The future landscapes of bioeconomy: Hungary

A Climate-KIC Bioeconomy platform study

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This study was accomplished within the frame of the Climate-KIC Bioeconomy Platform and carried out by the following Hungarian experts:

Zsolt Barta, PhD graduated from Budapest University of Technology and Economics (BME) in 2007 receiving a master degree in bioengineering. Between 2007 and 2010 he took part in the doctoral school program at BME in the field of second generation bioethanol production. During his PhD studies he spent several months at Lund University in Sweden and at CIEMAT Research Centre in Spain, where he performed research on biomass conversion into ethanol and biogas. In 2011 he successfully defended his PhD dissertation, and he received his PhD. Since 2011 he has been employed as assistant lecturer at the Department of Applied Biotechnology and Food Science, BME. Currently he carries out research on biorefining of corn fibre into value added products (xylitol, arabinose) and energy carriers (bioethanol, biogas) with three PhD students. His research group also performs techno-economic evaluations of biomass conversion processes, primarily investigating the biochemical route.

Miklós Gyalai-Korpos, PhD graduated from Budapest University of Technology and Economics (BME) in 2007 with MSc in bioengineering. Between 2007 and 2010 he participated in the doctoral school program of BME working on second generation bioethanol production, then in 2012 he successfully defended his PhD dissertation. During the doctoral school he was involved in education too, giving lectures on bioenergy and supervising undergraduate students. Between 2010 and 2013 he was employed by the Ministry of National Development of Hungary at the department responsible for long term energy policy and international energy relations. He participated in the drafting of the National Energy Strategy approved by the Hungarian Parliament in 2011. These experiences helped him to gain a complex insight into the energy landscape with emphasis on sustainable energy alternatives. In April, 2013 he joined the Climate-KIC Central Hungary team.

András Molnár, PhD is a Research Associate at Research Institute of Agricultural Economics, working in the area of agricultural and rural development policy assessments, recommendation, data analysis. He also works at National FADN Liaison Agency. He has strong competence on the field of sustainability assessment, with particular emphasis on climate change and bioenergy. He has been actively involved in FP6 and FP7 projects on the field of sustainability and sustainable farm management of soils. As a short term expert, he contributed to biomass project feedstock feasibility studies and in various policy assessments related to renewable energy. His PhD thesis analysed the possibilities of a new sustainable assessment method in the agricultural sector. In 2009 he participated in the “Intensive Program in Biorenewables” summer school at Iowa State University, Ames IA, USA with a certificate of excellence.

Gábor Dénes Szabó is an economist graduated from Corvinus University of Budapest (CUB) in 2009 with MSc in economics, specialized in Environmental Management and Rural Development. During the last year of his MSc in 2008, he started to work for a rural development advisory firm as economic analyst dealing with financial calculations of development plans. In 2009-2010 he worked at an agricultural research institute in Germany where he prepared cost-benefit analyses for *Miscanthus* production. He started his PhD studies in 2011 at CUB with a research topic of „bioenergy from the aspects of rural development” focusing mainly on economic aspects of bioenergy supply chains and second generation biorefineries. During his PhD studies he has collaborated as a research fellow with WWF Hungary, Aston University and Imperial College London.

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[1] 3R Zero Emission Pyrolysis processing & carbon refinery, http://www.3ragrocarbon.com

1 Introduction

This study intends to deliver an insight into the emerging field of bioeconomy with emphasis on the opportunities in Hungary by means of assessing natural endowments, key stakeholders and R&D infrastructure from the perspective of relevant Climate-KIC projects. The main European and global drivers as well as the basic technological knowledge are presented also here. This information underpins the importance of the topic and helps to understand win-win scenarios the bioeconomy can offer in Hungary. The study is based on the assumption that a knowledge-based and coordinated approach is required to catch the unfolding global bioeconomy wave. The authors believe that this study facilitates the uptake of Hungarian bioeconomy scheme on the full supply chain basis, possibly under the umbrella of Climate-KIC.

Disclaimer

The authors gathered most of the information through personal contacts and publicly available sources listed in the references chapter; hence some deviations from actual situation can arise. The authors do not claim to cover the given topic completely in the study.

In order to avoid misinformation the authors welcome any actual information from stakeholders and update the study accordingly.

2 General overview

The term bioeconomy originates from the recognition that today's fossil energy, mostly oil and coal based, society and economy should and can be put on biomass basis when considering the materials surrounding us. Many drivers, as detailed in the following chapters, have been identified to move forward to this vision.

The essence of the bioeconomy as extracted from policy papers

"*The bioeconomy […] encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy. Its sectors and industries have strong innovation potential due to their use of a wide range of sciences, enabling and industrial technologies, along with local and tacit knowledge.*"

(European Commission: Innovating for Sustainable Growth: A Bioeconomy for Europe, 2012)

"A bioeconomy involves three elements: biotechnological knowledge, renewable biomass, and integration across applications."

(OECD: The Bioeconomy to 2030: Designing a policy agenda, 2009)

"The bioeconomy has emerged as an Obama Administration priority because of its tremendous potential for growth as well as the many other societal benefits it offers. It can allow Americans to live longer, healthier lives, reduce our dependence on oil, address key environmental challenges, transform manufacturing processes, and increase the productivity and scope of the agricultural sector while growing new jobs and industries."

(The White House: National Bioeconomy Blueprint, 2012)

"The concept of the bioeconomy covers the agricultural economy and all manufacturing sectors and associated service areas that develop, produce, process, handle, or utilise any form of biological resources, such as plants, animals, and microorganisms. This spans numerous sectors, such as agriculture, forestry, horticulture, fisheries and aquaculture, plant and animal breeding, the food and beverage industries, as well as the wood, paper, leather, textile, chemicals and pharmaceutical industries, and aspects of the energy sector. Biobased innovations also provide growth impetus for other traditional sectors, such as in the commodity and food trade, the IT sector, machinery and plant engineering, the automotive industry, environmental technology, construction, and many service industries."

(Federal Ministry of Education and Research, Germany: National Research Strategy BioEconomy 2030, Our Route towards a biobased economy, 2011)

As the above examples present the vision for bioeconomy became high on policy agendas due to its diversified positive impacts among the economy and society. Basically, there are two basic fields of which developments and further R&D&I are necessary to the transition:

agriculture and biotechnology. There is growing pressure on agriculture that, besides delivering food and feed, in a complex and sustainable approach it should make by-products also marketable. Biotechnology, especially white biotechnology dealing with industrial conversion processes, is inevitable to turn biomass feedstock into a range of value added products.

2.1 The drivers of the bio based economy

Companies and consumers are constantly influenced by the changes in their environment in order to push them towards new, innovative solutions. The most important but not the most effective one is the status of the natural environment and the way it should evolve to sustain a healthy and liveable surrounding for the future generations. Of course, the most effective driver is the economic viability of the solution that – in several cases – also incorporates and internalizes externalities (such as carbon pricing). The management of externalities often depends on policies and governmental actions, as being the third driver.

All drivers come from the use of fossil fuel based materials (not only fuels) that has already been and will be leading to growing dependency and exposure to conditions set by suppliers, as well as having serious climate change consequences by emitting excess greenhouse gases (GHG) that may risk the operation of the ecosystem required for human living. Alternative processes – besides eliminating these concerns – can be a cradle of innovations and new start-ups building on local attributes by means of natural and human resources too. In return, multiplicative effects will also associate, such as economic growth, job creation and parallel development of connecting sectors.

2.1.1 Environmental and climatic drivers

The environmental quality of Earth means the framework for global economies and human living. Hence, the climate concern should be a shared responsibility for all: both by promoting innovation and alternatives but also by accounting externalities. Use of fossil fuels that represent "historical biomass" locked-in to geological formations, leads to surplus emission extracted from the atmosphere million years ago. As opposite, in case biomass is delivered in a sustainable manner into a biorefinery process the CO_2 cycle can be closed. Furthermore, depending on the life span of the product carbon could be even sequestered from the atmosphere for the longevity of the product use. Several experiences have shown more favourable GHG performance of biobased materials on a life cycle basis.

Another critical environmental concern related to the use of fossil based products is the question of waste management and recycling. These materials are very resistant to biological decomposition, thus discarded plastic packaging remains for long time in the nature. For instance, streams in oceans collect large amount of plastics into floating island leading to serious consequences on ocean life but also delivering a "grim sight". The utilization of biodegradable products of biomass origin can overcome this problem but of course without reducing the importance of waste management.

Fortunately, these issues above tend to be integrated into companies and consumers decision as shown by an ICIS survey[2]. The survey monitored the energy and environmental consciousness of sustainable chemical companies and the demand for sustainable product lines. Most important finding of the study is that more and more companies have the opinion

[2] http://www.icis.com/Assets/GetAsset.aspx?ItemId=793617

that investing in sustainability, in green chemistry and in renewables based processes is not a “waste of money” but real opportunity requesting business and operational decisions. Moreover, there is a clear trend that companies see sustainability as cost effective measure via improved raw materials and optimized processing. Practically, according to the survey, these measures include energy efficiency actions, improved waste management, elimination of toxic compounds and involvement of bio-based contents. The reason for this change is two-sided. On one hand using the innovation potential and knowledge required they realized the chance to become pioneers of a new, emerging field that holds the key for the future benefits. On the other hand consumers are also getting interested in the product life cycle, carbon footprint and environmental impact and in turn – with growing consciousness – they expect sustainable processes and products.

Additionally, chemical processing routes, such as the ones used in present refining and chemical industries, usually apply high temperature and pressure, use toxic solvents and expensive/non-regenerative catalysts resulting in elevated need for external energy, waste management practices and enhanced environmental load. Furthermore, specific end products, for example different isomers, are hard to obtain. Contrarily to chemical ways, microbial and enzymatic routes can operate under mild conditions in water-based solvents generating biodegradable products and by-products, and using the proper enzymes specific reactions can be performed with high yields. This way industrial biotechnology can represent a more sustainable option with decreasing GHG emissions (and closing carbon cycle), waste streams (and using waste streams) and energy consumption (and meeting its own energy needs as part of the process). Nevertheless, product yield and recovery (downstream processing) are the two main aspects of bioconversion to be improved in order to achieve economic viability.

The demand to reduce human and environmental impact during the production and use of chemicals means also a driver for the so called ‘green chemistry’. According to the definition of Clark et al. (2012) “green or sustainable chemistry is the design, development, and implementation of chemical products and processes that reduce or eliminate the use and generation of substances hazardous to human health and the environment”. The principles of green chemistry, such as less hazardous chemical syntheses, use of renewable feedstocks and design for degradation, prefer biobased materials as substitutes of chemicals considered harmful. The further changes of REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) and RoHS (Restriction of Hazardous Substances) predict that other chemicals will also be affected. REACH made it clear that the discovery, development, and application of greener substitutes for many important chemicals will be necessary.

2.1.2 Economic drivers

Nowadays the chemical industry and refinery sector mostly utilize fossil fuels, mainly crude oil. However, with the rising cost, price volatility and import dependence the economic pressure because of the reliance on oil is increasing. While this may create opportunities to switch to biomass based processes, one must take into account that raw materials for plastics and chemicals are side streams (fractions) of oil refining with the main output of various fuels. This means that there is a strong supply side pressure on the chemical industries in order to ensure the market for side products of refining. For a start, fossil-fuel subsidies (which global cost was estimated to $775 billion in 2012 and dwarf subsidies to renewable energy) need to be phased out to level the energy playing field and drive innovation[3].

Business opportunities encapsulated in innovations can be the real economic driver in the future, since it creates added value both in processes and products. Undoubtedly, switching in the supply side necessities R&D and innovation – the early movers can make their future top position.

Nevertheless, financing considerations prefer the investigation of integration possibilities into current or proposed factories (side stream optimization) rather than starting from scratch. For instance, the biofuel market is kept alive only through policies and subsidies that are – as recently shown in the European policy area – vulnerable foundations and do not necessary motivate market entrance or expansion. The future of biofuel applications is also limited by most vehicle engines in place in terms of having a maximum blend ratio. From a technological point of view, side and/or main products of first and second generation ethanol production can be processed further resulting in value added compounds. Consequently, a biorefinery concept can guarantee an additional revenue stream for biofuel plants and thus making steps forward market based operation.

Furthermore, bioeconomy contributes to the rural development through its processes using mostly local agricultural and/or forestry resources. The products are made in the rural region and they have high added value in the field of agriculture. Hence, similarly to biofuel factories, these products can provide a higher profit rate from which the farmers' proportion can increase as well by valorising the often unused by-products. Through a higher income rate they can realize more investments contributing directly to rural development. From this aspect it is advisable to manage bioeconomy as a main part of the multifunctional agriculture that provides new distribution channels and new added income opportunities for rural people.

2.1.3 Policy drivers in the EU & the USA

There are two main groups for policy drivers: i) the push side measures that aim to create the biorefinery industry itself by promoting R&D, innovation and investments and ii) the pull side measures destined to establish a market for biobased products. Examples regarding the application of these measures on penetration of bio-based products are delivered in Table 1.

Table 1. – Summary of policy measures to support the penetration of biobased materials, partially adapted from Hermann et al., 2011

Push side measures	Pull side measures
▪ R&D policies and focused grants ▪ dedicated subsidy measures (e.g. CAP Pillar II.) ▪ innovation friendly taxing system	▪ bio-based/green public procurement ▪ mandates/target for bio-based plastics ▪ plastic carrier bag ban ▪ subsidies for market introduction ▪ deposit system and packaging taxation (single use vs. biobased) ▪ carbon market measures (such as ETS) ▪ labeling and campaigns

[3] http://insights.wri.org/news/2013/02/how-can-we-pay-green-growth-new-report-provides-answers

Besides the concrete measures bioeconomy and green growth are high on policy agendas both in the EU and the USA.

The European Commission published the communication "**Innovating for Sustainable Growth: A Bioeconomy for Europe"** in 2012. Realizing the impact of bioeconomy on tackling societal challenges and at the same time enabling sustainable growth, the communication calls for the following actions in the framework of the Bioeconomy Action Plan: investments in research, innovation and skills (Knowledge and Innovation Communities – KICs are explicitly mentioned in the communication); reinforced policy interaction and stakeholder engagement for a coherent policy framework; and enhancement of markets and competitiveness in bioeconomy (knowledge based information flow, logistics, demonstration, standards). Bioeconomy will also contribute to the Commission's Europe 2020 goals on moving to a low-carbon economy by 2050 and to the flagship initiatives "Innovation Union" and "A Resource Efficient Europe".

The USA also has the strategic plan for bioeconomy published in 2012 and called "**The National Bioeconomy Blueprint"**. It defines five strategic objectives: support R&D investments by coordinated and integrated efforts; facilitate the transition from research to market by discovery, innovation and commercialization focused ecosystem; develop and reform regulations to reduce barriers in order to increase speed and predictability; update training programs and align academic institutions incentives with student training to develop bioeconomy workforce; identify and support opportunities for the development of public-private partnerships and precompetitive collaborations in order to pool resources, knowledge and expertise.

Taking into account the complexity of bioeconomy several other policies can facilitate its take-off. Hereby, a short overview is given on significant policies affecting the bioeconomy on European level:

- **R&D policy and grants:** in line with the Bioeconomy communication, research funding for bioeconomy under Horizon 2020 will increase, combined with stronger innovation drive and reinforced policy interaction. Bioeconomy-related research is part both of the 'Societal challenges' and the 'Industrial leadership' by having biotechnology as a key enabling technology. This way, it is estimated to generate an added value of about €45 billion and create new jobs in bioeconomy sectors by 2025. According to the Commission every euro invested in bioeconomy research and innovation under Horizon 2020 will generate about €10 in added value. The Commission also encourages other R&D funding schemes such as Era-Net programs and European Institute of Innovation and Technology (EIT) KIC instruments to contribute to bioeconomy. The Common Agricultural Policy (CAP) can enable rural areas to benefit from renewable energy technologies, including advanced biofuels in particular by facilitating the supply of wastes, residues and non-food raw materials.
- **Carbon markets and its income allocation**: NER300 is funded from the sale of 300 million emission allowances from the New Entrants Reserve (NER – hence the name) set up for the third phase of the EU Emissions Trading System (ETS). The aim of NER300 is to establish a demonstration programme comprising the best possible Carbon Capture and Storage (CCS) and Renewable Energy Sources (RES) projects and involving all Member States. The programme intends to support a wide range of CCS and RES technologies including bioenergy, concentrated solar power, photovoltaic, geothermal, wind, ocean, hydropower and smart grids. The winners of

the first call were published at the end of 2012. Among the winners there are 5 advanced biofuel projects and 3 bioenergy projects. Noteworthy, one of the projects, “Woodspirit” aiming to demonstrate the production of bio-methanol in large commercial scale using biomass torrefaction and entrained flow gasification as the new core technologies, received the largest amount of funding among all NER300 winners.

- **Industrial policy**: the European Commission published an industrial policy communication update in 2012 with the title of “A Stronger European Industry for Growth and Economic Recovery”. In this document six priority action lines were identified, one of them highlights markets for bio-based products. The Commission suggests that Member States must take them into account in their industrial policies (i.e. priorities, such as bio-based products, plastics), as well as in their strategies for social cohesion and economic development of their regions. The reason for this priority is that the volume growth of EU bio-based chemical products up to 2020, including bio-plastics, bio-lubricants, bio-solvents, bio-surfactants and chemical feedstock, is estimated at 5.3% p.a., resulting in a market worth € 40 billion and providing over 90,000 jobs within the biochemical industry alone.
- **Waste management, the end of waste criteria**: A number of EU legal instruments address the issue of treatment of bio-waste. General waste management requirements, such as environmental and human health protection during waste treatment and priority for waste recycling, are laid down in the revised Waste Framework Directive (2008/98/EC). It also contains specific bio-waste related elements (new recycling targets for household waste, which can include bio-waste) and a mechanism allowing setting quality criteria for compost (end-of-waste criteria, EoW). The revised directive introduces the possibility that certain waste streams that have undergone a recovery operation can cease to be waste if they fulfil the EoW criteria. The fulfilment of EoW criteria ensures that the quality of the material is such that its use is not detrimental to human health or to the environment. In view of a possible biorefinery processing waste it means that the facility needs to fulfil these criteria to be able to sell certain outputs as products.
- **Energy**: based on the assessment of the national renewable action plans, the importance of sustainable bioenergy cannot be questioned, since 56.7% of the 20% of the 2020 renewables share will arise from biomass. Hence, sustainability and biomass potential estimations are getting more and more attention. Recently, the European Commission, referring to the indirect land use change, has proposed to cap the share of first generation biofuels in 5% in favour of advanced biofuels and electric transport by providing multiple counting. (Although the aims of the proposal are clear and it targets sustainability, the industry claims that the investments got in danger.)
- **Agriculture**: as the production of biomass for advanced purposes necessarily correlates with agriculture and forestry as being key providers, the Common Agricultural Policy (CAP) after 2013 addresses the issue of biomass sourcing. Bioeconomy is an opportunity to increase the employment and use agricultural products locally as well. Therefore, the EU agricultural policy should facilitate the supply of waste, residues and non-food raw materials for the purposes of bioeconomy. The CAP recognizes that biomass use contributes to EU objectives on renewable energy, bioeconomy and decarbonisation, as well as rural economies

benefit from sustainable biomass utilization. The future CAP has six priority areas around the "Innovation, environment and climate change" issue, and one of these is "Resource efficiency, low carbon and climate resilient agriculture" covering the area of renewable energy sources. In order to enhance the utilization of by-products there is no direct support for production foreseen. Measures include support for investments & infrastructure, training and innovation in the framework of the European Innovation Partnership for Agricultural Production and Sustainability.

2.2 Supply side – sustainable biomass sources

There are plenty of biomass resources with specific characteristics and suitability as a sustainable feedstock for energy utilization. Therefore, it is necessary to assess their properties and availability, acknowledging the fact that their importance might vary depending on the ecological circumstances. Moreover, along with the biomass supply chain, there are conflicting interests and effects e.g. food supply, natural conservation that can limit feedstock availability. This report does not cover the possible utilization of grain (starchy feedstock) and oilseeds as biorefinery inputs since their sustainability in biofuel industries has been critically debated. In addition, their competing uses can lead to a serious supply side pressure.

Nevertheless, there is significant potential to expand biomass use by tapping the large volumes of the yet unused residues and wastes. The use of conventional crops for energy use can also be expanded, with careful consideration of land availability and food demand. Lignocellulosic crops (both herbaceous and woody) produced on marginal, degraded and surplus agricultural lands and aquatic biomass (algae) could also make a significant contribution.

According to the PRIMES energy model (a simulation model of the energy markets) used for energy forecasting the EU policy development, the primary production of biomass can be classified into five categories, namely energy crops, agricultural residues, forestry, aquatic biomass and wastes (Table 2). Depending on the type of the plants that are cultivated, energy crops are further distinguished into hay, sugar, oil and wood crops.

Table 2. – Types of primary biomass production

Energy crops	Agricultural residues	Forestry	Aquatic biomass	Waste
Hay crops Sugar crops Wood crops Oil crops	Hay residues Sugar residues Wood residues Oil residues	Wood platform Wood residues	Algae	Industrial solid Industrial bagasse Industrial pulp Used vegetable oil Municipal solid Sewage sludge Landfill gas Organic manure Animal platform

This classification is dictated by the differentiation of methods that each plant type may be processed with and the final outputs that derive from them. The same applies for agricultural residues. Forestry is split into wood platform, i.e. organized and controlled cutting of whole trees for energy use, and wood residues, i.e. the collecting of forestry residues only. Five types of waste were also identified. These are industrial solid, industrial wet, pulp and bagasse, used vegetable oil, municipal solid waste, sewage sludge, landfill gas, organic manure and animal wastes. This classification was based both on further processing differentiation and data availability. Through different conversion processes, three types of final commodities are produced: solid (solid biomass for direct combustion, pellets, charcoal, mass burn wastes, refuse-derived fuel); liquid (bio-ethanol, biodiesel, heavy bio-oil, bio-kerosene); gaseous (biogas, bio methane, bio-hydrogen).

Further classification of these main feedstock groups is also possible by providing examples relevant for Europe of raw materials:

- Energy crops:
    - wood crops: poplar, willow
    - hay crops: miscanthus, switchgrass, reed canary grass, different types of reed
    - sugar crops: sweet sorghum
- Agricultural residues:
    - hay residues: straws (wheat, oat, rice, rye, barley), corn stover and cob
- Forestry:
    - residues: bark, wood chips, logs
- Industrial organic wastes (solid and liquid):
    - wood industry: from sawmills and timber mills, pulp and paper side streams
    - food industry: dairy by-products, fruit and vegetable processing, vegetable oil production, slaughter house waste

Even though various estimations are available about the potential of bioenergy, there is a quite strong consensus that agricultural residues hold an enormous unused potential by means of volume and energy content (despite the different methodologies, boundaries, input data and frameworks resulting in relatively large deviation). Municipal solid waste (MSW) is also available in large amount in landfills, but not in homogenous composition and with toxic compounds. Given the hierarchy of waste management and the main focus on prevention and recycling, the potential of MSW will not be detailed further here. The organic waste generated on site with homogenous composition as derived from a certain process is also subject of further utilization. This way the factory can turn its by-product to value added product and improving its material and energy input-output ratio, as well as financial balance.

In order to provide an insight into the possible amount of agricultural residues available, a recent study of the Joint Research Centre of the European Union is used. Monforti et al. (2013) carried out the geographical assessment of potential bioenergy production in the EU-27 from residues available from eight crops (wheat, barley, rye, oat, maize, rice, rapeseed and sunflower). The method applied considers competitive uses and environmental constraints by retaining a minimum ratio of residues in soils. As a result it was found that on average (EU-27) 42% of produced residues could be sustainably collectable (Figure 1). There are also geographical differences in Europe, the most residues sustainably collectable was found for Hungary (46%) followed by Italy, France, Germany, Austria and Poland. Considering the competitive uses after collection (as ratio of the collected amount) an EU-27 average of 83% would be left as available amount (in case of Hungary it was found to be 96% also ranked as the highest).

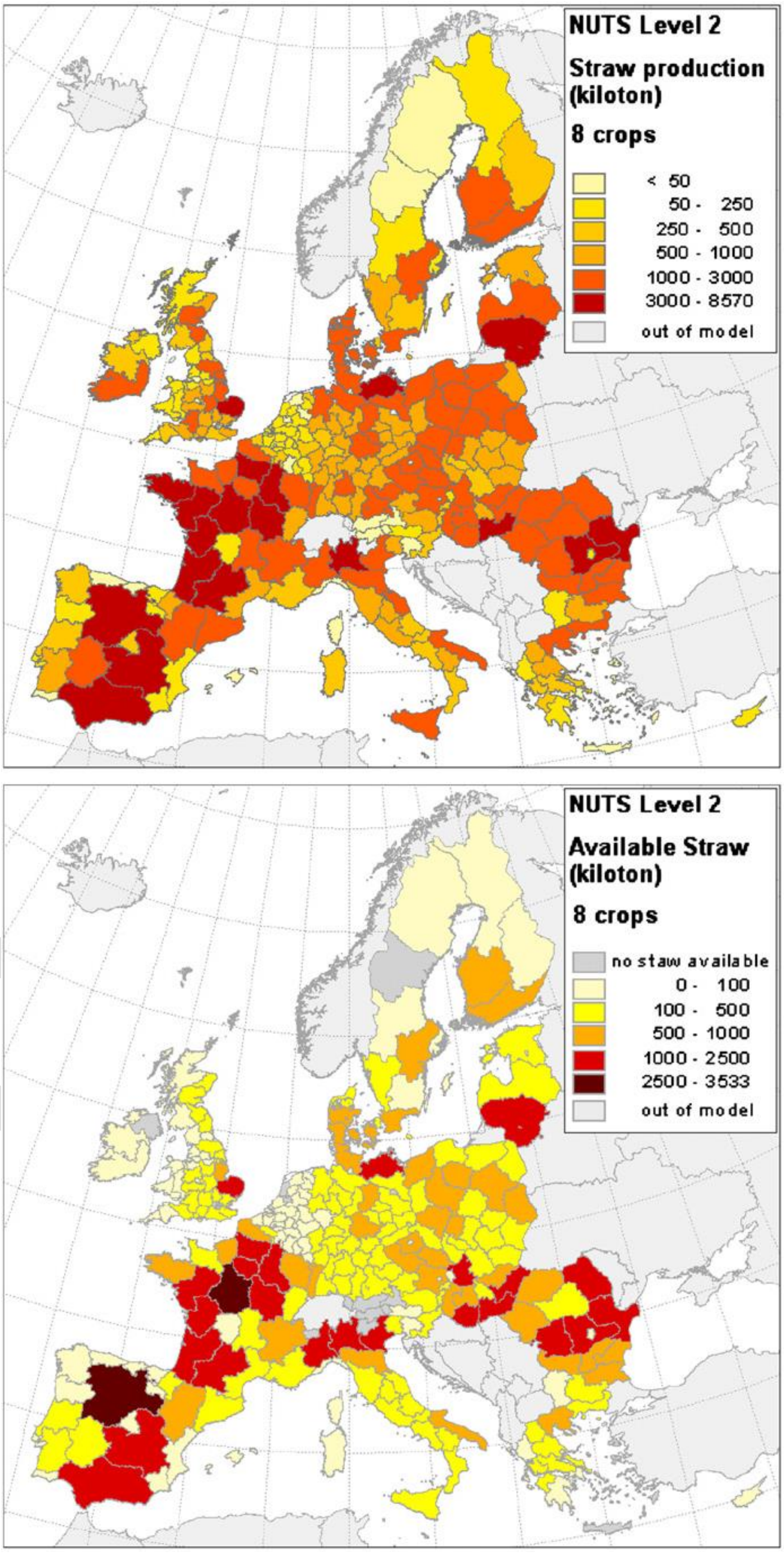

Figure 1. – Estimated amounts of produced (top) and available (bottom) agricultural crop residues in EU-27 NUTS2regions, Monforti et al., 2013

There have been many attempts defining and operationalizing sustainability of biomass based energy utilization with limited success. Often, sustainability is oversimplified to an environmental issue, however the social and the economic pillars play just as important role overall. Food, fibre and bioenergy crops can be grown in integrated production systems, mitigating displacement effects and improving the productive use of land. Lignocellulosic feedstocks for bioenergy can decrease the pressure on prime cropping land. The targeting of marginal and degraded lands can mitigate land use change associated with bioenergy expansion and also enhance carbon sequestration in soils and biomass. Stimulation of increased productivity in all forms of land use reduces the land use change pressure.

