4.1 Final Publishable summary Report

Executive Summary

The project SAHYOG (Strengthening Networking on Biomass Research and Bio-waste Conversion – Biotechnology for Europe India Integration), jointly funded by the European Commission and the Department of Biotechnology (DBT) of the Indian Ministry of Science and Technology, was mainly aimed at bringing together the leading organizations in the field of biomass production and bio-waste conversion research carried out within EU research programs and related programs by Indian national institutions.

The project consortium consisted of 7 EU and 6 Indian partners with overall coordination of ENEA, Italy. From Indian side the project was coordinated by TERI. The SAHYOG planned a major coordination approach, split into 5 work packages. The administrative management, project monitoring and communication management activities were supported by the project coordinators from EU & India.

Initial work was focused on the **elaboration of inventories** to document biomass production and biowaste availability in both regions. These were then complemented with the comprehensive inventories of research activities in Europe and India to identify common areas of interest and cooperation opportunities along with the knowledge gaps in various fields related to the biobased economy. Based on these inventories, a Strategic Research Agenda (SRA) was developed.

SAHYOG also aimed at broad networking of respective scientific and industrial communities, important tools to strengthen collaboration and promote networking in the areas of shared strategic interest. To accomplish this goal the **Twinning of large sets of research projects** from India and Europe in order to ensure exchange of information, **Short-term exchanges** of researchers for young talents and senior experts from India and Europe as well as organization of **Summer Schools in Europe and India** involving renowned international lecturers, were implemented. The two SAHYOG Summer Schools, one in Greece and another in Assam, India, were organized with distinguished international experts to present the latest developments in their respective fields to the students from Europe and India, who evaluated the Summer School very positively and reported that it was a significant learning and sharing experience for them.

The organization of Experts meetings**,** one in Copenhagen (Denmark) and the other in New Delhi (India) and the **Bio-economy event,** to explore the opinions and perspectives of European and Indian scientists, industries and R & D program managers and to ensure widespread communication, were also organized successfully. The results of the project activities performed during the project duration, were presented and discussed with various experts present at the meetings.

The work conducted under the elaboration of inventories documented the biomass and bio-waste potentials and the research projects/programs in Europe & MS and in India**.** With respect to biomass resources significant differences were identified between India and Europe. The dominant resource in Europe is biomass from forestry, followed by domestic and industrial organic waste, sewage, and cereal residues, while in India the most abundant and available feedstock are domestic and industrial organic and biodegradable waste fractions and cereal residues due to its important agricultural sector.

Priority research areas for EU-India cooperation include the development of uniform biomass resource databases, low input production intensification, harvesting and logistics (of residues), waste collection, separation and treatment, as well as sustainable algae production systems. In the area of conversion technologies and bio-refinery systems, the joint EU-India research priorities concerning the lignocellulosic bio-refineries, anaerobic digestion, and the demonstration of bio-refinery concepts, were identified. With respect to markets, products and policies it was found that in India clear priority is placed on food security (excluding the use of food crops for energy production) and energy production from biomass resources, whereas in Europe stronger emphasis is placed on the development of new markets (e.g. for for bio-based chemicals) within a bio-based economy.

Both continents acknowledge the need for increased valorization of biomass and bio-waste resources and an integrated bio-refinery approach in future. The main emphasis on joint EU-India activities in this field should be given to the development of common political frameworks stimulating a global bio-based economy, the elaboration of standards for performance criteria of bio-based products, as well as public awareness programmes and training and education initiatives for researchers and engineers to pave the way towards a future sustainable bio-based economy.

The joint **Strategic Research Agenda (SRA),** aimed to facilitate **concerted planning of future EU-India research initiatives**, led to define a R&D **Roadmap** for policymakers, researchers and other stakeholders in the field of biobased economy, **identifying key targets** to further scale up the EU - India collaborations.

This **coordination activity** is of great importance to systematically bridge the on-going respective activities from India and Europe that help providing the basis for novel applications in a sustainable bio-economy of the future - the so-called knowledge based bio-economy (KBBE).

