiesel production. [5]

Biofuel technologies and productions have advanced a lot and various generation of biofuels have been already put upfront. Biodiesel produced from oils and fats and bio-ethanol produced from fermentation of plants containing sugar and starch is considered first generation biofuel. The first generation biofuels are renewable and help in reducing greenhouse gas. However, the feedstock used for producing biodiesel or bioethanol are produced from the land where food can be cultivated so there is an issue of 'fuel vs. food'. In order to overcome the issues and limitations from first generation biofuel, second generation biofuel has been introduced. The required carbon is obtained from cellulose, hemicelluloses, lignin or pectin. The feedstock for second generation fuels is non-food biomass such as agricultural waste, organic waste, wood, specific fuel crops and biomasses which grow in areas where food crops cannot grow. So the issue of competing with food crop has been solved as well as they can compete with the fossil fuel market. [7, 8]

Further development has been done for biofuel as third generation biofuel. The feedstock for the fuel production are improved biomasses and engineered energy crops whose production value is low and contain high energy value and absolutely renewable, for example, algae. The research has shown that algae have the potential to produce more energy than conventional crops. Furthermore, algae can be cultivated anywhere with light, carbon dioxide and nutrients where food crops cannot be cultivated, therefore, reducing the pressure on the cultivable lands. One more feature is that the variety of fuel can be produced from algae such as petrol, diesel, and aviation fuel. [7, 8]

Recent researches have made further improvement in biofuel and forth generation of biofuel has been introduced. Not only aiming for the sustainable energy but also finding the solutions for capturing and storing carbon dioxide, is the aim of fourth generation biofuel development. The production process is same as for the second and third generation fuel but the difference is that the fuel production process involves processes such as **oxy-fuel combustion** resulting in the final emission with mostly carbon dioxide which can be collected and stored [9]. This

helps in reducing the carbon dioxide from the atmosphere and also reduces the production of carbon dioxide by replacing the fossil fuel. Advanced biofuels with improved properties such as bio-petroleum, bio-jet fuel, bio-butanol, etc are also great development. [7, 8]

## **4 Results**

This chapter includes the results of the research work and answers for the five questions mentioned in the introduction part in their respective order.

### **4.1 Definitions**

Bioeconomy is a knowledge based concept which acts as a link between life sciences and their sub-aspects such as biology, botany, zoology, microbiology, biochemistry and physiology, material science, engineering, economics as well as social science, enabling bio-based sustainable economic development. Bioeconomy refers to the economic activities related to the bio-based products and technologies. The main aim and objective of bioeconomy are economic development based on the innovative and competitive development of biology providing sustainable and smart products to fulfill the growing needs of the population while also protecting environment and resources. Bioeconomy can be a way towards sustainable, green and healthy living. Therefore, it is very important to have public awareness on the significance of bioeconomy.

Bioeconomy is a very new concept which officially came into light for discussion at the beginning of the 21<sup>st</sup> century and there has always been a debate on what exactly is bioeconomy and how important it is for discussion. Various organizations have defined the term "Bioeconomy" in their own words. Though the definitions vary, there is a common connection in terms of defining the inputs and outputs of bioeconomy. Some definitions provided by respected organizations on bioeconomy are provided below:

According to European Commission, "The bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea such as crops, forests, fish, animals and micro-organisms to produce food, materials, and energy." [10]

According to Organization for Economic Co-operation and Development (OECD), "From a broad economic perspective, the bioeconomy refers to the set of economic activities relating to the invention, development, production and use of biological products and processes." [11]

According to Biotechnology and Biological Sciences Research Council (BBSRC), "All the economic activity derived from bio-based products and processes which contribute to sustainable and resource-efficient solutions to the challenges we face in food, chemicals, materials, energy production, health and environmental protection." [12]

According to National Bioeconomy Blueprint, USA, "Bioeconomy refers to the economic activity that is fueled by research and innovation in the biological sciences." [13]

There is no unified definition to the term "Bioeconomy", however, there are some common attributes. Agricultural biotechnology, sustainable food and animal production, synthetic biology, pharmaceuticals and antimicrobial innovation, genetic study, medicines and cell therapies, industrial biotechnologies, biofuel and bioenergy development are few of the topics which are discussed under bioeconomy.

## **4.2 History of Bioeconomy**

Humans began farming about 10,000 BC in order to get easy access to the food and lead to agricultural development to vast lands. Previously, the food supply depended on hunting and gathering wild plants [14]. The biological and agricultural science have developed a lot since then. With the introduction of biotechnology and various bio-based researches, the agricultural productions have gained more quality and quantity. At the same time, industrial developments have also progressed and flourished, which is based on the use of fossil raw materials. Still, today fossil resources are taken as a key component for all the industrial practices. A lot of products available today for consumption are based on fossil resources as raw materials or fuel. [15, 16]

Various environmental and economic issues and problems that came along with development in the world took the headlines in the global level, which made public conscious about the necessity of sustainability. Thus, bioeconomy concept came to highlight. Development in latest scientific knowledge and technical expertness to utilize various resources, chemistry and industrial processes for practical purposes and applications has lead to the progress of bioeconomy concept. Advancement in life sciences and biotechnology acted as stepping stones for the start-off of the concept of bioeconomy [13]. It has been suggested that

bioeconomy is one of the oldest economic sectors since the beginning of the human race but the refinement and advancement of study and research in life, natural and material sciences have helped it metamorphose into one of the newest topic for discussion among the experts and leaders.

Some examples of early bio-based product development can be taken to highlight the fact that bioeconomy is not new. In 1940, plant breeders had already learned about the genetic modifications in seeds which are big steps towards agricultural biotechnology [14]. Henry Ford who is considered the father of modern automobile already had planned to use bioethanol produced from cereals in his model in the beginning of 20th century [17]. This idea was promoted by the fact that Kansas region in America was already producing about 18 million gallons of ethanol a year by 1938 [17]. A similar example is use of bioethanol in vehicles in Brazil since the 1970s. In 1990, Rudolph Diesel showed that biodiesel produced from peanut oil can be used in diesel engines after which various methods like pyrolysis, blending and micro-emulsification were used for biodiesel production from vegetable oil [18].

In total, USA, Brazil and Europe count for about 87% of the total global biofuel production until 2011. About 47% of the total energy demand of America is fulfilled by biomass and biofuel. The main feedstock for the bio-ethanol production is corn. With the American grain-based biotechnology, the ethanol production using corn and corn waste has advanced and expanded rapidly and this is also acting as a bridge technology for the new industries for using other biomass such as wheat plant waste, fast growing trees and other grasses like switchgrass, miscanthus and even the municipal bio-waste, beer waste, potato waste, cheese whey and others as new feedstock resource. There are about 137 already existing, 61 under construction and 7 under research biorefineries until 2008 with the total capacity of about 13425 million gallons per year. The ethanol production helped in enhancing the economic status of the country by increasing the national income as well as local income with the increase in employment from biorefineries as well as agricultural sectors. [19,20]

Brazil is the second largest bioethanol producer and the main feedstock is sugarcane followed by beet, corn, and cassava. With almost 42 percent of the liquid fuel demand already being replaced with ethanol, Brazil has made a lot of progress in biofuel development. After the introduction of flex-fuel vehicles in 2003, the production and consumption of ethanol have

increased drastically as vehicle fuel which resulted in the decrease in carbon dioxide emission by more than 300 million tons since then. The available technology is able to convert only one third of the sugarcane into the fuel and the new technologies are being developed in order to also use the remaining two third of the sugarcane waste in the better way to produce fuel efficiently with less loss. [21]

In Europe, Germany is the leading biofuel producer followed by France, Spain, Italy and others (see figure 2). The main ingredients for biodiesel production are palm oil, rapeseed oil and sunflower oil and other vegetable oils. There are about 200 biodiesel plants under operation in Europe with the production capacity of over 8.5 million tons. [22]

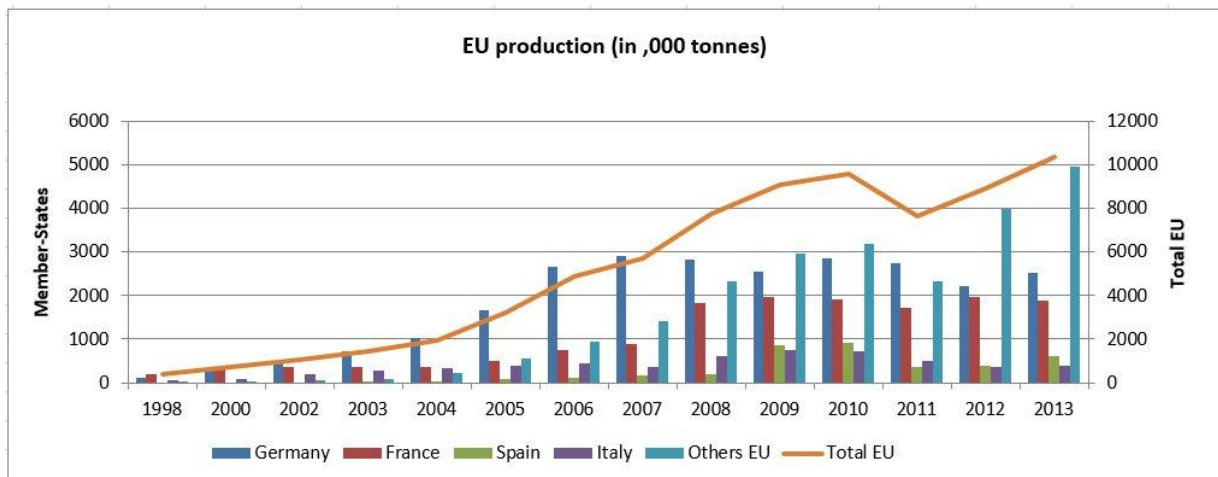


Figure 2 Evolution of the biodiesel production in the EU [22]

Certainly, development in biofuel and biorefineries area is one of the main aspects of moving towards bioeconomy and further from green concept to greener.

When talking about Finland, the history of Finnish bioeconomy is very old which goes back to 10,000 years ago when humans started farming and keeping animals. When hunting became difficult then first inhabitants in Finnish land started growing rye as a major crop and began skinning animals for fur which was an important commodity for trade. People began living permanently by building solid log houses which helped the development of log expertise. The dependence on fields and forest for the economy was heavy during early 20th century Finland. Wooden ships and tar were the first to be introduced as the industrial product which relied on forest resource. In addition to this, the market for sawn goods and increasing demand for the

pulp and paper led to the development of new technologies and rise in dependency on biomass from the forest. This had a huge effect in Finnish economy and sawn goods, pulp and paper became the most important merchandise for export for the Finnish industry. [23]

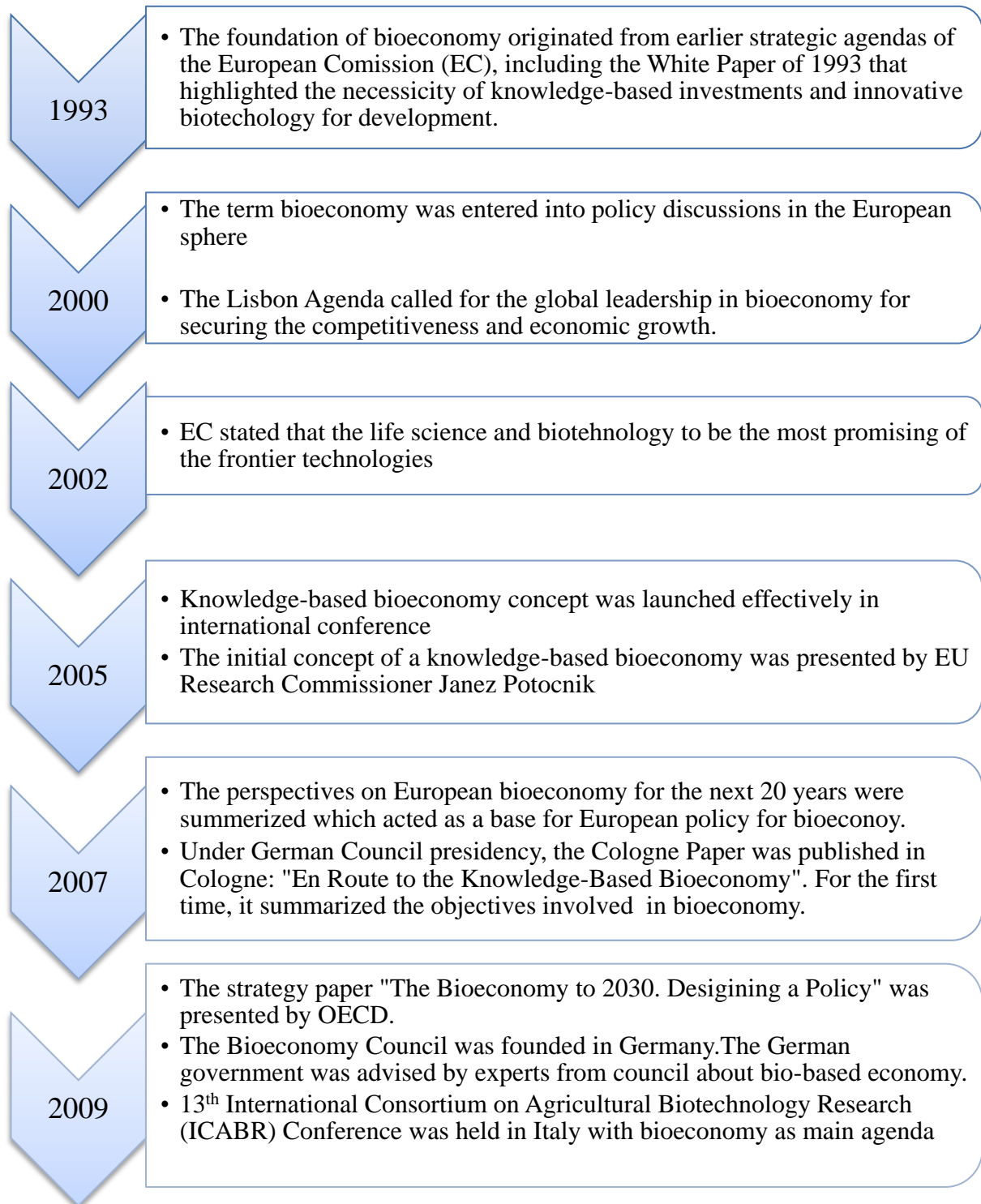
Finland has been independent for decades when it comes to food production because of efficient farming methods and techniques. The forest was a very important aspect of Finnish economy and lifestyle, so the efforts of sustainable forest management had already taken root in the 18th century. The Forest Act was passed in 1886 with the main aim to preserve the forest resource and later in 1996 the act was added with ecological and social sustainability principles. During warring period also Finland depended on wood as main fuel and timber and timber products became the vital commodities for after war reparations. The starting of the culture of appreciating and living closely in nature and the culture of summer houses, the so-called ecosystem services, also increased the importance of forest significantly. Forestry, in particular, has a big and unique role in Finnish bioeconomy. [23]