Attention should be paid on the assumption taken in order to fulfil sustainability or regarding the production system in general. For instance Simon and Wiegmann (2009) assume that all agricultural area not in use for food production is available for biomass production. With yields growing and food demand stagnating in Europe, available area will increase in the future. Moreover, the issues considered are almost always limited, e.g. Simon and Wiegmann (2009) describe the scenarios being considered along the followings: extent of organic/extensive agriculture; land use for building and infrastructure; additional area for nature conservation; land use restrictions; residue use; grain self-sufficiency; sugar self-sufficiency.

Another often used approach is the maximum sustainable amount of energy potentially available from agricultural and forestry residues by converting crop production statistics into associated residue, while allocating some of this resource to remain on the field to mitigate erosion and maintain soil nutrients.

2.3 The conversion – routes and platform products

The basis of the main conversion routes is introduced here with focus on bottlenecks, current status and barriers to overcome by means of technology and economics. Lignocellulose based processes are highlighted.

In general, conversion processes can be classified into two main groups:

- **Feedstock dependent routes:** the properties and composition of the feedstock are considered in this approach. This makes possible the valorisation of minor components in the feedstock and the extraction of compounds in their natural form for further processing. Consequently, specific and directed microbiological, enzymatic and chemical catalytic processes can be applied resulting in a wide range of product derivates. In order to exploit this approach a certain type of bulk feedstock with homogeneous composition must be available in large amount. For example, agricultural residues (such as corn stover and wheat straw) can be used in advanced (second generation) processes. Other raw materials, such as algae and glycol (by-product of biodiesel production) can be processed specifically.
- **Feedstock independent routes**: regardless the composition, the substrate is processed into an intermediate that is further utilized. One example for this approach is the thermochemical route with severe conditions resulting in 3 phase (solid, liquid, gas) components to be utilized further. The ratio of these phases can be controlled with the process parameters. The most sought and investigated products are syngas (a mixture of carbon monoxide and hydrogen usually further subjected to Fischer-Tropsch synthesis) and biochar (used to sequester carbon in soils with improving the

soil texture and water management). On the other hand, a spontaneous, naturally occurring biological process, the anaerobic digestion resulting in biogas (a mixture of carbon dioxide and methane) formation can also be classified into this category. All of these process options can be fed with non-selected and non-typified wastes (such as the organic fraction or the whole municipal solid waste), waste waters and sludges, as well as industrial by-products and waste streams. Consequently, with the application of these technologies not only the biorefinery side but the waste management options should rather be considered and exploited.

2.3.1 Feedstock dependent routes

Second generation ethanol production/lignocellulose based biorefinery

The real potential of second generation/advanced biomass processing technologies is that a wide range of abundant raw materials can be used from dedicated energy plants to agricultural residues. Lignocellulose is composed of three polymers, namely cellulose, hemicellulose and lignin. The ratio of these components varies from species to species, and even with age of the plant as cell wall types change. In general, cellulose fraction is the most dominant constituent of the cell wall, which makes up 40-51% of the dry weight, hemicelluloses represent 28-37% followed by lignin with 13-28%; however, in some cases hemicelluloses can even account up to 50% of the cell wall.

Hemicellulose and cellulose are carbohydrate polymers and thus possible subjects of ethanol or other fermentative processes. Cellulose is a linear chain homopolymer of glucose with β-1,4 bonds where alternating glucose residues are in an inverted orientation. One must note that cellulose shares compositional similarity with starch: both are composed of glucose molecules the difference is only the type of chemical bonds between the monomers. Hence, the product spectrum that a starch based biorefinery can deliver also can be produced on lignocellulose basis with the additional flexibility arising from other compounds, such as hemicellulose and lignin. Hemicellulose is not a chemically well-defined compound but rather a family of polysaccharides with highly branched structures. Hemicellulose may contain pentoses (β-D-xylose, α-L-arabinose), hexoses (β-D-mannose, β-D-glucose, α-D-galactose, α-L-rhamnose, α-L-fucose), and uronic acids (α-D-glucuronic, α-D-4-O-methylgalacturonic and α-D-galacturonic acids). Lignin is a complex, non-sugar polymer coating the other two polymers of cell wall and thus delivering recalcitrance towards microbiological attacks. The main building blocks of lignin are three different phenolic monomers (p-coumaryl alcohol, coniferyl alcohol and sinapyl alcohol) that can form a wide variety of bonds such as β-aryl ethers, phenylcoumarans, resinols, biphenyls and biphenyl ethers.

This composition of the lignocellulose residues, such as agricultural and forestry by-products delivers a wide range of valuable compounds to be extracted by chemical means or by microbial conversion. Nevertheless, this chemical complexity of lignocellulose creates also barriers in the exploration and isolation of certain compounds. Pretreatment is necessary to disrupt the resistant lignocellulose matrix. The main aim of pretreatment is to make the cellulose surface accessible for cellulase enzymes by means of removing lignin coating and loosening cellulose fibrils. In turn, enzymes in subsequent hydrolysis liberate monomeric C5/C6 sugars, mostly glucose, further subjected to fermentation usually by baker's yeast in case of ethanol production. During the time the cost of cellulases has been decreased considerably, but still it is one of the barriers of industrial-scale spread of the technology.

The key step in lignocellulose based biotechnological processes is the pretreatment that liberates accessible and usable carbohydrate derivates for enzymes and microbes. As a result of constant development of pretreatment techniques, many biological, chemical, physical and mixed methods have been identified and further developed; some of them have reached the maturity to be applied in pilot plants (for example steam explosion).

Although ethanol production has been the driver for technology development, there are further options for fermentation based on C5/C6 sugars mixture liberated in hydrolysis of pretreated material:

- acetone-butanol-ethanol (ABE) mixed fermentation,
- hydrogen production,
- xylitol production,
- lactic acid production,
- succinic acid fermentation,
- other specific, high value compounds.

After utilizing the carbohydrate fraction by fermentation, the residue is usually considered as the remaining lignin. Lignin, by its native structure can be a good source for various chemicals (Figure 2); however, due to the difficulties of the depolymerisation process and the contaminations this use is limited. With processes considering the quality and purity of the lignin, as well as introduction of new extraction technologies, derived products can significantly contribute to the economy of the biorefinery.

Lignin

Syngas products	Hydrocarbons	Phenols	Oxidized products	Macromolecules
Methanol DME Ethanol Mixed alcohols Fischer-Tropsch liquids C1-C7 gasses	Benzene Toluene Xylene Cyclohexane Styrenes Biphenyls	Phenol Substituted phenols Catechols Cresols Resorcinols Eugenol Syringols Coniferols Guaiacols	Vanilin Vanilic acid DMSO Aromatic acids Aliphatic acids Syringaldehyde Aldehydes Quinones Cyclohexanol β-keto adipate	Carbon fibre fillers Polymer extenders Substituted lignins Thermoset resins Composites Adhesives Binders Preservatives Pharmaceuticals Polyols

Figure 2. – Potential chemicals originated from lignin, from de Jong et al., 2012

Given the complexity of the process there are many side streams arising from the separation of fractions and components. Often the utilization of certain side streams may be difficult due to various reasons but in order to extract the valuable compounds it may be worth depending on market conditions. Side streams that cannot be valorised can be digested to biogas or burned directly (depending on moisture content) in order to fuel the process.

Main feedstock types	agricultural, forestry residues
Technology bottlenecks	pretreatment, enzyme, product specific downstream processes
Sustainability bottleneck	supply side: maintaining soil carbon stock, long distance shipping of raw materials
Main products:	C5/C6 sugars and their derivatives (ethanol, other fermentation products)

Opportunities in the pulp and paper industry

A special case for the previous technology option is to integrate biorefinery – with its many process alternatives – into existing pulp and paper mills. These are recovering more of the biomass left in the forest, by removing lignin from the black liquor in the digester, pyrolysis of bark, etc. Before mills can implement the "forest biorefinery" (FBR), there are challenges: to increase its energy efficiency, to eliminate fossil fuels from their operations, and to maximize carbon availability for the FBR. This appears to be a valid point since many of the activities today regarding the FBR are motivated by the Kyoto Protocol.

The biorefinery technologies currently under development are typically characterized as biochemical and thermochemical processes. Biochemical processes use steam, dilute acid, concentrated acid, and/or enzymatic hydrolysis to convert the hemicellulose and cellulose of biomass into simpler pentose and glucose molecules. The thermochemical processes use slow / medium temperature gasification or higher temperature pyrolysis to create a high hydrogen content synthetic gas (syngas) that can be used for electricity generation or catalytically converted into liquid biofuels. The technologies of hemicellulose pre-extraction, lignin precipitation, tall oil extraction are biochemical, while black liquor gasification is thermochemical. The choice of biorefinery technology will depend firstly on the choice of appropriate products as they relate to markets and the supply chain. Depending on the choice of technologies implemented, the yield, the impact on the pulp and paper process and the capital cost will vary. Since the processes in a pulp and paper mill are strongly linked, it is difficult to foresee what impact of implementing these different technologies might have on the entire mill. Plus, adding two or more technologies to one mill bring process issues that are too complex to anticipate. One of the key criteria for FBR options is that the processes are adaptable. The concept of adaptable FBR makes the mill less economically vulnerable, since the products can be changed over time considering their value cycle.

Main feedstock types	Forestry feedstock
Technology bottlenecks	C5 fermentation, gasification
Sustainability bottleneck	a key component of the FBR concept is sustainable forestry practices
Main products	ethanol, itaconic acid, carbon fibres, tall oil, methanol, etc.

Opportunities in the biodiesel industry – vision of the glycerol biorefinery

Glycerol is a platform chemical with a wide variety of uses in different industries. The demand for pure glycerol traditionally arises from the food, pharmaceuticals, cosmetics, plastics and tobacco processing. However, with the exponential increase of biodiesel production volumes the amount of glycerol available, as it is the by-product of biodiesel production, has been also growing steadily. This has led to an excess amount in the global market, since 1 litre of crude glycerol is obtained for every 10 litre of biodiesel produced. This, however, contains impurities resulting from the processing technology of the vegetable oil to biodiesel, such as methanol, salts, soaps and water. In order to sell this glycerol for traditional uses and markets, it must be purified to meet compatibility and standards. Another option is to use this glycerol as input into further processing, possibly on-site of the biodiesel factory. Basically, there are two ways to realize this approach: the microbiological and the chemical routes. Careful assessing of options needs to be carried out to use glycerol as input material depending on the market demand, technologies and environmental regulations for disposal.

Many microorganisms (including bacteria and fungi) have been tested for utilizing crude glycerol to a wide spectrum of products. However, according to the authors best knowledge, none of the investigated routes have made out of the laboratory to pilot scale. With having said that, there are numerous options for processing, without a possible winner for up-scaling yet. The most studied route of biotechnological valorisation is the conversion of glycerol to 1,3-propanediol (1,3-PDO), followed by 2,3-butanediol (BDO) and butanol. Nevertheless, usually the main fermentation product is the 1,3-PDO, thus the others are available in minor amounts. In total, recently fourteen compounds including the above mentioned ones, different acids and polyols, have been produced at lab scale by microbial fermentation from glycerol. Near all of these chemicals can be used to produce different plastics and thus to replace some fossil fuel based materials. A more common way for biotechnological utilization is the biogas and/or biohydrogen production from crude glycerol. The co-digestion of glycerol with other substrates could improve biogas yield and utilize waste glycerol.

Besides microbial conversion, glycerol also can be a platform chemical based on chemical catalytic reactions leading to a wide range of different functional chemicals. Main chemical reaction steps include selective oxidation, etherification, hydrogenolysis, syngas reforming and dehydration. Glycerol carbonate (membranes, biolubricant and solvent) and epichlorohydrin (epoxy resins) can also be obtained by chemical reactions.

Even though there is a definitive oversupply of glycerol currently, the survival of first generation biodiesel factories still remain a political and subsidy issue. The fact that current biodiesel factories mostly process feedstocks (rapeseed, sunflower, soybean and palm oil) in focus of lively debates on food competition, land use change and real climate impact can lead to policies imposing limits on the uses of such raw materials. Nevertheless, with increasing supply side volumes the price of glycerol has declined, therefore instead of purification, the further processing of glycerol to value added chemicals can create a more realistic business case option for the biodiesel industry based on sustainable feedstocks.

Main feedstock types	by-product of biodiesel production
Technology bottlenecks	purification need, no established technology option, no pilot scale operation, further engineering of microbes is needed
Sustainability bottleneck	no, it could help to alleviate a by-product stream
Main products	many chemicals – no upscale yet

Algae-based solutions

Most microalgae are unicellular photosynthetic microorganisms that can fix the dissolved inorganic carbon and CO_2 in the gaseous effluents through photosynthesis and this way produce biomass. Moreover, the majority of microalgae have much higher cell growth and CO_2 fixation rate (around 10–50 times higher) than terrestrial plants. Production of microalgae can be integrated into different processes: energy and industrial processes to utilize and sequester CO_2 after combustion or waste water treatment. In general, microalgae can be cultivated in seawater or brackish water on non-arable land, and this way do not compete for resources with conventional agriculture. Essential substances for the growth of microalgae are sunlight, CO_2 and inorganic nutrients like nitrogen and phosphorous.

Considering the variable composition of the microalgae, after harvest it could be converted to a variety of biofuels, pigments, cosmetics, nutritious food and animal feed. Microalgae, depending on species, culture and operation conditions, are composed of 28-63% protein (all 20 amino acids), 4-57% carbohydrates, and 2-40% lipids/oils by dry weight. Moreover, the lack of lignin makes it easier to process algae carbohydrates compared to lignocellulosic feedstock.

Microalgae species can also contain other valuable minor compounds, such as pigments, antioxidants, fatty acids, vitamins, antifungal, antimicrobial, antiviral agents, toxins and sterols. Long chain fatty acids are valuable health food supplements, while microalgal pigments and proteins have considerable potential for many medical applications. Thus, some microalgal species themselves can be microbial biorefineries utilizing waste streams of other processes (such as CO_2 and waste water). The variety of uses of microalgae is summarized in Figure 3.

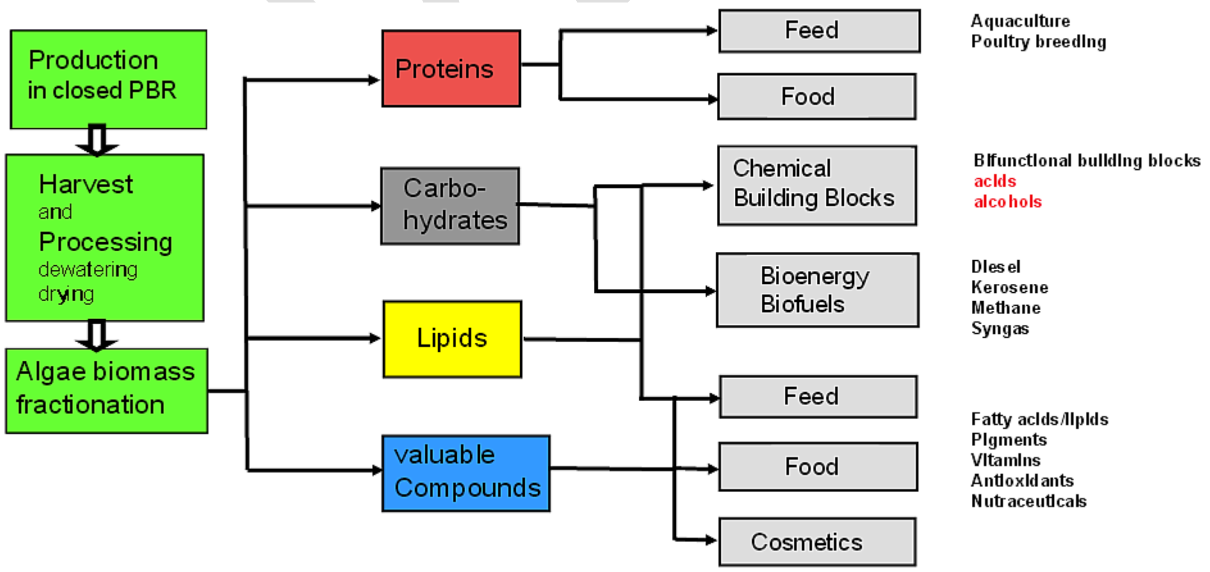

Figure 3. – Product spectrum of microalgal biomass, from Schmid-Staiger, 2009

There are several reactor types to grow algae, including open ponds, tubular and plate photoreactors. Considering the size and nature (especially in case of open systems) of the cultivation area and volume the difficulties of cultivation are controlling the conditions, contamination, unstable light supply and weather conditions. After non-seasonal harvest by means of separation, filtration, precipitation or flotation, the cells got dried, disrupted and the valuable compounds extracted by different methods. In case of lipophilic compounds, such as lipids, the extraction is performed from the wet biomass. The challenge in the process is to concentrate the low density and high moisture content biomass into a volume worth to extract.

Main feedstock types	CO_2, waste water, N, P
Technology bottlenecks	low biomass density, high water content, recovery of N, P and solvents used for extraction
Sustainability bottleneck	water need
Main products	lipids, valuable compounds
Status	algae are used in a number of industries to commercially produce useful end products including food (Spirulina for example), pharmaceuticals and medicines, animal feed (algae cake), fertilizer (algae cake) and as fuel.

2.3.2 Feedstock independent routes

Anaerobic digestion – biogas production

Anaerobic digestion is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen. Almost any organic material can be processed with anaerobic digestion. It is used to manage waste and/or to produce energy. As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere. In the biorefinery concept anaerobic digestion can play an important role by converting organic by-product streams (with high moisture content that cannot be burned) into energy to fuel the process. Depending on the organic waste feed different technology solutions can be applied to produce biogas. For example in case of industrial waste water with high organic content UASB (Upflow anaerobic sludge blanket) and EGSB (expanded granular sludge bed) reactors are available, while in case of solid organic wastes or sludge handling different types of tank reactors operate.

The process produces biogas, consisting of methane, carbon dioxide and traces of other contaminant gases. This biogas can be used directly in combined heat and power gas engines or upgraded to natural gas-quality biomethane fed into the natural gas grid or used compressed as transport fuel, turned into methanol or any other alternative ways natural gas is used for. The leftover after digestion, the nutrient-rich digestate, can be used as fertilizer and sprayed on the field closing nutrient cycle.

The anaerobic digestion process can be divided into four key stages catalysed by different groups of microbes working in synergy. Depending on the system design the following four steps take place in one or two reactors:

1. Hydrolysis – carbohydrates, fats and proteins are hydrolyzed to mono- and oligomers: saccharides, fatty acids and amino acids;
2. Fermentation – mono- and oligomers are converted into intermediates (volatile fatty acids, alcohols), hydrogen and carbon dioxide;
3. Acetogenesis – the volatile fatty acids are converted into acetic acid, carbon dioxide and hydrogen;
4. Methanogenesis – the products from acetogenesis are converted into methane and carbon dioxide.

The two conventional operational temperature levels for anaerobic digesters are determined by the species of methanogens in the digesters. Mesophilic digestion takes place optimally around 30 to 38°C, while thermophilic digestion takes place optimally around 50 to 55°C, or at elevated temperatures up to 70°C.

Anaerobic digestion can be performed as a batch process or a continuous process. In a batch system biomass is added to the reactor at the start of the process. As the batch digestion is simple and requires less equipment and lower levels of design work, it is typically a cheaper form of digestion. In continuous digestion processes, organic matter is constantly added, and the products are constantly removed, resulting in constant production of biogas. A single or multiple digesters in sequence may be used. Examples of this form of anaerobic digestion include continuous stirred-tank reactors, upflow anaerobic sludge blankets, expanded granular sludge beds and internal circulation reactors.

Biogas is currently produced at many sites across the world. In Hungary the most common substrates one part of the plant is based on agricultural by-products, while the other segment is represented by biogas plants connected to communal waste water treatment facilities.

Main feedstock types	manure, sewage sludge, different organic wastes and waste waters, agricultural by-products, collected organic waste, etc.
Technology bottlenecks	sensitivity of microbes to fluctuation in process parameters
Sustainability bottleneck	
Main products	biogas used further directly in a CHP engine (combined heat and power) or upgraded (biomethane for feed-in or for transport)

Thermochemical processes – carbon recycling by pyrolysis and biochar products

Thermochemical routes of biomass utilization are rapid processes and usually produce a 3 phase mixture consisting oils, gas, char or ash. Depending on technology details the ratio, quantity and quality of each phase can be altered, thus providing the intended products. The thermochemical conversion processes, such as pyrolysis are nonspecific and generally require high operating temperatures (>500°C). Basically, thermochemical technologies can process any feedstock with carbon content without pre-selection.

One valuable and important product of pyrolysis is biochar, a carboniferous product, produced from biomass by pyrolysis treatment at 450°C – 550°C (plant biomass) or 550°C – 650°C (animal by-products), obtained from wide range of feed materials by a manufacturing process, which product is having high variation in composition.

There are two major types of biochar, such as the lignocellulose based high carbon content biochar soil improver with usual application doses 5 t/ha to 20 t/ha and the food grade animal bone based high mineral content biochar “ABC” Animal Bone bioChar organic P fertilizer with usual application doses 0.2 t/ha to 0.6 t/ha in horticultural faming. The plant based biochar does not containing nutrients with economical value, while the ABC is a full value phosphorous fertilizer with 30 % of P_2O_5. The biochar products are suitable for a wide range of carbon negative application areas including improvement of horticultural soils, plant fertilisation, livestock farming, different environmental applications and carbon sequestration. If applied correctly (considering soil conditions and other practices) a wide range of economical, technical and environmental benefits can be achieved, including crop yield and fruit quality increase, improved nutrient and water retention to support drought tolerant cultivation, slow release organic fertilization (in the ABC case only) and improvement of soil microbiological life.

The use of biochar substances in open ecological soil environments with direct interlink to subsurface water requires strict environmental safety and advanced product quality aspects. The safe biochar is a fully quality controlled natural product with strictly defined, legally permitted and labelled content. The sustainable feedstock criteria guarantee that it does not compete with human food, animal feed and plant nutrient supply. The feedstock may not contain toxic contaminants (such as heavy metals and chemicals), while the product’s volatile organic and PAH contents must be constantly analysed. These toxic residuals in biochar are depending on the efficiency of biochar processing; incomplete reductive heat transfer to the feedstock during the process.

Hence, the pyrolysis process, its conditions and technology design performance, as well as the feedstock characteristics are the key determinants factors for process conditions and the output biochar quality. Most pyrolysis technologies are designed specifically for energetic applications, with no key objective for output char environmental or ecological quality. In this context, application of low efficient pyrolysis technologies usually results in low quality or non-qualified biochar products. Therefore, many, if not most of the traditional carbon processing technologies are not suitable for safe biochar production under the end of waste legislation criteria. Consequently, it is vitally important to define the pyrolysis process and technology design performance conditions, providing very high efficient reductive thermal treatment that results in removed toxic compounds (such as VOC/PAH) and remaining tar in the biochar product.

Biochar production systems within Europe differ technologically and economically due to the fact that biochar industry is in early stage of the development. Most of the traditional producers deliver charcoal which quality investigation is made from energetic point of view and not from environmental one. Advanced processing technologies are designed towards zero emission performance and include comprehensive utilization of the produced 3 phase mixture: the solid one for biochar while the large amounts of gas-vapours for syngas, transport fuel and other useful applications.

As of 2014, there is an ongoing European Commission revision of the Fertiliser Regulation (Reg. EC No. 2003/2003) to extend its scope to other fertilisers and fertilising materials including organic fertilisers (possibly ABC), growing media, soil improvers (possibly compost and biochar) and possibly biostimulants. The aim is to ensure that the proposed biochar quality and safety criteria are consistent with other EU level directives and regulations in order to reduce the environmental risks from heavy metals and organic compounds in agricultural soils. Biochar production is also regulated by the REACH legislation, such as chemically modified substance with high variability in composition, for which registration is mandatory above 1 ton/year biochar production and import from June 2018.

Main feedstock types	basically anything with carbon content and low level of moisture
Technology bottlenecks	define appropriate conditions that meet the criteria
Sustainability bottleneck	energy balance, GHG and toxic emissions
Main products	gas, oil, biochar – their ratio depends on process parameters

2.4 Emerging market for bioproducts

Based on the aforementioned ICIS survey more and more companies are showing readiness and openness towards biobased processes and products. In order to obtain the business case for certain bioproducts two approaches can be differentiated based on the current/possible use of the chemical considering its fossil counterpart.

2.4.1 Case of drop-in chemicals – analogues for the oil refinery

The first approach is based on the oil refinery analogue. In this context, the demand market is the same since the biorefinery produces so called drop-in chemicals, the biobased homologues of fossil based ones. In this case full chemical similarity and approved compatibility are required that may result in technical challenges. Therefore, the market strategy should concentrate on the creation of new, integrative supply side businesses that builds on cooperation with current demand market (chemical companies).

The main products of oil refining are the aromatics (BTX – xylene, toluene and benzene), butadiene, ethylene and propylene. Considering the compositional similarity and hypothetical routes of production the following adequacy can be provided, Table 3.

Table 3. – Products of oil refinery and their biobased alternatives adapted from Cherubini and Stromman, 2011

Chemicals	Possibility to deliver it from biomass	Uses with further processing	Note
BTX	components of lignin further processed	B – nylon, polystyrene, resins, solvent, chemicals, plastics. T – foam polyuretanes X – polyesters fibers and films	cutting edge, non-selective technology needed to depolymerize lignin bonds (once they are accessible)
Butadiene	further chemical conversion of ethanol (from fermentation of C5/C6)	polybutadiene rubbers, resins, chemicals, solvents, plastics.	potential chemical route via dehydrogenation, alcohol condensation and dehyration
Ethylene		HDPE, LDPE, LLDPE, PET, antifreeze, PVC, polyesters	no technological barrier: high temperature dehydration of ethanol (key: cheap and available bioethanol)
Propylene	C5/C6 fermentation	polypropylene, fibers, plastics, resins, solvents, epoxy resins, polyols	only theoretical possibilities: fermentation or alternative, multistep route via ABE fermentation from acetone

Additionally, with the exception of BTX, these compounds can be produced on starch basis (C6 fermentation). This can help to overcome the technological problems related to the resistant structure of lignocellulosic materials and the associated additional cost while offering the integration possibility.

Besides this hypothetical connection between biomass and oil refinery products, there are more convenient biotechnological and other routes that derive not exactly the oil based compounds but a novel product similar to it, with potential to substitute.

2.4.2 Novel products

With the complexity of feedstocks, diversity and specificity of microbiological and enzymatic processes, the product spectrum on biomass base is practically unlimited. Hence, this approach holds a huge potential. However, in this case novel but established, well designed processes are assumed requiring the creation of the market for the takeoff. This supply driven innovation necessitates careful business planning and strategy in order to grow successful start-ups aiming for niche markets.

Several compounds have been identified as possible future game changers. The US DOE carried out a report in 2004 naming 12 top chemicals. This list got updated leading to the drop out of a few ones but still keeping the majority of the same chemicals on the list. This ensures the potential of the chemicals on the list in both cases. A report of the web portal Biofuels Digest[4] also checked the potential of the compounds based on companies actively investing in those productions (Table 4). Nevertheless, the main product reaching the final consumer shares similarity with the one to be replaced. The differences are the routes and intermediates, how the products are obtained. In order to gain a market penetration the compatibility and adequacy for everyday uses considering also environmental and human impact during the whole life cycle should be verified.

