Appendix B - Project description

1. Summary

A central pillar in the future Biobased Society is biorefining, which involves processing of biomass into a spectrum of value-added products such as chemicals, fuels, feed and food products. The present proposal addresses the scientific and technological challenges associated with development of sustainable biorefinery solutions. The idea behind the BIO-VALUE SPIR is to establish a strong strategic platform for innovation and research on value-added products from biomass. This will be achieved by assembly of a consortium of major universities, companies and technology organisations (GTS and Innovation Networks).

The research and innovation activities will deliver the science and technologies required for exploration and upgrading of all components in biomass, turning these into products that are commercially and sustainably viable. The main objectives are to: (a) develop a strong research base delivering fundamental knowledge on processes pertinent for conversion of plant biomass into value-added products, (b) develop a direct innovation flow and an innovation pipeline structure targeting biorefining technologies, (c) develop novel core technologies, (d) demonstrate sustainable, competitive large-scale upgrading of biomass into intermediates and specific products, (e) educate qualified manpower, and (f) disseminate knowledge. The consortium has all the competences required to address the entire value chain from biomass production, separation, purification and conversion to final products, thus providing the basis for development of sustainable and competitive solutions for large-scale implementation. The concerted effort will lead to novel methods, tools and strategies to separate and convert carbohydrate, lignin, protein and nutrient streams into value-added products. Specific targets are carbohydrate mixtures of specified purity, lignin and lignin-derived components, chemicals and biobased products such as carboxylic acids, amino acids, and protein rich feed to substitute soy in animal feed for milk production.

The activities in the BIO-VALUE SPIR are at all levels based on a tight link between research and innovation. All projects are organized as innovation-driven pipelines that span from competence-building research to innovation. The innovation components are to a large extent defined by the involved companies, and the specific activities pursued target strategic goals for rapid establishment of business opportunities. The governance structure which will be implemented ensures dynamic interaction between research and innovation, and allows new projects to be accommodated via a pool of unmarked financial resources or new grants.

2. Vision, strategy, objectives and anticipated results of the platform

2.1. Vision and strategy for the platform

Vision: That Danish companies and research institutions are global technology leaders in conversion of biomass into commercially competitive and sustainable products and that the BIO-VALUE SPIR is internationally recognised as a world-class research platform for biorefining.

Background and focus

The research and innovation activities in the BIO-VALUE SPIR address the challenges of providing a competitive platform for the future development of sustainable value chains for industrial production of biobased products. The platform will develop the science and technologies required to enable production of sustainable consumer products from biomass at sufficiently low costs. The key in this endeavour comprises production and conversion of plant biomass feedstocks and further processing of the biomass components into intermediates and value-added end products. Only by addressing the entire value chain via an innovation pull, it is anticipated that novel sustainable and competitive solutions for large-scale implementation can be developed.

During the last decade, it has become increasingly clear that carbohydrate mixtures may potentially provide an alternative platform for the entire chemical industry, which today is almost exclusively based on a fossil platform, i.e. coal, gas and oil. Currently, 15% crude oil