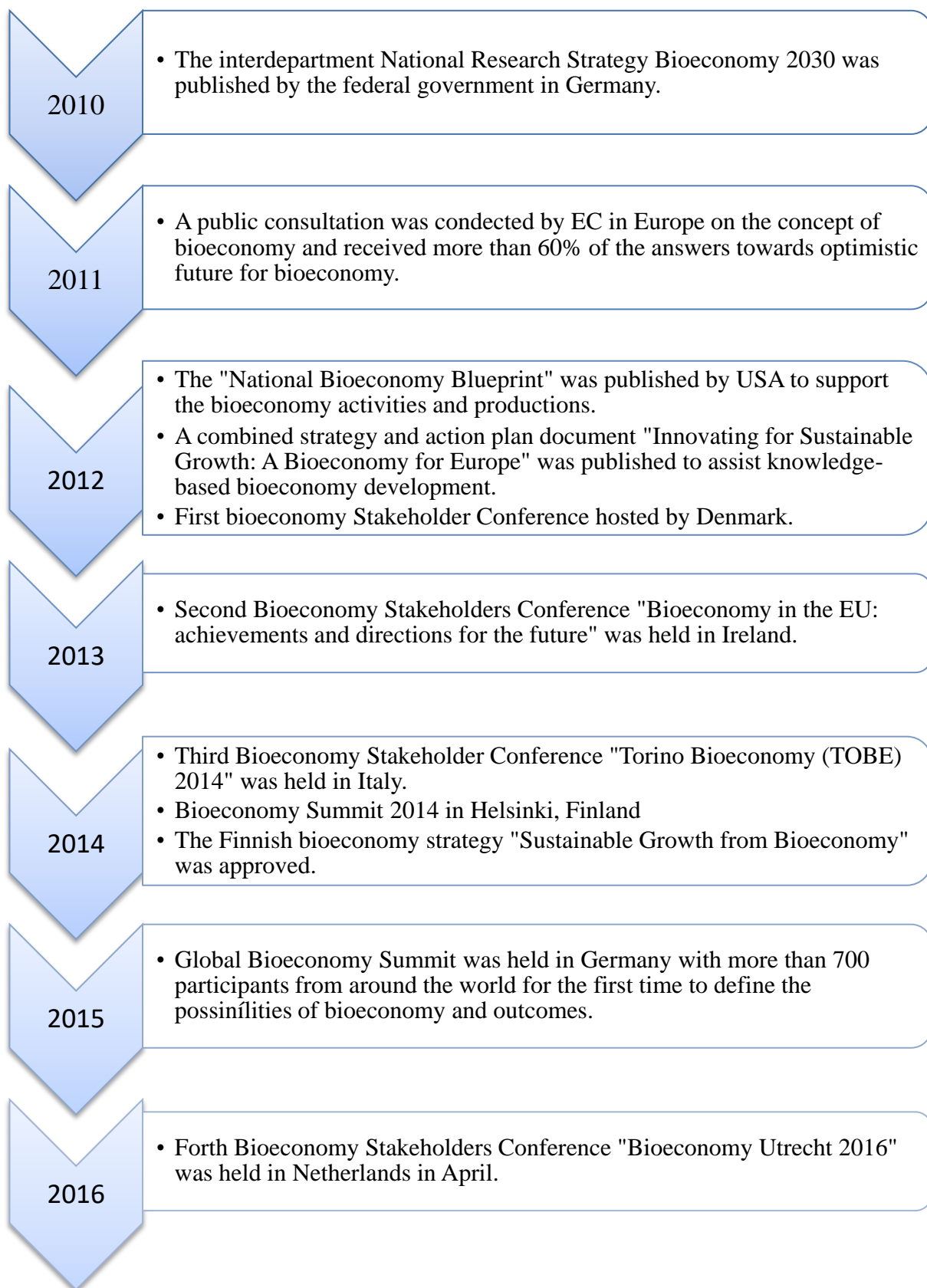
The rapid industrialization after the World War II quickly led the country towards economic growth but also resulted in environmental pollution, for example, because of waste waters from the forest industry. The necessity of the act of environmental protection led to efficient development with clean technology. Also, the development of technologies and increase in production of wood-based fuels and energy have made Finland a pioneer in bioenergy production. Finnish lifestyle of living together with nature, development of cleaner and adaptive technologies and responsibility towards environment have pushed Finland towards bioeconomy. [23]

Finland is already in outstanding position among the world leading countries in bioeconomy development. The role of bioeconomy is crucial in Finnish national economy with more than 16% share and the current output of Finnish bioeconomy exceeds € 60 billion and has created employment for more than 300,000 people. Apart from the specific goals mentioned above, the Finnish bioeconomy is also aiming for the self-sufficient and sustainable energy development, biodiversity conservation and uniform and stabilized regional development. Finland is also supporting the bioeconomy internationally under EU strategy. [23]



Based on the previous works [12, 13, 15], the events and milestones that acted as boosters for the development of bioeconomy especially in Europe and the USA have been compiled, which is provided below as figure 3.





**Figure 3 Events and milestones for bioeconomy [12, 13, 15]**

From figure 3, it can be seen that the term bioeconomy was officially presented as a knowledge-based economy in the end of 20th century and within 15 years there has been many bigger steps towards addressing bioeconomy in national and international level. In 2012, America and Europe took a big action to promote bioeconomy by publishing "National bioeconomy Blueprint" and "Bioeconomy Strategy- Innovating for Sustainable Growth: A Bioeconomy for Europe " respectively.

It is obvious from the history presented above that the use of bioresources was a significant part of life and clearly shows that the bio-based activities were already creating impacts in development from way back before bioeconomy term was introduced officially about 15 years ago.

### **4.3 Relation with development, political economy and environmental sustainability**

Bioeconomy is interrelated with development, political economy and sustainability of the environment. This section shows how bioeconomy is related to these three aspects.

#### **4.3.1 Bioeconomy and Development**

Bioeconomy can be related to various development factors. Such as employment of biotechnology and bioscience in agricultural production, improvement of the food quality and production, and thus ensuring the food safety, similarly research and production of biofuel in sustainable way, and thus reducing the fossil fuel consumption, developing the production systems with reduced emissions, and thus mitigating and adapting to the climate change and environmental disorders and devising the ideas for the bio-based products together with the industrial biotechnology and marketing, and thus opening new job opportunities. [24]

It has been estimated by United Nations Population Fund that the world population will continue to escalate by more than 30% in the coming 40 years from 7 billion in 2012 to more than 9 billion in 2050. It is obvious that the food consumption will also increase along with the demand for the various products. It will become necessary to produce the required quantity of healthier and sustainable food, medical and other daily use products to meet the requirements. If the exploitation of the available natural resources continues in unsustainable way, it is sure that there will be a big catastrophe. In order to overcome such situation, it is absolutely

necessary to develop the strategy for planned innovative and sustainable changes in lifestyle and resources use that elevates the society and the economy. Agricultural biotechnology refers to the employment of scientific knowledge and tools to apprehend and manipulate the genetic composition of organisms in agricultural production and processing. Technical advancement in horticulture, animal husbandry, aquaculture along with agricultural biotechnology will contribute in production of the food as well as raw materials for other various products such as fuel, feed, fiber, chemicals, medicines and daily materials. [24]

Fossil resources are highly relied on for the carbon and energy. Industrial development was made possible because of the extraction of the coal and fuel embedded in nature. However, the fossil resources are limited and depleting day by day and cannot be renewed. The issue of carbon dioxide emission due to use of coal and petroleum also follows the problem of degradation of the fossil resources. The concept of renewable resources has already been a very hot topic with the ideas of harnessing the energy from renewable sources such as sun, wind, water, waves and also the developments have been made regarding the bio-based energy, bioenergy or biofuel. It has become a matter of utmost importance to create cleaner environment. One of the best ideas is to develop resource efficient industries, bio-based products and bioenergy contributing to the green environmental as well as economic growth. Bio-based development can be sustainable, long-term, sufficient supply and renewable. It is also very important to do more research on current and future biomass demand and availability and competition between the use of biomass as energy source, raw material or food supply including the after effects such as the potential climate change mitigation, carbon balance and easy accessibility of fuels.

Agriculture-based industries as well as industries related to biomass and waste, bio-refinery, chemicals and materials, food and feed ingredients are the base of bioeconomy. Development of these industries means more requirement for the skilled and technical manpower, which means more opportunities for jobs. Proper research on the consumer needs and requirements might be necessary for biotechnology innovation and to open up the new markets for bio-based product. Further development in techniques and new approaches to the life-cycle analysis can be the next step towards the scientific enhancement and industrial advancements towards the bio-based productions and trade opportunities. This will help to boost the economy and development.

#### **4.3.2 Bioeconomy and Political Economy**

To meet the increasing demand of the key elements of bioeconomy which are food, feed, fiber and fuel, two pathways can be followed, one is by increasing the cultivating land for food crops and biofuel and second is by increasing the per-unit production on existing land. However, increasing the cultivable land and productivity both puts environment on pressure. Biotechnology is the answer to increase the productivity of food, feed, fiber and fuel but there are many issues that comes along with it such as policy and regulations situations and governance issues to the bioeconomy. The recent advancement in biological sciences, new innovations in agriculture with vertical and horizontal integration in supply chain management, growth in inter and intra industry trade, upgraded information and communication technology, rise in globalization, resources management and the climate change issues are major factors for increasing the significance of bioeconomy. [25]

Different countries have different regulatory facilities regarding biotechnology which is one of the constraints for growth of biotechnology. The existing regulations in European countries and United States can be taken as an example to explain the difference between the regulatory frameworks. US regulations allow the use of the genetically modified plants along with the modern biotechnology whereas Europe is very strict in use of genetically modified plants. Also, the technology transfer between the borders is strictly regulated by the local government. However, partnership between the different countries for the bio-product development is gaining attention and also the process of making the regulations for bioeconomy development more flexible to work with and management of the intellectual property rights are being forwarded. Regulations for the approval of use of genetically modified seeds for better crops, co-existing cultivation and identity preservation of new seeds are the important regulatory aspects which are needed to be considered. [25]

Not only biotechnology sector is facing the governance issues, but also bioenergy sectors are affected by the various political difficulties. Being one of the very important aspects on bioeconomy, the limitations and constraints on bioenergy from the political part are acting as a barrier for new developments in bioeconomy. Variation in energy regulations can lead to difference in the requirements for the new energy technology development, carbon tax, import

and export tariff on biofuel, import and export tax on the biofuel feedstock, biorefineries development, subsidies and other various economy-related activities. [25, 26]

The environmental regulations regarding the climate change have addressed the production and use of biofuel in many ways. The common goal is to reduce the environmental externalities and increase the social welfare while encouraging public towards the use of clean biofuel products. It is necessary to address both macro and micro level considerations for constructing the regulations to make it more efficient and profitable for the nation. Increased use of biofuel means less dependency in fossil fuel and energy security since unlike the fossil fuels which are stored in specific countries in the world, biofuel can be produced in any part of the world with biomass. It is also necessary to investigate various key aspects of political economy such as consumers, agricultural sectors, producers, environmentalists, fossil fuel industries, alternative energy sectors, transportation companies, automobile companies, airlines and others to understand the perspectives and opinions from them towards the policy development and the impacts. This is required to help create balance between production, trade, consumption, national economy and environmental issues. [27]

#### **4.3.3 Bioeconomy and Environmental Sustainability**

Since bioeconomy deals with various aspects such as food production, bioresources, biofuel, health and environment, economy and related research and development, it can be said that bioeconomy has close interrelationship with environment and sustainability.

One major part of bioeconomy is bioenergy or biofuel. The energy generated from bioresources is renewable and can be used for producing heat and electricity and cooling by absorption chillers as well as the transportation fuel. Since, the fuel produced can be extracted in liquid, solid or gaseous form, it can be stored. It is one of the reasons why biofuel is becoming more popular among the rapidly growing renewable energy technologies. The energy generated from other alternatives such as the wind, solar or water sources are not as easy to use for vehicles as biodiesel or bioethanol. Though both biofuel and fossil fuel are the product of bioresources, the main difference is that biofuel are produced in shorter period of time than the fossil fuel which are the result of the process of millions of years. Biofuel can be produced with simple bio processes like fermentation or with quicker chemical processes.