[4] http://www.biofuelsdigest.com/biobased/2013/01/08/top-molecules-the-does-12-top-biobased-list-whats-worked-out/

Table 4. – List of top biobased chemicals

Original DOE top 12, 2004	DOE authors update, Bozell & Petersen, 2010	Biofuel Digest check, 2013	Production route
1,4-dicarboxylic acids (succinic, fumaric and malic)	Succinic acid	HOT	Fermentation of C6 sugars
2,5-Furan dicarboxylic acid	Furanics	HOT	Decomposition of glucose to HMF processed further either chemically or microbiologically
3-Hydroxy-propionic acid	Hydroxypropionic acid/aldehyde	HOT	???
Glycerol	Glycerol and derivatives	WARM	Biodiesel production by-product further processed to derivates
Sorbitol	Sorbitol	COLD	Catalytic dehydrogenation of glucose
Xylitol/Arabinitol	Xylitol	COLD	Fermentation of C5 sugar
Levulinic acid	Levulinic acid	WARM	Decomposition product of hemicellulose
Aspartic acid	-	WARM	
Glucaric acid	-	WARM	
Glutamic acid	-	COLD	
Itaconic acid	-	COLD	
3-hydroxybutyrolactone	-	COLD	
-	Biohydrocarbons		From syngas via Fischer-Tropsch synthesis
-	Lactic acid		Fermentation of C6
-	Ethanol		Fermentation of C5/C6

Besides the above listed and rated compounds, Figure 4 presents the possibilities that biomass can offer through fermentation. In view of this broad portfolio, it is expected that, as a result of process and product innovation, by 2025 biobased products will reach a share of 22-28% in the chemical industry from 9-13% in 2010.

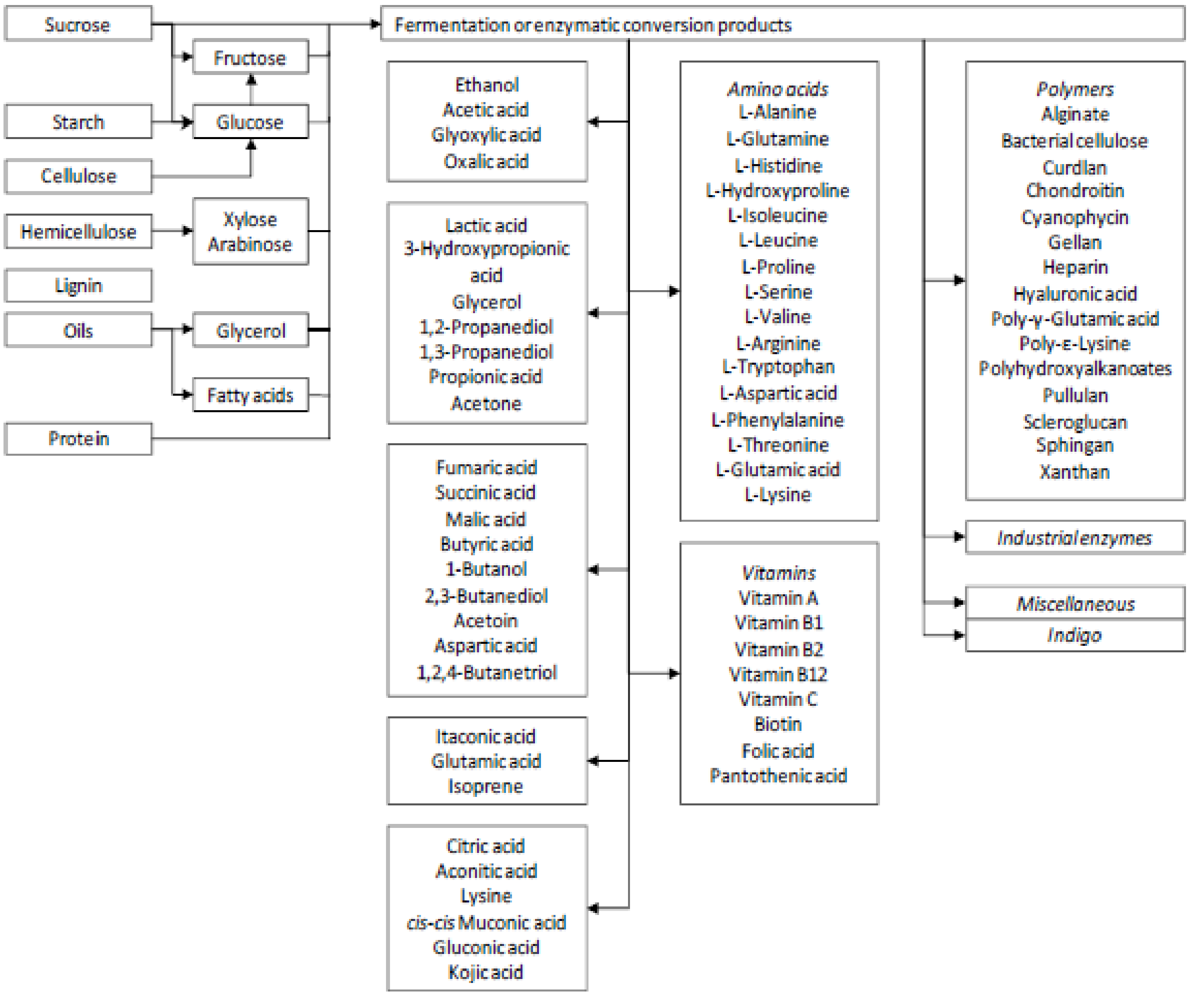

Figure 4. – Biobased products scheme, from 'Future prospects of industrial biotechnology, 2011, OECD Publishing

Probably the most prominent biobased platform and bulk chemical, a substitute for the fossil fuel based maleic anhydride, is succinic acid. There are already numerous companies aiming for commercial production of it based on biomass. The current, mostly fossil fuels based global succinic acid production is between 30 000 and 50 000 tonnes per year, and due to the significant growth a global market of 100 000 tonnes is foreseen by 2015 (and even much more calculating with its direct derivatives).

Succinic acid has a wide range of industrial applications, such as being used as a chemical intermediate for the production of lacquers and perfume esters as well as a flavour, bacteriostatic, or neutralizing agent in the food industry. Furthermore, succinic acid also has a special chemical market for producing coatings, surfactants, dyes, detergents, green solvents, biodegradable plastics, and ingredients stimulating animal and plant growth. Based upon the structure of linear and saturated dicarboxylic acid, succinic acid can be readily converted to other bulk chemicals, such as 1,4-butanediol, gamma-butyrolactone, tetrahydrofuran, adipic acid, n-methylpyrrolidone or linear aliphatic esters. Succinic acid can be turned into biodegradable plastics as well, such as poly(1,3-propylene succinate) and poly(butylene succinate) (PBS).

The production of succinic acid based on biomass feedstock via microbiological conversion route is getting into focus. The fermentation is based on the tricarboxylic acid cycle, when using glycerol or glucose as carbon source with the fixation of CO_2 certain microbes are able to produce succinic acid. The fact that CO_2 is assimilated during succinic acid fermentation can be considered as an environmental advantage. Nevertheless, it is a promising option, but not yet economically feasible in large scale. Further developments should concentrate on to enhance product concentration, reduce co-production and improve downstream processing.

2.5 Vision

As a summary of the previous chapters, here a flexible scheme for a biorefinery is presented that is based on an ethanol factory showing the integration possibilities in order to use as much components of the biomass as possible. Nevertheless, not necessarily the ethanol is the main product. The first stage of an integrated biorefinery is the extraction of valuable secondary metabolites.

The mass and energy flows of an integrated biorefinery are presented on Figure 5. The system follows the closed loop approach with keeping the flow recycled into the process and thus limiting the inputs and valorising the outputs.

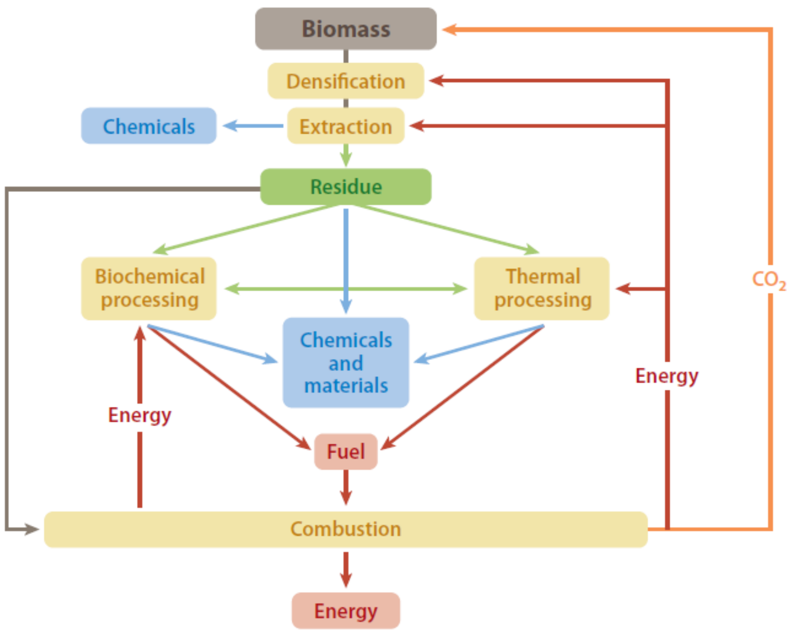

Figure 5. – Mass and energy flows in an integrated biorefinery complex, from Clark et al., 2012

Regarding the products via the biochemical line, the parameters of pretreatment should be chosen in line with the wanted product. The ratio and quality of the different fractions depend on the pretreatment conditions.

Figure 6 shows how the different conversion routes can be integrated into the lignocellulose to ethanol process. Obviously, this selection is only indicative to represent the potential outputs, in-between a flexible switch could also be possible. Basically, the options are unlimited to process biomass into value added products

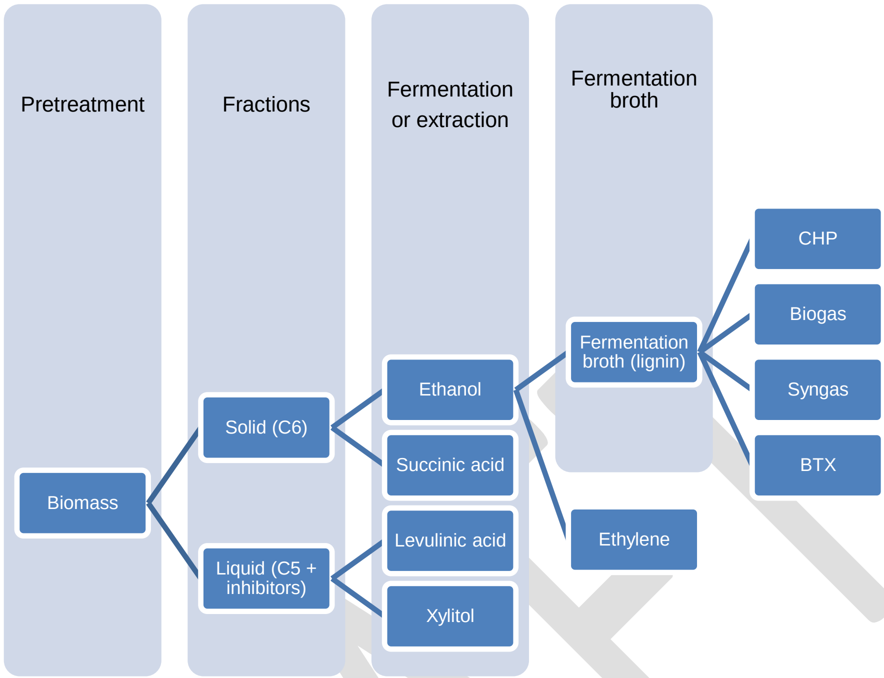

Figure 6. – Scheme of the biochemical line of an integrated biorefinery complex

3 Climate-KIC and its bioeconomy platform

3.1 European Institute of Innovation and Technology (EIT)

The EIT is a body of the European Union established in March 2008 and headquartered in Budapest, Hungary. Its mission is to increase European sustainable growth and competitiveness by reinforcing the innovation capacity of the EU. The concept of the EIT was developed within the framework of the Lisbon Strategy for Growth and Jobs, specifically to address Europe's innovation shortcomings.

In order to deal with these issues, the EIT has created integrated structures (so called Knowledge and Innovation Communities, KICs) that link the higher education, research and business sectors to one another thereby boosting innovation and entrepreneurship. This way the EIT and the KICs – as the first European initiatives – fully integrate all three sides of the Knowledge Triangle (research, education and business).

KICs will form enhanced partnerships within the innovation web, sharing common strategies and objectives, and going beyond traditional networks of innovation actors in terms of scale, ambition and life-span (7-15 years). They will seek to form strong innovation cultures and identities, driven by common visions and goals, and to build innovative "webs of excellence". The relationship between the KICs and the EIT is organized on a contractual basis, leaving a great degree of autonomy to the KICs to define their own legal status, internal organization and working methods.

The current KICs focus on priority topics with high societal impact: Climate change mitigation (Climate-KIC), Information and Communication Technologies (EIT ICT Labs), Sustainable

Energies (KIC InnoEnergy). Future KIC themes have been proposed by the EIT for the period 2014-2020.

3.2 Climate-KIC

Climate-KIC was created in 2010 and by 2014 the community has grown to involve more than 200 partners from 6 Co-location Centres (CLC) and 6 Regional Centres (Regional Innovation and Implementation Community, RIC; one of it is Central Hungary) across Europe. These partners are from academic institutions, businesses of various size, local authorities and innovation clusters. Consequently, Climate-KIC connects global and local, small and large partners from the private, public and academic sectors.

The 6 CLCs, each managed by a director, and 6 RIC Regions, collectively managed by a steering group, are well established in leading hotspots of climate innovation (Figure 7). The CLCs and regions complement each other, both geographically and in their contribution to the KIC. The CLC partners include world-class business, research institutes and universities, clustered to drive innovation. The public, private and academic partners of RICs have leading expertise in testing, implementing and delivering innovation. The partnership's capacity to create high growth companies to reduce the effects of climate change is of primary importance.

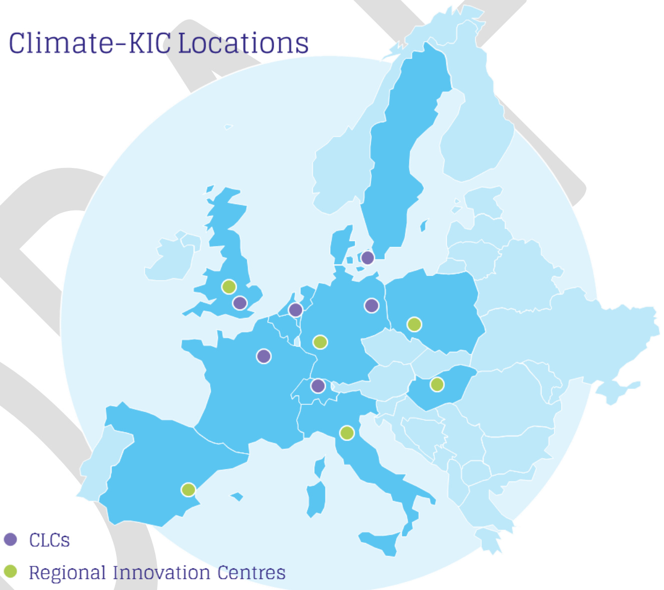

Figure 7. – Partnership network of the Climate-KIC

The main aim of the Climate-KIC is to accelerate and stimulate innovation in climate change mitigation and adaptation. The activities of the Climate-KIC are based on three pillars:

- **Education** pillar is destined to develop and deliver education and training activities in order to create world class climate change innovators and entrepreneurs. The applied approach is progressive, innovative and experimental with proactive involvement of the students. The results are students with entrepreneurial attitude.
- **Entrepreneurship** aims to catalyze and scale the creation of new business from climate mitigation and adaptation related inventions. This is achieved by running incubation programs in some of the best entrepreneurship hotspots in Europe.

- **Innovation** activities entail funding and delivering Innovation and Pathfinder projects that are the seeds for new products, services and policy. Projects deliver high innovation value, globally marketable outcomes and positive climate impact by testing new methods to link world leading innovators with cities, regions and large companies.

These activities are driven by eight thematic challenge platforms (themes) addressing different areas of climate change and are aimed to provide new solutions by supporting education, entrepreneurship and innovation. The challenge platform is an impact oriented, dynamic community with a leadership team that formulates specific focus for innovators to create economic growth by addressing climate change. Platforms encourage translation of climate change challenges into significant business opportunities through innovation, capacity building by involving partners and extensive synergies between research and development, education and entrepreneurship.

The platforms are the following:

- Transforming the built environment: development of resource-efficient new and retrofit buildings by catalysing system innovation and the development of low carbon substitutes for building materials.
- Sustainable city systems: support the transition from centralized but separate energy, transport, waste and water utilities to decentralized, integrated utility systems.
- Making transitions happen: creation of an adaptive and low-carbon culture to engage companies, communities and citizens in the development of a low carbon society, to reduce GHG emissions and connect to global issues related to climate change.
- Industrial symbiosis: increased resource efficiency and turn waste –including food waste and CO2- into resource.
- Greenhouse gas monitoring: mitigation actions through GHG measurements, reporting and verification and associated financial tools.
- Bio-economy: development and adoption of a bio-based economy, closing the loop and producing polymers, chemicals and biofuels.
- Land and water engineering for adaptation: adaptation of water engineering and agriculture to climate change and link it to enhanced land use and ecosystem services delivery.
- Adaptation services: increase of the adaptation capacity and resilience of societies, infrastructure, cities and services.

3.3 Bio-economy platform

The Climate-KIC Bio-Economy platform (KBioE) supports the transition to a bio-based economy by developing an integrated, holistic approach across entire value chains from feedstock production to efficient processing and conversion, and ultimately the production and marketing of bio-based products. Using the strategic tools offered by the KIC community (Education, Innovation and Enterprise), KBioE fosters a collective innovation strategy that will involve acquiring vital input from all value chain stakeholders, thus determining technical bottlenecks and barriers. Likewise, reacting to stakeholder analysis, KBioE is developing activities addressing the following challenges:

1. improve feedstock production, optimize for both yield and sustainability;
2. maximize feedstock efficiency obtaining maximum amount of food and non-food products from crops, while minimizing inputs and closing loops;
3. maximize product value, obtaining the highest revenues and/or ecological benefits from feedstock components, before making lower value products;
4. develop and deliver to the market both "drop-in" chemicals (products originated from biomass feedstocks as replacements for petroleum-based products) and new biobased products with improved functionalities;
5. devise ways to limit capital investment costs, thus assist fast take up of new technologies in the bioeconomy sector.

The aim of Climate-KIC Bio-Economy platform is to be an essential part of Europe's bioeconomy strategy, providing comprehensive knowledge-based services to enterprises, with a particular focus on SME's. The KBioE's practical and operational approach is built on existing capacity within the KIC, in particular centres of research excellence, universities and regional-based public-private partnerships.

The key role is to identify important bioeconomy value chains, whose development will provide climate benefits, then in direct collaboration with industrial stakeholders to initiate an innovation process that will mobilize KIC added value, thus facilitating the progression of climate-efficient products towards the market. This platform will connect regionally-based Public Private Partnerships (PPPs, e.g. local business clusters) and/or single enterprises to the Europe-wide KIC network creating a unique efficient innovation eco-system.

The core activities of KBioE are a range of project coordination services, including engineering project consortiums, networking and matchmaking, signposting projects towards financial support and R&D capabilities. In addition, KBioE will develop bioeconomy statistics and metrics that will be used internally to evaluate the relative climate benefits of target value chains and will also be offered to enterprises. Finally, KBioE will devise and offer bioeconomy-related education to students (Master and PhD level) and tailored educational services for professionals.

For SME's the benefits obtainrd from working with KBioE will be increased chances of success, improved resilience and insight into new opportunities and industrial progress. Existing regional-based clusters will benefit from a broader partner network, greater European visibility and market feedback, reduced risk and new scientific research ideas. Investors will benefit from higher quality dealflow of investment opportunities through the validity and credibility of the platform. EU regions working with KBioE will benefit from better focus on their resources and strengths and optimize solutions in local conditions. Moreover, regions will have the opportunity from different approaches across Europe and will benefit from higher rate of regional growth.

Relevant parts of the KBioE early stage (2013-14) implementation what this study addresses in terms of Hungary:

- Mapping KBioE business potential in KIC regions: identify KIC R&D/technology nodes and expand affiliate member base. Organizing participative innovation events.
- Initiate flagship projects: select some nodes to found a pilot demonstration hub and for innovation projects through expression of interest call.
- Master programs and PhD training.

4 Hungary's relevance in the bioeconomy

The aim of this chapter is to deliver insight into the Hungarian bioeconomy scene by introducing some of the stakeholders through the entire supply chain. Taking into account the preliminary nature of this work and the not fully developed method to contact stakeholders no full picture was targeted. Nevertheless, this study can be a precedent for the KBioE Biohorizons project by building on these results and experiences gained.

Besides the introduction of the possible players, presentation of connection points to the Climate-KIC and gaps that hinder the creation of bioeconomy, as well as suggestion of solutions to overcome these were also attempted.

Horizon Scanning the European Bioeconomy – BioHorizons

The overall goal is to develop European Bioeconomy, create a better support to climate change mitigation and adaptation strategies through business innovation. This project will map the current European Bioeconomic landscape by quantifying and characterising existing bio-based businesses, supply chains, and markets within Europe. The information obtained from the survey will provide an insight into regional differences, market failures, business opportunities/barriers, market and research needs. The project relies on utilisation of an online survey tool to capture information via questionnaire that is promoted and disseminated through RICs and CLCs beside ongoing business activities. The data and network contacts gained will be available for further KIC innovation projects, education and entrepreneurship activities and will help to improve visibility and extension of Climate-KIC within the sector.

4.1 Methodology of the survey

As part of the study, a written interview was sent to relevant stakeholders representing each step of the supply chain. The questions (Annex I) refer to the interviewees own activity, to relevant stakeholders and to the Hungarian situation generally. The interview's main goal was to perform a preliminary mapping of the bioeconomy related activities and stakeholders in Hungary. The questions were organized to the following 13 groups, each containing 1-3 questions:

1. Supply general
2. Supply specific
3. Conversion general
4. Conversion specific
5. Demand general
6. Demand specific
7. Policy
8. International connections
9. Possibilities
10. Human resources
11. Multitude effects
12. Acceptance
13. Financing

A total of 22 answers were received through mainly personal contacts. Although the replies cover the opinions of well-recognized experts of the Hungarian biotechnology scene, the results of the survey cannot be considered as representative. In the first round 47 stakeholders were addressed but after that many more via personal connection, thus the exact answer ratio is undefined.

The main conclusion of the assessment was that the willingness for answering is very low among the Hungarian stakeholders. In order to improve cooperativeness more effort should be made, e.g. personal communication or emphasizing the advantages, and also an easy-to-use but informative interface should be built up. During implementation of Biohorizons these barriers should be overcome, otherwise the outcomes of the project are risked by disinterest of potential stakeholders.

The results of the multiple choice surveys are attached in Annex I.

4.2 Relevant national policy documents – assessing the drivers

Policy drivers are captured by the key relevant Hungarian policy papers concerning at least one of the many aspects of the bioeconomy identified and introduced shortly here. Noteworthy, the case of bioeconomy as a whole cannot be found in any of them, which is probably because of the complexity of the field. In our opinion bioeconomy could have a more pronounced position in the relevant strategies, more dominant in R&D and rural development strategies. Currently, there is no dedicated strategy or policy framework aiming the formation of the Hungarian bioeconomy, and more importantly due to its complexity the responsibilities (agriculture, R&D, biomass, energy, etc.) are not clear and interfaces are not provided.

4.2.1 Renewable Energy – Hungary's Renewable Energy Utilisation Action Plan

The Renewable Energy – Hungary's Renewable Energy Utilisation Action Plan, 2010-2020 is based on the EU directive 2009/28/EC. It specifies how Hungary intends to achieve the legally binding target of 13% by 2020, and to exceed it to 14.65% in terms of renewable energy ratio of final energy consumption. Regarding biomass use, which is the largest fraction of renewables in order to meet the target, the document puts it in a wider complex of agriculture and rural development and introduces the term of green economy. It is stated that the use of biomass for energy purposes, based on the favourable agroecological conditions of the country and taking into account sustainability criteria (especially the protection of biodiversity and soil quality), can contribute to the retention of agricultural jobs and to the creation of new ones. The use of organic matter from animal husbandry for energy purposes (biogas) can enable productive waste management, increasing the competitiveness of the sector. The use of by-products and other solid wastes from agriculture and forestry (e.g. by-products from crop-lands, cuttings from orchards and vineyards) for local energy purposes and their conversion into end-products will result in additional income for farmers and producers, and can significantly reduce the need of communities for fossil energy sources.

The above statements, however, can also be applied for biomass utilization, regardless the purpose (other than energy). In order to highlight the importance of biomass the document also adds that Hungary possesses excellent agro-ecological conditions for a competitive production of biomass. Hungarian agriculture is capable of sustainably producing biomass in excess of food and feed demands, and at the same time, there is a significant biogas production potential. The theoretical potential of energy sources from biological origin (bioenergy) could exceed as much as 20% of the energy source demand estimated for 2020. Regarding transportation, more than 10% of the estimated consumption for 2020 can be fulfilled from first generation biofuels only, while at the same time ensuring the fulfilment of food and feed provision objectives; and with the emergence of second generation biofuels through the expansion of the scope of raw materials, this volume can be increased even further depending on the seasonal variations in the amounts of agricultural production.

4.2.2 National Energy Strategy 2030

The National Energy Strategy 2030, approved by the Hungarian Parliament in 2011, contains the elemental part of the renewable energy action plan, but also introduces new measures for the biomass based solutions. This is the establishment of bipolar agriculture, possessing the required market-oriented flexibility enabling the shift between food production and energy-geared biomass production. The gradual conversion of the areas that are unsuitable for food production at the required efficiency, therefore currently left uncultivated, to arable lands by the cultivation of energy crops is encouraged. The strategy also recognizes that biomass and waste are also potential industrial feedstock, available for use in numerous areas of a fast developing biotechnology-based economy. It enables the production of pharmaceutical and fine chemical commodities by biotechnological processes considerably reducing the GHG emissions of recent industrial manufacturing processes. This statement is a clear development compared to the strictly energy orientated approach for biomass resources. Furthermore, the advanced biofuel production techniques and other biomass-based solutions are also pictured as driving forces for “greennovation” and potential contributors to economy with the provision that the required training, industrial and innovation knowledge base is developed.

4.2.3 Hungarian National Environmental Technology Innovation Strategy

The Hungarian government adopted the National Environmental Technology Innovation Strategy at the end of 2011 as its framework for eco-innovation within the Hungarian National Reform Programme. The government's vision is to facilitate environmental industries and technology, to focus on environmental innovation, to reduce primary material use and encourage reuse and recycling, and to ensure a paradigm shift from an “end-of-pipe” approach to prevention of environmental problems.

The strategy contains targets and development areas around the following eight topics: 1) Waste 2) Water 3) Air 4) Noise and vibration 5) Agriculture and soil protection 6) Remediation 7) Renewable energy 8) Construction industry. The reason for selecting these priority groups is that they have a common feature: in each area there is great room for ameliorating the current level of environmental impact by various means. In each of the eight priority areas, considerable positive changes can be made. There is also a chapter, called horizontal type technological innovations aiming resource efficiency and containing bio-based products as a development area.

The strategy entails a systematic approach; environmental technologies are not just individual technologies, but total systems that include know-how, procedures, goods, services, and equipment, as well as organizational and managerial procedures. Regarding the bioeconomy vision the strategy states that environmental technologies use all resources in a more sustainable manner, recycle more of their waste and products, and handle residual waste in a more acceptable way than the technologies for which they are substitutes. In order to meet the targets the strategy introduces a set of tools including greening governance, legal tools (tax, public procurement) and social tools (environmental awareness, education).

4.2.4 Darányi Ignác Plan Framework Programme for the Implementation of the National Rural Development Strategy

The Ministry of Rural Development adopted the Darányi Ignác Plan – Framework Programme for the Implementation of the National Rural Development Strategy (2012-2020) in 2012. It fits into the EU and national policies and aims to reverse unfavourable processes predominant in the countryside. The vision is based on delivering sustainability, viable agricultural and food production and values of rural life. The strategy defines the objectives and principles of the country's rural development policy and provides a framework for the implementation of the relevant programs and measures.

The main goals of the strategy are "increasing rural employment, balanced and varied agriculture and forestry that utilize resources in a sustainable manner, re-establishment of a diverse production structure, local food production and markets, rural-urban relations, the exploitation of export opportunities of high value-added food products, the strengthening of cooperative alliances, local energy production, rural local communities, improvement of the standard of living, a reversal in the rural population decline, and the conservation of ecosystems and biodiversity." Many of these goals are directly or indirectly connected to the bioeconomy, but there is no direct connection in the strategy established between advanced biomass processing and rural development.