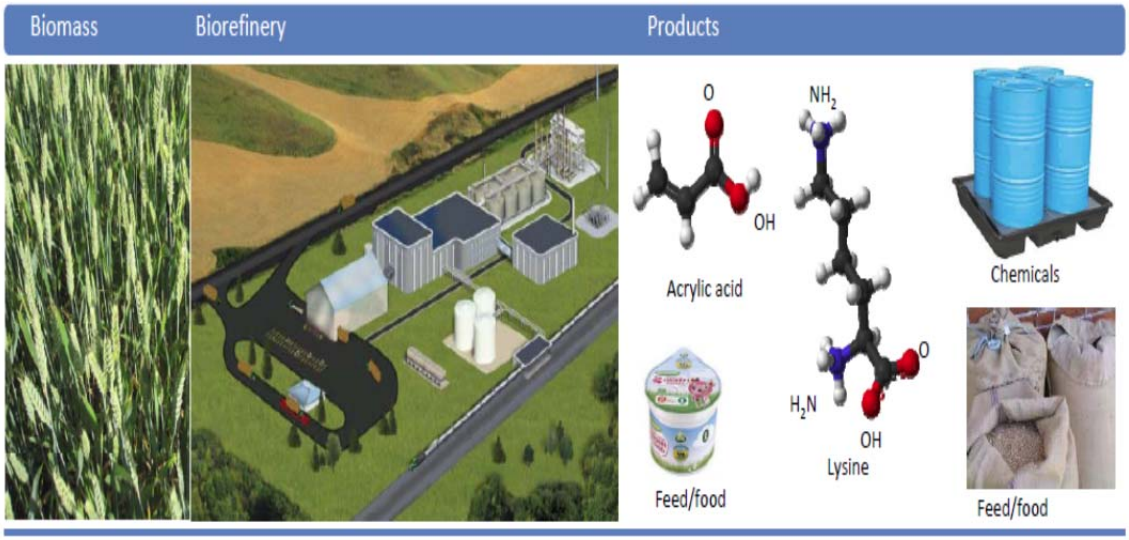
and gas is used in the production of chemicals and intermediates, and this accounts for almost 50% of the added value in the total fossil oil processing chain (Turnover 2007: €2300 billion and expected in 2012: €2700 billion). The BIO-VALUE SPIR focuses on value-added products such as specified sugar streams, chemicals and protein-based feed, thus complementing already ongoing activities targeting bioenergy. This approach is an urgent requirement for development of a viable biobased society being independent of fossil resources. Danish industrial companies have specific knowledge and a competitive edge in this area, providing a great opportunity for Denmark to create new workplaces and to lead an international 'green boom'.

Strategy and objectives

The strategy is to establish a product-driven research and innovation platform embracing major Danish companies, universities and technology institutions (GTS, Innovation Networks).

The main objectives of the platform are to:

a) Deliver novel knowledge based on scientific excellence that can promote the design of new sustainable biorefinery value-chain concepts.
b) Demonstrate sustainable, competitive large-scale upgrading of biomass into intermediates and specific products:
    i. Carbohydrate mixtures of specified composition and purity grades
    ii. Lignin and lignin-derived components of specified purity
    iii. Biobased chemicals such as selected carboxylic acids and amino acids
    iv. Protein rich feed to substitute soy in sustainable animal feed.
c) Develop a direct innovation flow and innovation pipelines targeting biorefining technologies from a fundamental research base, encompassing three main competence areas:
    i. Quality biomass production for biorefinery purposes.
    ii. Separation and purification technologies.
    iii. Conversion of carbohydrate and lignin streams into value-added products.
d) Develop core technologies covering (see figure below):
    i. Innovative biomass production systems and improved logistics for multi-product biorefinery utilization.
    ii. Pretreatment and bioproduct isolation via optimised separation engineering.
    iii. Conversion of biobased intermediates into high value products.
e) Educate the qualified manpower required for this production and for the next generation of advanced biomass upgrading development.
f) Disseminate knowledge to existing and emerging small- and medium-size enterprises (SMEs) and to the general public via creation of networks, events and websites.



2.2. The scientific objectives and anticipated results – in relation to state of the art and in relation to societal and business challenges

The overall research objectives in the BIO-VALUE SPIR target innovative biomass supply chains in combination with pretreatment and separation processes that yield biomass components for further processing by biorefinery conversion processes. These objectives are addressed via a set of integrated end product-driven research projects as further specified in section 4. Development of new technologies will be an integral part of all research activities along with development of rational tools and frameworks for sustainability assessment.

Expected results are:

- Strong links between fundamental research in chemical engineering, plant biosystems and industrial innovation for production of new processing streams and products for the biobased society.
- An improved scientific basis for development of diverse and flexible biomass production systems and logistics, which are able to supply biorefineries with a wide variety of biomasses tailored for biorefinery purposes and produced under sustainable conditions.
- Novel science-based biomass conversion and separation technologies to deliver tailored biorefinery product streams for different purposes, thereby defining a set of new sustainable and efficient processing principles.
- New reactive separation technology systems in which the separation takes place in conjunction with a conversion reaction, as opposed to being a separate unit operation.
- New processes for converting carbohydrate and lignin streams into value-added products including chemicals.
- A coherent and integrated economic and sustainability assessment methodology to assess new biorefinery based production systems and their potentials in a biobased economy.