Summary Description of the project context and the main objectives

The project SAHYOG was mainly aimed at actively and effectively linking research activities in the field of biomass and bio-waste implemented within EU research programmes and related programmes by Indian national institutions. Under the main objective of the project, a major coordination approach was planned to support the setting up of the sustainable bio-economy.

Inventories of biomass and bio-waste potentials and research projects/programs elaborated and analysed within SAHYOG were the basis for the joint Strategic Research Agenda (SRA) finally leading to a Roadmap for policymakers and researchers.

SAHYOG ensured wide-range networking of relevant industries and scientific communities and established linkages between on-going research and innovation projects from EU and India. A broad knowledge on the common future plans and priorities at political, industrial and societal level was gained as a result of SAHYOG broad communication strategy.

The project activities were initiated with the elaboration of comprehensive inventories on Biomass and Bio-waste resources and the Research Projects and Programs. The main objective of this activity was to bring together the available databases existing in both regions, leading to a detailed inventory preparation of resources & scientific interventions,

identify common areas of interest, understanding the current bottlenecks and future cooperation opportunities.

The most up-to-date data on biomass production and availability from three major sectors: forestry, agriculture and wastes in Europe and India, was collected and analysed at the state level through an intensive consultation of existing databases and reports in Europe and India. A common feature found was that in both EU and India, a great part of the available biomass from all the three major categories remains unexploited. Under the framework of SAHYOG project plan, the work on the ongoing research on new data was continued throughout the project duration to update the biomass and bio-wastes inventories. The inventory database for both EU and India, was made available at the separate web-site, with proper guidelines (http://www.sahyog-biomass-database.eu). The results of inventories were further used in defining the EU and Indian priorities in biomass utilization and technology implementation.

The second inventory on the European and Indian biobased projects and programs contains a total of about 924 projects in the EU and 280 in India. The Inventory presents an overview of existing programs and research projects in both regions, searchable with respect to all the categories related to biobased research. The overall analyses of the data reveals that the Bio-based Research in the EU covers the complete area and the projects funded by both national and EU contribute to the development of the bio-based economy that could be achieved in good cooperation with other countries, and also in collaboration with India. The categorization of the projects enables the collaboration in specific areas. All projects have been made available at the fully searchable on-line database at the website: http://www.sahyog-projects-database.eu/.

On the basis of this database **the twinning of specific research activities** between research leaders from Europe and India as well as the general EU-India cooperation for the realisation of a sustainable biobased economy, was organised successfully during this period.

Based on the inventories on available biomass and biomass production potential and biobased research projects and the state of the art technology, a road map and a Strategic Research Agenda (SRA) were prepared to help paving the way for a bio-based industry and economy in Europe and India. The SRA was prepared taking into account comments and concerns of the different stakeholders. A number of brainstorm meetings with SAHYOG partners both from EU and India were organized to reach agreements on the contents of the SRA, the basis of SRA and the division of tasks, details of the template etc.

The structure of the SRA consists of three main chapters each describing the strategic research needs in the collaboration between Europe and India in specific domains. The first one is focused on feedstock including wastes and its production (original name biomass production), the second one on biorefineries (or alternatively biomass/waste valorisation and technologies), and the third one on products, markets and policies (but with a focus on the research needs related to these topics).

The first draft of the SAHYOG joint SRA and a RTD roadmap for India and Europe, was discussed at the Stakeholder workshop held on the 6th June 2013 in Copenhagen.

Inaugural session, Bio-economy event, New Delhi, India

The new production oriented value chain focusing on food products, biobased products, and existing non-food-products was presented at this occasion, while keeping into view the main drivers for the biobased economy such as environmental problems, climate change, scarcity of resources, and the decrease in biodiversity. The main recommendations of this meeting were taken into consideration for further development of the SRA, that needed more stakeholder consultations for its completion.

It has been observed that the drivers are certainly different in India with respect to the EU, with food and energy security being the main drivers and no existing policies for the biobased economy in India. As biofuel production from non-food feedstock on marginal land will be one of the main priorities in India, a specific RTD focus shall be placed on sustainable resources from marginal lands (e.g. dedicated perennial crops, grasses).