Although the strategy highlights the major problem in the agribusiness, namely products with predominantly lower added value due to lack of further processing, and names the increase of added value as a preferable strategy. Despite this, it deals neither with the idea of the bioeconomy nor the advanced biomass technologies delivering opportunities for by-product valorisation. The locally produced renewable energy appears in several parts of the strategy as an important factor of the rural development, but it is connected more to the wood utilization and then to the organic residues and wastes. There are more opportunities to use agricultural by-products, organic residues and wastes as valuable feedstock in various processes, as today it is an advantage to produce tradable, value added products besides energy.

4.2.5 National Research and Development and Innovation Strategy 2020

The strategy, approved by the Hungarian Government in June, 2013, recognizes that the support of research and development and innovation can be considered as a long-term investment in the future. The National Innovation Strategy aims to raise investments in R&D&I in Hungary involving all kind of partners (including SMEs, research institutions and companies), and as a result, to mobilize our economy and to strengthen our competitiveness. The strategy aims to raise the amount of R&D expenditures to 1.8% of GDP in Hungary by the end of the decade. It supports the formation of an environment in which public institutions, companies and innovative enterprises can develop and grow.

The strategy focuses on the knowledge creation, knowledge transfer and utilization. It deals with the whole business sector, including small enterprises, medium-sized and big companies. The strategy also targets to raise the overall R&D capacities. Among others, the essential part of the strategy to create a Hungarian R&D infrastructure that is competitive in

EU aspects and able to deliver more active participation in related programs, such as Horizon2020.

In an effort to spring these processes to life in a more effective way, the strategy aims at (i) promoting the collaboration among all the relevant actors and (ii) supporting the diffusion of solutions that already exist, e.g. technological and service innovations.

The strategy – in its form – functions as a general framework for R&D and innovation and avoids mentioning concrete sectors. The reason for this is that policy is not capable of predicting appropriately the innovative industries or sectors that should be promoted in the future.

4.2.6 New Széchenyi Development Plan

Improving Hungary's competitiveness, creating one million new jobs within ten years along seven break-out points – these are the main objectives of the New Széchenyi Plan launched on 14 January 2011. The economy development programme of the Hungarian government responds to the challenges what Hungary is facing, and ensures a growth scenario that can be sustained over long term.

The break-out points for Hungary as identified in the plan are the followings:

1. Healing in Hungary – health industry
2. Renewal of Hungary – development of green economy
3. Network economy – development of business environment
4. Transport – transit economy
5. Knowledge economy - science – innovation – economic growth
6. Employment – work and performance oriented economy

Common in the above break-out points is that all of them integrate numerous sectors and all of them carry the potential to create competitive Hungarian products, services and businesses already in the midterm. The main aim of the development plan is to identify the major principles for allocating funds from different sources (mainly Cohesion Policy) in a well aligned way with the respective policies as detailed above.

4.3 Supply side assessment

In this section we seek to reveal as much data as possible on the potential of biorefinery feedstocks including bioenergy plantations, agricultural and related industrial by-products, forest products, organic wastes and waste waters. Depending on the scope and scale of the assessment, one might find a relatively wide range of available figures about the Hungarian biomass feedstock potential. We attempt – to a limited extent – to give estimates about missing/unavailable data using various techniques. There are many factors influencing the uncertainty regarding the potential availability of agricultural residues, for example the extent to which existing uses compete for this resource, as well as the maintenance of the soil carbon stock as defined by agricultural practices and geographical conditions (location, slope, irrigation, erosion, etc.).

4.3.1 Sustainable biomass potential of Hungary

Hungary is considered as a biomass rich country (in line with the studies quoted in chapter 2.2) in general with biomass potential enough (or even more) to meet the 2020 renewable energy requirements with the existing technologies. The annual quantity of required biomass is already available and it should be possible to meet the demand for solid biomass for direct combustion without the need for significant areas dedicated to energy crops. Moreover, Hungary has great potential to produce first generation biofuels, particularly ethanol, not only for domestic uses but also for export.

Although numerous studies reviewed the Hungarian biomass potential, most of them claim that “there is very little reliable information on the available quantities of the different types of biomass and their energy potential in Hungary”. Data are scattered throughout the literature and usually consist only of the calorific value of the different types of biomass, so this information cannot be used for estimating the potential of Hungarian biomass.

A background study was written to the Hungarian Renewable Action Plan summarizing various existing potential estimations. The summary showed that Hungary has 420-500 PJ/year theoretical potential out of which 203-328 PJ/year is convertible in long-term (2050). The technical potential of all biomass sources is 215 PJ/year, the economic potential is 220 PJ/year and the sustainable potential would be 208 PJ/year on the long run (2030). In medium term (2020) 122 PJ/year sustainably exploitable potential can be estimated. Nevertheless, the concrete methodology and framework conditions may be not known and differ, thus leading to very diverse potentials. (As comparison the gross inland annual consumption of primary energy in Hungary is around 1000-1100 PJ).

Table 5. – Summary of some analyses on the biomass potential of Hungary

Source	Low value, PJ/a	Top value, PJ/a
Hungarian Academy of Science, Renewable Energy Subcommittee (2005-6)	203	308
Energy Club (2006)	58	223
European Environment Agency (2006)	145,5	
Ministry of Agriculture and Rural Development (FVM)	260	

More detailed classification of the different biomass resources is also available. The latest one by Garay et al. (2012) estimated the available amount of solid biomass from different sources, and then calculated the energy potential of the biomass that can be used for electricity and thermal energy production.

Starting with forestry, about 13 million m^3 of wood is produced every year from the two million hectares of forests in Hungary of which 10.5 million m^3 (about 7.5 million tonnes) can be harvested in a sustainable way. By comparison, 7 million m^3 (about 5.3 million tonnes) was logged yearly in the last decade and about 50 per cent of this amount was used for energy generation. Assuming that 50% of the sustainable potential is firewood, currently only 67% of this energy source is utilized. In addition to the timber, every year about 300-400 thousand tonnes of logging waste remains in the forest because it cannot be collected using the common technologies. Every year about 700 000 m^3 (525 000 tonnes) of wood by-products (waste wood, wood chips) are generated in the wood processing plants. Because these are often contaminated with chemical substances, only about 50% of this quantity, mostly sawdust and bark could be used for energy production.

After the timber, agricultural by-products provide the next highest amount of biomass. Every year 4-4.5 million tonnes of straw is produced from the cultivation of grain cereals and of this about 2.4-2.8 million tonnes could be used for energy production in a sustainable manner. In addition, 8-10 million tonnes of maize stover is produced annually (more than the weight of the grain) and 2.5-3.0 million tonnes could be utilised as biomass for energy production. Significant amount of sunflower stem and oilseed rape straw are produced annually as well, and about 150-200 thousand tonnes of residual biomass obtained from pruning of vineyards and a further 400-500 thousand tonnes from orchards. Although the heating value of these horticultural by-products is very similar to wood, and the pruning chips can easily be stored and transported, most of the residual biomass is either burnt on site or chopped and used as soil amendment.

Table 6. – Potential of agricultural residues in Hungary, results of a few analyses

Source	Note	Amount
Monforti et al. (2013)	GIS based methodology considering environmental (soil) limits and competing uses. For Hungary, 46% of produced residues was found sustainably collectable of which 96% is available considering competing uses.	Available amount of straws of eight crops (wheat, barley, rye, oat, maize, rice, rapeseed and sunflower): 6.3 million tonnes (2000-2009 basis)
Fischer et al. (2010)		Amount of agricultural residues: ▪ observed 2000-2002: 9.4 million tonnes (88 PJ) ▪ 2020: 7.1 million tonnes (66 PJ) ▪ 2030: 5.9 million tonnes (56 PJ)
Hungarian Academy of Sciences		74-108 PJ/year
Garay et al. (2012)		8.5 million tonnes/year

There are 400 hectares of perennial and 2,122 hectares of herbaceous energy crops in Hungary (REAP, 2010). On this production area, assuming an average yield of 20 tonnes/ha, about 50 000 tonnes of biomass is produced annually. Although there is increasing interest in growing energy crops, the production area has not changed significantly in recent years. The main reason for this is that the price of chips from energy crops and the price of firewood are almost equal, but the production of chips from energy crops is more expensive than logging. Therefore the production of energy crops can only be envisioned if the distance to the recipient plant is not more than 50-80 kilometres.

Regarding the potential, Fischer et al. (2005) assessed that roughly 1.4 million hectares (15.2% of the country's area, delivering 327.6 PJ) are suitable for poplar, willow and miscanthus, excluding forests, and land highly suitable for cereals. The applied agro-ecological zones methodology (AEZ) used for global regional and national assessments of agricultural potentials enables evaluation of potential productivity of forest tree species. AEZ follows an environmental approach; provides a standardized framework for the characterization of climate, soil and terrain conditions relevant to crop and forest species production; uses environmental matching procedures to identify limitations of prevailing climate, soil and terrain for assumed management objectives. This high potential for energy crops is also supported by the fact that large area of land (pastures) is available without limiting and jeopardizing the food and feed production (Figure 8). Based on the calculation of the former Ministry of Agriculture and Rural Development, the traditional structure of production can be feasibly maintained on 3.3-3.4 million ha arable land, therefore at least 1 million ha land could be utilized in alternative manner (not for food) e.g. for energy crops.

Clearly, the authors of the REAP also envisage a dominant role for energy crops. They estimate that there are about 1 million hectares of land that are not suitable for agricultural production, and from this area some 200,000 hectares could be used for the production of energy crops. The REAP anticipates the production of 5.6 million tonnes of energy crops annually.

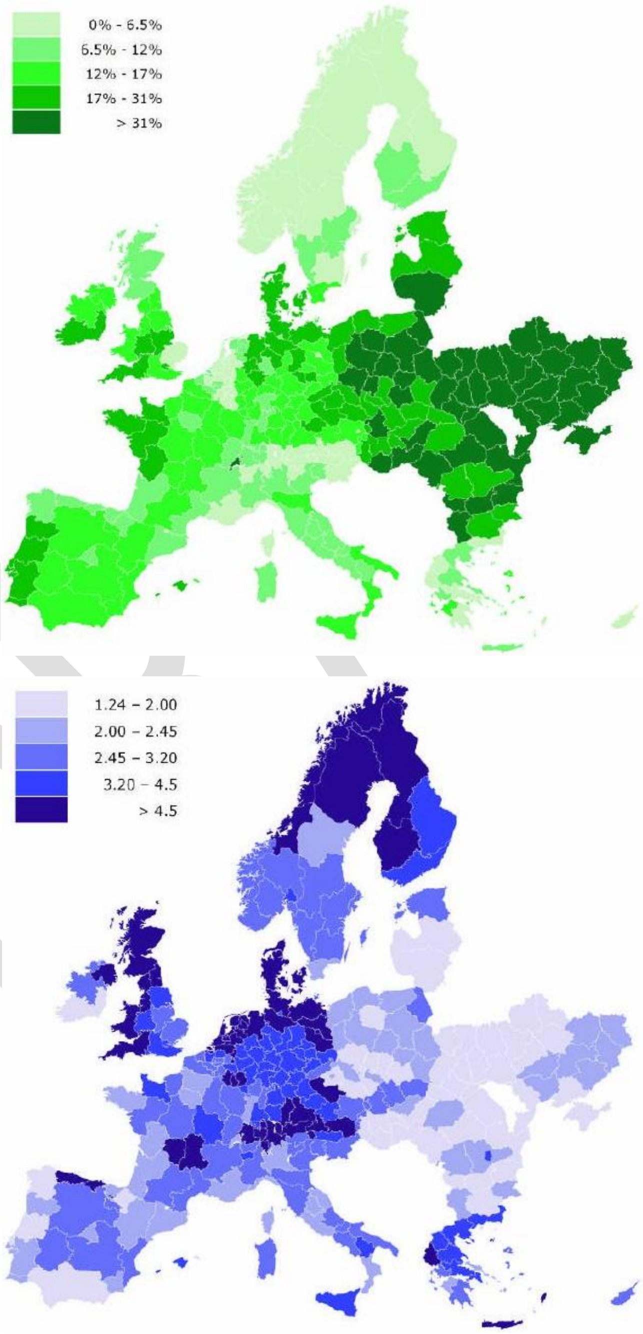

Figure 8. – Lands available for biomass production by 2030 as percentage of the total land (upper figure) and the production costs of woody crops in 2005 in €/GJ (lower figure), from Wit et al., 2010

Besides these typical agricultural residues, manure and industrial organic wastes also have potential, mainly in biogas production. Municipal solid waste and its yet not selected organic fraction show enormous potential as well of which utilization mostly depends on waste management policy framework and on possible introduction of separate collection of organic wastes as foreseen by EU policies.

4.3.2 Available literature and data gaps

Overall, available assessments and data sources are weak in one or more aspects regarding the latest information, feedstock coverage, documentation of methodology, detailed regional supply or considering sustainability criteria. Preliminary literature search indicates that there is no comprehensive estimation with established and transparent methodology including sustainability criteria, land use balances and competing uses.

The methodology should support the intention of European Commission to set minimum percentage values for agricultural by-products available in sustainable manner considering soil carbon stock and competing uses. Therefore, a more accurate calculation is needed that ensures a solid basis for the availability of excess biomass for different purposes.

The amount of potential industrial organic waste should be mapped on a factory-by-factory basis including the estimation of prospective uses.

4.3.3 Stakeholders in feedstock data analysis

Although currently no detailed, comprehensive, up-to-date biomass potential estimation is available, there are several research institutes from government and science pools that could carry out such a task. An already available example is the "Energy map"[5] project, which was carried out by Energy Centre and VÁTI. VÁTI (http://www.vati.hu) is a non-profit company, covers the full scope of research, planning and consultation activities related to strategic planning and regional development. Experience of over fifty years, extended national and international contacts, the uniquely rich information data base and the highly qualified staff ensures that VÁTI performs its non-profit tasks properly and always meets the requirements of its clients. The company participates in identifying short- and long-term goals for a comprehensive strategy on national and regional development, in the coordination and methodological support of planning. The Energy Centre has been reformulated recently as The National Environmental Protection and Energy Centre (http://www.energycentre.hu/). Its role includes facilitating the use of renewable energy and it is the main coordinator of the Green-economy Program and participates in many international renewable projects (e.g. 4BIOMASS).

The Forest Research Institute (www.erti.hu) is involved in forest related research, including forest management and also energy plantation. The institute develops varieties with high yield that can be safely grown under domestic environmental conditions, and modern agro technological methods and active in development and analysis of the production economics and sustainability performance. ERTI has three main priorities in its research activities:

- climate change, with the task to assess the impacts of climate change on the environment and on the forest management;
- improvement of management methods based on natural processes;

[5] https://teir.vati.hu/Energiaterkep/main

- research in connection with the establishment and utilization of energy plantations aiming to improve varieties that are suitable for high-yield energy crop plantations.

The Research Institute of Agricultural Economics (AKI, www.aki.gov.hu) is the most significant centre of agricultural economics research in Hungary. It bridges the gap between decision makers and farmers, processors, distributors and universities; it connects Hungary with the rest of world with theory and practice. The Institute collects and analyses information performs research and distributes the results obtained through its publications. AKI operates the FADN (Farm Accountancy Data Network) and collecting representative data about the 87 thousand farms that cultivate 93% of the total agricultural area used by all farms. AKI carried out several bioenergy projects (feedstock potential) and published many bioenergy related studies about the current situation and the opportunities for the production and utilization of biomass in Hungary (e.g. Production of Biomass for Energy Generation in Hungary).

4.3.4 Opportunities and challenges of stakeholder engagement

Beyond the opportunities provided by the biophysical endowments there are several factors from the farm structure and legal framework point of view that put barriers to increased utilization of biomass for energy. Biomass for energy requires a somewhat different view and certainly openness from the land user side. The concept of path-dependency; that is, the tendency of agricultural regions to be locked into development paths set by their pre-existing traditions, resulting in an inability to adapt to changing economic conditions, and consequently facing ever worse economic shocks. However, path-dependency can also be seen in a more favourable light, and involve the transfer of positive traditions, productive cultures, organisational solutions and institutions. In the industrial transformation of Central Europe, both the positive and negative understanding of path dependency can be observed.

There are several tools with different goals and possibilities available to achieve more stakeholder involvement. Formal organisations (economic chambers, promotion agencies, local governments, etc.) as much as informal cooperation of economic stakeholders (development coalitions, interest groups, etc.) may play important roles, or a broader social background encompassing education, training, entrepreneurship, and even less tangible cultural elements. Institutional factors, although hard to quantify, have a demonstrable effect on the success of adaptation; their development, although heavily tied to long-lasting legacies, should be one of the foremost concerns of local–regional elites.

In the general sense a cluster is a tool for regional networking, regarding its form it is a voluntary cooperation of firms and organisations operating in the same production chain. It involves businesses and institutions that are capable of increasing the value added in the value chain. The Hungarian businesses have to reach by “clustering” and by closer cooperation with research institutes and universities the size that is needed for being competitive in Europe. In technology intensive industries, formation of clusters is of special importance. From this aspect, all efforts should be made to establish clusters in manufacturing of tools and equipments used for environmental protection. The recognition of this need is indicated by the growing number of clusters in the environmental industry e.g. the First Hungarian Alternative Energy Cluster. The goal of the companies engaged to alternative energy integration is the knowledge dissemination on alternative energy and the promotion of its widespread use.

4.3.5 Addressing the feedstock needs of KBioE projects

Taken into account the deviation of potential estimations, development and testing of a coherent and transparent model could help the use of available biomass resources of Hungary in a sustainable manner. It also could help to ensure all stakeholders about the biomass potential.

Moreover, in line with the findings of Kretschmer et al (2012) the following issues may also be addressed in order to facilitate the takeoff the bioeconomy:

1. Infrastructure: the lack of investment in appropriate on-farm machinery and infrastructure for biomass collection and harvest, as well as lack of local biomass supply chains related to underdeveloped markets and lack of market information
2. Sustainability: lack of guidance on optimal use of straw as soil improver and associated farming practices, thus the ratio of by-product to be removed sustainably cannot be determined. This can lead to an unnecessary high level of straw being incorporated into the soil, which reduces the surplus available for other purposes.
3. Acceptance: given the alternative uses, the underdeveloped market and the previously mentioned lack of information, farmers in many places are still to be convinced that it is worth in long term to change existing practices.

4.4 Converting biomass into value-added products in Hungary

The aim of this chapter is to provide an insight into companies, research institutes and universities in Hungary that can be interested in biorefinery related activities. The main emphasis is on the introduction of the operation, market opportunities and innovation potential of the company. The research institutes are characterized by main fields of research areas.

Given the preliminary nature of the mapping exercise, most of the information presented has been extracted from publicly available sources (such as web pages). These basic pieces of information were gathered by the authors concerning bioeconomy; however, some of the stakeholders have contributed also to the interview. Thus, this chapter is only an insight into the possible Hungarian bioeconomy scheme, but some of the potent players could have been excluded. One possible task of the Climate-KIC Biohorizons project is to deliver more information regarding possible bioeconomy players and also to reveal the whole landscape.

4.4.1 Overview of existing processing plants and refineries

Basically the plants introduced in this chapter can be categorized into the following groups by means of technology applied: biogas, biofuels and others.

Biogas based existing practices in Hungary

Even though there are several biogas factories in Hungary (of which number is far below the potential) running on different feedstock types, here only a few are introduced. The basis of selection was the uniqueness of those factories by means of feedstock (integration), innovative solutions or other aspects.

Magyar Cukor Ltd.

Magyar Cukor Ltd. was established by five Hungarian sugar processing facilities in 1995. AGRANA took over a majority share in the company in 1996 and this step gave impetus to advance on the way to become a European player in the market. In the past decade AGRANA has continuously ensured financial means and know-how for the development. After a rationalization period a firm structure has been established, consisting of the last sugar plant (Kaposvár Sugar Plant) of Hungary, as well as headquarter and sales centre in Budapest. Magyar Cukor belongs to the medium-sized distributors of Europe, it has the sugar production and sales quota of 105 000 tonnes. The company refines agricultural raw materials into high-grade foods and technical products for industrial use. It makes quality products for wholesalers, retailers and industrial customers. Industrial sugar is used in the following industries: alcohol and soft drink production, baking industry, preserve production, fruit processing, dairy products, sweet production, etc. Besides sugar products the company distributes Süssina sweeteners as a wholesaler and retailer, and products of Orafti, Beneo (inulin, oligofructose) and Remy (rice flour, rice starch, rice protein) for further processing in Hungary.

Regarding the bioeconomy field, a modern biogas plant was built in 2007 as part of the Kaposvár facility, which utilizes the extracted sugar beet slices. In this way the facility reduces the process waste while producing energy on-site.

The research and development centre of AGRANA is Zuckerforschung Tulln Gesellschaft m.b.H. (ZFT) in Austria. Within the sugar area, the working focus of ZFT is on the development of new, environmentally friendly and energy-saving applications and processes. Because the economical use of processing aids within sugar production is becoming more and more important, the department of sugar technology have started and implemented projects in recent years to help to reduce the consumption of processing aids.

BioEco rating: This model represents well the possibility of a biobased solution together with by-product stream utilization in order to establish integrated biorefinery. It shows that integration of bioeconomy and realization of innovation, if well implemented, can contribute to more efficient operation of a large scale company.

Budapest Sewage Works Ltd.

Approximately 50% of sewage of Budapest generated in dry periods are treated at the North-Pest and South-Pest plants of Budapest Sewage Works Ltd., whose joint nominal capacity reaches 235 000 m^3/day.

The South-Pest treatment plant – in operation since 1966 – has a biological treatment and a nutrient removal capacity of 80 000 m^3. At this facility constant developments have been carried out, for example the first sewage sludge based biogas plant in Hungary was installed here to provide energy for the operation. The biogas is transformed into electrical and heat energy by two gas engine-generators (their electric performance is 494 kW and 836 kW respectively). The so produced energy covers 90% of the plants electricity needs and 100% of its thermal needs.

A new technology, developed by Organica was installed at the retrofitted South-Pest wastewater treatment plant in November 2012. The biological reactors were transformed into an Organica Food Chain Reactor (FCR), which is currently the world's largest living machine system. The change results in improved treatment efficiency in the biological reactors – translating into lower operating costs – along with a dramatically improved appearance and elimination of bad odours. All these improvements go along with a sewage treatment facility that looks like a botanical garden (more information on the Organica system see in a later chapter). The facility was also completed with a visitor centre where inhabitants can learn about the treatment process.

The North Pest waste water treatment plant was put into operation in 1980 and now treats 155 000 m^3 wastewater a day on average, but from time to time, this quantity reaches 200 000 m^3. In 2007, a large-scale environmental and bioenergy project was launched in order to introduce an energy-efficient and environmentally safe solution for sludge treatment at the plant in form of a biogas reactor. Further investments have been also carried out to remove nutrients (nitrogen and phosphorous) from wastewater. In the framework of these investments, an algae technology line has been built that uses sludge leachate water as a nutrient and consuming the generated CO_2 in the biogas utilization process.

BioEco rating: This chapter shows that the sewage – regardless of its origin, i.e. communal or industrial – is not only a waste stream to handle but a source of energy and probably biobased materials, and thus subject of innovation. In this way processes based on sewage waters are also possible targets of bioeconomy.

Pilze-Nagy Ltd.

Pilze-Nagy Ltd. in Kecskemét is a family enterprise growing and selling oyster mushrooms since 1991. The fresh oyster mushroom traded by the Pilze-Nagy is in compliance with the most severe quality requirements that enable the company to sell its products – besides the domestic sales – on the continuously extended markets of the European Union using its own refrigerator truck fleet. The most important market is Germany, but the sold quantities of mushrooms are significant on the Austrian, French, English and Belgian markets, while demands are increasing in the neighbouring countries (Czech Republic, Slovakia, Romania and Croatia) as well. The trading partners of Pilze-Nagy are normally wholesaling companies and supermarket chains.

The company has a biogas plant that produces 1.2 million m^3 of biogas annually by processing 7 000 to 9 000 tonnes of organic agricultural material. A significant portion (about 3 000 tonnes per year) comes from mushroom cultivation, and the rest is covered by liquid swine manure and maize silage. The resulting biogas is converted to power and heat. A part of the heat is used for covering the biogas fermentor own need, while about 2.68 million kWh annually, is used for heating the mushroom tents. The excess power is fed into the grid.

BioEco rating: The operation of the company is another good example for the integration of waste management into the process cycle, even if the process is not a widely spread application.

ZALAVÍZ Waterworks Company

The main activities of the ZALAVÍZ Waterworks Company are water production, management and distribution, disposal and cleaning of sewage. Now – after having built out provincial public utilities, sewage disposal and cleaning systems – it runs 38 drinking water plants and 8 sewage plants in 124 settlements of Zala County. On its operational premises 120 000 people are supplied with the water services of ZALAVÍZ.

The Zalaegerszeg town sewage treatment facility is equipped with a biogas plant running on sewage sludge. The reason to mention this facility here is that the produced biogas is upgraded in order to provide fuel for the company's own fleet of 12 cars and also a CNG bus running in Zalaegerszeg public transport system. There is the first bio-methane filling station in Central and in Eastern Europe put in operation in September 2010.

As a result of the upgrading process the original methane content of about 70% in the biogas is increased to more than 99% by removing other compounds, mostly CO_2. Biogas upgrading comprises 2 steps: activated carbon absorber is used to reduce hydrogen sulfide (H_2S) concentration and a water scrubbing is used to remove carbon dioxide (CO_2) from the raw biogas. Upgraded gas is compressed (to 200 bars) and stored on-site. The amount of the upgraded biogas is currently only a small fraction of the total biogas produced the rest is converted to heat and electricity.

BioEco rating: The utilization of upgraded biogas as transport fuel carries multiple benefits, mainly by reducing the environmental load of transport, introducing a renewable energy carrier and also directly attracting consumers. This shows the ability of bioeconomy to achieve multiple results and impacts, as well as highlights ways of use those are directly pictured to consumers. This latter case can help to raise perception and also to focus on problems and solutions.

Biofuels-related solutions

There are a total of three first generation ethanol production facilities in Hungary producing for different purposes including fuel ethanol for both domestic use and export. Two of the three plants market other products than ethanol closely related to corn processing. The country's total production capacities exceed the need created by the current EU blending target. The one biodiesel plant delivers the blending component for diesel fuel.

Hungrana Ltd.

Hungrana Ltd. in Szabadegyháza was one of the first Hungarian companies privatized through the selling of the state-owned Szabadegyházi Szeszipari Vállalat. This way the company became collectively owned by both Agrana International as well as Eaststarch (Tate & Lyle and ADM) in 50-50%. Considering the size and product range of the company, it is among the field leaders of European manufacturers. During the process the starch content of the raw material is extracted and processed further into starch, sugar and alcohol products. The raw material is 100% corn from which valuable products are made through wet processing of grains:

- Native starch powder and suspension of corn starch (starch milk) production: In the paper making process starches are used for surface sizing to improve printing characteristics, and as corrugated cardboard adhesives.
- Syrup production: Different types of fructose-glucose syrups are produced, e.g. HFCS – High Fructose Corn Syrup that partly replaced the beet sugar or invert sugar used as sweetener. HFCS is a high-calorie sugar syrup (like sucrose) and its sweetening ability is somewhat higher than that of beet sugar. Various types of glucose syrups

are also produced that can replace crystallised sugar in confectionery industry. Hungrana is the leading manufacturer of isoglucose in the European Union.

- Sugar production: Crystallised dextrose monohydrate, i.e. glucose is a pleasantly sweet, easily digestible sugar with a refreshing taste, which is suitable for use in a wide variety of foods.
- Ethanol production: Different grades of ethanol are produced and delivered to various industries (pharmaceutical, chemical, cosmetic, food and paint industries) and end users (bio content of gasoline in form of E85).
- Animal feed production: A part of the remaining protein, fat, fibre and starch can be utilised as good raw materials in the feed industry. Wet (corn gluten feed) CGF and CGF powder/pellet are non-storable and storable animal feeds, respectively. Corn gluten powder is a product containing concentrated protein and it is recommended as a protein supplement for feeding. Corn germ is a product containing 40-45% germs oil with 95% dry matter. It can be used as oil supplement for feeding.