Climate change, pollution, global warming, acid rain, oil spill and health problems are some of the issues resulted from the fossil fuel consumption. Greenhouse gases emitted after the burning of the fossil fuel like coal, oil and gas are the main reasons of the global warming. Melting of the snow in mountains and Arctic regions, rise in sea level, climate change and alteration in weather pattern, drought and more are the result of global warming. The extraction of the fossil fuel by drilling, explosion and other processes have a great impact on the fragile ecosystems. Along with the problem of global warming due to the use of fossil fuel, the issue of limited source of fossil fuel follows and it means the continuous extraction will lead to the end of the supply in next century. Since the stored amount is limited, the source will run out at some point leading to the need of setting the extraction set-up in another location. These factors increase the price of the fuel. The price of fuel always affects the global economy. [28, 29]

The combustion of fossil fuel is also one of the major factor which emits pollutants such as carbon monoxide, nitrogen oxides, sulfur oxides and other hydrocarbons and particulate leading to air pollution. The particulates combine with the gases and form smog. These increase the health issues in humans and all the living beings. Also, the emissions with sulfur and nitrogen compounds help in creation of acid rain affecting plants and animals as well as crops and buildings. Oil spillage has also created major problems for many animal and birds in their habitat and reproduction and also causing water contamination. [28, 29]

Biofuel is the alternative to the fossil fuel because it is renewable although renewable energy does not necessarily always mean green energy. Renewable means which can be produced again and again but green means which is healthier for the environment and do not cause pollution, harm ecosystem or increase global warming. Biofuel also produce greenhouse gases. There are various environmental and socioeconomic impacts from the production of the biomass feedstock for fuel generation. The land use for the feed production, competition between the various feedstock, initial setup cost, energy policies and regulations, restrictions and constraints, impacts of use of food crops for fuel production, distributions are among the many factors associated with the sustainability of biofuel production and possible for affecting future energy demand. [28]

Some limitations for the first and second generation biofuel have made them not an ideal substitute for fossil fuel. First issue is the primary feedstock which are for example corn and sugarcane for ethanol and rapeseed, soybeans and palm, are food crops which compete for the cultivation land, water and fertilizers. Second issue is the requirement of the modification of the vehicles to use these fuels and are not suitable as jet fuel. The third issue is the greenhouse gas emission as stated earlier. Biofuel from algae has been considered as third generation biofuel which surpass the limitations from the first and second generation biofuel. The potential to produce fuel from algae is very high in terms of both quality and quantity compared to other feedstock. Using algae as feedstock, various types of fuel can be produced such as biodiesel, biobutanol, gasoline, bio-methane, bio-ethanol, vegetable oil and jet fuel. One possibility is that algae can be genetically modified to produce better product. Fuel produced from algae can be used in the vehicles without modifications or energy damage and furthermore, they have improved emission profile so they can be considered green. [30]

With an approximation of the world population to grow to 9 billion by 2050 [24] and limitation in natural resources, it becomes necessary to move towards renewable and sustainable strategy not only to secure the food supply but to supply healthy food and feedstock as well as daily materials. For this bio-based product development can be answer because biological resources are renewable and are the source for almost all the needs such as food, feed, fiber, fuel, chemicals, medicines, and others. The innovative exploitation of biological resources and sustainable bio-based development means optimizing the production, qualitative and quantitative production from less including the waste and at the same time narrowing the negative effects and impacts on the environment. This also gives a way to lessen the dependence on fossil resources in considerable amount while reducing the climate change and other environmental problems due to emission.



## 4.4 Efforts towards bioeconomy

This section presents the various efforts from different countries in Europe, America, and Asia towards bioeconomy development.

### 4.4.1 Bioeconomy Strategies

Bioeconomy is a multidimensional topic with the diverse possibility for innovation and development. In order to tackle the various issues like depletion of food resources, medical challenges, environmental degradation and world economy, it is necessary to enforce radical change towards the processing, production, storage, consumption, reuse, recycling and disposal of biological resources for which it becomes fundamental to develop innovative strategy and policies. It also becomes essential to implement the established strategy for the bioeconomy as a crucial element for smart and green development everywhere around the world. There have been a lot of seminars and conferences with bioeconomy and its features as an agenda for discussion in international level, especially in Europe and America. This paper focuses on the following three works as steps towards bioeconomy governance.

#### **"Bioeconomy Strategy: Innovating for Sustainable Growth-A Bioeconomy for Europe"**

European Commission has set a goal for an efficient and sustainable economic development in Europe. The main target is to develop resource efficient innovative technical development with low emission and green environment integrating with sustainable production of food through agriculture, aquaculture and ensuring the food safety, biodiversity and environmental protection and economic growth. To acquire the goal European Commission has developed a **Bioeconomy Strategy** in 2012, with the planned actions to be taken for bioeconomy development. The key aspects of the strategy include development of new and better processes and technologies for bioeconomy, development of the market place and competitive trading with bio products and pressing the policy makers and stakeholders to cooperate with each other for betterment. With the fact that the world population will keep growing continuously in future and the resources are limited, bioeconomy strategy was developed to help Europe not just to cope the situation and live within its limit but also for securing healthy food, animals production, bio-based daily products and biofuel. It also aims for the renewable resources utilization and exploitation of biological resources with reduced environmental impacts. [24]

With a lot of bio-based industries and sectors like agriculture, forestry, fisheries, food and chemicals, already established in Europe the significance of bioeconomy has already become a big matter in European economy with about an annual turnover of two trillion euros and job opportunities for 22 million peoples. Europe also has strong base for the technology as a result of which there are already many well-established bio based industries such as food, paper and pulp, biofuel, etc. Since bioeconomy is already about growth, development, employment and economy, it has become very necessary to direct the efforts towards same direction and reinforce the path that will gather together all the stakeholders, government, policy makers, scientific disciplines, researchers and developers, customers and all the concerned peoples. The strategy calls for committed action through already existing policies as well as new initiatives in order to develop markets and fair and competitive bioeconomy. The strategy describes the stakes involved in bioeconomy with the possible challenges to be faced and development of the coherent and systematic bioeconomy. [24]

The bioeconomy strategy includes the Action Plan which describes the main actions that can be taken for the bioeconomy development. First plan is to ensure the fund from national and international level for the investment in bioeconomy research, innovation and development. One example is Horizon 2020 programme which is the biggest funding programme in Europe with nearly €80 billion of funding for research and innovation with the vision of integrating research and innovation for excellent science, industrial leadership and dealing with societal challenges [31]. Second plan is to reinforce the policy interaction and engagement between the stakeholders. The plan includes mapping the already existing research activities, expertise and infrastructures in Europe, creating a bioeconomy panel to accelerate the involvement of the stakeholders and create synergy and coherence between policies, initiatives and economic sectors related to bioeconomy. The plan also includes the activities to join the global challenge for food security, medical demand and climate change as well sustainable supply of biomass supply. Third plan includes the creation of market for bio-based products and managing marketing and competitiveness in bioeconomy. Studying the life cycle of the product for innovative and sustainable impact and supporting the future development, providing the knowledge-based backing for the primary products, improving the understanding of the potential of biology and bioresources, taking the added value into account, ensuring resources safety and green development, promoting the logistic and communication network for bio-

products promotion, expanding the new markets with standardized methodologies and promoting healthy and sustainable lifestyle and much more comes in the action plan. [24]

➤ **Policy Recommendations from the 13<sup>th</sup> ICABR Conference on The Emerging Bioeconomy**

The 13<sup>th</sup> International Consortium on Agricultural Biotechnology Research (ICABR) Conference was held in Ravello, Italy in 2009. The main agenda of the conference was bioeconomy and various research results and ideas from various institutions, government agencies and industries were presented. The importance and potentials of bioeconomy in development for the developing countries were presented and discussed along with the future possibilities with the policies regarding the bioeconomy development, funding for research, international regulations and sharing the technologies. The conference discussed the various issues affecting the emerging bioeconomy and also examined the possible constraints for the further growth. The conference investigated on six unique constraints and their distinct prospects. [32]

The first one is agricultural biotechnology's response to the global food crisis. There has always been criticisms about the use of land for fuel production instead of food production. Due to the increasing demand on the energy supply or fuel production, the land has been used for biofuel crop production resulting in reduced land for food crop plantation and increase price for food products. While it is sure that the demand for both fuel and food will not decrease but increase in coming future, it becomes necessary to find a balance between these two for the food safety as well as biofuel supply. It can be possible that the biofuel crop production can be done where the food crops cannot be grown as well as with advanced and innovative biotechnology, the food crop production can be increased with better nutrient value and made sustainable. Additionally, it can be possible to reduce the pressure of biofuel crop production to some extent with the agroforestry, food crop residue and food waste. [32]

The second constraint is the long-term sustainability of the biofuel. Requirement of development of alternate fuel caught the eye of everyone during the fuel crisis and high rise in fuel price during 2007-2008 when the price of crude oil rose from US\$60 per barrel to US\$140 per barrel within the span of 18 months. Thus, the biofuels which are produced

directly or indirectly from organic matters was considered one of the alternative not only because they can be renewed but also can be easily converted to liquid fuel for easy storage and transportation. Bioethanol and biodiesel are two popular forms of biofuel. The biofuel produced directly from biomass such as fuel-wood, wood chips and pellets are considered primary source and the fuel produced after processing of biomass such as ethanol and biodiesel are secondary source. These products are first generation biofuels. However, due to the advancement in scientific research, microbiology and genetic studies, there has been further development in the biofuel sector with the introduction of the second generation biofuel. It has been anticipated that the second generation biofuel production will contribute to sustainable and green future than first generation biofuel [8]. Additionally, there has been development of third generation of biofuel with algae. But due to lack of proper funding, further development with the second and third generation of biofuel is very slow. Also, the issue of lack of scale-up capacity and market price for biofuel is creating a big barrier for the financial competition with the existing fossil fuel market. [32]

The third issue is the food safety regarding the nutrition as well as the continuous supply. The staple food varies among the countries around the world hence changing the food habits. However, it is necessary to make sure that everyone receives nutrient and healthy food and do not die of hunger. Drought and climate is hugely affecting the crop production in various parts of the world resulting in less yielding and not to forget the population increase and increasing food demand. Even though many developments have been done regarding the food production technology, due to different regulatory provisions in many developing countries and lack of international harmonization, it becomes difficult to transfer the technologies. [32]

The other issue is the constraints and incentives for innovation and globalization. Many researchers and scientists have developed new innovative technologies regarding the various bioeconomy related sectors but due to intellectual property rights and the role of patents, it has become difficult to transfer the technologies to other countries. This issue has become one of the constraints for the further bioeconomy development. To reduce the constraints many international and global level conferences and discussions have been organized for mutual co-operation and create international intellectual property to contribute and facilitate the global bioeconomy. There is still the challenge to increase the global interest in bioeconomy promotion and increasing the funding from various investors with the possibility of rewards

and incentives for the investors. Also, it is true that no two countries have the same regulatory facilities so there is a need of improvement in the regulatory systems to address bioeconomy on global level. [32]

The other two issues are related with the coexistence of the genetically modified crops with the other crops and intellectual property rights for scientific innovations. [32]

From the discussion of various constraints and possible issues in bioeconomy development in both developed and developing countries, three crucial policies were proposed to be synthesized for further growth of bioeconomy in global level. First was to emphasize on the biofuel research and production with more innovative and sustainable technologies and advancement from lab to the market. The new researches has shown that the second generation biofuel have considerable potential which needs scale-up for commercialization [8]. While there is still a need of global agreement for the biofuel production and commercialization, the research results support that the second generation biofuel is more sustainable and long-term than first generation technologies. A significant step of responsibility and commitment to continuous funding for the further research and development is required in order to make a systematic assessment of the technologies to advance towards commercial level. Second was to allow the trustworthy international organizations such as Organization for Economics and Co-operation and Development (OECD), Food and Agriculture Organization (FAO) and others to initiate the effort to create a peaceful trade of the technologies and products since the regulations regarding the technology trade is different specially in many developing countries. This will help in the foundation of international regulatory framework so that every corner of the world can gain benefits from the newest technologies. Third was to refine the regulations related to the technology transfer from the developed countries to the developing countries in efficient way. Since all the constraints mentioned above are interrelated to each other, it is very important to develop solid strategies to move towards the scale-up of bio-based production and trading for the bioeconomy to gain governance. [32]

➤ **National Bioeconomy Blueprint, U.S.**

To support the scientific research and development and newer technological discoveries a National Bioeconomy Blueprint was released under president Obama in 2012 which shows his commitment towards the sustainable economic growth and green earth. The main vision of the blueprint is to recognize the potential of the U.S. bioeconomy and highlight the steps towards the achievement of the goals. The blueprint includes five strategic objectives for bioeconomy development. [13]

--The first priority is to fund the research and development in bioeconomy because technologies are the tools for successful and sustainable bioeconomy. Best available technology is always the option for the successful and long-term business. In order to ensure the payback and profit for the investors it is important that finest and leading technologies to be used in production which requires the continuous research and refinement in technologies. Thus, coordinated and systematic strategies for continuous funding for R&D is required to always be updated with new technologies and possibilities. [13]

--The second objective of the blueprint is to facilitate development and progress of bio inventions from the lab to the market along with the regulatory sciences. To move beyond the research and laboratory it is essential to transfer the potential ideas to implementation for which focus should be on the planning to discover the ways to combine the resources, translational sciences, regulatory sciences and innovative technologies. Coordinated, systematic and strategic investments will accelerate growth in bioeconomy sectors. Integrating the commercial and industrial involvement into the university research can also be an option for the new ideas from fresh mind to reach the market. [13]

--The third objective is the development and reformation of the regulations to reduce the constraints because of the regulations and speeding the regulation management while protecting the human and environmental health. To accelerate the improvement of the regulatory works and increase the efficiency and safety it is necessary to reduce the cost, augment the existing regulations and provide the authority to multiple agencies with coordinated and parallel reviews and guidance. It is equally important to collaborate with the stakeholders in productive ways with improved regulatory processes in order to make the

efforts more efficient, reduce the cost, save time and ensuring the safety and benefit to the public and environment. [13]

--The fourth objective is to produce well-trained and skilled workforce required for bioeconomy development by providing the necessary trainings, updating the existing facilities and aligning academic institution incentives with student trainings. To ensure the sustainability of bioeconomy it is required to produce appropriately trained workforce. Development in bioeconomy sector also means opportunity of employment. With better training programs and facilities future skilled workforce can be prepared. [13]

--The fifth objective is to figure out and support the opportunities for the development of public-private partnerships and collaborations so that lessons can be learnt from successes and failures. Coordination with private investors and industries, government agencies, academic institutions, scientific scholars will help in pulling the resources and expertise together around same idea increasing the efficiency and chances of success. The blueprint highlights the fact that federal government, companies and universities should work as a team to devise, expand and scale-up the cutting-edge technologies which will produce new job opportunities, leap forward to revolution and provide fuel for changes for today and future. [13]

The above mentioned three steps are well known for bioeconomy promotion. Government policy, regulations, intellectual property rights, human resources, political conditions, social constructions and market structure are few of the factors that are influencing the growth of bioeconomy in many ways in global level. However, requirement of food safety, fuel supply and raw materials acts as a catalyst for the necessity of accepting the challenge of analyzing the constraints and factors and producing the innovative and sustainable solutions. The global bioeconomy is a topic which is gaining attention from policy makers, corporate decision makers, researchers, developers, investors and the general public. So, establishing various strategies and working according the plans helps in concrete development.