In the coming years, biorefinery based production is expected to grow significantly both in Denmark, the rest of Europe, and globally. Current crop production systems are optimised for food and feed output. Due to an increasing world population, the production of food and feed will have to be substantially increased over the coming years. At the same time, there is a growing demand for biomass for bioenergy, which competes directly with the traditional uses. Under these conditions, biomass supply and carbon efficiency will be key factors in determining the potential for biorefinery development world-wide.

Visions and strategies for biorefining have been developed at the European level (www.star-colibri.eu) and considerable efforts have already been put into both identifying the potential of biorefinery platforms and defining the most commercially competitive products (de Jong et al. 2012). A few companies in Europe have already started developing biobased chemicals (see e.g. Mandl 2010; de Jong et al. 2012). While these companies are pioneers individually, the scientific basis needed for future development of a broader array of sustainable biobased products is still just in its infancy. Existing technologies, currently also being demonstrated in Denmark, allow production of bioethanol and lignin for use as renewable fuels (Inbicon/DONG Energy). Cost-effective release of bio-convertible monosaccharides as well as co-utilization of lignocellulose components have recently been listed as the most vital priorities required for advancing profitable biorefining of cellulosic biomass (Zhang 2011). Hence, in addition to improving the efficiency of the core conversion technologies for biofuel production, it is important to add economic value and sustainability to the biofuel process via concomitant production of higher value products from the biomass. This biorefinery manufacturing concept also encompasses the utilisation of other biomass components than glucose to produce for example building block compounds, fine chemicals, and various advanced functional compounds (Ragauskas et al. 2006).

Denmark has excellent opportunities for making rapid scientific progress in biorefining and for efficiently translating this progress into innovative solutions and commercially competitive production chains. The companies and university research groups participating in the BIO-VALUE SPIR consortium have already contributed with significant discoveries which will form a strong basis for future cross-disciplinary collaboration. These discoveries cover

biomass quality improvement (Lindedam et al. 2012), enzymatic conversion technology development (Quinlan et al. 2011), rapid measurement methods for biomass conversion (Baum et al. 2012), separation technology systems (Barbaras et al. 2009, Vinther et al. 2012, Alam et al. 2011), modelling frameworks (Morales-Rodriguez et al. 2012), delivery of new products via fermentation or innovative catalytic routes (Holm et al. 2011, 2010; Liu et al. 2012), and large-scale biomass conversion optimisations (Petersen et al. 2009). Most of these recent research successes have been achieved in one-on-one company-university collaborations, but bear witness of the immense potential of combining an innovation drive with fundamental research in the biorefinery area. By joining forces in a concerted action, the universities and companies will achieve the necessary size and synergy which can make Denmark a world leader in innovative biobased technology and product development.

The development of new multi-purpose crops for biorefining, novel targeted separation principles, and exploration of new conversion routes for different biomass feed streams will deliver new fundamental understanding of the interactions between biomass composition, separation and conversion technologies. In addition, new knowledge about biorefinery product streams and their separation will be obtained. The integration of socioeconomics and sustainability analyses with the science and engineering projects will provide the economical and ethical decision base required for development of new sustainable biorefinery value chains.

2.3. The innovative objectives and anticipated results - in relation to societal and business challenges

The underlying innovation paradigm of the BIO-VALUE SPIR is that all components of the biomass must be processed into value-added products in order to make the processing commercially viable. At the same time, both the biomass production and the processing must be based on sustainable methods.

Specifically, the innovation activities will initially focus on producing carbohydrate mixtures, protein fractions and lignin with the following success criteria: 1) lowest possible costs, 2) purity required for further downstream processing and 3) proper account of sustainability. The BIO-VALUE SPIR will establish an advanced technology platform which is commercially competitive and delivers value-added bioproducts based on biomass feedstocks.

The innovative objectives and anticipated results embrace:

Technologies which ensure cost-effective delivery of biorefinery feedstocks throughout the year: (i) New multi-purpose cropping systems yielding increased biomass quantity with optimised quality; (ii) Logistics processes, including de-centralized conservation and pretreatment; (iii) Recirculation of nutrients from side streams.

Technologies which allow cost-effective sequential separation and purification of biomass streams: (i) Novel enzyme-assisted dewatering concepts for biomass streams; (ii) Enzyme-based valorisation of carbohydrates and protein from green biomass; (iii) Purification processes to obtain purified carbohydrate and lignin streams.