Within the starch area, the main goal of ZFT (Agrana's innovation centre in Austria) is to develop new application fields for products based on starches and to adjust existing products to special applications. Work within the starch area concentrates on:

- Development of special starch products (potato starch, cornstarch, waxy maize-starch) by means of deriving physically and chemically for applications in various technical fields (paper, corrugated board, textiles, construction, ceramics, pharmaceuticals, etc.).
- Practical technical investigations for widely different areas of technical applications.
- Development of innovative starch products for the construction sector.
- Bio-starches, AGRANA is the market leader in this area for applications e.g. in fruit preparations, mayonnaise, etc.
- In the area of bio-ethanol production: testing and development of wheat varieties that are richer in starch, for the production of bioethanol, and investigations to optimize the production process of bioethanol, in particular through speeding up fermentation, by means of adding special additives (e.g. complex nitrogen sources such as PNC – Potato Nitrogen Concentrate).

BioEco rating: This wide spectrum of products already represents the main philosophy behind biorefinery, namely to convert all possible part of the biomass into value-added products. The starch-related research and development priorities of Agrana also point toward a starch based biorefinery approach by widening the products range with new, innovative solutions. In turn, this can also facilitate the creation of new markets.

Pannonia Ethanol Ltd.

Pannonia Ethanol Ltd. is part of Ethanol Europe Renewables Ltd., produces fuel ethanol and animal feed. The company is located in Dunaföldvár, Hungary. The facility currently utilizes roughly 575 000 tonnes of corn annually, producing up to 240 million litres of fuel grade ethanol, and 175 000 tonnes of Pannonia Gold® Dried Distillers Grains with Solubles (DDGS), a high protein animal feed. The production process at the existing plant uses a closed system, minimizing waste as well as purifying and reusing water involved in the production. Construction of a similarly sized new facility is planned in Mohács, Hungary.

Pannonia Ethanol has a number of opportunities for further development. Some development plans are already presented and awaiting for decision, although there is a real chance for taking effect in short- and medium-term.

ICM Inc., the technology provider of Pannonia Ethanol, is working on cellulose-based ethanol production. If it can be implemented, the plants of ICM technology can be transformed to process cellulosic materials as feedstock, like agricultural by-products (e.g. corn stover) into ethanol.

The largest potential development is based on a recently developed technology. In one of the plants of Fagen Inc. (one of the owners of Pannonia Ethanol), an algae producing site has been brought into operation in which waste heat and CO_2 from the ethanol plant are used to cultivate algae. The management of Pannonia Ethanol already separated land at Dunaföldvár and Mohács for this purpose – the proposed development could use 5% of the emitted CO_2. The algae cultivation in Europe represents a unique, high-level technology in which high quality products for human consumption, such as omega-3 fatty acids, and animal feed can be produced. Currently only the ethanol plants are suitable in Hungary for producing clean CO_2 what is needed for algae production.

There are additional opportunities considered by the owners, for instance the extraction of corn oil, installation of biogas plant (with expanded feedstock portfolio to replace natural gas use by the plant) and investigation of ways to use the waste heat for green houses. There are neighbouring lands available to realize these investments both in Dunaföldvár and in Mohács.

BioEco rating: The vision of Pannonia Ethanol represents the numerous integration possibilities into a factory running on existing and technologically well-established technology. The integration of other, immature technologies can facilitate innovation while contributing also to the improvement of the original process by enhancing efficiency, optimizing by-product streams and reducing wastes and fossil fuel use.

Győr Distillery Co. Ltd.

Győr Distillery Co. Ltd. in Győr has been playing a determinant role in the alcohol market of the region since its founding in 1884. The activity is the production and sale of ethanol of 96% (V/V), and dehydrated ethanol in high quality in bulk. Győr Distillery has almost 100% market share in the Hungarian pharmaceutical industry – which is very sensitive to quality – but it is also present with considerable positions in the food and chemical industry. The company managed to become a supplier for bioethanol both in Hungary and in Europe in 2005. The capacity of the plant is 40 million litres of fermented and distilled ethanol and 26 million litres of dehydrated ethanol in a year. Győr Distillery mainly uses molasses as feedstock but it has a capacity to produce ethanol from grain too. The vinasse (concentrated stillage of distillation) and the residue of grain processing, the by-products of alcohol production, are sold to agricultural companies.

BioEco rating: the Győr distillery company currently carries out no specific advanced bioeconomy related activities; however, as a company having the proper infrastructure it has many ways – as already presented earlier – to evolve.

Rossi Biofuel Ltd. and Biofilter Co.

Rossi Biofuel Ltd. has a biodiesel production plant in Komárom, Hungary in operation since 2008 with an output capacity of 150 000 tonnes of biodiesel component (fatty acid methyl ester, FAME) annually. The facility can be recognized as advanced technology, since partially it processes used cooking oil into biodiesel (besides the usual feedstock of rapeseed and sunflower seed). At the facility the by-products of biodiesel processing are also treated on a sustainable manner; the annually 22 000 tonnes of glycerol is passed to partners for use, while the annually 18 000 tonnes of soap water is used to produce biogas on-site. In 2012 an additional investment was carried out to reduce the methanol use by 25% by installing a methanol rectifier.

The collection of used cooking oil from households is organized by MOL, the Hungarian Oil Company (it purchases the biodiesel for blending), the program started in May 2011 at 100 petrol stations countrywide. Till September 2013 188 tonnes of waste cooking oil was collected and the number of participating petrol stations was expanded to 170.

Biofilter Co. collects the oil from the designated MOL filling stations, and then cleans it before delivering it to Rossi Biofuel plant in Komárom, where it is converted to biofuel and biogas. Biofilter Co. is an environmental social company, specialized in bioenergy sector. It was founded in 1990, and now has a national collection and international processing network. The main profile of the company is supplying the second generation bioenergy sector, by providing the complex process of implementation of reverse logistics from the waste collected. The used cooking oil collection, procession and import of purified vegetable oils provides raw material supplies for biodiesel plants in Hungary and neighbouring countries also. The company also collects expired food and wastes, that is not allowed to be marketed, but can be used to produce biogas. In 2011, for expanding their company profile, Biofilter started to do complex waste treatment, thus it can collect and process 100% of the organic wastes, and 90% of hazardous wastes.

BioEco rating: Another good example is presented, how to make the consumers involved and interested in waste management and reveal the possible connections between energy supply and waste. With altering the route of a by-product stream into a controllable process, the environmental load and risks, as well as the disposed quantity can be significantly reduced.

On the other hand, it shows how the collection of waste can be organized involving different stakeholders realizing large enough costumer basis for business case. The careful planning and management of feedstock supply is so crucial that another company can be required for that.

Other facilities

Nitrogénművek Ltd. [Nitrogen Works Co. Ltd.]

Nitrogénművek Ltd. [Nitrogen Works Co. Ltd.] in Pétfürdő was founded in 1932 and currently the only nitrogen-based fertilizer manufacturer in Hungary. Due to the nature of the products the Hungarian market is entirely transparent, the manufacturers do not apply local strategies, the transactions are public and can be verified with international subscriptions. The main sales priority of the company is to meet domestic market demand; foreign sales are mainly directed into EU countries. The market share of Nitrogénművek is about 55-60% on the Hungarian fertilizer market. In order to reach and serve customers in a more efficient and intensive way the company operates subsidiaries in Serbia, Slovakia and Romania. Nowadays Poland has become one of the most important export markets of the company. In the interest of better service provision for the end users and the renewal of the sales activity, Nitrogénművek has established its direct sales network called Genezis Partner Network. This organization recommends the wide range of Genezis fertilizers with excellent quality.

The main products of the company are the Fertilizer CAN (ammonium nitrate with very fine dolomite powder), ammonium nitrate, urea and fertilizer UAN (Nitrosol, liquid nitrogen fertilizer, the aqueous solution of urea and ammonium nitrate). The distribution of the different chemical byproducts -formed during the process of fertilizer production– nitric acid, liquid ammonia, calcinol, industrial gases – take only a minor part in the sales of the company.

BioEco rating: Based on a written interview, which the authors carried out with a representative of the company, it is clear that there is interest in developing biobased solution. The objective is not the change of current production process and product range, but the use of existing infrastructure and knowledge of engineering and operation for developing biobased industries.

Organica Water, Inc.

Established in 1998, Organica began as a traditional wastewater design-build company focused exclusively on the Hungarian market. During the first nine years of its life the company built over 75 municipal, commercial, and industrial wastewater treatment plants, using a variety of different technologies, for clients ranging from large municipalities to multinational companies such as GM, Audi, Alcoa, Shell, Suzuki and GE. At the same time, Organica invested significantly into R&D with a goal of developing its own IFAS-type (Integrated Fixed Film Activated Sludge) solution for biological wastewater treatment. In 2007 Organica sold its design-build business to focus exclusively on the commercialization of its own biological wastewater treatment solution on a global basis.

Today, Organica is an international company operating on three different continents, and the world leader in Fixed-Bed Biofilm Activated Sludge (FBAS) technology, with dozens of operating references in France, Hungary, and China. Over the past two decades Organica has developed a truly unique approach to biological wastewater treatment, enabling customers to address urban water challenges in a cost and resource efficient manner. Organica's solutions are all founded on the fundamental belief that nature provides the most efficient means to treat wastewater, offering significant cost savings compared to other solutions, and harmonious integration into modern urban lifestyles.

The technology provides a stationary habitat that allows an incredibly diverse and robust biofilm to grow and thrive inside the reactors, ultimately offering significantly improved nutrient removal, energy efficiency, and resiliency, all in much less space than conventional approaches. With nearly two-decades of experience in the development and design of fixed-film wastewater treatment solutions, Organica's FCR (Food-Chain Reactor) represents the best-of-breed in FBAS wastewater treatment plants.

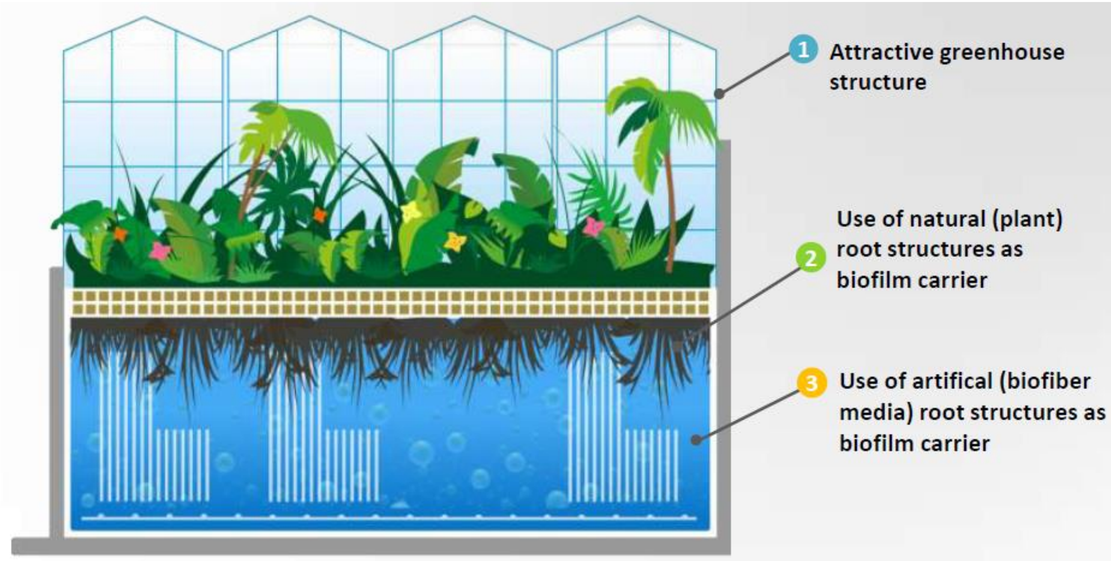

Figure 9. – Overview scheme of the Organica FCR technology

The Organica FCR is a complete wastewater treatment solution including solids removal, biological treatment/nutrient removal, phase separation, and final treatment for reuse quality (if required), all incorporated into a compact, single structure. The biological stage is preceded with a standard pretreatment step and followed by phase separation and final polishing to meet the client's specific effluent requirements.

Following primary treatment the influent travels through the biological cascade, and in doing so the nutrient content is consumed by biofilm cultures that live on both the artificial (Organica's proprietary bio-fibre media) and natural (plant roots) media in each reactor. As a result of the cascade design the composition of the ecosystem fixed in the biofilm changes from reactor to reactor, adapting itself to the decreasing nutrient concentrations. This design results in a small geographic footprint, lower energy consumption and enhanced treatment characteristics. Furthermore, it is applicable to both communal and industrial (organic) waste waters.

BioEco rating: The example of Organica demonstrates that innovative biological (natural) solutions can grow from local start-up companies to globally recognized and sought competencies. Furthermore, the need for sustainable and effective processes built on feedstock available at low cost creates a business case. The role of research and development is crucial in Organica's success. Another factor is that the technology is very consumer friendly providing an easy to use interface for understanding and perception.

Helia-D

The cosmetic company, Helia-D is a producer of different types of creams for skin care those are known of their plant-based active ingredients content. A total of nine patent applications have been submitted to trademark the product line that proves just how innovative the developers are. Among these patents, the first one has an exceptional significance, as it is the patent specification on which the first Helia-D product was based ("cosmetic product with skin and muscle regenerating effects and its manufacturing procedure").

The creams of Helia-D are based on sunflower stem extract. After the discovery and successful testing in the early 1980s, the company began to develop a cosmetic product line. By the mid-1980s the product line had expanded to more than thirty products and several million boxes of cream were being sold each year. A couple of years later, the cream even became a sought-after product on the American market.

The sunflower stem supports a flower with seeds that is very heavy in relation to the mass of the stem, and does this without breaking. Additionally it is flexible enough to follow the direction of the sun, while the plant's cells suffer no damage during all of these processes. The substance that makes the sunflower stem flexible is called auxin. Elasticity and firmness are two essential features of young skin, and auxin can provide the same benefit for human skin as it can for the sunflower stem through its ability to regulate protein synthesis. In practical terms, products with sunflower stem extract can be regarded as promoting collagen and elastin fibre production (by means of the auxin stimulating protein production). These fibres support the skin elasticity, enhance facial muscle function, and reduce wrinkling and looseness.

Not only the stem but also the seed (more exactly the seed oil) has favourable characteristics. Due to this reason the cosmetics industry uses considerable amounts of it. Linoleic acid is present in the oil in great amounts (58-60%) and it reduces water loss through the skin to prevent drying. Sunflower oil is absorbed well by skin, enhancing skin's protective abilities by maintaining the lipid-water balance, making skin velvety soft to the touch. In the unsaponifiable portion of the oil (about 1%) there are valuable phospholipids, lecithin, antioxidant vitamin E, all of which play important roles in cosmetics and nutrition.

BioEco rating: The case of Helia-D varies from the others, since it is neither connected to energy nor to waste treatment. Contrarily, it presents the possible uses of unique biomass components from an agricultural by-product. Biomass, depending on its type can contain special compounds of which extraction and purification result in a high added value. In order to improve the economic feasibility of biorefinery minor components of the feedstock should be more considered, since extraction of them can bring breakthrough.

TERRA HUMANA Ltd (3R Recycle-Reduce-Reuse Zero Emission Carbon Refinery technology)

TERRA, since 1989, has been an internationally leading, applied research and development based engineering company in the field of biochar solutions for the temperate climatic zone country markets (EU28, Australia, Japan, USA). The core competences are the biochar products and the original solution of zero emission pyrolysis processing, transport biofuel refining, biotechnological solid state fermentation and formulation. The mission is to develop, industrial engineering design and manufacture of novel bio-waste and biochar based technologies and added value organic waste treatment systems, resulting safe biochar products for agriculture and environmental industries. TERRA has developed and designed four generations of biochar scale ups from scientific laboratory scale and successfully tested field demo plants to full industrial scale. Since 2002, TERRA has been coordinator, key science and technology designer for several large scale EU Framework Research Programmes, including FP5, FP6, FP7 and CIP Ecoinnovation. The company has established an extensive scientific and SME industrial networks developed in 10 EU countries and in Australia with large number of stakeholders applied R&D partners, universities, institutions, SME and industrial organizations.

Between 2011-15 the company coordinates the EU FP7 REFERTIL project with the mission to contribute to the transformation of organic waste, food industrial by-products and farm organic residues from a costly disposal process into an income generating activity. One of the key objectives of the REFERTIL project is to provide a strong policy support for the EU Commission in revision of the Fertiliser Regulation (Reg. EC No. 2003/2003) and possible inclusion of biochar – as organic fertiliser and soil additive.

The 3R zero emission carbon refinery concept is equally important from the aspects of environment protection, climate change and high added value waste processing with carbon negative applications for the agricultural and food biomass streams. The 3R technology focuses on the followings:

1. Advanced 3R (Recycle-Reduce-Reuse) process technology development, industrial engineering and manufacturing. Low temperature carbonization (zero emission thermal processing) and integrated biotechnological operations for high added value conversion of agricultural and food industrial biomass streams into safe products. The main product is biochar, while the by-products are converted into biofuels.
2. Innovative and safe biochar products development for soil improvement and organic fertilization, restoration of natural balance and functionality of degraded continental agro soils with controlled microbiological activity and natural plant nutrient supply for sustainable, improved, economical and ecological food crop production.

Figure 10. – 3R zero emission pyrolysis industrial plant

The company has two advanced and well equipped research laboratories and field demo test facilities in Western Hungary with 12 high qualified work force and extensive SME cooperation on international level. The 3R pyrolysis center is dedicated to innovative and advanced agricultural, environmental, industrial technology scale ups and field demonstrations under different EU programmes. The specific works include pyrolysis technology and biomass added value biotechnological utilization processes, towards commercial production of animal bone biochar and natural phosphorous/nitrogen fertilizers.

The field demonstration of the advanced 3R design and innovative technology is the critically important bridge from the practical science and knowledge into industrial and SME application orientation, engineered scale up design development and economical commercialization. The 3R site installation and operations are authority permitted, including official authority permit for specific biochar production and application for open ecological soil environment use.

The “3R Pyrolysis” Center is suitable for renewable energy, biomass valorization and innovative agricultural biotechnology demo-training opportunities. Based on the field demo equipments of the center, it is possible to carry out a range of operations: from advanced applied science to economical scale up and industrialization of pyrolysis, solid state fermentation, agrobiotech and transport biofuel technologies.

BioEco rating: This case presents a very conscious, advanced and original solution environmental development for the temperate climatic zone country markets and conditions in the field of carbon refinery and recycling. TERRA is highly successful to develop advanced science and technology, furthermore transfer its multidisciplinary knowledge into economical industrial programmes through field demonstrated technology and product testing in ten EU countries.

Nitrokémia Environmental protection Consulting and Ministering Inc. Co.

The original company was established in 1921 with the sub- or hidden war industry profile to produce gunpowder and explosives. In the 1960s the production profile of the company changed significantly to replace war industry with chemical industry producing organic chemicals, paints, solvents, pesticides and insecticides and their production intermediates.

In the early 1990s the plant was producing a wide range of products – extending way over its original purpose – on more than 600 hectares of land. The state-owned Nitrokémia Industry Settlement was transformed into a PLC in 1993. The company is still 100% state owned, but its recent core activities are environmental protection and asset management.

Hunest Biorefinery Ltd., a project company, which is 50% owned by Nitrokémia, started the technology design of a biorefinery in Balatonfűzfő, and the preparation of the associated detailed feasibility study, which contains the initial environmental licensing of the facility. The “Balatonfűzfő biorefinery project” is envisaged to implement a model biotechnology facility where biodegradable polylactic acid, nutrition gluten, lactic acid, as well as ethyl and butyl lactate solvents are made, at present from wheat (starch) as raw material. In the plans the biorefinery will be supplemented with a biogas plant processing the waste water. The initial input capacity is set to 25 000 tonnes of wheat annually with the possibility to expand it to 100 000 tonnes in the future. According to the project, non-food plants may occupy a vital role in the enhanced production capacity.

According to the latest news of April 2011 the project is waiting for permits and investors. However, there is no publicly available information about developments in the last two years..

BioEco rating: If the project realizes it will represent the first real biorefinery in Hungary. The project seems to be very promising; however, also shows that despite a good design the planning and financing problems can hinder a project.

Enin Nova Ltd.

The company has developed a process for eco-methanol production based on municipal solid waste (MSW) via the syngas route. A pilot facility was built at Miskolc MSW disposal site that produces 300-330 kg methanol from 1 tonne organic part of MSW (supplemented with sewage sludge and forestry/agricultural waste). The company seeks the possibilities to upscale the facility and to build new plants.

The technology uses modified gas and solid flow direction and high carbon bed temperature. In this regime the syngas has no toxic organic (for example dioxins and tar) or inert components. The vapour and tar are separated and fed back into the combustion zone in order to solve the residue problem and to protect the catalyst of methanol production. The CO_2 is not released from the system but it stored and sold in liquid form, unless it is used in methanol production using wind and solar energy. The innovation is registered in the USA, EU, China and Former Soviet Union.

BioEco rating: One of the biggest challenges what humanity faces is handling of municipal solid waste. Innovations, like methanol production via syngas can be solutions to process the huge amount of forming waste into a value added product and decrease GHG emissions (contrary to landfilling). Moreover, manufacturing of syngas makes it possible to prepare not only one substance but a wide range of synthetic products.

4.4.2 Key R+D stakeholders and research centres

Hungarian Institute of Agricultural Engineering

Strategic aim of the institute is the realization of sustainable, marketing-conscious rural development through the enlargement of environmental resources. To this end, cooperating with other professional areas, it conducts research programs and developments with the use of valuable information in machine research and the measurements of rural lands and the environment, which result in competitive goods and services and contribute to the success of rural areas.

The institute has several accredited laboratories: the agricultural field testing laboratory, the energetic examination laboratory and the plant protection machine examination laboratory.

Research activities related to bioeconomy

Energetic examination laboratory with the main task of examination of renewable energy carriers and their utilizing apparatus:

- analysis and classification of biomass combustion furnaces: testing of furnace capacity and emission
- analysis of biocombustibles and biofuels: testing of chemical, physical, combustion

and mechanical properties

Department of Applied Biotechnology:

- Utilization of biomass for renewable and clean energy (agropellet, biodiesel), green chemicals (pharmaceuticals, other industrial raw materials, biopesticides, bioherbicides), functional food and feed;
- Detailed qualitative analysis of soil, fresh- and waste water, food, feed and biofuels (biogas, biodiesel, bioethanol, agropellets).

Bay Zoltán Nonprofit Ltd. for Applied Research – Institute for Biotechnology (BAY-BIO)

Bay Zoltán Nonprofit Ltd. for Applied Research is Hungary's leading applied research institution. It includes the Biotechnology Institute of Szeged (BAY-BIO), which was the first established organizational unit. The activity of the Ltd. and BAY-BIO within the biotechnological sector forms a technological bridge between the phases of basic research and experimental development.

The objective of BAY-BIO Department of Applied Microbiology is to implement targeted projects of methodological and technological development that meet the demands of industrial partners.

- Biorefinery: Utilization of industrial by-products and waste (utilization of whey as raw material for biogas, carotenoid synthesis and additive substance for environmental protection), measure biogas formation.
- Biocatalysis: design catalysts and integrate them into chemical industry technologies, synthetize compounds (e.g. malic acid, carotenoids).
- Algae biotechnology: design algae reactors and product development based on algae biomass.

The research projects newly launched by BAY-BIO Department of Industrial Microbiology are organized around renewable energy development:

- converting CO_2 into methane using bacteria
- CO_2 capture by algae and utilization of algal biomass
- study of the operation of microbial fuel cells
- real-time monitoring of bioethanol production

Budapest University of Technology and Economics, Department of Applied Biotechnology and Food Science

The 'Non-food' biotechnology working group at Budapest University of Technology and Economics (BME) has more than 20 years of experience in the field of biomass conversion. Extensive experimental and modelling knowledge has been accumulated regarding different conversion routes for bioenergy (second generation bioethanol and its subprocesses, sweet sorghum based bioethanol, biogas, biorefinery for xylitol production, etc.). The knowledge creates a collection of versatile technology options to convert different biomass into value-added products with an integrative aspect and modelling capacities. In the future, this knowledge could be expanded and used for learning and good practice sharing, as well as optimized to the demands and attributes of other bioeconomy stakeholders in partnership.

Cooperating with the Lund University, Sweden, the research group participated in the design of a lignocellulosic ethanol pilot facility in northern Sweden by performing a techno-economic study. Hungarian industrial partners of the group are Győr Distillery Co. Ltd., Hungrana Ltd., UTB Envirotec Ltd., and Budapest Sewage Works Pte Ltd.

Main activities are the technological and economic modelling (ASPEN) of innovative bioenergy conversion routes. Additionally, the laboratory is equipped with ethanol fermentation monitoring system and facilities suitable for enzyme production and characterization.

Key research activities - experimental facilities

- characterization of biomass
- biomass pretreatment / extraction of certain substances from biomass (e.g. arabinose) / biomass fractionation
- enzymatic hydrolysis of the pretreated biomass to obtain fermentable sugars
- fermentation of ethanol, xylitol
- anaerobic digestion
- kinetic modelling of certain process steps e.g. enzymatic hydrolysis
- process simulation with Aspen Plus and economic evaluation

Development of fermentation up-stream and down-stream processes

- mathematical modelling and flow-sheeting of fermentation processes and unit operations
- „white" biotechnological (biorefinery) developments
- fermentation of lactic acid
- enzymatic bio-conversion of 1-3 propane-diol

Szent István University

Szent István University is one of the leading higher education institutions in Hungary. It has nine faculties and one institute, located on seven different campuses. It is one of the most important research centres in Hungary, concentrating on agricultural and environmental sciences. The scope of education is quite broad, as in addition to conventional fields of agricultural sciences, there are courses in veterinary medicine, environmental sciences, mechanical engineering, economy and social sciences, architectural sciences, water supply management, medical sciences, as well as applied arts.

The university has the environment and sustainability in the focus of the education and research as well, which is characterized by the high number of the research groups related to bioenergetics:

- Climate Change Economics Research Centre
- Regional Economics And Rural Development Research Group
- Motor Fuels From Renewable Sources Research Group
- Research Groups at the Department of Environmental Economics

University of Debrecen – Centre for Agricultural and Applied Economic Sciences

The Centre for Agricultural and Applied Economic Sciences is the centre and coordinator of agricultural higher education, research and extension in the Trans-Tisza region. Its mission is to develop agriculture, environment and rural areas in Hungary. The institution's activities contribute to the development of Hungary and enhance the international reputation of the country.

The institution trains highly qualified professionals in the field of agriculture and technical engineering, as well as innovative experts with theoretical and practical knowledge. Outstanding managerial skills are acquired for food industry, environmental and nature protection, game management, service sector, technical administration and financial institutions.

In research and education the institution applies the latest results of agricultural and related sciences, the principles of sustainable economic and natural resource management and development, and the achievements of national and international intellectual progress. It is highly committed to the values of European integration and through its activities it contributes to the development of a sustainable economy and to the scientific foundation of understanding, preservation and effective utilization of the environment. In order to perform the fundamental tasks on a higher level and to complete its mission, the Centre maintains wide-ranging educational and research links to other faculties and institutions of the University, which are mutually beneficial in all areas of training and research.

Faculties

- Faculty of Agricultural and Food Sciences and Environmental Management
- Faculty of Applied Economics and Rural Development

Research Institutes and Study Farm

- Debrecen Farm and Regional Research Institute has the following tasks: implementing practical instruction of the agricultural engineer training going on at the different faculties; undertaking determinant functions of the existing practice firm network; providing the conditions of postgraduate practical training; implementing the practical conditions of technical assistance; implementing the practical conditions of R&D tasks and innovation; carrying out development work in the area; supporting rural development tasks related to agricultural production and market production on a commercial basis.
- Research Institute of Karcag has four main areas of research activity: research related to soil protection, cultivation, and nutrients management; plant breeding, seed-production; grassland management, sheep-farming; and land utilization, rural development.
- Research objectives of Research Centre of Nyíregyháza are the followings: to establish sustainable development in the region, to research the complex utilization of sandy soil, to provide the genetic basis of plants suitable for growing under the ecological conditions of the area, to develop the foundations of an environmentally sound farming. The centre’s activities also embrace the dissemination of knowledge and experience in the area of ecological farming, research into produces serving as a basis for functional food, agricultural recycling of by-products and research into renewable energies.