#### **4.4.2 Bioeconomy Activities in Leading Countries**

This section will present the bioeconomy activities in G7 countries including EU and also bioeconomy in Finland.

##### **4.4.2.1 G7 Countries**

G7 is a group of world's largest industrial nations including the United States, France, Canada, Germany, Japan, Italy and the United Kingdom along with the representatives from European Commission formed to facilitate global economy and to confer on various global issues such as economic governance, environment, energy problems and policies and international security [33]. Bioeconomy has become a very important topic for discussion in G7 regarding innovation, economy, and policy. Both biotechnology and bioenergy have been discussed regularly for bio-resources promotion and sustainable agricultural development. G7 has launched various research and development projects to address the use of carbon dioxide, microbes and waste for the production of fuel and other basic commodities. [34]

Various key strategies and policies have been developed in order to support bioeconomy development which is presented as follows in table 1 and further detail are provided for each countries below:



**Table 1 Overview on Bioeconomy policies and strategies in the G7 including EU [34]**

<b>Members</b>	<b>Strategy/ Policy</b>	<b>Responsible Authority</b>	<b>Key areas</b>
Canada	Growing Forward	Ministry of Agriculture	Research and development on renewable resources and bio-based materials, Bioenergy
EU	Innovating for Sustainable Growth	Research, Innovation	Research and Innovation (Horizon 2020), Public-Private-Partnerships
France	Bioeconomy relevant policies package	Ministry for ecology, Ministry for Research	Bioenergy, green chemicals, clusters, circular economy
Germany	Research Strategy Bioeconomy	Ministry for Research	Research and development on food safety, health and nutrition
	Policy Strategy Bioeconomy	Ministry for agriculture	Sustainable agricultural and industrial processes, bioenergy
Italy	no specific bioeconomy related policies		Participation in EU programs
Japan	Biomass Utilization and Ind. Strategies	Cabinet, national Biomass Policy Council	Research and innovation, circular economy, regional development
United Kingdom	Bioeconomy relevant policies package	Parliament, Department of Energy and Climate, Environment, transport, Business	Bioenergy, Agri-science and technology
United States	Bioeconomy Blueprint	White House	Life Sciences (Biomedicine)
	Farm Bill	U.S. Department of Agriculture	Agriculture (multiple areas)

## CANADA

Canada is a rich country in forest resource. About 40% of the total land is covered with forest making Canada the second largest country with forest resource [35]. Though Canada has not established any federal strategy on bioeconomy, it adopted a renewable energy strategy as a part of bioeconomy with timber as key raw material. With the provision of funding about 3 billion Canadian Dollar (see Appendix 1), the agricultural strategy "Growing Forward 2" was created for the period of 2013-2018 to define agricultural policy in Canada and move towards innovation, marketing and competitiveness. Similarly, with the budget of 92 million Canadian Dollar (see Appendix 1), Natural Resources Canada launched the Forest Innovation Programme (FIP) which focus on research and development and technology transfer. Canadian Biomass Innovation Network (CBIN) is active in research, management, policy making specially in bioenergy sector. Canada has moved towards the application of biotechnology in agriculture and forestry. Especially, British Columbia has taken many steps

towards bioeconomy development by establishing Bioeconomy Council to promote the utilization of the forest and agriculture resources for bioenergy production. It aims for establishing long-term vision regarding bioeconomy with various other objectives integrated such as environment protection, addressing climate change issues, introducing and creating new markets and marketing, creating employment and nurturing bioenergy production. Similarly, Alberta is also moving towards bioeconomy through agricultural development. [34]

Research on the wood based bioeconomy is becoming a topic of discussion in Canada which is taking an important role in encouraging bio-based materials production, distribution and production. To meet the energy demand of the nation, bioenergy is becoming the priority and efforts are being put in the research and development of the optimized utilization of natural resources. Some research regarding the sustainable chemistry from bioresources for the industrial consumption are also being done whose main aim is to develop bio-based chemicals. These are being done for provincial level. There is an issue that is acting as a constraint for smooth bioeconomy development which is, federal government has not defined the solid strategy for the bioeconomy which is restraining itself to the coordination of strategic goals. [34]

## **EUROPEAN UNION**

In 2012, the European Union a strategy was drafted under the guidance of the Directorate-General for Science, Research and Innovation dedicated for the development of bioeconomy in Europe called "Innovating for Sustainable Growth: A Bioeconomy for Europe". Additionally, the European Innovation Partnership (EIP-AGRI) specially for the agricultural sector was founded in same year which also plays a vital role in bioeconomy development. The main aim of EIP is sustainable agriculture and forestry with quality and quantity in food, feed production and production of bio-materials. The main themes of the strategy are investment in skills, research and innovation, coordination of policy with stakeholders and market development. Both strategy is supported and implemented with the research and innovation funding under Horizon 2020 program. The key research area is agriculture, forestry, innovation and technology and marine resources. For the research and development works, about 2.8 billion Euros (see Appendix 2) has been allocated for the time period of 2014-2020. [34]

This strategy is one of the few strategies which strongly support bioeconomy for developing countries' economy. The strategy aims to promote bioeconomy with strengthened and innovative competitiveness in bio-based industry and products among the member countries and back the sustainable industrialization. The strategy promotes small and medium-sized enterprises towards innovation and assist with investments. Furthermore, the bioeconomy support program are expected in modernizing the education and training systems with the cooperation between private and public sector to produce skilled manpower. Additionally, improvement in supply chains, security of food and medicine, environment and nature protection, emission and waste reduction and management, monitoring the development activities are also supported in the strategy. [34]

## **FRANCE**

France does not have specific strategy or policy regarding bioeconomy. However, instead of bioeconomy, France has defined the bio-based activities as green economy or discussed as industrial ecology. The main areas of discussion are biofuel, bioenergy, green chemistry, bio-based products, CO<sub>2</sub> management, water treatment and environmental engineering. Promoting the cutting edge technologies and motivating the ecological transformation are the two main approaches towards the bioeconomy development France has adopted. Since there is no specific policy for bioeconomy, the areas which comes under bioeconomy are addressed under independent strategies such as Strategic Agenda for Research, Technology Transfer and Innovation, National Plan for Climate Change, Biodiversity Strategy and more. [34]

Very important aspects of bioeconomy, industrial biotechnology and renewable and green energy are supported by the government through facilitated research and innovative agenda. To promote the cutting edge technologies in bioeconomy, the government funding program "Future Investments" plays a vital role. As a part of the program "Health and Biotechnologies" a lot of fund has been used for research, infrastructure development and training in biotechnology, agriculture, bioinformatics and nano-biotechnology. French National Institute for Agricultural Research (INRA) is active in founding multidisciplinary and incorporated programs in the areas of food, ecology and agriculture with about 30% (see Appendix 3) of the total INRA budget for the time period of 2010-2020. [34]

France is supporting the green development through bioeconomy and innovations for international competitiveness, increase economic growth, generate employment and develop the nation as a whole along with the reduction on the energy imports, contributions towards nature conservation, defend from health risks from environmental pollution, secure biodiversity and combat negative ecological transition. Doubling the organic farm-land area by 2017, reducing the use of pesticides by half by 2018, reducing the fossil fuel consumption by 30% by 2030, decreasing the energy consumption by half by 2050, implementation on green taxes on renewable raw materials, creation of jobs and more are some of the targets from various bioeconomy related strategies adopted and supported by the French government. [34]

## **GERMANY**

Germany has advanced a lot in bioeconomy sector with dedicated Bioeconomy Policy Strategy "Forschungsstrategie BioÖkonomie 2030" published in 2010. A bioeconomy council was established in 2009 which assists the government on bioeconomy matters. Germany is among the world leaders when it comes to bioeconomy policy. The strategy addresses various plans on utilization of bio-resources for the production of materials and energy. Renewable energies 2010 and forestry strategy 2020 are some other strategies which are boosting the bioeconomy advancement not only in national level but also encouraging bioeconomy globally to fight issues such as world food security, health and social standards. Bioeconomy Research Strategy 2030 is implementing various biotechnology related programs such as biotechnology 2020+, Innovative Alliances in Industrial Biotechnology and Renewable Resources Funding Program with the budget of about 2.4 billion Euros (see Appendix 4) for the time period of 2010-2018. [34]

Funds have been provided to various bioeconomy related researches and programs such as BonaRes working with land, GlobE working with food security, IPAS working with plant breeding, basic research in biotechnology and bioenergy and more and also pilot and demonstration plants on national, or regional level. The strategy covers the multi-dimension on bioeconomy and its value chain and provides the systematic and methodological action plans, funding schemes for research and development, various measures on advancement of biotechnology, bioenergy, agriculture, forestry and transfer of technology. The strategy also

supports the necessity of qualified manpower for future bioeconomy and importance of the education and trainings. [34]

The research and development activities in bioeconomy are not bound to any specific sector but are multidisciplinary which include life sciences, agricultural science and farming, plant and genetic engineering, mechanical and industrial engineering and social sciences. There are about 60 universities, 37 universities of applied sciences and 61 external research centers facilitated for the bioeconomy related researches or relevant activities among which 17 centers are operated by German ministries which shows the active involvement by government and institutions in advancing the bioeconomy development. Additionally, in order to promote the bioeconomy application in industrial sector, government has targeted the funding towards small and medium enterprises with emphasis on renewable raw material use and resource ideas and innovations. [35]

## **GREAT BRITAIN (UNITED KINGDOM)**

Great Britain also does not have any specific strategy regarding bioeconomy. However, various aspects of bioeconomy have been addressed through various other strategies, for example, Natural Environment White Paper (2011) dedicated to sustainable agriculture for the green food and food supply chain, Science and Innovation Strategy for Forestry in 2014 aimed to sustainable ecosystem with development in forestry and facilitate low-carbon timber industry, Marine Science Strategy (2010-2015) for marine research, Biomass Strategy (2007), Bioenergy Strategy (2012) developed in collaboration with Department of Energy and Climate Change (DECC), Department of Environment, Food and Rural Affairs (Defra) and Department of Transport (DfT) aimed for the utilization of energy crops and bio-waste for energy production, Agri-tech Industrial Strategy (2013) developed by Department for Business, innovation and Skills, Department for Environment, Food and Rural Affairs and Department for International Development addressing the technology transfer, agricultural commercialization and forestry research, High-value Manufacturing Strategy (2012) for the development of biofuels, bio-based products and industrial biotechnology, The Age of Bioscience developed by Biotechnology and Biological Science Research Council (BBSRC) to promote biosciences and more. Under BBSRC, budgets have been separated for implementation of various measures for bioeconomy development such as about 6 million

Great Britain Pounds (GBP) (see Appendix 6) for research and development in biotechnology and biochemistry, 24 million GBP (see Appendix 6) for Sustainable Bioenergy Center, 410 million GBP (see Appendix 6) per annum for Center for Agricultural Innovation, 23 million GBP (see Appendix 6) for Bio-processing Research Industry Club. [34]

Most of the strategy programs cover the areas such as agriculture, forestry and bioenergy and some parts in industry. UK has aimed in further development in life sciences, information technologies and trade and stimulate industrial regeneration with new sustainable energy and promoting rural development. The Bioenergy Strategy aims for the quantitative target of supplying the energy demand with renewable bioenergy by 15% by 2020 and also creating 50.000 new employment opportunities. [34]

## **ITALY**

Italy has also been the least active country among G7 members towards bioeconomy and the term "green economy" is used more than bioeconomy. There are no formal strategies developed and published regarding bioeconomy. Italy has focused its research more towards plant-based chemical industry rather than agriculture and forestry like other G7 countries. Although there are no special bioeconomy strategies published yet, EU bioeconomy Stakeholder Conference was hosted by Italy and also the World Fair 2015 was hosted addressing world food security. These two events are related to bioeconomy activities. Italy has been focusing more on research and supporting EU programs in bioeconomy related areas such as chemical biotechnology and bio-based chemistry or green chemistry. [34]