Technologies which allow cost-effective conversion and conditioning of biomass-derived product streams: (i) Selective enzymes for targeted carbohydrate conversion and modification; (ii) Conversion of carbohydrate and lignin streams into value-added chemicals; (iii) Integration of enzymatic conversion with simultaneous separation for upgraded C6 and C5 streams; (iv) Fermentative lysine production; (v) Minimised energy consumption and cost by directing the work via process cost analyses and modelling.

Methodologies for coherent and integrated assessment of socio-economic and sustainability aspects: (i) Comparative assessment of micro- and macroeconomic potentials, sustainability, ethical aspects and regulatory issues for biorefinery based production/value chains; (ii) Tools for sustainability assessments, which are a key part of the decision basis for biorefining.

2.4. Target group of institutions and companies

The partners involved in the BIO-VALUE SPIR provide a comprehensive source of relevant academic disciplines and are world-class technology leaders in their fields of expertise. The core consists of the companies Novozymes A/S (NZ), Haldor Topsøe A/S (HTAS), ArlaFoods a.m.b.a. (ARLA), DLG a.m.b.a., Rockwool, KMC a.m.b.a., Borregaard and Hamlet Protein who all contribute with substantial funding. The contributing Danish Universities include University of Copenhagen (KU), Aarhus University (AU), Technical University of Denmark (DTU) and Aalborg University (AAU).

In addition to the already mentioned large companies, the Danish Knowledge Centre for Agriculture (VFL) and a group of small and medium-sized enterprises are involved, each contributing with their specific knowledge and benefitting from the network (enclosure E). The biobased society is business-wise at an early stage of the development curve, where the presence of SMEs is relatively limited. A special effort will therefore be conducted with respect to incorporation of additional SMEs during the project period, facilitated by setting up demo-projects that deal with the application of new technologies or research results, or tech-transfer of industrially relevant technologies (see sections 3.2 and 4.1.9). The technology institution AgroTech in collaboration with the Innovation Network for Biomass (InbioM) and Denmark's Innovation Network for Health & Life Sciences (Biopeople) will play an important role with respect to the further involvement of additional SMEs (section 3.2). The BIO-VALUE SPIR thereby addresses a broad variety of companies providing input or using output from the platform. At the input-end it is farmers, technology-providing companies and farm-equipment manufacturers, providers of seed and biomaterials etc. In the process segment for pre-treatment, conversion and refining of biomass, the target is companies which are technology providers, process and equipment manufacturers and users of the refined products.

Several of the key scientists involved in the BIO-VALUE SPIR research are also participating in the platform entitled "Biomass for the 21st Century: Integrated biorefining technologies for shipping fuels and biobased chemicals" (B21st). The BIO-VALUE SPIR and B21st have very different goals and approaches and there is no overlap in the funded activities. Nevertheless, all options for harvesting synergy will be actively pursued. Links will also be established to The Danish Industry-Science Partnership for Innovation and Research in Food Science (InSPIRe) in order to initiate and coordinate joint activities. Several International partners and The NovoNordisk Foundation Center for Biosustainability (biosustain.dtu.dk) will be part of the knowledge exchange network too.

2.5. Cohesion between the research and innovative objectives and anticipated results

Bio-Value is a truly innovation driven platform with a strong involvement of industrial partners in all projects. In order to ensure tight links between research and innovation, the work in the BIO-VALUE SPIR is organised around a core of six end product-defined projects which all embrace components spanning strategic research and innovation (see details in section 4).

3. Methodology

3.1. Methodology for the research activities

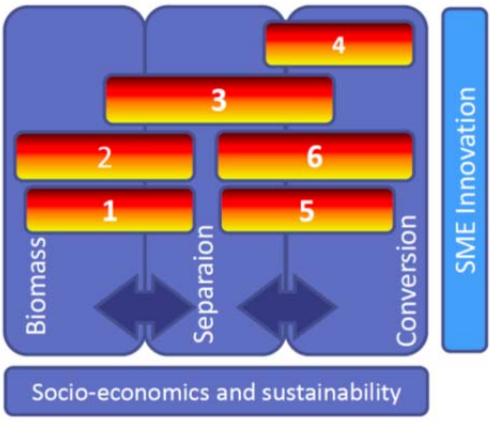
The research in the proposed BIO-VALUE SPIR will systematically target development of biomass supply chain management, new processes, products and services within the biorefining value chain. The activities will interlink different parts of the value chain in order to ensure that results obtained in one particular area will be able to support development of entirely new solutions both upstream and downstream. Accordingly, synergy between the partners will be effectively explored and new opportunities will have optimal conditions for being pursued.