The final draft of SRA was presented at the Final Conference and Bio-economy event held on 3-4 February 2014 at TERI in New Delhi, India. For this first edition of Bio-economy, the European Commission, Department of Biotechnology, Government of India and SAHYOG decided to combine their forces to deliver an ambitious agenda where more than 150 attendees had the chance to participate. The interactive event was planned to deliberate the various aspects of bio-based economy in EU, Member States and India through the sessions broadly planned in the important areas such as, Transition towards Bio based economy, Industry Academia interaction on Bio-Economy, Strategic Research Agenda, Panel Discussion on Bio-based Economy, Support initiatives, Funding and Financing – Current and new programmes and initiatives both from EU & India, Stakeholder Dialogues and policy perspectives. The discussions and recommendations of the brokerage event were fed into the development of the SAHYOG strategic research agenda and roadmap.

The final meeting of the project was organized **at ENEA Liaison Office, Brussels in November 2014** with the participation of EU-India SAHYOG partners, experts in the field of biobased research and EC representatives. In this meeting the results of the work carried out under various work packages during the three years of the SAHYOG project, were presented. In addition, the possibilities of future EU-India joint-ventures on the Biobased Economy, were discussed with the stakeholders present at this occasion.

Description of the main S&T results/foregrounds

As a first step in this project, the work was focused on the elaboration of inventories to document biomass production and biowaste availability in Europe and India. These were then complemented with the comprehensive inventories of research activities in Europe and India to identify common areas of interest and cooperation opportunities along with the knowledge gaps in various fields related to the biobased economy.

During the first year of the project, the most up-to-date data on biomass production and availability from three major sectors: forestry, agriculture and wastes in Europe and India, was collected and analysed at the state level through an intensive consultation of existing databases and reports in Europe and India. An analysis of the EU and Indian inventories demonstrated similarities as well as differences in the availability and usage of renewable biomass for energy, chemicals and materials. Being an agriculture-based country, India derives most part of its potential biomass from agriculture by-products, which is converted to energy through pyrolysis (57%), gasification (29%) and combustion/anaerobic digestion (14%). In the EU the 76% of biomass potential comes from forestry, while agriculture sector contributes only 13% of biomass. A common feature is that in both EU and India, a great part of the available biomass from all the three major categories remains unexploited. Under the framework of SAHYOG project plan, the work on ongoing research on new data was continued throughout the project duration to update the inventories. The updated Biomass and biowaste resources inventory database for both EU and India, is available at the web-site (http://www.sahyog-biomass-database.eu).

The second inventory on the European and Indian biobased projects and programs provides an overview of about 924 projects in the EU and 280 in India, searchable with respect to the categories Upstream/Downstream/Whole chain, Type of Biomass, Production and pre-treatment, Biomass conversion technology, End Products, Type of research, Organisation type, Drivers, and Sectors. The overall analyses of the data reveals that the Bio-based Research in the EU covers the complete area and the projects funded by both national and EU contribute to the development of the bio-based economy that could be achieved in good cooperation with other countries, and also in collaboration with India. The categorization of the projects, available at the fully searchable on-line database at the website: http://www.sahyog-projects-database.eu/, enables the collaboration in specific areas.

Based on the state of the art technology and the two inventories, a road map and a Strategic Research Agenda (SRA) were prepared to help paving the way for a bio-based industry and economy in Europe and India. The SRA was prepared taking into account comments and concerns of the different stakeholders. The structure of the SRA consists of three main chapters describing each the strategic research needs in the collaboration between Europe and India in specific domains. The first one is focused on feedstock including wastes and its production (biomass production), the second one on biorefineries (or alternatively biomass/waste valorisation and technologies), and the third one on products, markets and policies (but with a focus on the research needs related to these topics).