Italy has been receiving funds from various EU programs such as Horizon 2020 for the research in bioeconomy relevant scientific sectors. Ministry of Economic Development established Sustainable Growth Fund for supporting small and medium enterprises with research and development program in innovation areas addressed by Horizon 2020. One noticeable effort done by Italy in 2011 was banning the businesses from providing the non-biodegradable plastic bags which increased the demand in bio-plastics. Italy has also mandated the use of advanced biofuel from 2018 onwards at national level to promote bioenergy. [34]

The key governing bodies involved with the bioeconomy sectors are Ministry for the Environment, Land and Sea, Ministry of Economic Development and Ministry of Agriculture of Food and Forestry Policies. Though there is no significant support from the government towards specific bioeconomy sector, various programs are under progress with the support from EU research programs. And, also some other policies are creating the impact on bioeconomy sectors such as Biorefinery Decree aiming for the development of second and third generation biofuel refineries, National Environmental Decree addressed to the waste management and energy generation from waste and RES Promotion Law to promote biomass heating systems, pellet stoves and boilers. Ministry of Economic Development Italy has established a working groups including three National Technology Cluster targeted towards biotechnology and bio-based economic activities which are Advanced Life Sciences in Italy-ALISEI, National Agro-food-CL.A.N and Green Chemistry-SPRING. [34, 36]

## **JAPAN**

Japan has been very active in bioeconomy development and promotion. Biomass Nippon Strategy developed in 2002 was the first strategy towards the bioeconomy development in Japan which was aimed towards the sustainable economy through efficient utilization of bioresources. Though the term bioeconomy is rarely used various strategies and plans have been devised towards the utilization of bioresources which correspond to the main vision of bioeconomy. The law for boosting the utilization of biomass and defining the responsibilities from government, political parties and funding measures called "Basic Act for the Promotion of Biomass Utilization" was passed in 2009 and adopted from 2010. Similarly, in 2012, the Biomass Industrialization Strategy was established to encourage the use of biomass for energy production thus decentralizing the energy industry. This strategy addresses seven areas of action which are basic research, biomass supplies, technology, demand and market development, specific biomass strategies, broader support plans and globalization. National Institute for Advanced Industrial, Science and Technology (AIST) is active in research and development on industrial biotechnology, energy and environment, life sciences, materials and chemistry, aiming towards sustainable society through rich and eco-friendly society and healthy living. [34]

The various research and development activities are aiming towards regional, prefectural, national as well as global advantage from bioeconomy and establish bio-based and environmental friendly society. Various ministries, for example, Ministry of Economy, Trade and Industry, Ministry of Agriculture, Forestry and Fisheries, Environment ministry and some others are actively involved in bioeconomy activities through research, funding, policy making, public awareness activities and marketing. Japan has established various short-term and long-term programs regarding bio-based economic activities such as developing the technologies to utilize waste from sewage, agriculture, food business, household, paper, wood and other residues in energy production, develop and encourage biofuel, bio-plastics, and other bio-based products and developing new technologies for advanced fuel and biorefineries. [34]

Using 26 million tons of biomass per year, formulating plans and actions for all prefectures and all 600 districts and developing bio-based industry up to the economic value of JPY 500 billion are some of the quantitative targets specified under bioeconomy development. [34]

## **UNITED STATES**

The Bioeconomy Blueprint, published in 2012 by White House, is a very solid commitment towards bioeconomic society. Under this blueprint budget have been allocated for various research activities such as about 136 million American Dollar (USD) (see Appendix 7) for Agricultural and Food Research Initiative, 30 million USD (see Appendix 7) for synthetic biology research. Similarly, the agricultural Strategy "2014 Farm Bill" developed by the Department of Agriculture is also another strategy towards bioeconomy. Though the main objective is not directed specifically towards bioeconomy, the activities involved in the strategy are boosting the development of the key areas of bioeconomy such as agriculture, food and bioenergy. Under this strategy, USA has allocated about 112 million USD (see Appendix 7) for biomass research and development, 100 million USD (see Appendix 7) for organic farming research and 400 million USD (see Appendix 7) for research on special crops. Various agencies such as Department of Agriculture, Economic Affairs, Energy, Defense, National Security, Environmental Protection and Health are actively involved in development and promotion of the various strategies and policy making activities related to bioeconomy. "

[34]



Innovation promotion, policy and decision making regarding the innovation and technologies, technology transfer procedures, infrastructure development, capital management, funding for research, product development and production, marketing, commercialization, addressing demands and establishing framework for the policies and regulations are some of the common objectives of both strategies mentioned above. Additionally, new research and development activities are being promoted towards bio-based consumer goods for example sports, recreation, cosmetics, health care and daily goods. "Biorefinery Assistance Program" for the promotion of the biofuels and other bio-products, included under the program "Renewable Energies and Energy Efficiency", is a notable example which was undertaken as a part of the Farm Bill strategy. The US government is actively supporting the bioeconomy through various programs such as Biopreferred Program to utilize forest resource for bio-based products and also collaborating with other departments for creating and promoting new market possibilities for biofuel, for example, investing more than USD 200 million in the establishment of three biorefineries for the production of biofuel for the US Navy. Additionally, there are various package of programs aiming for the reformation of education and training courses to produce skilled employees required for the new technologies. The strategy is also firmly addressing the basic principle of bioeconomy which are food security and environmental protection. [34]

Among the G7 members, Germany, the USA and Japan are taking the lead in bioeconomy development with a solid strategy already developed and put into action. France, Italy, Canada and UK are also moving towards the bio-based development with various activities put to practice related to bioresources. European Union is following the bioeconomy development with a strong bioeconomy strategy as well and becoming a motivation with the availability of funding already planned for various programs under Horizon 2020. EU already has a history of getting involved in bioeconomy development for about 10 years. [34]

From the strategies and the activities mentioned above, it can be seen that the world leading countries are already very much involved in promoting bioeconomy and show the commitment towards sustainable future through bioeconomy. More detailed activities in each country are provided in table form as appendices (Appendix 1 - Appendix 7) of the paper.

#### 4.4.2.2 Finland

This chapter includes the information on bioeconomy development in Finland, how Finland is addressing the multidimensional aspect of bioeconomy and why Finland is considered a pioneer in bioeconomy.

##### ➤ The Finnish Bioeconomy Strategy 2014

The Finnish bioeconomy strategy "Sustainable Growth from Bioeconomy" was approved by the Finnish Government on 5 May 2014. The strategy was prepared in a joint effort of the Ministry of Agriculture and Forestry, the Ministry of Employment and the Economy, the Ministry of the Environment, the Ministry of Social Affairs and Health, the Ministry of Finance, the Ministry of Education and Culture, the Prime Minister's Office and their administrative sectors as well as the Finnish Innovation Fund Sitra and VTT Technical Research Centre of Finland. [37]

The main target of the strategy is to stimulate the renewal in the Finnish business, industry and economic growth through bioeconomy development and clean technology. The strategy supports the fact that the next economic wave will be from bioeconomy after the fossil economy (figure 4). The strategy also aims for building competitive and sustainable bioeconomy to address the global problems and establishing new opportunities for international markets and creating jobs through growth in business, high value added bio-based products and services while protecting the environment and the natural ecosystems. The government aims in increasing the bioeconomy yield from € 60 billion to €100 billion and generate 100,000 new bioeconomy related jobs by 2050. [37, 38]

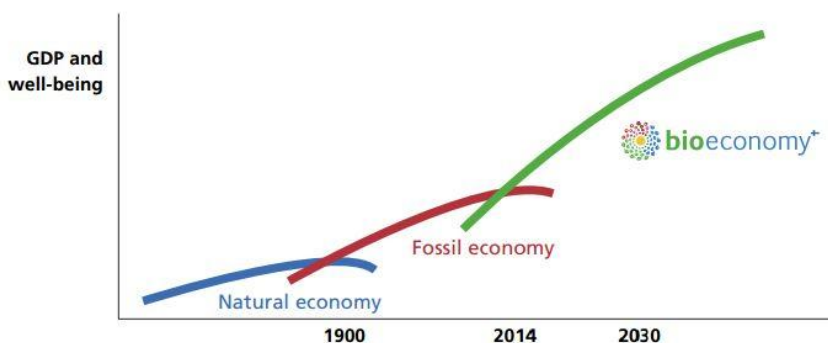


Figure 4 Bioeconomy as next economic wave [38]

The Finnish Bioeconomy Strategy focus on following four key points:

- creation of a competitive operating environment for the bioeconomy,
- creation of new bioeconomy related business and industry through research and development, experiments and erasing the boundaries between various sectors,
- building a refined bioeconomy competence base through various education, training and research activities,
- attaining the continuity and sustainability of biomasses and bio-resources. [38]

Finland boasts on the abundance of renewable resources, skilled expertise and industrial strength which makes Finland a potential country to be a global leader in bioeconomy and contribute in providing the global solution for the problems caused by population growth and demand, depletion and degradation of natural resources and biodiversity and climate change. Finland is rich in forest resources and considered the most forested land in Europe. More than 75% of the total Finnish land is covered with forest. Though the tree growing season in Finland is only about 80 days, the amount of wood in the forest is increasing every year with the rate of daily growth over 1 million cubic meters. Thus, the bounty from the forest sector has a significant role in Finnish bioeconomy since most of the present successful bio-based business are based on forest resource. The bioeconomy concept is helping to bring together different aspects such as forestry, forest resources (wood, peat, wood waste), processing and technologies, energy, chemistry, national economy, as well as various sustainable solutions related to nutrition and welfare. The Finnish strategy for bioeconomy has also been defined as a growth strategy since the strategy aims for the generation of innovative and sustainable economic and social growth for the well-being of Finnish people. [23, 37]

#### ➤ **Current Finnish Bioeconomy**

Finland has advanced very much in technology development and applications related to bio-resources. With the availability of resources and technical experts, Finland has already made a huge progress in bioeconomy. The number of success stories in bio-resources related industries highlights the bioeconomy development in Finland. A very good example is the well-established forest industry whose main products are paper, pulp, timber and plywood for constructional works and furniture, by-products such as wood chips and sawdust used for particle board manufacturing as well as feedstock for energy generation. Metsä Group is a

well-known forest industry with more than 80 years of history. It boasts the best renewable raw material in the world (northern wood) and products made from it such as tissue, cooking papers, paperboard, pulp, and fiber. Another example is UPM located in Lappeenranta, South-Eastern Finland, which is the world's first biorefinery to produce wood-based renewable diesel and produces approximately 120 million liters of biodiesel per year. Similarly, bio-based chemistry is also developing very much in Finland. Sugar produced from birch trees, plastics made from trees, cloth fiber made from wood, transport fuel from microbes are some of the innovations from Finland. [23, 39, 41]

Many new bioeconomy business ideas have been proposed in recent years in Finland. The bigger opportunities and possibilities for growth are expected to be found in fresh and unique products and goods especially in the forest, chemical and energy industry along with the related applied and industrial science.

**Variation in bio-based products:** As it has already been mentioned before, Finland has the expertise required for innovations so the possibilities for new business development is possible through new technology development. In addition to already successful traditional wood business, with newer technologies, the wood-based industry in Finland is being diversified significantly with various new and high value timber and other possible wood related products. Likewise, integration in various bio-chemical processes with innovative biomass refining technologies is giving new possibilities towards completely new and better biomaterials and products. Additionally, regarding sustainability in bioeconomy, the ideas for the waste and leftovers produced also to be utilized in better way as raw material for completely new produced are being developed. Finland is increasing its expertise in wood based products such as bio-composite materials, bio-textiles, bio-plastics and carbon neutral biofuels. [23]

**Leading the innovation in bioenergy development:** Awareness in using biofuel is increasing rapidly in Finland. It has been mentioned before also that Finland is a pioneer in producing bioenergy with biomass specially forest. Finland has already launched manufacturing of wood-based oil, for example, pine oil as well as refining the oil into second generation biofuel is starting to take stage. Finland is leading the world in combined heat and power (CHP) generation with about 80% of the district heat production based on CHP generation. The

feedstock for the plants are both fossil fuel and biomass. However, due to the concept of moving towards clean tech, the percentage of use of biomass is increasing and replacing fossil fuel in great amount. The feedstock contains mainly forest residues and wood-based fuels, peat and to some extent municipal bio-waste and agricultural waste. Alholmens Kraft Power Plant, Pietarsaari is the world's largest CHP plant based on biomass feed whose main feed are wood-based fuel, sawing and forest residues, peat which sums up to 100% of the total feed with coal and oil as starter or backup fuel. [23, 40]

**Using bio-based raw materials in chemical industry:** The study shows that the use of biomass in chemical industry in Finland dates back long before the concept of bioeconomy took the global attention. For instance, use of Carboxymethyl cellulose produced from plants (used in food products, beauty products, detergents, paper industry, ceramic industry, mining and construction industry, health and medicine industry and textile industry), tooth friendly sweetener xylitol produced from plant, use of bio-based raw materials in paint and adhesives industry, biodegradable bags, etc are good examples to support the fact that bio-based chemical are already taking significant role in chemical industry. Additionally, new ideas to combine bio and chemical industry are giving possibilities to produce better chemicals as intermediate products which supports other industries. This plays a vital role in bioeconomy value network. [23, 42]

**Increasing Timber for urban construction:** The idea of using timber for modern construction as a part of ecological housing is also increasing in Finnish society. The available timber expertise is being put to efficient building and construction as well. "Wood City" in Jätkäsaari, Helsinki (2015-2017) is a good example of urban timber construction (a project by the team of Stora Enso and SRV) which took use of timber in construction to next level. According to the plan, it consists of two eight storied buildings with 98 rental apartments, working areas and hotel facility. Another example is a 10,000 square meter newly build school in Pudasjärvi constructed almost only from log. Besides these, a company KONE which innovated the UltraRope, carbon fiber to replace the conventional steel cables in lift construction is also world known for using bioresources for raw material. [23, 43, 44, 45]