University of Miskolc

With its highly qualified academic staff, well equipped laboratories, instruments and equipment, the Miskolc University is a major research centre of national scientific research and technical development. The series of research activities going on at the university comprise fundamental, applied and development research in the following fields: natural, technical, social and medical sciences, as well as the humanities and arts.

Regarding bioeconomy the university has two departments dealing with bioenergy

- The Institute of Raw Material Preparation and Environmental Processing has research projects on bioethanol productions with an engineering approach
- Alternative fuel (biomass and waste) Research Lab – Faculty of Agricultural Engineering Science: The main profile of the laboratory is the combustion analysis of biomass and other fuels (wastes, conventional solid and liquid fuels) and characterization of the end products. In addition, solid fuel burning processes are tested and modelled in the experimental combustion equipment.

University Of Szeged

Agricultural education has a 115 year tradition in Hódmezővásárhely. The college became, after several reorganizations, a faculty of the University of Szeged in 2000.

Research fields

- breeding, reproduction, nutrition and health of cattle, pig, poultry, sheep, roe deer and wild boar;
- fermentation of silages,
- the effects of agro techniques, chemicals and plant breeding on the yield and quality of arable crops;
- micro-propagation of ornamental plants and breeding of pritamin paprika;
- pollination by insect fauna of cultivated plants;
- water purification by constructed wetlands;
- biogas production from communal waste and biomass;
- business management, innovation and valuation of farms;
- marketing of agricultural products and foods;
- resources and strategic planning of rural areas.

Biogas and hydrogen production from organic wastes is investigated at the Institute of Biology at the Faculty of Science and Informatics. The most significant research activity of the team, which has developed in collaboration with the Institute of Biophysics, the Biological Research Center and the Hungarian Academy of Sciences, is focused on hydrogen production by biological systems. The extension possibilities of the technology's life span, and the methods to increase the working stability of the hydrogenase enzymes, one of the key molecular players in these systems are investigated. A range of related basic and applied development projects are studied as well. One of their outstanding achievements is the internationally registered patent for a method that increases biogas production by 30 - 50% by adding specially selected hydrogen producing mesophilic or thermophilic bacteria.

Methods are also being developed that provide the opportunity to engineer microbial communities that are able to utilize optimally the available raw materials, and are also exploitable in the daily operations of biogas facilities. This way, the efficiency and the security of biogas producing power plants can be significantly improved due to the results of an exciting new basic research project on the understanding of the relationships within microbe communities.

Károly Róbert College

The College has carried out numerous research programs, in order to determine the most effective ways to produce and utilize green energy in Hungary and in the North Hungarian region. One of the topics of these experiments is the selection of those trees that have the greatest energy output in particular habitats.

The researchers of the College have worked out the Social Green Energy Program and the Forced Vegetable Program Based on Renewable Energies. The College initiated the setup of the Mátra Wood Splitting Cooperative in 2008; in March 2010 it founded the Mátra Energy Plant Production Ltd, which planted 500 acres of energetic tree plants in 3 years. The Bioenergetic Innovation Cluster has been operating since 2009 under the auspices of the College. The 1 MW-power wood-splitting boiler, which provides heat energy for a 2000 m^2 greenhouse, is located in the Green Energy Research Center in Tass-puszta.

Faculty of Natural Resources Management and Rural Development

- solid biomass utilization for heat recovery,
- biomass and fermentation of organic materials (eight research units),
- research and development of liquid biofuels (biodiesel, bioethanol)

Fleischmann Rudolf Research Institute

The institute carries out research on crop production in arable lands in the region aiming to enhance production effectiveness and to define new utilization methods. The institute has opened new tracks towards environmental management and sustainable agriculture too:

- plant sublimation,
- agro technology,
- nutrient management,
- plant protection,
- energy analysis of arboreal plants.

University of West Hungary

Legally and practically, The Faculty of Agricultural and Food Sciences is one of the longest established institutions of agricultural higher education in the world. Successfully combining education with research, the professorial staff of the institution founded ten experimental stations in Mosonmagyaróvár in the late 1800's, thus establishing the professional agricultural research system in Hungary. The main directions of research are plant, animal, food, agro-engineering, social and economic sciences.

The Faculty of Agricultural and Food Sciences is organized into nine institutes:

- Institute of Animal Science;
- Institute of Plant Biology;
- Institute of Plant Production;
- Institute of Food Science;
- Institute of Mathematics, Physics and Informatics;
- Institute of Biosystems Engineering;
- Institute of Environmental Science;
- Institute of Economics;
- Institute of Corporate Economics and Management Science;
-

The major R&D&I projects of the Institute of Biosystems Engineering include:

- Effects of microwave treatment on various biological and agricultural materials;
- Examination of processes in biological materials as a result of combined energy transfer;
- Utilization of renewable energy sources;
- Determination of soil moisture levels in the region of the river Danube;
- Research on plant-based biofuels with special emphasis on vegetable oils;
- Research on soil heterogeneity, plant protection and agricultural engineering issues for precision farming purposes;
- Measuring the agro-physical parameters of biological materials; thermophysical modelling;
- Investigation of *Chlorella* strains.

The Faculty of Forestry carrying out research in the following areas: the forest as an ecosystem, the natural and economic conditions of forest management, impact assessment of the changing environment (e.g. climate change), nature conservation, wildlife biology - wildlife management, molecular bases of the physiological processes of forest trees and dendrochemistry.

In order to increase efficiency and expand the scope of research themes, the faculty cooperates with Hungarian scientific institutions, with professionals at academic and scientific institutions (Forest Research Institute), and with researchers at the partner universities and industrial research centres. The faculty has traditionally good connections with forest managers and the supervisory bodies of the individual disciplines. Having a high level of basic research, the education program is continuously updated to meet demands of the industry and requirements for scientific and technological research. The focus of research is on results that can be applied in practice.

Knowledge and research centres

The concentration of the research, development and innovation activities of the institutes and the utilization of the faculty's intellectual capacity for the industry is managed by two independent organisational units.

1. The Environmental Cooperation Research Centre was established to enable a quick practical application of the R&D results in the field of environment, environmental resource management. The R&D activities of the centre are divided into three distinct research areas:
   - Environmental impact assessments;
   - Waste management and recycling;
   - Eco-energetics.
2. Forest and Timber Utilization Regional Knowledge Centre (ERFARET), was established with the Faculty of Wood Sciences to enhance forest and timber utilization in the region working effectively and intensively with the business sector. The Forestry Faculty cooperates with ERFARET in the following research areas:
   - Development of forest resources management in the region;
   - Nature-oriented forest management and forest conservation,
   - Technical development of forest management;
   - Establishing conditions for sustainable wildlife management.

   The R&D work of ERFARET has gained nationwide recognition. The funding scheme for research at universities is continually changing, and to get additional grants, the tender system will be used. Lately faculty members achieved excellent results in tendering. Beyond the development of instruments, the IT network and infrastructure, recent grants provide scope and facilities for the mobility of teachers, researchers and students, and open doors to the extension of libraries and facilitate the organization of conferences.

University of Pannonia

The Research Institute of Chemical and Process Engineering performs basic research with application potential and also applied research in the fields of technical chemistry, biochemistry with the propose of establishing new units and processes of technological applications. Second generation biofuel processes and different pretreatment methods are investigated in the institute.

The Department of Process Integration and Intensification aims to deliver schemes, research and educational tools for economic and environmental evaluation of the waste to energy conversion, integration or other renewable sources of energy and application in the industry and in the city of the future. European industrial and domestic sectors stimulate introduction of more efficient and advanced waste to energy management systems to reduce emissions, improve energy efficiency and to effectively utilize waste energy sources.

Biomass utilization and fermentation research topics of the Department of Bioprocess Engineering are:

- lignocellulosic bioethanol production;
- microbial production of organic compounds (e.g. succinic acid) with more functional groups;
- biofuel production from microalgae;
- biogas research.

Main research topics of The Department of Process Integration:

- Integrated energy management framework in waste to energy
- Life cycle analysis and supply chain analysis
- Integration of renewable sources of energy into energy supply chain

4.4.3 Industry engagements: Clusters and industry associations

There are many Hungarian clusters and associations related to bioenergy and biotechnology, however, current activity is questionable in some cases; therefore more effort is needed to map the clusters and attempt to bring them to a common ground for more effective management.

The Hungarian clusters and associations are organized mostly locally or regionally and not really on the basis of their members' activities. Consequently there are numerous players in the field of biotechnology but their operational areas overlap each another. There are exceptions but they do not seem to be efficient enough because of the small cluster membership.

We think that the cluster system could function more efficiently in a small country like Hungary if the clusters are organized rather on the field of activities than on the local positions.

Hungarian Biotechnology Association (Magyar Biotechnológiai Szövetség)

The Hungarian Biotechnology Association (HBA) was established by Hungary's leading human biotechnology companies with the aim of promoting the development and representation of the Hungarian biotechnology sector. The HBA's major objectives include obtaining support for the continued development of national life sciences and the commercialization of scientific achievements as well as representing both Hungary and its members at international exhibitions and conferences.

HBA regards the representation of Hungary's biotechnology sector as its most important activity. Furthermore, the HBA's goals include winning governmental support for the biotechnology sector – in order to reach this, the organization prepares documents and carries out harmonized lobbying activities. HBA is also a member of various international biotechnological organizations such as EuropaBio (http://www.europabio.org/), the Biotechnology Industry Organization (www.bio.org) and the European Federation of Biotechnology (www.efbweb.org).

HBA regularly forwards information and enquiries about international conferences, grants and events to its members and acts as a coordinator in emerging collaborations. HBA also represents its members at major international conferences and exhibitions where it displays company posters, brochures and flyers. The most important contact details of its members and direct links to their websites can be found at HBA's website.

HBA is located in Szeged and the most relevant biotechnology firms are represented in the list of members such as the biggest Hungarian pharmaceutical factories and other biotech companies, but there are only a few universities and research institutes. Eleven committees are within HBA, the leaders of them and the whole board of the HBA are assembled from the main R+D and industrial members.

HBA is running actively, representing the majority of the whole (red, white, green) biotechnology industry in Hungary. It has recently released the Biotechnology in Hungary, Sector report 2012 that contains statistics and vision for the Hungarian biotechnology industry.

Hungarian Biogas Association (Magyar Biogáz Egyesület)

The Hungarian Biogas Association was formed with the hope that it would provide an informal forum of the exchange of scientifically based information about biogas. It aims to bring together research laboratories, planning and development institutes, agricultural and industrial organizations, developers, researchers, technical and financial experts, politicians and any other citizens interested in the future of our society. The forum provided by the Association guarantees continuous and free exchange of opinions and provides a creative working environment.

The aim of the Hungarian Biogas Association is to create an intellectual working environment, to assist in the presentation, research and education about scientific, technical and financial issues regarding the production and use of biogas. The Association's aims are considered to be of general public value, thus it is qualified as a public service activity that performs this non-profit work as a public service association. The Association carries out scientific activities, research, education and the distribution of information. The Hungarian Biogas Association intends to reach its aim through the organization of presentations, study trips, continuing education courses, panel discussions and conferences on biogas.

The Association appears to be active. There are some international members, it helps to establish cooperative work with national and international partner associations and partnerships between Hungarian and international (particularly EU) biogas experts, as well as to disseminate information on the subject. The news and events on the webpage of the association serve the researchers in all biogas related areas and contribute to making biogas widely popular and available.

National Biomass Cluster (Országos Biomassza Klaszter)

The National Biomass Cluster was established from independent companies, individuals and the associated economic, educational and non-profit institutions as members that are directly or indirectly related to the production or marketing of biomass, using each other's products and services, based on a similar knowledge and infrastructure.

The aims of the cluster are:

- to promote networking and cooperation among the organizations related to biomass
- to enhance innovation performance in enterprises and to increase the efficiency of the existing cooperation,
- improving supply chain capabilities and implementing more effective supply system,
- to facilitate and speed up the process of becoming a supplier in the cluster.

It seems that the National Biomass Cluster is currently not working.

Union of Biomass Product Line (Biomassza Termékpálya Szövetség – BITESZ)

The Union of Biomass Product Line intends to be a “bridge” between the Hungarian governance and biomass utilization in practice. The previously highly ambitious BITESZ has no new/current information available on its website. The Union is located in the capital, Budapest, and its Advisory board was renewed in 2011 involving key people from the main biomass utilization fields.

The association has set a target to cover the full supply chain of energy production from biomass and contribute to the presentation of the chain from the production of biological bases to the end-user tasks. Spreading of financial literacy and tender watch are among the aims. The association intends to work closely with all interested governmental bodies.

The founding members of the association includes the agricultural and other biomass producers in addition to academic institutions interested in the bioenergy topic, the technical supply (asset sales) organizations, representative professional organizations in the agricultural sector and public bodies. Among founding members there are some end-users, such as the Hungarian Electricity Ltd., the Regional Development Holding Plc. and the Hungarian Development Bank Ltd.

Biogas and Biorefinery Cluster (Biogáz és Biofinomító Klaszter)

The Biogas and Biorefinery Cluster was created in Győr in 2008 by six founding members with the original name of Biogas and Fermentation Products Cluster. The cluster was created by Sokoró Naturezone Ltd. and aims to connect renewable energy production and rural development. Its mission is mitigating climate change due to the use of renewable energy sources, to which belongs biomass utilization (directly as solid fuel, biodiesel production and anaerobic fermentation to biogas or ethanol).

The Cluster aims to contribute in strengthening of companies participating in the cluster by:

- flowing private information of economic, scientific informations;
- common investments in order to reduce operational (production)costs;
- operation of feedback mechanisms in the continuous upgrading of fermentation technologies used in the cluster (innovation).

The cluster is ambitious to become a significant actor of the bioenergy field in the north-western part of Hungary. It has already 7 other industrial members from this region and present itself on the most important events. The Cluster has its own periodical with 4 issues in 2012. No current activity is visible on the website and despite of the name no biorefinery related activity can be connected to the Cluster.

Hungarian Bioethanol Association (Magyar Bioetanol Szövetség)

The Hungarian Bioethanol Cluster was founded in 2011 by 11 members. Founding members represent the entire ethanol industry in Hungary encompassing all actors from feedstock production to use of ethanol. The Hungarian Bioethanol Association is a member of the European ethanol industry organization – ePURE.

The Hungarian Bioethanol Association aims to promote the use and spread of fuels produced from renewable raw materials possibly by green technology in Hungary and Central Europe with the least possible environmental impact creating opportunities for sustainable development. This association supports the most extensive use of bioethanol to promote government action and regional programs through lobbying and promoting programs.

The association is also responsible to transfer the latest important professionally correct data and knowledge to the members, the press, policy-makers, fuel producers, users, vehicle distributors and the public. The association organizes trade forums, visits relevant events and supports the research.

The association is active, organizing events and preparing position papers.

Bioenergy Innovation Cluster (Bioenergetikai Innovációs Klaszter)

Bioenergy Innovation Cluster, based in Gyöngyös, was founded in 2007 by eight members. Currently the number of cluster members is 48 plus one supporting member. The Cluster intends to create a voluntary cooperation network of organizations that are active in the renewable energy sector. An additional objective is to promote coordinated activities of the value chain actors, to enhance innovation performance of the participating actors and/or associated companies, and increase the efficiency of existing collaborations.

The Cluster’s mission is to contribute the development of existing and new, innovative bio-energy technologies, and to set concerted targets and implement by coordinated activities of companies operating in the sector.

To achieve the objectives the Cluster cooperates with national and international partner organizations. The Cluster programs are financed from local, regional, national and international projects and supported by the members. The website of the cluster contains no information about current activities, not even the member list is available.

LEADER Association of Bükk-Region (Bükk-Térségi LEADER Egyesület)

The LEADER Association of Bükk-Region (local action group, HACS) is a descendant of a very ambitious association based in a small village in North-East Hungary, Bükkaranyos. It was renamed in 2012 because of the law but the activity of the association remained, it has 145 members (42 members of the public, 61 members of the civilian community and 42 members representing the business community). It is a cluster that involves local small towns and villages from the region of Bükk Mountains that are located in a ring around the town of Miskolc. This is another way of the clusters in the bioenergy sector that can be successful in Hungary.

The aim is to contribute to the sustainable development of the smaller settlements of the region using clean technologies and renewable energy sources in accordance with the national rural development policies, supported by EU programs. The cluster started the “1 MW 1 village” program, where the principle is reflecting the self-supply decentralized philosophy. This association is not a typical bioenergy association but it deals with that type of energy source and seems to be efficient in combining and utilization of local energy sources and the support channels.

The cluster is very active in delivering projects in a complex manner based on the accepted local rural development strategy 2008-13. Moreover, recently the University of Debrecen and the cluster signed an agreement that the University will establish a department of renewable energy in Bükkaranyos, where the centre of the cluster is located.

4.4.4 Addressing the data and refining needs of KBioE projects

Based on this preliminary mapping it is already clear that there are several players in Hungary who could contribute to a possible KBioE project (based on the currently running project portfolio including biogas upgrading and succinic acid production). The spectrum includes stakeholders from near all technology options (lignocellulose based technology, biogas production, thermochemical conversion, etc.). There are also clusters and/or associations that cover the given sector and in case of a possible cooperation more stakeholders could be reached and involved.

However, in order to realize a coordinated and successful approach the stakeholders must know about each other in order to find the complementing activities and to build up a complex project.

4.5 Demand side assessment of bioeconomy products in Hungary

In line with the previous chapter and with the results of the interviews, it can be stated that not only the product side but the demand side towards biomaterials needs to be mainstreamed in order to have a functioning market and a mature bioeconomy. Despite its importance, the preliminary mapping could not reveal any potential stakeholder in this field.

4.5.1 Market assessment to establish range of substitutable products

No market assessment could be obtained regarding Hungarian situation. Due to the lack of methodology no primary assessment has been carried out.

4.5.2 Demand side stakeholder engagement

Taking into account the products arising from biorefinery, the following sectors could be interested:

- energy sector,
- pharmaceutical companies,
- chemical industry.

In all cases there are companies in Hungary active on the field, however, since it is not their main activity; their attitude towards biobased products is unknown at the moment. Hence, as it is also supported by the findings of the interview, efforts should be made to involve them.

4.5.3 Gaps and possibilities – potential connection points to KBioE

This information gap should make the KBioE aware that it is very necessary to study and attract the demand sector. To this end, a survey aiming to know the possible buyers should be conducted and also the general public perception should be assessed.

For Hungary, a survey methodology development and an awareness raising project targeting the possible demanding companies with emphasis on possibilities and business cases could help the takeoff of the industry.

4.6 Promoting KBioE and bioeconomy in Hungary

Bioeconomy is a science and innovation oriented field, however, marketing and networking are also important factors. The possible biobased start-ups need to be presented and introduced for the wider public. There is growing need to establish an innovation ecosystem, and currently there are a few organizations facilitating networking and providing opportunities for start-up to step forward. Nevertheless, there is no bioeconomy specialized player in this sector, the below presented organizations do not act in a sector specific way.

4.6.1 Stakeholders promoting innovations

The Governmental R&D structure and the role of the National Innovation Office

The Hungarian Government launched the new RDI policy and measures including a comprehensive review of support programs, starting new programs, management system and related institutional transformation, and improvement of the relevant legal framework. Research and development, innovation and the governance of science policy at governmental level, conceptual reorganization brought about significant changes. The laws regulating the research, development and technological innovation of powers and responsibilities are divided as follows:

- The Minister of National Economy is responsible for R&D and technological innovation.
- The Minister of National Development is responsible for the developmental policy, targets managing the development, regulation and control of development.
- The Minister of Public Administration and Justice is responsible for the coordination of science.
- The Minister of National Resources is responsible for the governance of science policy.

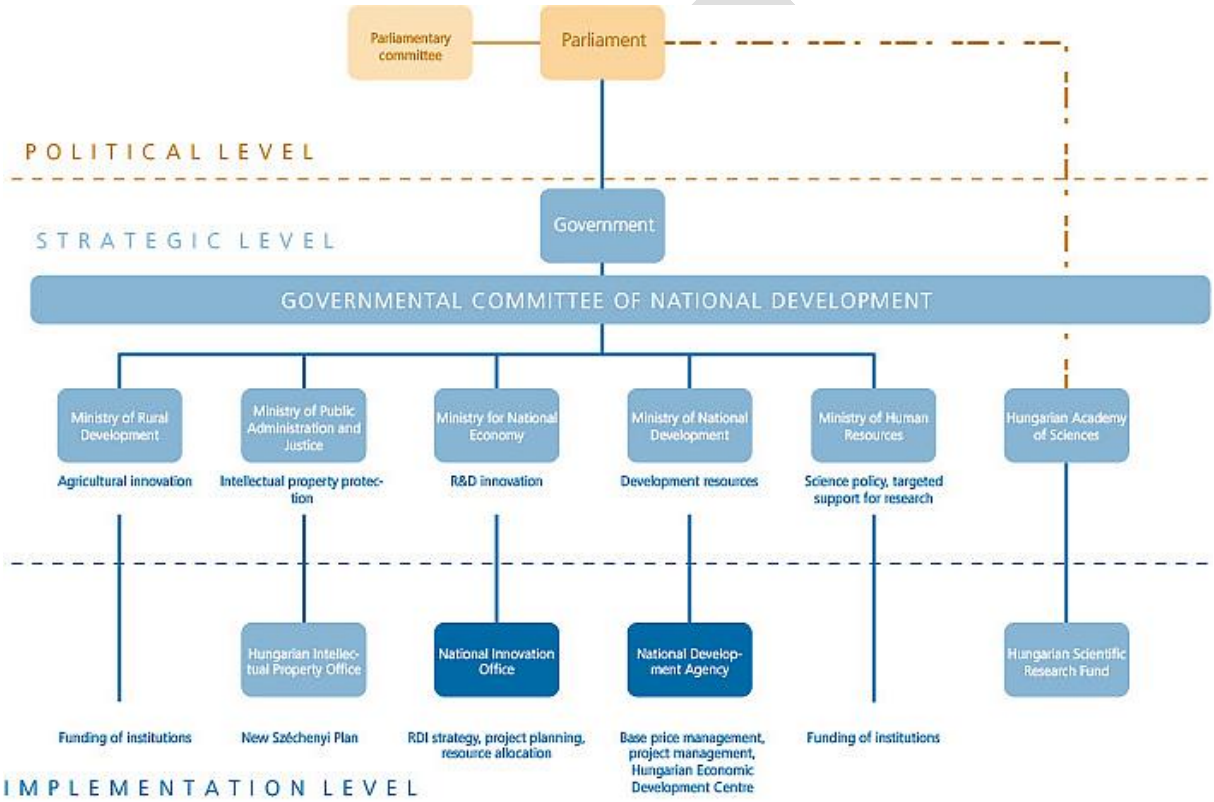

Figure 11. – Structure of the Hungarian government R&D policy scheme

The National Innovation Office operating under the supervision of the Ministry of National Economy is responsible for:

- science, technology and innovation policy development and implementation of collaboration, as well as the enforcement of governmental measures required for initiation and execution;
- science, technology and innovation policy enforcement to promote government information and supply analysis work, including statistical and domestic research, development and innovation infrastructure, maintaining databases;

- science, technology and innovation in the field of international and European cooperation in integration of professional tasks;
- stimulating investments in field of research and development in cooperation with the Hungarian Investment and Trade Agency;
- small and medium-sized enterprises and innovation activities, encouraging innovation capabilities and the promotion of incubating young innovative enterprises;
- stimulating the results of domestic research and development to access the international market in cooperation with the Hungarian Investment and Trade Agency, in particular to small and medium-sized enterprises;
- networking and research cooperation to support national and international levels;
- encouraging adaptive and non-technological innovation activities in the mainly small and medium-sized enterprises.

The office operates a database in order to map the R&D activities. This, the so called Science and Technology Observatory, is an analytical-evaluation database system and knowledge base that contains in a homogenous structure all the relevant information from the field of RDI – in particular about the RDI tenders – to facilitate networking and the evidence-based decision-making.

The Observatory takes part in the development and research of the international statistics and creates an information system that provides adequate knowledge to understand the trends. By this it contributes to good governance, to the competitiveness of the RDI policies, to the research strategy of the enterprises and research organizations.

The Kaleidoscope[6] is the information system of the National Innovation Office's Science and Technology Observatory that is designed to promote the networking of the RDI stakeholders. The Kaleidoscope includes establishment and operation of the Science and Technology Observatory and furthermore it creates a homogenous RDI database that contains the sector's relevant organizations and those data and analysis that are important for the policies.

The services of the Kaleidoscope:

- general and sectoral RDI analysis and statistics,
- data structures as basis of the analysis,
- information about the state supported RDI projects,
- research infrastructures,
- map based research organizations and enterprises register,
- consortium partner search engine and project generating functions.

Hungarian Investment and Trade Agency

The Hungarian Investment and Trade Agency (HITA) was established by the Government of Hungary in order to support the foreign trading activities of Hungarian small and medium-

[6] http://kaleidoszkop.nih.gov.hu/en

sized enterprises and to encourage and help foreign enterprises invest in Hungary. The Agency is a separate budgetary institution with its own budget; it is – together with the related trade houses - assigned to the State Secretary for Foreign Affairs and External Economic Relations.

The most important relations of the Hungarian Investment and Trade Agency are focused, in line with the Széchenyi Plan and the foreign trading strategy, on retaining Hungary's traditional export markets (Germany, neighbouring countries) as well as on gaining a foothold on new dynamically growing markets (Balkan countries, East Europe, Far East).

HITA is also in charge of directing the activities of diplomats promoting foreign trading activities, assisting the strengthening of Hungary's foreign trading relations at 63 local representations in 49 countries all over the world. HITA is the head of the Hungarian consortium of the Enterprise Europe Network. This enterprise development network was set up by the European Commission's Directorate General for Enterprise and Industry with the aim of encouraging small and medium-sized enterprises' business development efforts in the European Union.

HITA considers renewable energy and biotechnology sectors of Hungary as key fields to invest due to their potential. According to HITA the Hungarian biotech sector can become one of the globally recognised and significant bioregions of the European Union, and that several of its segments will develop a global prominence. The emerging renewable energy market in the region is based on the significant potential and unused resources with developed infrastructure, logistics and skilled labour force.

REECO Hungary Ltd.

REECO has been organising trade fairs, conferences, seminars and workshops since 1998. The main focus areas are renewable energy and sustainable buildings. In the central European region REECO is present with many events and fairs organized on yearly basis. The conferences take place parallel to the trade fairs providing the chance to both listen to renowned speakers and to meet contacts on the same day. Through these events start-ups can reach new markets and contact with decision makers.

Regarding Hungary, REECO organized its 7th RENEXPO trade fair in April 2013. Usually, the RENEXPO® Central Europe is considered as the most significant meeting point of the region. On the one hand, it enables the yearly meeting of renewable energy branch, and on the other hand, it provides the scene for the presentation of firms and organisations.

4.6.2 Public acceptance of bioeconomy initiatives

The collection of biomass and the building and operation of a biorefinery facility affect the local communities in many ways. Besides delivering positive impacts, such as creation of market for by-products and new jobs, there could also be related negative side effects, e.g. enhanced transport due to biomass collection.

As a consequence, the information flow and public acceptance are crucial factors when developing a bioeconomy related project. Despite its importance this field has not been addressed deeply and thus the knowledge on the public acceptance in Hungary towards bio-based investments is limited. Bujdoso et al. (2012) carried out a survey in Heves county of Hungary (north-eastern part of Hungary) in order to explore the general knowledge, innovative attitude, acceptance and willingness of application as well as the estimation of the benefits of the use of renewables among the local population. Main outcomes of the survey include:

- The knowledge on various bioenergy-related technologies can be regarded in general as moderate. Only about 20% of the respondents had heard about short-rotation forestry, whereas 23% is aware of bio-briquette and bio-ethanol has nearly 25%, thus these are the least well-known ones after photovoltaic technologies. Knowledge on biogas, biodiesel and combustion of biomass exceeds 40%.
- As the source of information, 86% of the respondents indicated television or radio, this figure was followed by 62% of the press far ahead of all other categories. However, taken into account the rural attributes of the county, the low number of internet connections had also contributed to these results.
- The study states that no significant opposition was experienced against a RES project to be implemented in the neighbourhood of the residential area.
- About half of the inhabitants are aware of the fact that an installation to be implemented would not only bring environmental but also socio-economic benefits (increasing tax revenues, creation of jobs). Only 12% thought that an investment of this kind would prove to be disadvantageous. A similar picture is drawn for the benefits on the level of individuals; however socio-economic benefits for the inhabitants are recognized by significantly fewer people (23%) than in the previous case.