The SAHYOG SRA was built upon the vision document put forward by the Public Private Partnership on Biobased Industries – BRIDGE 2020 (Biobased and Renewable Industries for Development and Growth in Europe). The vision foresees to the use of renewable resources, bio-waste and side streams as the major input source for materials, food and

feed ingredients, fuels and chemicals, maximizing the added value along the value chains. At the centre of this vision, bio-refineries will gradually replace oil-refineries, by sustainably processing biomass into a spectrum of marketable products and energy.

The three main chapters of the SRA provide the present status and strategic research needs for collaboration between Europe and India in specific domains, focusing on feedstock including biomass and waste production, bio-refineries (or alternatively biomass/waste valorisation and technologies), and on products, markets and policies (but with a focus on the research needs related to these topics). Each chapter deals with the description of the vision relevant to the Chapter, the current status (state of the art & problems & challenges), description of the strategy and the recommendations for R&D.

The roadmap, defining the different implementation steps, was developed at the last phase of the project. The Upstream/Downstream Roadmap compiled the needs and challenges, and the shared vision for the EU and India on the latest developments in the bio-based economy in line with the SRA. Based on several stakeholders meetings, both in Europe and India, research recommendation, considered to be of importance for the EU-India collaboration, were prepared.

Participants at the SAHYOG workshop in Pune, India

The final Strategic Research Agenda and the Roadmap prepared under the SAHYOG project provide a list of recommendations that might be of extreme importance for future concerted actions planning between two regions. Another highlight of these documents is a broad knowledge on the common future plans and priorities at political, industrial and societal level as a result of SAHYOG broad communication strategy.

The current factors constraining the development of the biobased economy in India include an inadequate focus on biomass availability and supply chains, low feed-in tariffs and procurement prices, as well as inadequate appreciation of social and environmental benefits. The current Indian vision on biorefineries, as stated in India's Twelfth Five-Year (2012-2017) Plan, underlines the importance of biorefineries using agro-wastes as source

for the production of energy and biomaterials. Thereby, biorefineries should be capable of sustainably producing a wealth of marketable products and energy.

The program on the wide-range networking of relevant industries and scientific communities and linkages between on-going research and innovation projects from EU and India has been accurately organised in the SAHYOG project. The dissemination activities of the project included project twinning, short-term exchanges of researchers, stakeholder workshops, and summer schools. All these activities are resulted important and are expected to have a significant socio-economic impact in India and Europe.

The first SAHYOG Summer School (S3) took place at the National Technical University Athens, Greece, in June, 2013. The Young Researchers, 25 in total, from India and Europe, were selected to participate. The distinguished experts from 10 countries presented the latest developments in their respective fields. The selection of the candidates for the Summer School ensured gender mainstreaming, with an equality of young – mature participants and balanced geographical distribution. The students evaluated the Summer School very positively, especially the quality of content and lecturers.

The 2nd Summer School was held at Tezpur University, Assam, India, where eighteen speakers from Europe and India gave lectures to the 21 young Indian researchers. The program ended with good feedback from all the participants who reported that it was a significant learning and sharing experience for them.

The Project Twinning Workshop was organized in October 2013 in Utrecht, The Netherlands in conjunction with the SAHYOG project meeting. Through facilitating and coordinating project Twinning, mapping candidate projects from the SAHYOG inventories and based on pre-agreed identified priority subject areas, SAHYOG aimed to bring together project coordinators and other lead partners from past and on-going projects as well as international networks and industry representatives from India and Europe in order to consolidate R&D results, exploit synergies and thus build up a critical mass for future EU-India research collaboration in the Biomass and Biowaste valorisation area.

Another effective element of SAHYOG was to enhance the networking through connecting young talents in Europe and India, an important pillar for a sustainable and long-term cooperation. Therefore focus of the Short Term Exchange Programme (STE) was to create conditions for mutual learning as well as to involve young scientist in the decisions about future EU-India science and technology cooperation (STC). Furthermore the awardees had the chance to present their ideas (e.g. in context of discussion sessions within the hosting institutions) and the possibility to strengthen their networks. To conduct this activity, two joint calls for proposal addressing junior experts are published at the SAHYOG web-site in July 2013 and January 2014. The winners were selected for their outstanding academic records and their innovative and creative ideas.The objective was to strengthen the inter-regional exchange: Indian researchers invited to visit a few European research institutions, while the European researchers went to visit some of the important Indian research organizations.