**Increasing efficiency in biomass utilization for cost-effectiveness and environmental benefits:** Various studies, research and developments have already been done and some are in

progress for the sustainable and efficient utilization of bio resources specially forest. Forest policy actions are being addressed strictly for secured exploitation of forest along with the biodiversity protection. Exploiting the forest biomass in an efficient way is helping manufacturing industries to increase cost-efficiency in raw materials. Furthermore, many other types of biomass such as agricultural waste, food waste in addition to forest biomass are being utilized to recover as much as possible in the form of raw materials, nutrients and energy. The planned way of exploitation helps in reducing the stress and negative impacts in nature. [23]

**Gateway for clean tech:** Because of the availability of technical expertise and high level of automation technologies, Finland is moving towards clean technologies as a part of sustainable bioeconomy. Finland is well known for its technologies for energy generation, emission treatment, waste and water processing, nutrient recovering and recycling as well as world-class biotechnology competence. The skill and knowledge towards industrial biotechnology and its applications is of high quality and various industries such as chemical, food, energy, pharmaceuticals, forest, brewery as well as mining are benefiting from it. The use of bio-based chemical compounds, antibiotics, citric acid, proteins, enzymes in various factories are also increasing. [23]

**Expanding the possibilities of food industry and health sector:** Apart from helping the conventional food industry grow better, bioeconomy is helping in new product development as well as increase export which helps in boosting turnover in food business. New ideas to integrate biorefinery or energy generation plant along with the food production industry as side stream businesses are being developed in order to open new and sustainable opportunities. The idea is to utilize the by-products from the food industry to produce completely new product such as raw materials for chemical industry or extracting energy fractions from them. Similarly, the Finnish biotechnology is also promoting the pharmaceutical research, health technologies and health sectors for the sake of citizen's well-being. [23]

Current Finnish bioeconomy is continuously moving towards bioeconomy prospects. Finnish bioeconomy is also helping in bioeconomy value chain with partnership between companies and service business related to wood product and side streams. Finland is also developing tourism as a part of bioeconomy. The sustainable bioeconomy and clean-tech applications have helped in maintaining nature and natural values. In addition to tourism, nature and

nature-related activities are providing opportunities for many types of businesses such as well-being services, recreation services and ecosystem services. Finland is also advancing in its aquaculture, for example, alga-culture for energy production. Along with the new developments, the old factories, plants, mills and biorefineries are being improved and reconstructed with new technologies for more efficient productions. [23]

#### **4.4.2.3 Possibility towards Universal Strategy**

From the information provided above about the G7 countries and Finland, it is clear that various efforts through various strategies have been put in order to promote bioeconomy and bioeconomy has been acknowledged as a significant factor for sustainable economic and environmental development. Different countries have difference in approaches and ways of working towards bio-based development, the main reason for this is the availability of knowledge and experts as well as the bio-resource. For example, Canada and Finland are very promoting forest-based bioeconomy because of abundance of forest resource whereas USA is focusing towards agricultural biotechnology and food safety.

There is a big variation on the working ways and the political objectives for each country. Their motives vary from securing the resources for raw material to the overall regeneration of the innovation system and transformation of the economy. The ways of measures and approaches towards the issues also vary with the country as well as within the country with various regional and prefectural development activities, for example, British Columbia and Alberta region in Canada have developed their own bioeconomy related activities to promote the region. Even though the individual efforts have their own goal, global needs and requirements are also being addressed. Developing the bioeconomy activities are anticipated to achieve environmental protection and maintain ecosystem from ecological perspective whereas all the countries involved in bioeconomy activities have also acknowledged the benefits towards the innovative and sustainable economy through economic perspective and developing the society with the creation of high-tech employment and skilled manpower through social perspective. Hence, from the activities described above and the tables in appendices from 1-7, table 2 has been constructed as follows with the common traits among the discussed countries.

**Table 2 Bioeconomy related activities in different countries**

Country	key Areas of Bioeconomy Related Strategies				
	Innovation Promotion	Infrastructure	Commercialization	Demand-side Instruments	Political Framework
Canada	Funding for research, development and promotion programs in <b>agriculture, forestry, biotechnology, biorefineries, bioenergy</b> , biomass conversion technology and more	Facilities for <b>research, pilot projects and demonstration plants</b>	Funding provision and marketing strategies for innovative <b>bio-based products</b>	<b>Public procurement and promoting green living</b>	
European Union	Research and development activities, promotion of <b>agricultural sector, food security, energy sector, biotechnology</b> and <b>forestry</b>	<b>Research and development</b> facilities for innovations	Funding for innovations, promoting <b>small and medium enterprises</b> and access to investments for <b>bio-based products</b>	<b>Public procurement and promoting green and sustainable living</b>	Bioeconomy observatory
France	Special programs for the promotion of research, education and innovations in <b>biotechnology</b> and <b>bioenergy</b>		Encouraging private investments	<b>Public procurement</b> and improving tax provision for sustainable energy	Collaboration between Green economy concept and policy makers



Germany	Research and development in <b>biotechnology</b> and promoting <b>biorefineries</b>	Facilities for <b>research and development</b> and <b>pilot and demonstration plants</b> , specialist trainings	Promoting <b>small and medium enterprises</b> , marketing strategies	Facilitating feed-in tariffs for bioenergy production, <b>labeling the bio products</b> in sustainable and methodical way	Interministerial bioeconomy working group
Italy	Research and development in chemical <b>biotechnology</b> and green chemistry				Policies for second and third generation biofuels
Japan	Research and development in industrial <b>biotechnology</b>	Facility for world class bioeconomy research program, <b>pilot projects</b> for industrialization of regional biomass production and development	Development of business models and marketing and <b>commercialization</b>	Tax consolation in biofuel business, <b>labeling for bio products</b> , promoting green and eco living	Implementing <b>green taxes</b> for example, carbon dioxide tax
United Kingdom	Research and development in <b>biotechnology</b> , bio chemistry and bio informatics	Facilitating farmers with bio digestors, <b>integrating academic courses and research</b> in bioenergy	Coaching, training and partnership programs for product and technology development and <b>commercialization</b>	Grants, funds for tax relief and feed-in tariff for bio energy producers, <b>globalizing businesses</b>	Provision of <b>Green taxes</b>
United States	Research and development in <b>agricultural biotechnology</b> and <b>biofuel</b>	Vocational training and education, <b>integrated engineering and education</b>	Ideas for technology from lab to market, promoting <b>small and medium enterprises</b>	<b>Globalizing the businesses</b> , providing certifications to bio based products	New regulations for technology development and control

Finland	Research and development in <b>biotechnology, bioenergy, agriculture</b> and specially in <b>forestry</b>	<b>Research and development</b> facilities, pilot and demonstration plants	Promoting <b>commercialization of forest based products</b> in particular and <b>biofuels</b>	Partnership between different companies for side stream businesses	Collaboration between funding organizations and government for innovations
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In table 2, the common characteristics that the strategies have are highlighted with bold letters. As it can be seen that agriculture, forestry, biotechnology and bioenergy are commonly addressed by almost all the countries that were studied. Also, some other objectives such as promoting bio-based products, globalizing the products, promoting small and medium enterprises, labeling the bio-products, green taxes, integrating academic courses with bioeconomy related research are common to many countries. Every country is promoting green and clean technology for sustainability and environmental protection. This shows that bioeconomy concept can be universalized with a unified definition and universal strategy.

#### 4.5 Innovative bioeconomy businesses in Finland

This section includes the information on innovative business cases from Finland in bioeconomy.

Finland has acknowledged the fact that bioeconomy is significant in Finnish economy particularly with forest-related bioeconomy. In recent years, Finland has gone through rapid changes to upgrade from traditional forest industry to fresh industry for biomaterials, biofuel and bio-products production. Government is also assisting the bioeconomy development with various facilities, funds, motivations and most importantly with supporting policies and regulations. The strategy developed with plans and actions are goal-oriented and are implemented with determination. [46]

Research shows that Finland with the current forest resource have the potential to become self-sufficient entirely for energy and with efficient exploitation the need for fossil fuel can be removed completely. Finish bioeconomy is forwarding with the goal of low carbon and energy efficient country and earth. Helsinki, Jakobstad, Lappeenranta and Vaasa region are well known for the bioeconomy activities. As mentioned above Metsä, Stora Enso, Kone,

Alholmens Kraft Power Plant, UPM and others for example Fortum, Neste Oil NEXBTL, St1 Biofuels Oy, Biovacka Suomi Oy (biogas company), Stormossen (biogas) are the leading companies in utilizing forest and bioresources. Some other bio-based businesses are Atria Plc (Meat and Convenience), Fazer (food industry), fur farming, fisheries, etc. However, there are many emerging companies having great potential towards bioeconomy. Some of them will be discussed below. [47]

### ➤ **Spinnova**

Spinnova is a company located in Jyväskylä founded in 2015 which developed a technology which uses wood to produce the fiber. The technology fiber to yarn (F2Y) is different from the conventional textile technology. The technology used transfers the wood fibers mainly spruce and pine directly into yarns ready for weaving. The technology is environment friendly and no chemical are involved in the pulp fiber treatment. There is no need to use dissolution chemicals to generate cellulosic filaments since the technique uses wet spinning process where the filaments are produced directly without the need of chemicals and converted to yarns. Spinnova turns the raw biomaterial into durable and functional fiber for clothes. The fibers are completely recyclable and cost competitive. [48, 49]

Spinnova was able to make itself known by winning the International Biorefinery competition in 2015 as an innovation to revolutionize both forest and textile industry, and Spinnova is a patented company and was selected as one of the most promising startup company among top 20 Finnish companies in 2016. [48, 49]

Spinnova's technique is the only technique available which takes the advantage of long fibers in Finnish woods and manufactures the yarn from the wood fibers directly without involvement of any chemical processes. It has been calculated that with Spinnova's technology if 20-30 million cubes of wood would be refined, it would replace about 20 percent of total global consumption of cotton used in traditional textile industry. This is expected to significantly reduce the negative impacts caused due to cotton farming on water and land resources and environment. Likewise, the chemical consumption can be reduced and since Spinnova's products are recyclable, biodegradable and environment friendly there will be no problems of disposing after use. [49]

### ➤ **PAPTIC Ltd**

PAPTIC Ltd is a company located in Espoo and founded in 2015 with the patented technology of producing fiber from wood with plastic-like properties to reduce and replace the use of plastic for example in packaging and carrier bags. The PAPTIC bags are lightweight, durable, soft, affordable, recyclable and 70% renewable. The company states that it will replace the plastic bags and even alternatives such as paper bags and biodegradable plastics. The PAPTIC bags overcome the problems like unsuitability of paper bags for multi use, poor durability and non-recyclability of biodegradable bags and expensiveness of bio-based plastics. [50]

The main raw material is Nordic wood based fiber which is renewable. The bags are able to stretch and twice as durable than paper so do not rip easily. The bags can be recycled with cardboards after use. The weight is 50% lighter and takes less space than paper bags. Apart from packaging and carrier bags, PAPTIC can also be used as base material for other applications which requires tough but flexible material. PAPTIC meets the highest standard of demanding brands. One of the main features of PAPTIC is that it can be manufactured in already existing infrastructure and no new mills or factories are required. [50]

Seppälä, a Finnish fashion chain, is the first company to use the bags from PAPTIC in their business as a way of supporting Finnish innovation. [50]

### ➤ **Woodcast**

Woodcast is the product of a Finnish company Onbone Oy in Helsinki, which is an expertise in medical technology. The product was launched in 2010 and all the Finnish hospitals are using it. Woodcast products include various items which are used in orthopedic and traumatology mainly for fracture treatments, rehabilitation therapy immobilizations and post-surgery immobilizations. The products include Woodcast ribbons, colored splints, folded splints, heating devices and others. Woodcast products are manufactured from clean wood and biodegradable plastics which are very light compared to traditional cement and fiberglass casting. Woodcast products are biodegradable and there is no involvement of water or chemicals during the casting. It is non-toxic and easily moldable and also re-moldable just by heating. It is easy for the doctors to put the cast since they do not have to put on gloves and

use water and the patients can be comfortable with lighter but sturdy cast. One other feather is that it does not need to be removed for x-ray which makes it a lot more convenient. [51]

This product has already expanded its market in Scandinavia, German-speaking Europe, UK and Benelux. This innovation was awarded with Chemical Industry Innovation Award in April 2012 and was described as a metamorphosis in cast industry. Various departments and funding organizations as well as hospitals are cooperating for further research and development as well as marketing. [52]

### ➤ **UPM Biofuels**

UPM is a well known Finnish forest-based company with various products already been successful in the market. Recently (from 2015) the company started the commercial production of the wood-based renewable biodiesel UPM BioVerno which reduces the greenhouse gases emission by 80% in comparison to the traditional fossil diesel. The biorefinery is located in Lappeenranta and is first of its kind in the world. The main feed is the crude tall oil which is a residue from pulp manufacturing. Since, the raw materials originate from forest, the biodiesel is renewable and do not compete with the food crops. UPM biodiesel is compatible with any diesel engines, have cleaner combustion, lower emission and almost like the fossil diesel. St1, Volvo and Transdev Finland are supporting the product. [53]

The four companies discussed above are considered to be a huge breakthrough in Finnish bioeconomy development. Finnish government is developing various plans and strategies for more and better research, development and innovation. Funds have been allocated by the government for bioeconomy activities for example the Finnish Funding Agency, TEKES, has been provided with twenty million euros for equity financing and sixty million euros for supporting various demonstration activities. Similarly, Finnish Industry Investment has been allocated with one hundred million euros for regeneration and growth of the industries. Both are mainly directed towards bioeconomy. The government is focusing on public-private cooperation in investment as well as participatory activities to promote bio-based living. [54]

## 5 Discussions

This chapter briefly summarizes the key points and findings from the work and interpret the results with the personal opinions. This chapter also summarizes the answers to the questions mentioned in the thesis purpose and will show how the work has been able to fulfill the main aim of the thesis that is to review the history of bioeconomy and find the bioeconomy activities that have helped in bioeconomy development and also how bioeconomy is being addressed in current time.