The experimental work in the BIO-VALUE SPIR is organised in six R/I projects as shown in the diagram on p. 6. Each project has well-defined objectives, resource allocations and a designated project leader who is responsible for meeting the objectives that are set out within each individual project (see sections 4.1.1 - 4.1.6).

In order to ensure coordination, research coherence and knowledge transfer across the projects and partners, three competence centres, viz. (i) Biomass, (ii) Separation, and (iii) Conversion, are established. These three centres will also promote scientific excellence,

scientific progress and optimization of methodologies and technologies. The competence centres are anchored at the universities and will provide a vehicle for establishing and maintaining an intimate interaction between partners across the different projects. The six R/I projects span the competence centres to varying degrees, reflecting their cross-disciplinary scope.

Issues related to sustainability, socioeconomics, ethics and legal issues will be integrated in all R/I projects. The interaction will involve a two-way information flow where the projects on the one hand deliver data to the sustainability analyses, while they on the other hand receive specific decision and assessment tools and knowledge relevant for integrated economic and life cycle analyses (see further details in section 4.1.8).



The research and innovation activities are clustered around a core of six end-product-defined projects:
(1) Innovative biomass production systems
(2) Products from green biomass
(3) Upgraded sugar streams from biomass
(4) Lysine production
(5) Catalytic conversion of carbohydrate streams
(6) Value-added products from lignin

The six projects span the three competence centres (Biomass, Separation, and Conversion) to varying degrees. In addition, a platform for Socio-economics and sustainability will be established together with an SME innovation platform.

3.2. Methodology for the innovation activities

The objectives within each of the six projects that form the core of the SPIR activities are all defined by their innovative pull, targeting specific end products. This structure has been established in order to ensure a tight integration of research and innovation activities. In addition, the methodology for the innovation activities includes incorporation of additional SMEs during the project period. The GTS Institute AgroTech will specifically focus on this aspect in collaboration and shared responsibilities with the innovation networks InbioM, Biopeople and all other project partners.

InbioM has since 2004 been one of the key platforms for knowledge dissemination, development and commercialisation of new technologies and concepts in relation to biomass. Today, InbioM embraces 583 members from 335 organisations of which more than 225 are Danish SMEs (www.inbiom.dk). Similarly, Biopeople has a large network clustering universities, research organisations, industry associations as well as pharma, food and biotech companies with the aim of stimulating innovation (www.biopeople.dk). The innovation networks will assist the SPIR consortium by supporting strategic development of smaller companies within the biorefining area. They will furthermore promote knowledge transfer activities such as facilitating educational cooperation at the regional and national level.

3.3. **Cohesion between methodology for the research and innovation activities**

The innovation components are to a large extent defined by the involved companies and the specific activities pursued will target competence-building and rapid establishment of business opportunities for the companies. Initially, about 85% of the total budget is allocated to well-defined research and innovation activities. The remaining budget is reserved to initiate new innovation projects that emerge as the technologies and knowledge developed in the BIO-VALUE platform become available. These funds are targeted at new SME partners that will complement the large industrial partners, providing drive in complementary areas within the field of the platform. It is the intention that the reserved budget will be used as innovation vouchers for financing relevant partner activities with a strong commitment including at least 50% leveraging from the involved SMEs. It is anticipated that a dominant fraction of these vouchers will be used for knowledge transfer and development involving AgroTech. A number of commitment letters have already been received from SMEs (enclosure E).

4. Project plan and activities

4.1. Activities related to the research and innovation components as well as cohesion between the research and innovation activities

4.1.1. Innovative biomass production systems, harvest and conservation technologies

Objectives: (i) Increase the quantity and quality of biomass raw materials available for biorefining by development of innovative multi-purpose production systems, embracing annual and perennial plant species and exploiting the potential of genotypic differences; (ii) Increase resource use efficiency by extending the crop growing season and exploring plant complementarity; (iii) Optimise land management, logistics, biomass harvesting and storage; (iv) Develop cost-effective management practices for marginal lands to harvest their biomass potential.