4.6.3 Gaps and possibilities – potential connection points to KBioE

There is missing information on the real public acceptance and perception towards biobased projects in Hungary. On the other hand, the promotion of bioeconomy projects should be embedded in the general policy framework with the integration of a non-governmental body representing the sector independently.

ADMIT Biorenewables

The ADMIT Biorenewables project provides a platform to integrate biorenewables-related innovation activities of the partners in the Climate-KIC network. It allows us to effectively exploit the climate mitigation and adaptation opportunities available in the integration of food, energy and biomaterials production in the EU. Through a series of workshops and meetings with participating CLCs, their academic and industrial partners as well as other relevant stakeholders, a roadmap to the realisation of integrated low-to-zero-to-negative carbon production systems in the food, energy and biomaterials production will be developed. This pathfinder project helps to establish the biorenewables Climate-KIC community (academic and industry), leading to a proposed follow-on project that would define the core principles and metrics for a pathway to low-to-zero-to-negative carbon biorenewables supply chains and markets. A strong ethos of open collaboration will be developed, aimed at facilitating communication, research and activity both within and outside of Climate-KIC. It supports other projects targeted at specific biorenewable sub-sectors and innovations highlighting the size of the prize and pathways to materialize a zero-carbon future using cost effective technologies and biorenewable resources.

5 Next steps

In order to fully use the attributes and competencies of the Hungarian bioeconomy scheme it is necessary to carry out a more detailed and entire mapping of the stakeholders in the framework of the Climate-KIC Biohorizons projects.

In view of the results it will be possible to strengthen project participation and partnerships by coordinated approach under the umbrella of Climate-KIC and also to identify international projects to join.

6 Conclusions

RIC Central Hungary with great natural endowments by means of untapped biomass resources, as well as R&D competencies as showcased in this study, present a value in the Climate-KIC Bioeconomy Platform to be developed as potential area for pilot projects, market developments and innovation based start-ups. The academic partners active in the bioeconomy field offer also the possibility to involve activities of the KBioE into the education.

In order to realize this potential for the KBioE and present the advantages it offers clearly, more structured and oriented information dissemination and partner involvement are necessary. The communication should attract possible stakeholders that this coordinated approach delivers advantages and added value without jeopardizing the partner competencies.

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ZALAVÍZ

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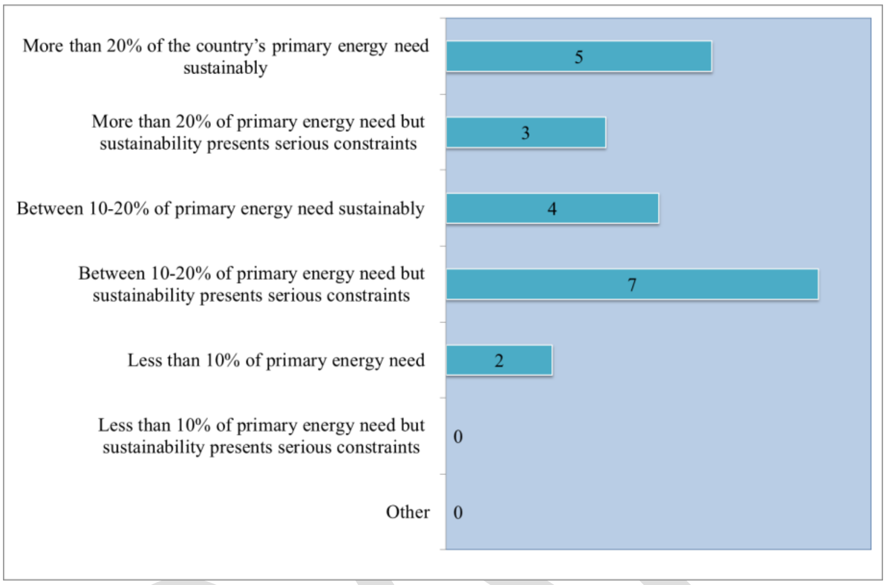
8 Annex I – Interview

Each respondent could select multiple answers. The ratio of a given option is calculated by dividing the number of answer for that option by the number of people answered to the question (and not with the sum of the answer considering the multiple answers).

Question 1.1

What is your estimate of the potential biomass supply in Hungary (assuming economic viability and environmental sustainability)?



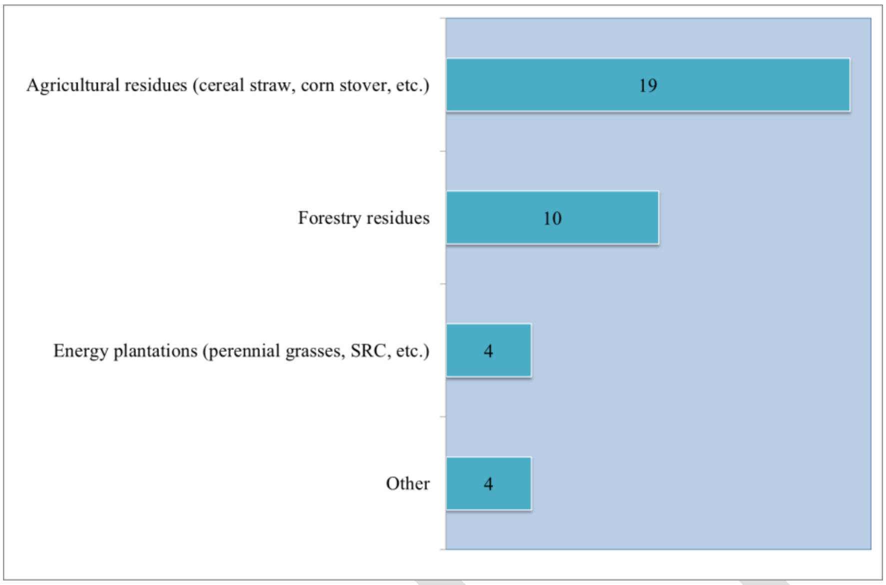
Most of the respondents (90%) agree that the biomass potential of Hungary could deliver above 10% of the primary energy demand of the country. However, if sustainibility is taken into account there is no agreement on the potential. The deviation among the answers explains well – and some of the responds noted – that further R&D based on coherent and transparent methodology is needed in order to quantify the potential. One of the answerers highlighted that differences in the yield determining the potential could significantly vary year by year, hence R&D related to biomass resources and agricultural practices, aiming for reduction of this varience should be put first.

Regarding the question who could carry out an assessment of the biomass potential for Hungary, cooperation of concerned stakeholders (research institutes and universities) in form of a consortium was recommended since there is no single body capable of it. Another important issue is that the body should be empowered with rights to obtain data, this way inclusion of authorities and/or ministries may be inevitable. However, a few certain stakeholders claimed to be competent for biomass potential estimation were mentioned:

- Hungarian Renewable Energy Platform pooling the relevant Hungarian renewable energy associations and stakeholders, http://www.megujuloplatform.hu/index.php/hu/
- SEEGER Engineering AG., specialized on biomass based solutions, http://www.seeger.ag/en.html
- Dr. Attila Bai, associate professor, Centre for Agricultural and Applied Economic Sciences of the University of Debrecen (Climate-KIC Central Hungary partner)
- University of West Hungary, Environmental Cooperation Research Centre, http://kkk.nyme.hu/
- Ministry of Rural Development and its background bodies, such as the Research Institute of Agricultural Economics, http://www.aki.gov.hu

Question 1.2

What could be the main feedstock for bioenergy/biorefinery purposes in your view?



Respondents were unanimous, 86% of the answers put first agricultural residues as the main source for biomass followed by forestry residues (46%). Energy plantations were ranked as last alternative with only 18% mentioning, which is somehow surprising in view of the land available.

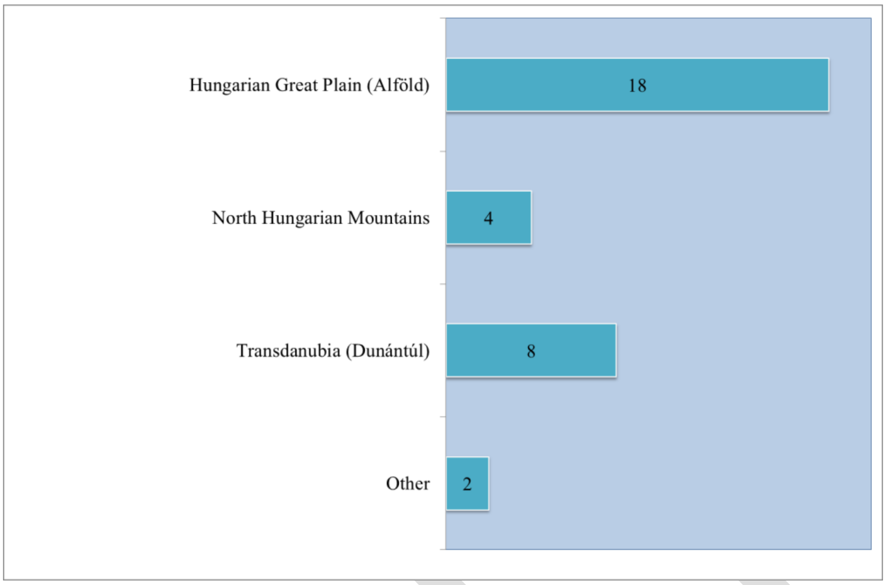
Other options mentioned:

- different corn varities
- organic fraction of municipal waste and organic industrial waste (e.g. from food processing), waste water
- “Szarvas” energy grass with yield up to 15-17 t/ha

The biodegradable fraction of household constitutes a real untapped potential, however, its selective collection is not solved in Hungary yet. According to the EU policy framework on waste managment, this potential will be exploited in the future. The potential of organic industrial wastes, generated on-site in a concentrated form is indeed yet to be utilized.

Question 1.3

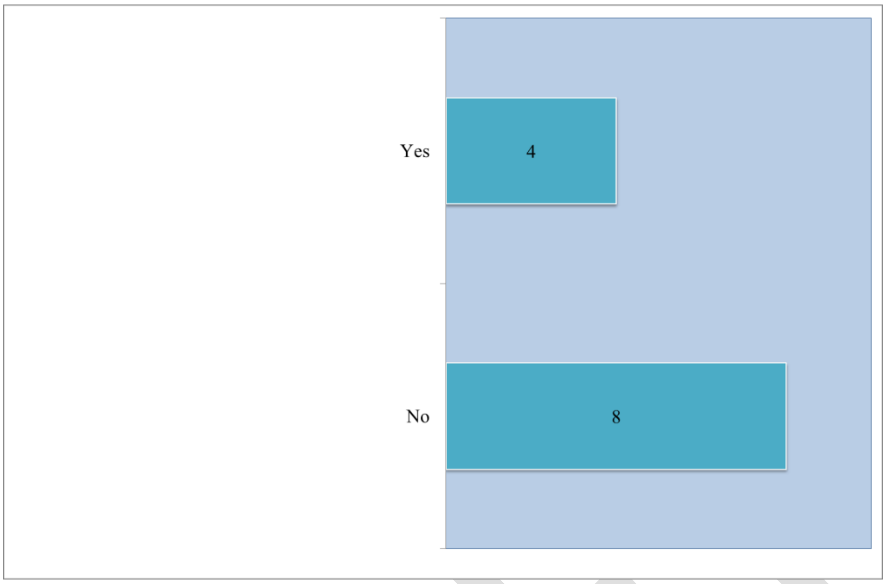
What part of the country possesses outstanding potential for biomass production?



In line with the previous question, the important agricultural areas, the Hungarian Great Plain and Transdanubia together received the 82% of the answers. As other options a certain part of the Great Plain was mentioned as ideal area for energy plantations, and it was raised that bioenergy production should be connected to flood and water management along the rivers. This way more stable production could be realized with all the necessary natural conditions given: sun, water and fertile land exposed to high risk of flooding. Currently, the flood management constitutes a huge and growing problem that has also a negative impact on agriculture because some land used for growing cereals is regularly flooded. This also confirms the relevance of connecting flood management with biomass production utilizing species nonsensitive towards flooding.

Question 2

Does your business or any of your stakeholders grow/collect biomass for non-conventional/advanced (biorefinery) purposes (i.e. other than food, feed etc.)?

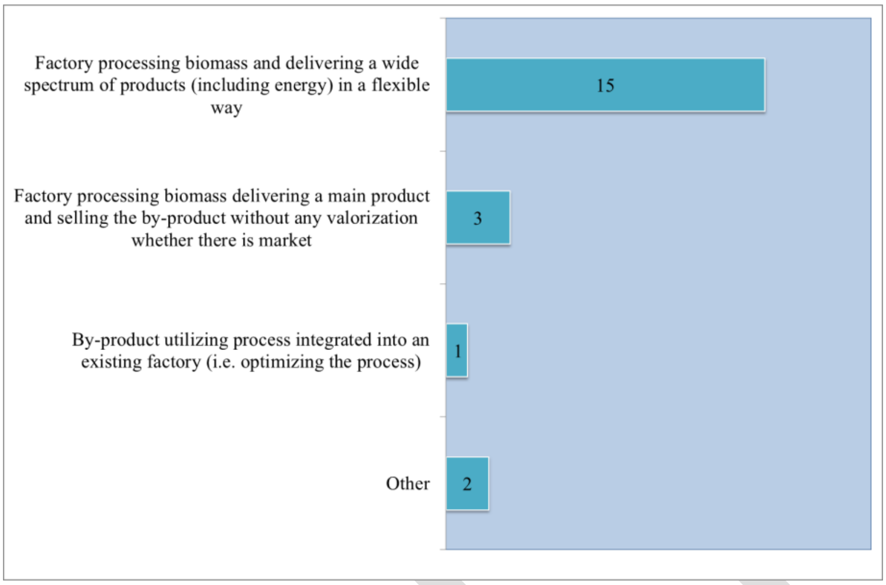


Due to the wide spectrum of the stakeholders answered to the interview, only a very few of them responded to this question. One third of the respondents are directly or indirectly concerned in advanced biomass sourcing. Furthermore, 2 out of the 4 positive answers indicated that only for R&D purposes, i.e. small amounts only. The other two carries out collection/harvest of the following biomass types:

- energy reed, fast-growing tree
- food waste, food industry sludge, oil, grease for biogas plant

Question 3.1

What is your definition of the biorefinery concept?

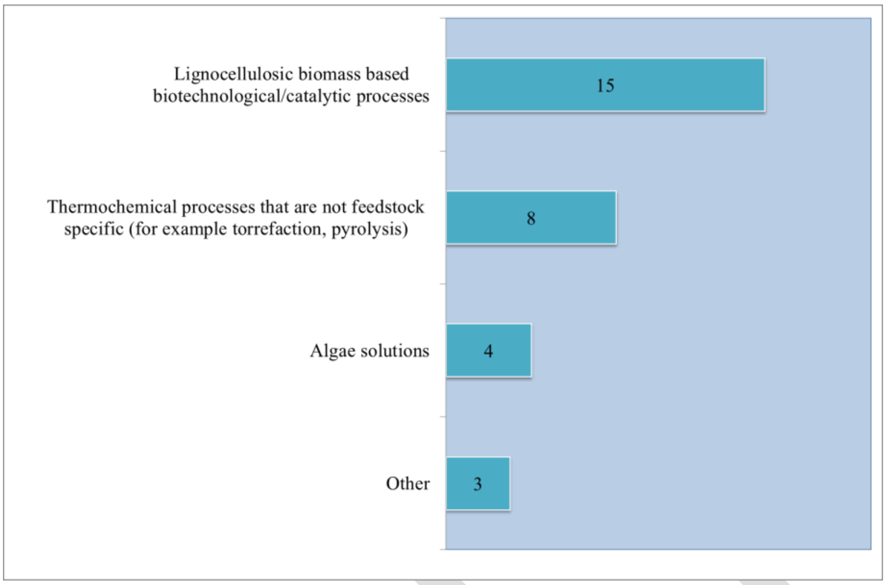


Regarding the definition of biorefinery, the main building block of the bioeconomy, there is considerable consensus among the respondents. According to this accepted definition the basis of biorefinery is processing of biomass into a spectrum of bio-based products in a flexible way. Other options:

- reference to the article by Kamm & Kamm (2004) Principles of biorefineries, Applied Microbiology and Biotechnology, 64:137-145)
- pulp and paper factories

Question 3.2

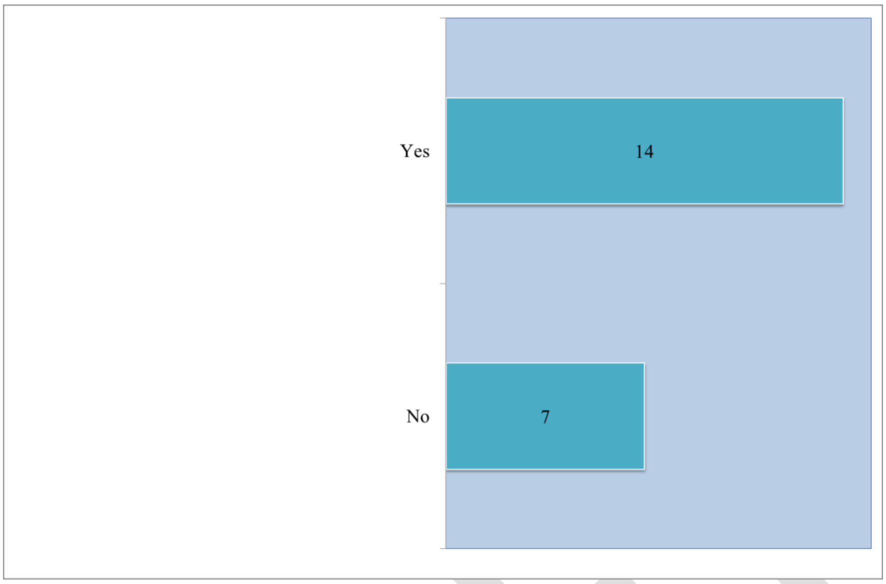
Which is the most prominent advanced biomass based technology for Hungary in your view?



Two thirds of the respondents (68%) foresee the lignocellulose based processes in which various feedstock specific components are valorized as the most prominent advanced technology for Hungary. On the other hand, thermochemical means of biomass processing are considered also promising by more than one third of the respondents (36%). It was noted that it is hard to predict in general, the technology should be chosen depending on the local features. Biogas was mentioned as another option, however, according to the authors biogas production process is not classified as advanced technology. Regardless the classification, biogas production is indeed a promising but mature and proven technology that can be a part of a biorefinery in terms of by-product streams handling.

Question 4.1

Do you know any organizations/companies in Hungary performing biomass upgrade/biorefinery process?

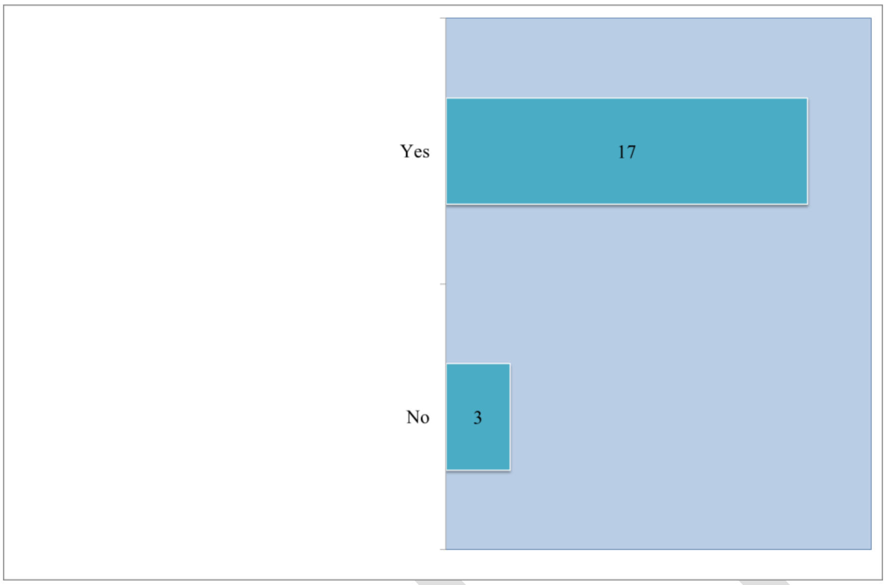


Two thirds of the stakeholders answering this question were aware of at least one Hungarian company performing biomass upgrade. This result indicates that Hungarian companies are already active in bioeconomy related fields, delivering the necessary knowledge and infrastructure. The mentioned companies were the followings:

- Hungrana Starch and Isosugar Manufacturing and Trading Co. Ltd.
- Agrana Magyar Cukor Zrt. (Hungarian Sugar Co. Ltd.)
- MOL Hungarian Oil and Gas Company
- Nitrokémia Environmental Protection Consulting and Ministering Incorporated Company
- Monergo Ltd.
- Envihorizont Ltd.
- Agroetanol Ltd.
- Pannonia Ethanol Ltd.

Question 4.2

Do you see a role for your business participating in a biorefinery related project?

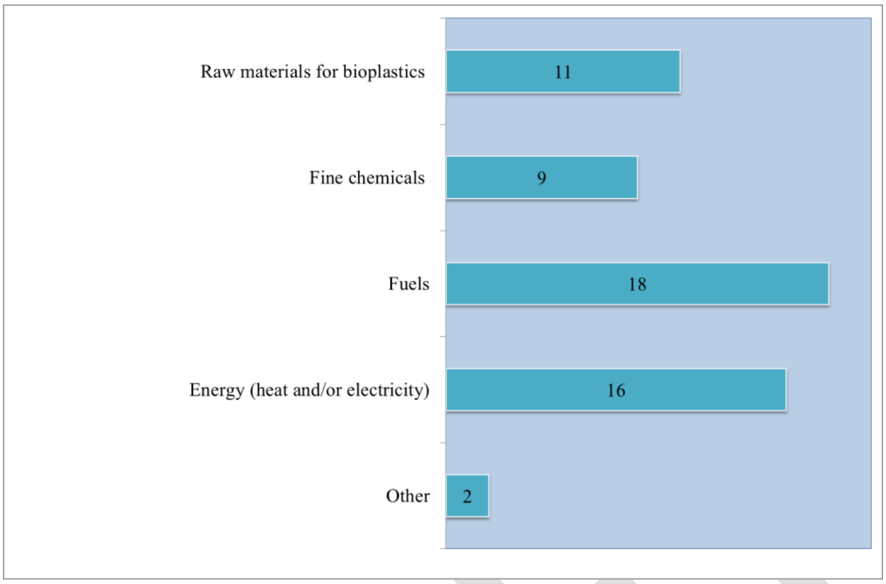


Regarding the participation in a biorefinery related project 85% of the respondents see a role for their business. This result indicites also that there are significant competences and this way Hungarian partners could effectively contribute to related initiatives, such as the Climate-KIC Bioeconomy Platform. Proposed specific roles were also included in most of the answers. Basically, foreseen tasks can be categorized into 4 groups covering well the necessary steps to realize a project:

- R&D: laboratory experiments, consultancy, and processing technology analyses in the fields of energy production from residues and wastes, and lignocellulosic biomass processing
- Engineering, design: sustainability and potential assessments, technology design, biomass plantations, biomass based CHP and pyrolysis
- Technology & other supplier: enzyme supplier for lignocellulose breakdown
- Financing services

Question 5

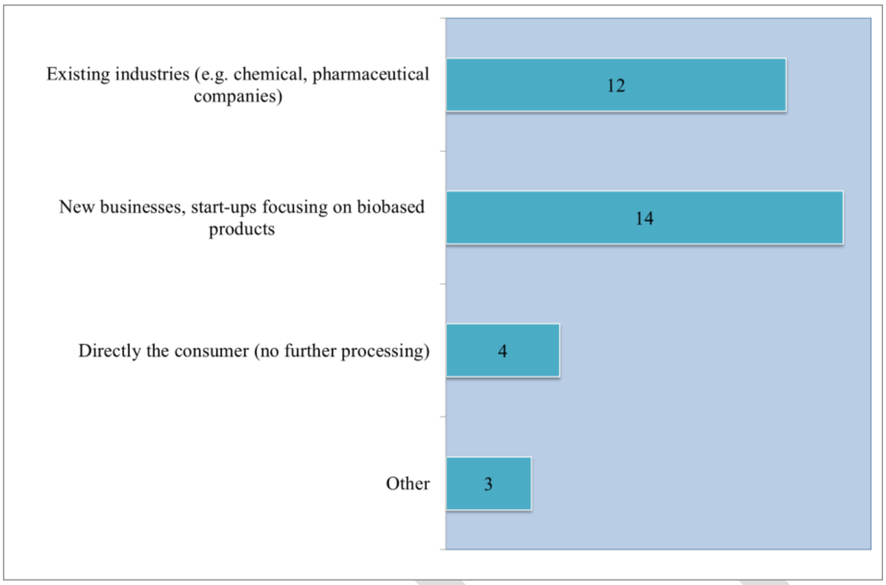
What are the possible marketable products of a biorefinery in Hungary (domestic sale or export)?



Despite the definition, most of the answers reflect rather a conventional thinking: 82% provided fuels and 73% energy as marketable products. Nevertheless, these products are currently the driver for biomass utilization, though their market depends strongly on subsidies. Half of the respondents answered that raw materials for bioplastics and fine chemicals are also marketable products. One respondent noted that the products depend on the technology, i.e. if the technology is there fine chemicals and bioplastics could be produced as well. Platform chemicals and animal feed were mentioned as further options.

Question 6.1

What are the existing or potential markets available to you for your biorefinery products?



About the same proportion of the respondents would rely on existing companies and new businesses to sell their biorefinery products. A systematic approach is needed to address and/or create these markets along the innovation chain and to attract and convince existing companies and newcomers. The low number of answers to the directly sold products may show the lack of enterprising approach. The answers here clearly present the deficiency for which the EIT and KICs were created. Therefore, the future KBioE project should cover all aspects of the Knowledge Triangle in order to convince existing markets or create new ones.

Question 6.2

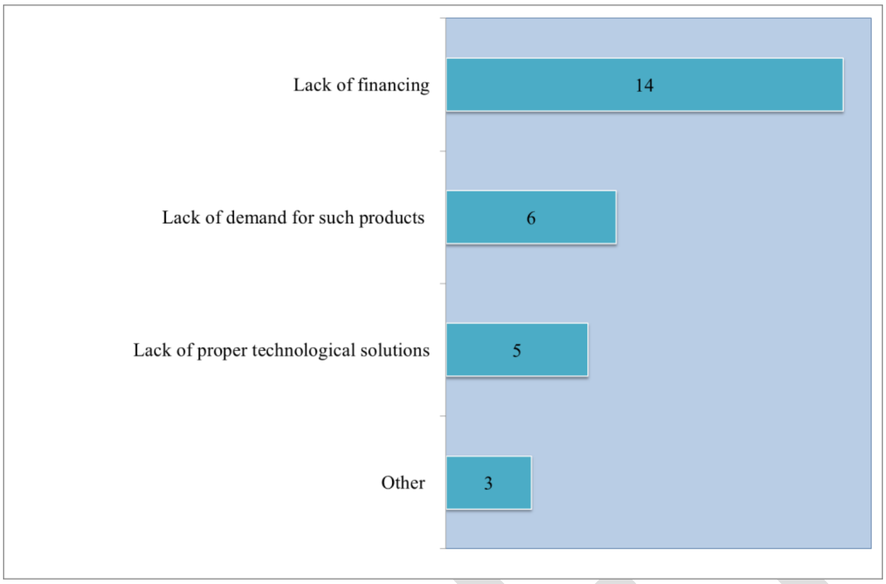
Would you perceive a vertically or horizontally integrated biobased business in your current company?

If specific conditions set by the respondents are taken into account 61% of them would perceive an integrated biobased business. This indicates that not only start-ups but companies holding competencies and infrastructure should be addressed with possible projects as well. Two conditions for having an integrated business were mentioned – in line with previous answers:

- stable and predictable market,
- R&D funding for technology experiments

Question 6.3

What would you see as the greatest risk to your business investing or diversifying into such products and/or services?