The **first** task of this work was to review and find the definition for the term "Bioeconomy". From the collection of definitions from various respected organizations presented in the report, it can be seen that there is no unified definition, however, all the definitions include similar characteristics. Thus, bioeconomy can be summarized as all the activities which are related to biological resources including from resource origin, processing, product manufacturing, production, marketing, utilization and disposal of products. It can also be seen that bioeconomy is mostly related to renewability, sustainability and innovations for green and healthy living.

The **second** task of this work was to find out whether bioeconomy is a new concept or old. The literary review of bioeconomy and its history presented in this paper shows that its origin is not new. Various activities which incorporate bioresources have always been a part of living which started about 10,000 years ago. Agricultural revolution and industrial revolution brought a big change in lifestyle of people. Bioeconomy was not defined officially in early days. People were just engaged in various bio-based activities as per the need and demand. The world population was less than now so nature provided the food and resources in plenty. Discovery of fossil fuel and its uses in industries and transportation was a significant step towards development which continues till today. However, the environmental problems and climate change issues caught the eyes of everyone. Thus the importance of sustainable development came to light. The concept of bioeconomy was forwarded as a better way towards sustainable economic and environmental development. The various bio-based industries, bio-products, bio-based technologies developed from ancient times shows the existence of bioeconomy. This fact can also be supported by the involvement in bio industry mainly forest industry in Finland which dates back from the beginning of the agricultural era

about 10,000 years ago. Bioeconomy a bio-based knowledge concept though existed from ages ago, newer approaches towards multi-dimension of bioeconomy have gained more attraction for over a decade now. Furthermore, the compilation of events that occurred from the end of the 20<sup>th</sup> century till the present date (see figure 3) shows the drastic development in bioeconomy promotion activities. So bioeconomy is an old concept with new and multidimensional approaches.

The **third** task was to familiarize with the topics discussed under bioeconomy and also define the correlation of bioeconomy with its political, economical, environmental dimensions along with sustainability and development. The materials presented in the paper in the third part of result section shows that bioeconomy is interrelated with development, political economy, and environmental sustainability.

It can be clearly seen that biotechnology and bioenergy are the driving factors for bioeconomy to develop to the present stage. Agricultural and industrial biotechnology have helped in increasing bio-based activities along with economical activities. The introduction of biotechnology helped in the various development and establishing new and better technologies for further developments, thus boosting bioeconomy activities. The problems such as global food security, bioresources production, medical sectors are being answered with the help of development of agricultural biotechnology as bioeconomic activities. Increasing demand for food means increasing demand from agriculture which puts land and water resources in pressure. Biotechnology helps in increasing agricultural production with new sustainable methods and technologies with less pressure on land and water as well reduces the use of fertilizers and pesticides yet with higher quality and quantity. Along with agricultural sector, the industrial sector can also take great advantage of biotechnology as industrial biotechnology helps in realizing bioeconomy through utilization of bioresources in the industrial sector rather than non-renewable fossil materials.

Similarly, development and advancement in biofuels have helped answer the problems of alternative energy source to reduce energy crisis problem. New developments and innovations have helped in solving feedstock issue for the biofuel extraction. Bioenergy takes a big share of bioeconomy development. Biofuels are clean and renewable energy source and environmental friendly. Advancement in biofuel production and refining processes have made

the biofuel gain world's attraction. Many possibilities for new biorefineries are being researched and also being installed to move towards bio-based energy environment. USA and Brazil are leading the biofuel production and Europe is following with great pace as well.

Bioeconomy has been related to environmental, economic and political developments. Bioeconomy has been recognized by many countries like United States, Japan, Germany, Finland and more as a way towards sustainable development in terms of both environmental and economical aspects. The increase in bioeconomy activities can be related to development which leads to independence to fossil resources and resolves energy crisis, mitigate climate change issues, secure food, and medical safety, availability of daily products, job opportunities, economic development, clean and healthy living. For the bioeconomy to advance, solid strategy and policies are required. This will help in organized and planned development and better results. Planned exploitation of the bioresources helps in increasing the production while reducing the negative impacts and preserving the environment. Similarly, proper and flexible regulations help in increasing the possibility of technology transfer and cooperative development among many countries. This helps in increasing trade and marketing of bio-based products and increasing economic activities. This also helps in establishing and increasing bioeconomy activities in less developed countries.

The **fourth** task was to find how bioeconomy is being addressed by world leading countries. As it can be seen from the fourth part of the result section that the bioeconomy activities are taking fast pace in many European countries as well as some American and Asian countries. Many strategies specifically towards bioeconomy development have been developed for innovations as well as policies and regulations regarding the activities among which three major efforts were summarized.

European Commission has developed a bioeconomy strategy "Innovating for Sustainable Growth- A Bioeconomy for Europe". The main aim of the European bioeconomy strategy is to assist research and development for new technologies for efficient utilization of bioresources for green economic and environmental growth resulting in sustainable production of food, fuel, feed and fiber and ensuring environmental protection. The strategy assists in collecting and providing funds for innovation development and pilot demonstrations. Additionally, the strategy also provides information regarding the regulations and policies for various national



and international bioeconomy related activities to increase international communication and collaboration.

Similarly, various strategies for policies and regulations framework development in order to facilitate bioeconomy development smoothly also have been established. Regulations regarding energy, technology transfer, international marketing, environmental regulations for bioeconomy related activities, funding and financing, patents, etc are being included and addressed in various national and international discussions. For example, the 13<sup>th</sup> conference for the policy recommendations on the emerging bioeconomy whose main aim was to study the constraints for bioeconomy development and find the possible solutions through policy propositions.

Another example of a very strong commitment towards bioeconomy as a part of national development is the National Bioeconomy Blueprint from the US, whose main aim is to assist the scientific research and development for sustainable economic and environmental growth. The blueprint aims to put the bioeconomy potential of U.S. to utilization for the national political, economic and environmental development. The blueprint includes five strategies towards distinct objectives which are funding research and development in bioeconomy technology, providing regulatory support for lab to market development, reforming regulations and policies for reducing constraints from regulations, integrating the various education systems and institutions for trainings to produce skilled manpower and encourage public-private partnership for increasing opportunities in bioeconomy businesses.

Most of the European countries take the reference from the bioeconomy strategy developed by EC for the bioresources related activities. Many European countries have developed their own strategies as well since different countries have different resources available so in order to take the maximum benefit from the available bioresources countries have established their own actions and plans for innovative bioeconomy development. A very good example is the bioeconomy strategy from Finland. The Finnish bioeconomy strategy "Sustainable Growth from Bioeconomy" has its own goal and targets, however it also addresses various objectives from the bioeconomy strategy from European Commission. The Finnish bioeconomy strategy is a growth strategy mainly focused in forest-based bioeconomy due to the abundance availability of forest. Germany is also forwarding towards bioeconomy development with

various strategies and plans. Bioeconomy is a hot topic for discussion in G7. Other countries such as UK, Canada, and Japan are also moving towards bioeconomy with various strategies and related activities.

Finland is considered a leader in bioeconomy development because of the long history in bio resources related activities mainly forest industry. With the available resources, experts and technologies Finland is creating new bioeconomy trends with innovations. Finland is developing various products to replace current products which are manufactured with fossil resources with bio-based materials for example plastics. Finland is increasing its area of bioeconomy not only in biofuel and biotechnology but also in other areas such as construction, recreation and health care, tourism, chemical industry and clean technology.

The **fifth and final** task was to study hands-on business cases in bioeconomy development for which new developed products in Finland were taken. Spinnova, PAPTIC Ltd, Woodcast and UPM Biofuels were studied. All the mentioned products are recently developed and established. Either environmentally friendly technology from Spinnova to transfer wood fibers to yarn for weaving with better qualities or the technology from PAPTIC Ltd to produce wood-based fiber with plastic like properties to replace the conventional as well as biodegradable plastics or the product developed for medical use Woodcast from Onbone Oy used for easy casting and replacing traditional cement or fiberglass casting, all the patented products are very innovative and use bioresources as main feedstock for manufacturing. Similarly, biorefinery which transforms biomass into valuable products such as fuel, materials, chemicals is already developed a lot in Finland and they are the production engines for new bioeconomy businesses. With UPM biofuel refinery established and already running commercially, Finland is moving more further in bioenergy promotion and development. But, there is a big interest in the newly developed products mentioned above and their success. It would be interesting to follow up the growth and improvement of these bio-based products. The consumer behavior towards these products is also of interest which will decide the sustainability of the products.

When talking about the environmental prospects of bioeconomy the main idea is addressing bio resources and biodiversity. The origin of resource, optimal utilization, resource conservation, modification in resources, continuity in supply of materials are some of the

aspects that bioeconomy addresses. Similarly, answering the environmental issues such as environmental depletion, depletion of natural resources, depletion of fossil resources, climate change, emission, through sustainable acts is also one of the prospects of bioeconomy. Reduction in carbon footprint through clean technology is a huge step towards mitigating climate change issues. Promoting green or eco living through sustainable products is another prospect of bioeconomy. Similarly, innovative developments mean new products with better quality through optimal utilization of resources. Innovative and sustainable products help in economic growth as well as creates job opportunities.

Future success in bioeconomy development depends on many factors. Production and availability of bioresources is the first thing which will affect the further development. It is obvious that it is necessary to develop new and better technologies to produce bio-based raw materials with the sustainable approach and utilize efficiently to reduce the use of primary material that means reusing and recycling as much as possible. Also, the price of the raw material will affect the production cost as well as consumer price which will have a significant effect to the global economy. Similarly, industrial infrastructure is also another important factor. The development of the ground-breaking technologies with increased efficiency and optimization is required to be integrated with the best industrial infrastructure and logistics for the production of goods which will ensure rewarding and advantageous development.

Developing competencies for future is also another important factor for developing bioeconomy which helps in creating skilled and trained manpower for further innovations. For example, the collaboration between national and international educational institutes and academies for bioeconomy related knowledge and skills related educations can help develop competencies required for sustainable bioeconomy development with production and consumption of bio-based materials and goods. The knowledge required for approaches towards systematic and strategic planning evaluating the environment, lifecycle analysis, analyzing social and economic performances as well as understanding technologies and local circumstances can be gained from proper education systems. Open learning platforms can be a good option for sharing knowledge and information.

Sharing the new technologies and knowledge through international collaboration between government, private and public partners will help in promoting and increasing partnership and

develop new possibilities for bio businesses. Since high technical knowledge is advancing more in developed countries, it is necessary to increase the participation of developing countries as well in order to address bioeconomy in the global level. The variation in availability of bioresources from the forest, agriculture, fisheries, animal cultivation to sea products, have different potential for new businesses through technological, organizational and social innovations. Similarly, establishing the businesses not only in large scale but also in small and medium scale in rural parts of the world will help increase utilization of local resources and create local jobs.

Another factor is regulatory framework regarding intellectual property, technology transfer, flexibility in genetically modified plants, standards, international bio business marketing, and trade, which is required for increasing national and international participation in developing new bioproducts and new ways of utilizing bioresources. Global agreement in most important aspects of bioeconomy is needed to globalize the standards and policies regarding resources utilization, product development, and marketing, for supporting the global economy. This will help in increasing the private and public funding from national and international level for new research and developments.

Public awareness is a very important factor for the transparent communication on bioeconomy which is necessary to lighten up the opportunities and challenges. The utilization of bio-based resources and innovation and development has already opened up possibilities for new and better products. Bioeconomy and the activities are expected to bring positive changes regarding the economy, environment and lifestyle. However, there are various environmental, economic, political as well as social challenges and constraints for smooth development and open discussion. Reducing the fossil fuel dependency through sustainable bioeconomy, producing environment-friendly products, creating new job opportunities, increasing the economic growth and promoting green living are the positive development through bioeconomy. Meanwhile, there are some other issues such as possibilities towards adverse effect on land, water, air and biodiversity. It is very necessary to be aware of both positive and negative sides of the new developments to make it sustainable.

## **6 Conclusions**

To conclude the work, it can be seen that the goal of reviewing the bioeconomy concept in global perspective was achieved and the questions mentioned in the aim and purpose were answered in the work. The bioeconomy concept is not messy anymore. It is clear that the history of bioeconomy began about 10,000 years ago but was officially highlighted as a term or concept in 1993 by European Commission. Bioeconomy was highlighted along with the discussion on knowledge-based investments and innovative biotechnology then. With a long and old history, bioeconomy is moving with newer approaches. It is clear now that bioeconomy is not just a concept that policy makers care about but it is a knowledge based concept acting as a connection between technology, innovation and sustainability whose importance is very significant. Bioeconomy concept is an important booster for innovative businesses and sustainable environment, economy and society. It can also be concluded that it is possible to construct a universal definition of bioeconomy as well as a strategy since the strategies that different countries have developed address many common goals and objectives.