STE participants at the CSIR-IICT, Hyderabad, India

In the exchange program young talents had the unique opportunity to gain first hand insights of the respective research landscape, make contacts and build new networks. Linkages among the institutes, thematic foci, available infrastructures and current research topics were addressed, thus laying a solid foundation for possible mid- or long-term collaboration. For most of the participants, the STE program was their first chance to visit these countries, thus getting a first impression of the regional customs, culture and research landscape. For the participants being at an early stage in their research career, these first experiences abroad might help them making it easier to get similar chances in the future.

Broad networking of respective scientific communities was done throughout the project via various stakeholder meetings, Summer Schools, Short-term Exchange Programs, planned under the project. During these events the results of the work were with the experts. A database with stakeholders active in the biomass and bio-waste field was developed and it has been continuously updated and extended during the project duration. In Nov. 2014, the database contained more than 4,000 contacts.

As an initial step, a website for the dissemination of project activities and results was created under www.sahyog-europa-india.eu. The website provides an introduction to the SAHYOG objectives and main activities (inventories, project twinning, short-term exchanges, summer schools, stakeholder workshops, SRA and RTD roadmaps). In addition, publications, events, and news related to the field were presented. Furthermore the website also served as a communication platform for project partners.

In order to keep stakeholders updated on SAHYOG project activities and results, a bi-annual SAHYOG newsletter was also produced and sent via email to stakeholder database contacts. The project introduction flyer and the bi-annual project newsletter which can also be downloaded from the website served as the important dissemination tools within the project. In order to ensure dissemination of project results after the end of the project, the SAHYOG website will be maintained and updated for at least 2 years after the project duration.

Potential impact and the main dissemination activities and the exploitation of results

The dissemination activities of the project had been an integral part of all work packages of the SAHYOG work programme. The main objective was to widely communicate and disseminate SAHYOG project activities and results among European and Indian scientists and R&D program managers. The activities included project twinning, short-term exchanges of researchers, stakeholder workshops, and summer schools. All these activities resulted very important in actively promoting knowledge exchange between RTD experts, stakeholders and key actors and are expected to have a significant socio-economic impact in India and Europe.

The SAHYOG results presented and discussed at the various stakeholders meetings organized both in Europe and in India, led to a clear roadmap of activities leading to identifying pathways in promoting technologies and policies that might drive Europe and India to an increased exploration of biotechnology for biomass production and biowaste conversion. It furthermore strengthened EU-India linkages within on-going and future research and innovation projects and contributed to the planning of joint EU-India research initiatives in the field of biomass production and biowaste conversion through biotechnological approaches.

The SAHYOG website for the dissemination of project activities and results created under **www.sahyog-europa-india.eu**, provides an introduction to the SAHYOG objectives and main activities (inventories, project twinning, short-term exchanges, summer schools, stakeholder workshops, SRA and RTD roadmaps).

In addition, publications, events, and news related to the project were also published regularly. The fully searchable online database of two inventories: updated Biomass and biowaste resources inventory and the projects/programs inventory, for both EU and India, was made available at the two separate web-sites (http://www.sahyog-biomass-database.eu and http://www.sahyog-projects-database.eu/, respectively. The information provided in these databases, might be of great use to support the EU-India collaboration in specific areas.

Furthermore, in order to keep stakeholders updated on the project activities and results, a **bi-annual SAHYOG newsletter** was also produced and sent via email to stakeholder database contacts. It is also available to be downloaded at the website. The newsletter issues inform readers about all the activities and events realised in the framework of the SAHYOG project focusing on EU-India research cooperation in the fields of biomass production and bio-waste conversion biotechnologies.

Finally, active dissemination of the recommendations from the SRA and Roadmap was done via press releases and direct communications.

The work conducted under the joint EU-India initiative will assist both the sponsors of this project to have insights on current status on biomass and bio-waste valorisation research and to strategize the research priorities in the important field of Bio-economy.

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