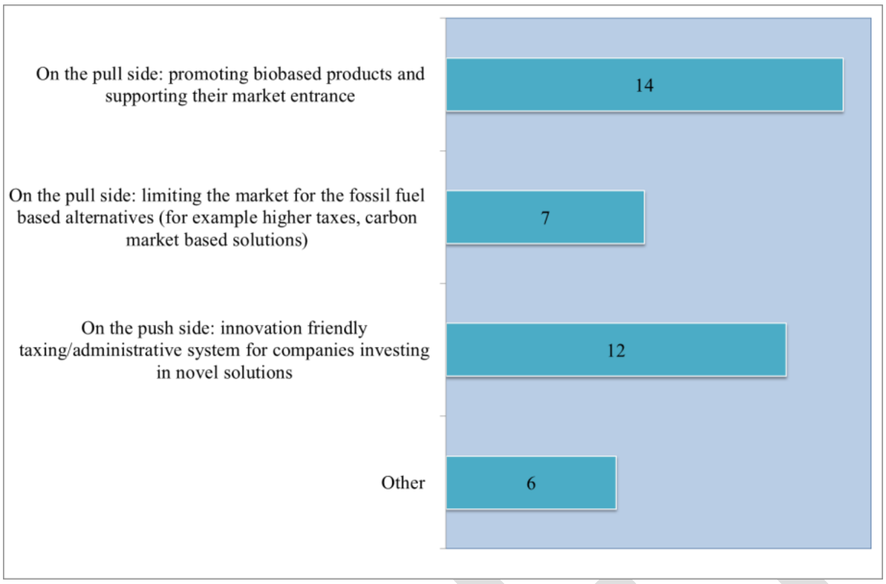


In connection with the previous question, 82% of the respondents named here the lack of financing as the greatest risk regarding biobased businesses. Funding is a general problem that may be overcome with coordinated, systematic and concentrated approach offered by various initiatives and communities such as the KICs. Other answers (35-29%) indicate that – in line with previous questions – market development and awareness raising is necessary, moreover, technology oriented R&D should be also in focus. In addition, the following risks were mentioned:

- market intervention by governments (e.g. biodiesel production in Germany),
- there is no social recognition due to lack of information flow, furthermore, a strict nature conservation approach prevails,
- high interconnection of the sector with international/EU legislation and related support

Question 7

How could the EU and the Hungarian government improve the policy framework for the Bioeconomy (what is your policy innovation need)?

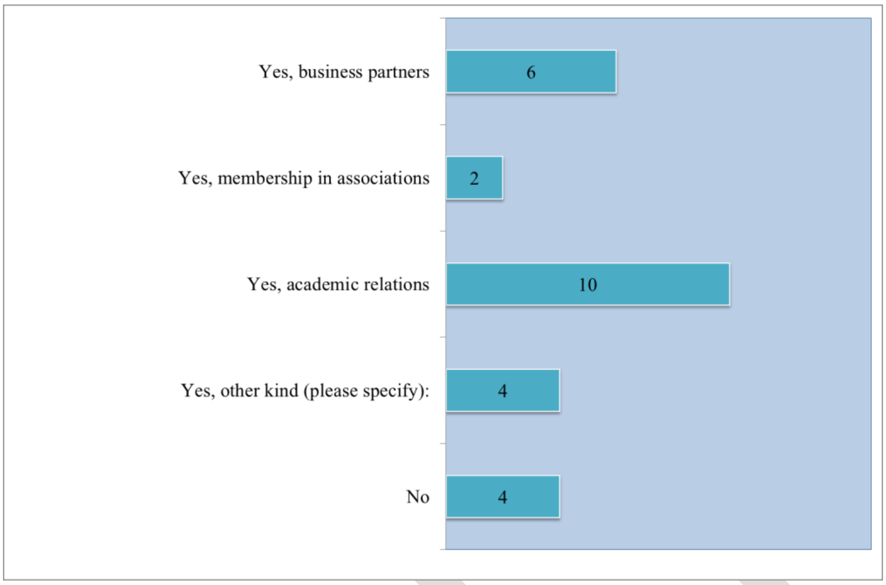


Regarding the policy framework both pull side and push side measures can be effective according to the answers. While push side measures can be more general with supporting innovation-based investments, pull side ones concentrate rather on the biobased products. The requirement for pull side measures is in line with the need to create market for biobased products. Limitation of the fossil fuel based market could improve the policy framework according to 32% of the respondents. Consequently stakeholders may opt for direct measures what they can exploit. Among other options the followings were mentioned (most of them are general suggestions for policy makers but in the others the Climate-KIC can also make a difference by recognizing these needs):

- significant and predictable investment support,
- legal regulation should provide a long term and stable playing field in order to let the market find the optimum and overcome challenges,
- adaptation of R&D results – facilitating knowledge transfer (even should be a condition to obtain grants),
- global cooperation,
- obvious and predictable legislation for renewables-based electricity and heat,
- evaluation of the support system for certain investments.

Question 8.1

Do you have any international business links and/or collaborations related to bioeconomy?

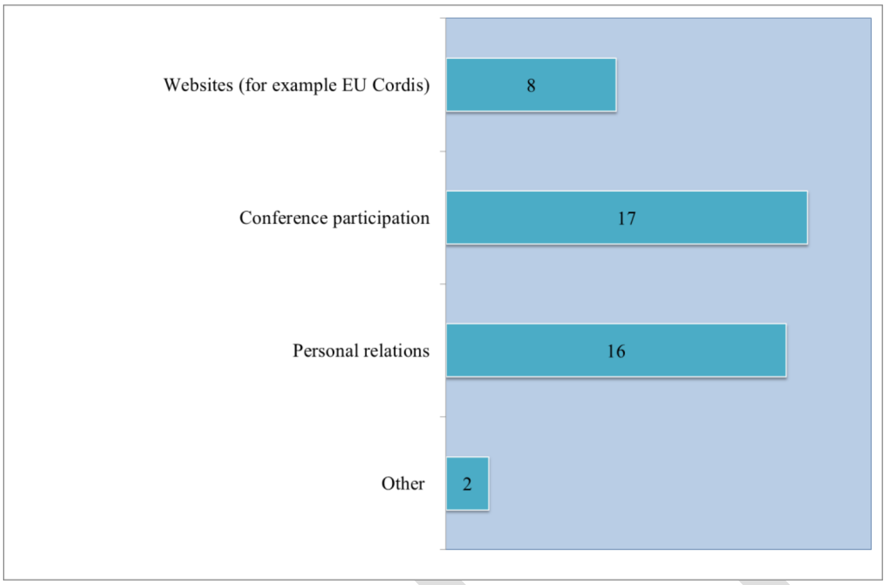


Most of the respondents have one or more types of international links. Reflecting the spectrum of the interviewees and the state of the advanced biomass technologies 53% of them has academic relations while 32% has business partners. This result indicates willingness and openness in collaborating with international partners, and proves the competencies as well, but international business/collaboration can also be considered as a source of financing. The following further options were considered by the respondents:

- branch of an international company,
- FP7 project partner,
- regular discussion with stakeholders.

Question 8.2

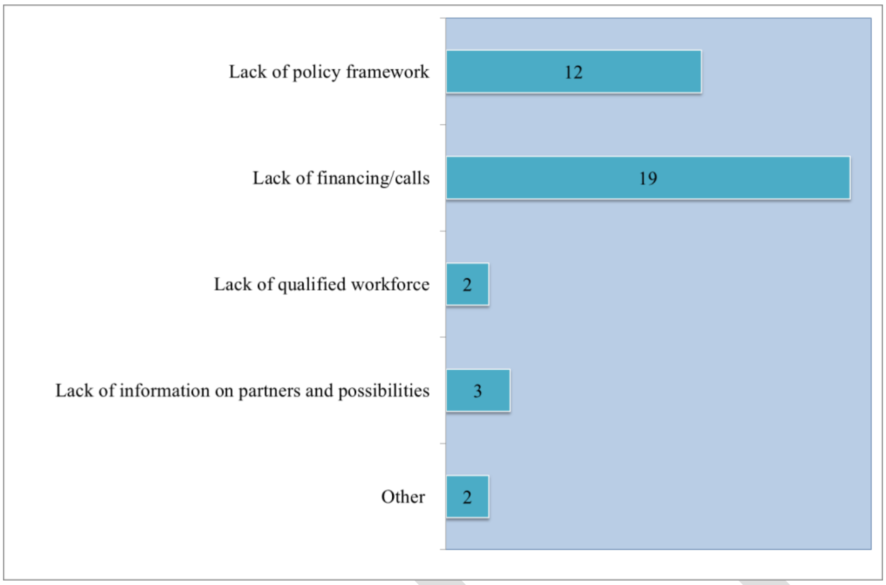
What method/platform do/would you use to seek international partners in your field?



Methods providing personal contact and impression are predominant in seeking new partners. The answers to conference participation and personal relations make 90% and 84%. The web based platforms having no opportunity to meet personally are preferred by 42%. This result shows that methods developing personal impression should be put first to attract and contact the stakeholders effectively although those are more time consuming and expensive. Partner finding in associations was mentioned as another option. A possible task for Climate-KIC platforms in general is to facilitate the networking of partners by providing a unique forum for it.

Question 9.1

What are the main barriers for Hungary to become competitive in the European bioeconomy?

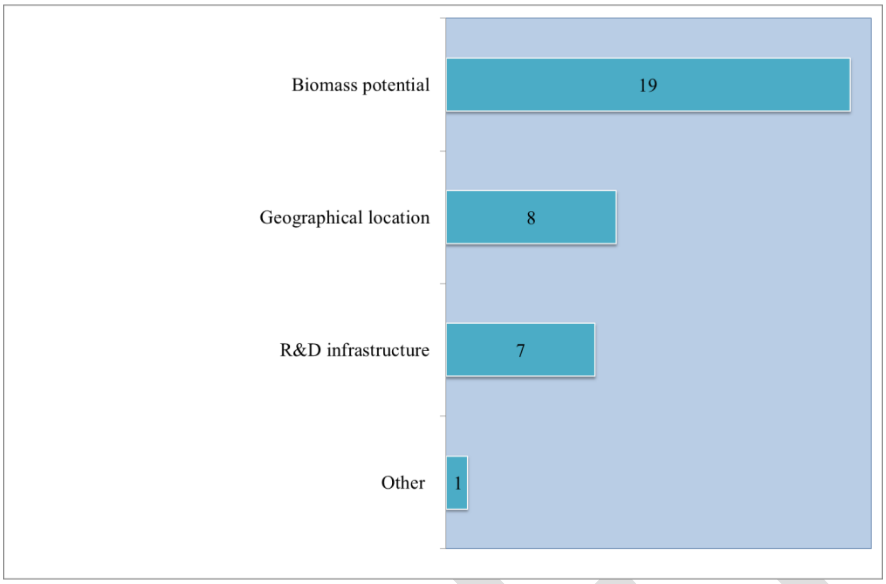


In line with the previous questions the main barrier, mentioned by 86% of the respondents, is the lack of financing, followed by the lack of policy framework by 55%. In terms of bioeconomy, there are no focused and oriented calls, and the comprehensive framework is also missing only some aspects are concerned in strategies. The lack of workforce and lack of information are considered as barriers only by a few. Further possible barriers noticed among others:

- lack of practice oriented training courses,
- bio topics got de-emphasized in higher education,
- lack of market.

Question 9.2

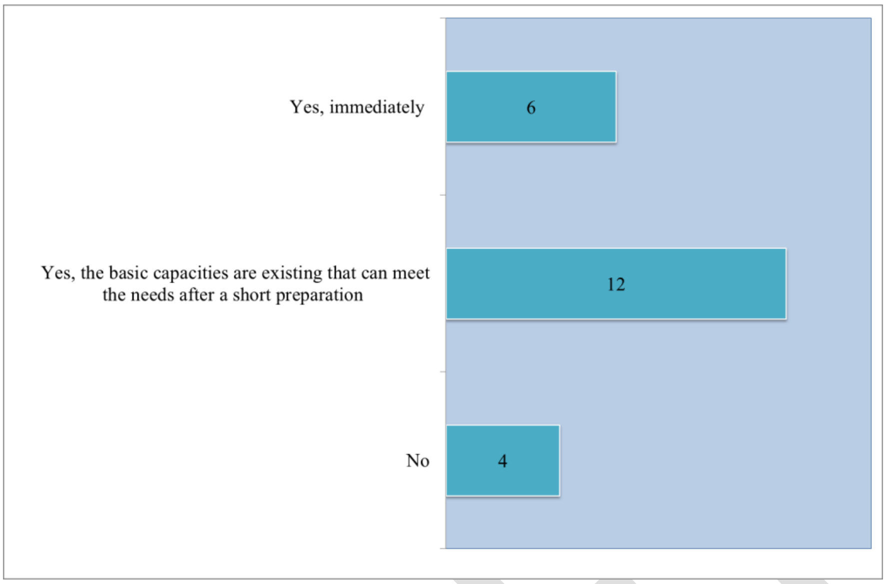
What are the main opportunities for Hungary to become competitive in the European bioeconomy?



Despite the fact that there is no consensus on the exact biomass potential in Hungary, all respondents consider it as a main opportunity. The geographical location and the R&D infrastructure got 42% and 37%, respectively, showing their importance. The high energy import dependency of the country was highlighted as another possible field. This opportunity matches well with the concept of the RICs, namely to implement projects on the local attributes and competencies.

Question 10

Does Hungary possess the necessary human capacities, knowledge and R&D infrastructure to implement a biorefinery project?



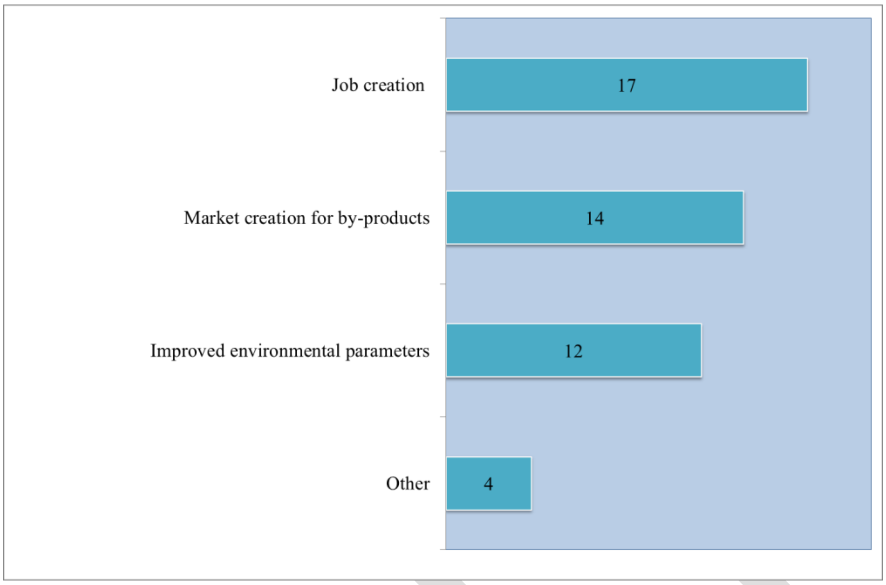
The vast majority of the responses indicates that necessary human capacities for a biorefinery project are present in Hungary (82%), either already (27%) or after a short preparation/education/training (55%). Considering the lack of skills the followings were noted:

- there is no specially skilled workforce on creating and processing energy plantations,
- lack of network of local experts on biomass by-products utilization,
- lack of developers, installers and operators of biomass furnaces,
- lack of entrepreneurship skills – the bureaucratic approach is still decisive.

The answers reveal that there is a solid base and demand for bioeconomy related education programs, probably complemented by entrepreneurship training and mobility programs embedded into the Climate-KIC.

Question 11.1

In your view what are the positive side effects of the bioeconomy locally?

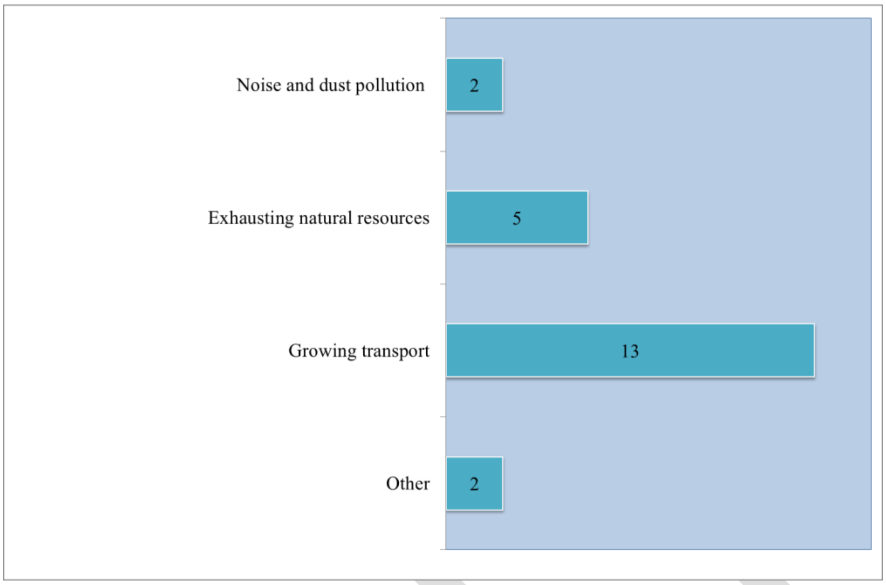


Nearly all answers recognized all of the provided options as real, positive side effects for bioeconomy development. In case these side effects become proven for a given project option, it could help to attract the local decision makers and authorities (by creating new jobs), the local farmers (by creating market for by-products) as well as the local population and environmental activists (by improved environmental conditions). To this end, their active involvement can be necessary and could facilitate perception and the progress of the project. The results also indicate that partnerships, such as the Climate-KIC should be open for these kinds of stakeholders to deliver balanced and accepted outputs. Among other options the followings were mentioned:

- reduction of energy and protein feed imports,
- fulfilment of EU targets,
- improved environmental and social safety,
- improvement of local energy/biomass supply chain,
- development of environmental friendly waste utilization technologies.

Question 11.2

In your view what are the negative side effects of the bioeconomy locally?

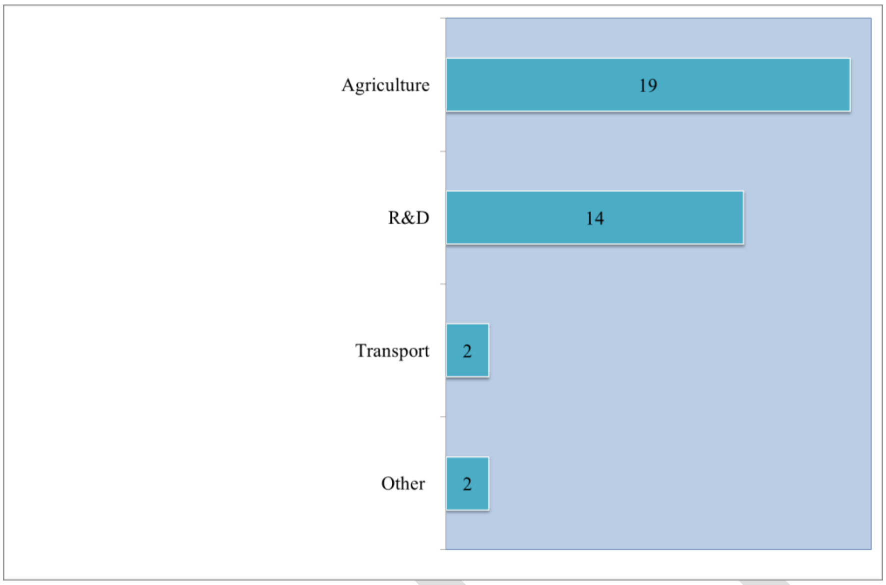


72% of the respondents consider the increased traffic due to the transportation of biomass as the main negative side effect. Regarding this impact, it was noted that wastes and by-products should be processed on site and the maximal transport distance should not exceed 20-40 kilometres. During the establishment of local biomass supply chain, logistics should be designed carefully. Various options to bypass villages and use rail (and water) transportation should be considered, as well as different harvesting and collecting technologies to reduce volume and moisture content thus achieve more compact structure for shipping. In order to deliver successful project, the KBioE cannot avoid the investigation of transportation options, since besides being a side effect influencing the population heavily, the GHG balance can be also affected. On the other hand, 28% thinks that bioeconomy can lead to depletion of natural resources. This highlights the sustainability issues regarding to biomass supply.

It was emphasized in one of the answers that there are many possible negative side effects unless the project is fitted to local features and attributes. This indicates that thorough evaluation of local potentials and options should be carried out during the design of a project in order to find the best technology and scale for the area thus minimize negative impacts and enhance acceptance.

Question 11.3

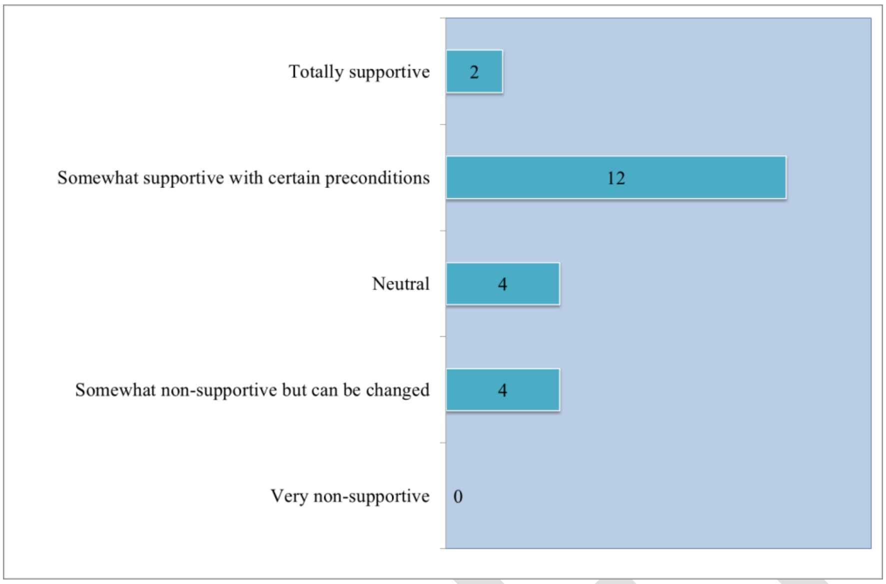
Which are the fields most influenced by a possible bioeconomy related investment?



In line with the previous question, near all of the respondents (90%) believe that agriculture and two thirds that R&D are the most influenced fields by bioeconomy investments increasing utilization of by-products and developing new technologies, respectively. It was noted that local municipalities are also heavily influenced by new jobs, tax incomes and local energy supply supervised by their own. These findings suggest that a partnership should be built up mostly on these stakeholders but involving – in certain issues and at certain points – other partners also as indicated previously.

Question 12.1

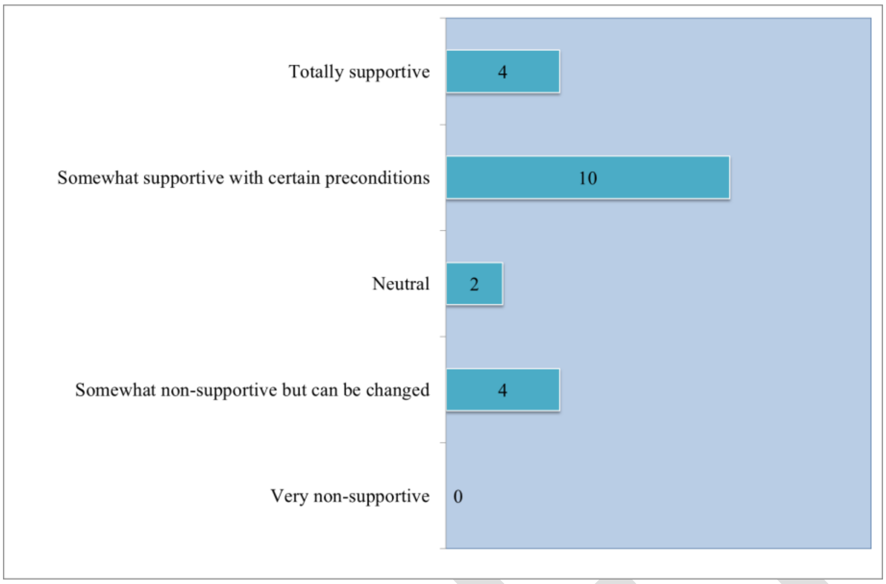
In your opinion what is the general public perception and acceptance in Hungary of biomass based solutions (bioenergy, biorefinery…)?



Based on 64% of the answers the general public perception is supportive towards biomass based solutions. According to 18% there is non-supportive public opinion, however, it can be changed with information and involvement. These findings, although they should be confirmed by a public survey, also suggest potential and a good base for the development of the bioeconomy.

Question 12.2

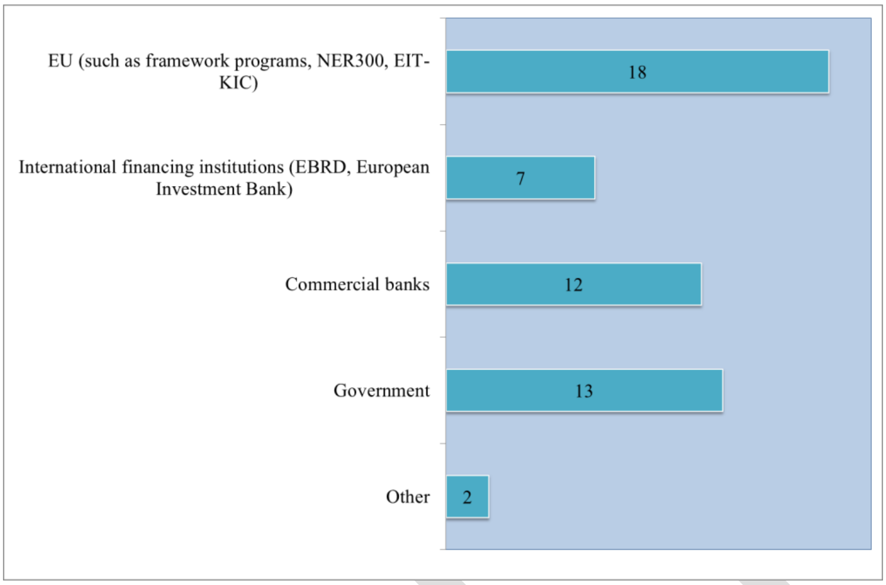
In your opinion what is the public perception and acceptance in Hungary of biomass based solutions (bioenergy, biorefinery…) if locally affected?



Regarding the perception if locally affected, the results are very similar. Based on 70% of the answers the local public perception is supportive towards biomass based solutions. It should be noted that none of the respondents predict very unsupportive manner.

Question 13

What financing sources would you rely on?



As the results of the survey have already indicated, the main problem is the lack of financing for bioeconomy related projects. Most of the respondents, 90% would rely on EU funded programs, followed by 65% waiting for governmental support. It was noted that higher financial support from the state would be needed. Similar ratio, 60% voted for commercial banks, even though it is complicated today to calculate the return of a bioeconomy related investment, as it was highlighted in a respond. Nevertheless, the need for such a financing also indicates that the issue should be addressed involving banks aiming return calculations and risk evaluations. Lastly, 55% mentioned international financing institutions as possible supporters of large scale projects but government policy guarantees may be necessary in return.

The respondents in general remarked that today the financing possibilities for bioeconomy are very limited or non-existing. Other notes underlining the highly risky nature of novel technologies included:

- The support for an evolving market with novel technologies/products always carries larger and more risky investments. Mitigation of long term risks depends significantly on legal / policy framework.
- Once the market is available, there should be no more financing difficulties.
- In lack of long term credits and predictable energy prices there is no chance to finance these kinds of investments.
- Financing can be secured in case of (a) mature technology, (b) financially stable partners and long-term agreements for feedstock/market and (c) stable legislative framework.
- Without non-repayable grants the first projects cannot be financed due to high operational risk of the novel technology.

The innovation chain approach and the EIT Knowledge Triangle view may help projects to minimize risk associated with novel technologies and in start-up financing.