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## Appendices

### Appendix 1: Important steps taken to promote bioeconomy in Canada

Key area of the strategy	Strategy, Programs, Organizations involved	Measures	Implementation	Budget (CAD)	Time period
1. Innovation promotion	"Growing Forward 2"	Basic and applied research	Promoting the innovative works in various agricultural research areas and commercializing the innovations with the help of funding programs.		2013-2018
	Natural Resources Canada- Forest Innovation Program (FIP)		R & D and technology transfer in forestry sector in Canada with bio-based material as main key point.	92 m	2013-2016
	Natural Resources Canada- EcoENERGY Innovation Initiative and Clean Energy Fund		Projects for the innovation of various areas related to sustainable resources, biomass conversion technologies, biorefineries and sustainability performance measurement.		2009-2013
	Canadian Biomass Innovation Network (CBIN)		Active in research, managing programs, making policies, advising from the experts in the industrial, academic, governmental and non-governmental organizations and other international communities to support the sustainable development of bioeconomy in Canada specially in bioenergy sector.		
	Sustainable Development Technology Canada (SDTC)- NextGen Biofuels Fund	Pilot projects and demonstration plants	Second generation biofuels demonstration plants.	500 m	2007-2017
2. Commercialization	"Growing Forward 2"	Marketing strategies	Provision of funds for various agri-tech innovations and commercialization programs.		2013-2018
	"Growing Forward 2"	Supporting biomass producers and production	Funds for biofuel production and tax relief		
3. Demand-side instruments	"Green" procurement policy	Public procurement			2006-

## Appendix 2: Important steps taken to promote bioeconomy in EU

Key area of the strategy	Strategy, Programs, Organizations involved	Measures	Implementation	Budget (Euro)	Time period
1. Innovation promotion	"Horizon 2020"	Researching and Development	Main area of work is towards food security, innovative and sustainable agriculture, marine and maritime study and the bioeconomy.	2.8 bn.	2014-2020
			Main areas addressed are clean and efficient energy security, action towards climate issues, resources and raw materials efficiency, demographic changes, health and well being and innovative and secured society.		2014-2020
	"Horizon 2020" - Industrial leadership and Competitive Frameworks	Developing key technologies	Promoting the development of bioeconomy with relevant technologies such as biotechnology and material science.		2014-2020
2. Commercialization	"Horizon 2020" - Industrial leadership and Competitive Frameworks	Financing and venturing capital	Promoting small and medium sized enterprises towards innovation and access to investments.		2014-2020
3. Demand-side instruments	"Horizon 2020" - Bioeconomy	Public procurement	Public Procurement Network		
		Developing standards and labels	For example: CEN/TC 411; Standardization for biobased products and labeling		ongoing
4. Political framework conditions		Consistency in policy	EU Bioeconomy Panel		2013-2015
			EU Bioeconomy Observatory for modelling and monitoring		2013-2016
		Enabling key technologies observatory	Monitoring of the development of industrial biotechnology in European Union.		2013-2015

### Appendix 3: Important steps taken to promote bioeconomy in France

Key area of the strategy	Strategy, Programs, Organizations involved	Measures	Implementation	Budget (Euro)	Time period
1. Innovation promotion	French National Institute for Agricultural Research (INRA)	Basic and applied research	Founding multidisciplinary and incorporated programs in the areas of food, ecology and agriculture	30% of the total INRA budget	2010-2020
	Centres of excellence in the area of non-fossil energy (IEED)		Special programs for the promotion of research, education and innovation in biotechnology, bioenergy and green chemistry.	2-3 billion	2010-2020
	Report on the strategic sectors of the "économie verte" (2013)	Pilot projects and demonstration plants	Biorefineries (e.g. Bio HUB, Biobutterfly), Bioplastics (e.g. Plastipolis, Xylofutur, PEP), Biotechnology (e.g. Toulouse White Biotech)		
2. Commercialization	White Paper on financing ecological transition (2013)	Private innovation capital	Three official labels for sustainable investment funds.		
3. Demand-side instruments	White Paper on financing ecological transition (2013)	Relieving the tax on sustainable investments	Improving the tax provision for sustainable energy investments.		2014
	Plan national d'action pour les achats publics durables (PNAAPD)	Public procurement	National action plans for public procurement in sustainable way in the areas of bio-based products, energy efficiency and life cycle assessments.		2014-2020
4. Political framework conditions	The new face of industry (2014)	Industrial regeneration	Analyzing the constraints in investment and industrial turning points such as green chemicals, bio-feed, bio resources, biofuels and more.		2014-2020
	Comité stratégique des éco-industries (COSEI)	Participation and political representation	Collaboration between green economy and policy makers		2008-
	Comité pour la fiscalité écologique	Green taxes	Tax privilege on biofuels and increasing taxes on CO <sub>2</sub> emitting propellants and fossil fuels.		
	Law on the future of agriculture, food and forestry (2014)	Laws and regulations for biodiversity	Banning the production and use of plastic bags and support bioplastics and banning chemical pesticides and ariel spray and approving natural pesticides.		2014

## Appendix 4: Important steps taken to promote bioeconomy in Germany

Key area of the strategy	Strategy, Programs, Organizations involved	Measures	Implementation	Budget (Euro)	Time period
1. Innovation promotion	Bioeconomy Research Strategy 2030	Basic and applied research	Various biotechnology related programs such as biotechnology 2020+, Innovative Alliances in Industrial Biotechnology, Renewable Resources Funding Program.	2.4 bn	2010-2018
		International collaboration	Collaboration with non-EU countries on research and development on bioeconomy aspects and German-African research on various networks regarding food systems.		
	Forest Carbon Fund		Researching the CO <sub>2</sub> reduction potential of forests and cleaning emissions and deal with climate change issues.	100 m	2013-2016
		Pilot and demonstration plants	Funding the pilot biorefineries plants in various places, Cluster bioindustries 2021 and Bioeconomy Cluster Central		
2. Infrastructure	Bioeconomy Research Strategy 2030	Centres of competence, research networks and specialists training	Researching bio-systems, bioinformatics, collaboration with educational institutes in thematic subjects such as Bioeconomy Science Centre Jülich, Hohenheim University, Halle Plant Bioeconomy-Science Campus.		
3. Commercialization	Initiative Sustainable Supply of Raw Materials for the Industrial Use of Biomass (INRO)	Developing market	Creating a network for the certification of renewable resources under sustainability criteria.		
	Bioeconomy policy strategy	Initial set up investment and financing and venturing capital	Initiatives for renewable energy export, founding biotech and life science researchers such as GO-Bio, support to small and medium enterprises with finance and knowledge.		ongoing
4. Demand-side instruments	Revised Renewable Energy Sources Act 2014	Supporting biomass producers	Facilitating feed-in tariffs for bioenergy and bioenergy production from biomass waste.		ongoing
	Bioeconomy policy strategy	Communication initiatives	Exchanging information and social connection and recommendations of bio-based products, food waste, etc.		2004-2014
		Labeling the products	labelling the bioproducts in sustainable and methodical way.		

5. Political framework conditions	Bioeconomy policy strategy	Consistency in policy, approach to renewable resources	Partnership in biomass in international level with sustainability criteria, management and monitoring of information and knowledge, Interministerial bioeconomy Working group.		ongoing
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## Appendix 5: Important steps taken to promote bioeconomy in Japan

Key area of the strategy	Strategy, Programs, Organizations involved	Measures	Implementation	Budget (JPY)	Time period
1. Innovation promotion	National Institute for Advanced Industrial, Science and Technology (AIST)	Basic and applied research	Research and development on various bioeconomy aspects such as industrial biotechnology. Energy and environment, life sciences, materials and chemistry, aiming towards sustainable society through rich and eco-friendly society and healthy and safe living.		
	Advanced Low Carbon Technology Research and Development program (ALCA)	Research and development	Moving towards green innovation with new high-potential scientific knowledge and steady reduction of GHG, creating low-carbon society.		
	RIKEN, Japan	Basic and applied research	Broader and world class bioeconomy research programs.		
2. Infrastructure		Annual reporting on the Environment, The Sound Material-Cycle Society, and the Biodiversity in Japan	Rural development programs and pilot projects for industrialization of regional biomass production and infrastructure development.		
3. Commercialization	Biomass Industrialization Strategy	Developing market	Development of business models in collaboration with the neighbouring countries		
4. Demand-side instruments	Biomass Industrialization Strategy	Supporting biomass producers	Rigid and homogenous feed-in tariff for biomass		
	Act on Promoting Green Purchasing	Supporting biofuel producers	Facilitating the biofuel business and producers with tax consolation and green procurement policy.		2012
		Labeling	Provision of various labels in bio-based products to encourage consumers to use bio products for example, Biodiversity label, Ecoleaf, Greenpla and BiomassPla (for bioplastics)		
5. Political framework conditions	Climate Change Mitigation	Implementing Green taxes	Regulating the carbon dioxide tax		
	Establishing a Sound Material-Cycle Society (2013)	Plannings for Recycling	For example: Food Recycling Act		

## Appendix 6: Important steps taken to promote bioeconomy in UK

Key area of the strategy	Strategy, Programs, Organizations involved	Measures	Implementation	Budget (GBP)	Time period
1. Innovation promotion	Biotechnology and Biological Sciences Research Council (BBSRC)	Basic and applied research	Research and development programs related to bioeconomy aspects such as biotechnology and bio-chemistry.	6 m	2008-2013
			Sustainable Bioenergy Centre	24 m	2009-2014
			UK Global Food Security Program	410 m p.a.	2011-2016
			Centre for Agricultural Innovation for promoting sustainable intensification	90 m	2014-2018
			Bioprocessing Research Industry Club	23 m	2005-
	Wrap program- Anaerobic Digestion Loan Fund	Pilot and demonstration plants	Providing grants from state to build anaerobic digestion plants	10 m	2011-2015
2. Infrastructure	Agri-tech Strategy- Centre for Agricultural Informatics and Metrics of Sustainability	Developing key technologies	Research and development on bioinformatics and data.		
	Wrap program- On Farm AD Fund	Rural areas development	Facilitate the farmers on building small scale anaerobic digestion plants with advice and loan.		2013-
	BBSRC Research Clubs and Bioenergy Centre	Education programs	Integrating with academic courses and doctoral programs in relevant research activities and bioenergy		
3. Commercialization	Agri-tech Strategy- "Agri-tech Catalyst"	Studies on feasibility	Provision of funds for the study of the feasibility of innovations on near-market agriculture.	70 m p.a.	2014-2018
	Agri-tech Strategy	Providing business advices	Helping life science related companies to increase the capital and globalize with the help of coaching, training, networking and partnership programs.		
	Technology Strategy Board- "Industrial Biotechnology Catalyst"		Product development process and product commercialization	45 m	2014-2015
	Technology Strategy Board- "High-value Manufacturing Catapult"		Production technologies commercialization		
4. Demand-side instruments	Biomass Energy Centre	Grants and supports	Providing support to the biomass producers with grants, funds for tax relief and feed-in tariff for bioenergy producers.		
5. Political framework conditions	Biomass Energy Centre- Green Taxes	Grants and supports	Exemption of tax for renewable energy but tax on commercial consumption.		

## Appendix 7: Important steps taken to promote bioeconomy in USA

Key area of the strategy	Strategy, Programs, Organizations involved	Measures	Implementation	Budget (USD)	Time period
1. Innovation promotion	2014 Farmbill	Research on bioeconomy related aspects	Biomass Research and Development Initiative USDA-DOE	112 m	2014-2018
			Research on organic farming	100 m	2014-2018
			Researching special crops	400 m	2014-2018
	GS program		DOE Genomic Science program and Joint Bioenergy Research Centres		2013-2018
	Bioeconomy Blueprint		Agricultural and Food Research Initiative	136 m	2011-
			Advanced Research Projects Agency-Energy		2009-
			Living Foundries Program-Biomanufacturing		2011-
		Cross-cutting technologies	Synthetic biology: DOE Biological and Environment Research Program	30 m	
		Interdisciplinary research	NSF Research at the Interface of Biological, Mathematical and Physical Sciences	50 m	2014
			NSF Projectt "Science, Engineering and Education for Sustainability"	30 m	
2. Infrastructure	Bioeconomy Blueprint	Vocational training and education	Availability of courses at community colleges		
			21 st Century Science, Engineering and Education		2011
	2014 Farmbill	Education and training	Basic and beginners training for new farmers and rancher training	100 m	
		Rural development programs	Biomass Corp Assistance Program aimed for the grants for development in biorefineries and establish value chains with agriculture and forestry.	125 m	
3. Commercialization	Lab-to Market Interagency Summit		Planning the ideas from the technology from lab to the actual market.		2013-
	Bioeconomy Blueprint	Small Business Innovation Research Program and Small Business Technology Transfer	Researching on the bio-based products and biofuel and preparing for the market penetration.		
		America Invents Act	Facilitaing the patenting process and making the process faster as well as marketing of the innovations.		

	2014 Farmbill / U.S. Department of Agriculture (USDA)	Biorefinery, Renewable Chemicals and Bio-based Products Manufacturing Assistance Program	Providing the assistance through capital.	200 m	2014-2016
		Tax	Researching and extending the tax credit fo the small and medium sized enterprises to start-up the business.		2014-2015
		Foreign Market Development and Market Access Program	Globalizing the businesses	200 m p.a.	2014
4. Demand-side instruments	BiopREFERRED program	Public procurement on federal level	Providing guidelines for the treatment of the bio-based products and providing certification to bio-based products.	25 m	
	Farm-to Fleet Program		Acquisition of biofuels by the US Navy and encouraging the biofuel production by the Defense Production Act, Advanced Drop-in Biofuels Production Project and USDA Commodity Credit Corporation Funds.	400 m	2013-
	2014 Farmbill	Utilization of Bioenergy	Use of biomass for energy and heating in the biorefineries, investment in energy efficient renewables and advanced biofuels.		2014-2018
5. Political framework conditions	Bioeconomy Blueprint	Regulations and approval of new technologies	Development of new regulations for the control of technologies.		2014
	Food and Drug Administration (FDA	Safety and Innovation Act	Increasing the involvement of patients and industry in approval of the products.		
			Reformation of the risk assessment and regulations and demonstration projects for the approval process of the genetically modified organisms.		