State-of the-art: Among genotypes of wheat with similar grain yields, there is a large difference in straw productivity and sugar release (Lindedam et al. 2012). Also, in the so far undeveloped energy crop species, there are genotypes which are much more efficient in converting solar energy and tolerating abiotic stress than others (Dohleman and Long 2009). Breeding and selection may further increase photosynthetic efficiency (Zhu et al. 2010). Perennial grass systems with low inputs can either be optimised by multi-species mixing which has been shown to increase total yield due to complementarity (Tilman et al. 2006) or by selecting species with efficient photosynthesis (Jorgensen 2011). The cell wall composition of grass mixtures can be strongly manipulated by management, including harvest time (Allison et al. 2011). There is also a large biomass potential to be harvested from perennial grasses and grass-clover mixtures on marginal lands (Gylling et al. 2012).

Scientific novelty: (i) To understand the fundamental interactions between genotype, environment and management factors that can be exploited to sustainably intensify the biomass yield per unit land area and to deliver tailored biomass qualities for biorefineries; (ii) To achieve basic understanding of key factors controlling the productivity and resource-use-efficiency of novel biomass production systems (critical growth stages, plant density, canopy structure, day-length responses, low temperatures, nutrient and water exploitation).

Research and innovation activities: The experimental work focuses on: (i) composition of agricultural systems that more efficiently utilise resources, including the incoming solar radiation and mineral nutrients, while at the same time preserving soil quality and reducing nutrient losses and greenhouse gas emissions. Innovative production systems including perennial low-input, high-diversity grasslands and double crops will be established and thoroughly scrutinised to evaluate their productivity and sustainability in terms of carbon sequestration and nutrient emissions; (ii) characterisation of cereal genotypes and grass species mixtures with optimised yield and quality for biorefinery purposes in interaction with environmental and management factors; (iii) development of suitable machinery and web-based planning tools allowing a continuous supply chain of biomass with optimised quality for refining purposes. The research work will mainly be based in competence centre 1 (Biomass), but will deliver biomass materials and data on biomass composition to projects in the other centres as well as receive feed-back from these which is relevant for tailoring biomass sources to end-product features.

Commercial potential: Biomass constitutes the basic raw material for biorefineries and crop production systems capable of delivering high-quality resource-efficient biomass have an enormous economic potential for farmers, plant breeders and machinery suppliers. Reduced environmental impact can also help secure the right of farmers to produce crops on environmentally sensitive areas.

Milestones: (i) Criteria and technologies for genotype selection and establishment of new multi-purpose cropping systems (M12, 24, 36, 48, 60); (ii) Prototypes of novel grass mixtures (M60); (iii) Targeted production conditions (nutrient recirculation, water, genotypes) for optimisation of biomass quantity and quality for sustainable biorefining (M60); (iv) New flexible harvest procedures reducing biomass losses (M36); (v) Design and modelling of operational and cost-effective procedures for conservation and storage of biomass (M48); (vi) Documentation of environmental impacts of different cropping systems (M60).

Project leader: VFL (Michael Støckler). *Additional key partners:* AgroTech (Henning Høgh Jensen), AU (Uffe Jørgensen), KU (Jan K. Schjørring), DLG (Birger Eriksen), ARLA (Kjell Lundén Pettersson), VFL (Jan Mousing). *Total project budget:* ~21mill. DKK.

4.1.2. Products from green biomass (protein, storable fibres, inorganic elements)

Objectives: To develop a decentralised, robust and overall optimised pretreatment process for green biomass for production of animal protein feed and a storable fibre fraction that can be used as substrate on centralised biorefineries.

State-of the-art: The pivotal work on leaf protein extraction from biomass was done in the UK by Pirie (1987), aiming at production of human protein-rich food and feed for monogastric livestock. However, low prices on e.g. soy protein have not endorsed further development until now. Recently, several groups have investigated green biorefining with extraction of protein (e.g. Kamm et al. 2009, Dale et al. 2010). The yield and quality depends on the crop chosen (optimised in collaboration with project 1) and the complexity of the processes used. In order to achieve viable processes, it is crucial to integrate and optimise the whole process, e.g. wet fractionation, filtration recovery input and energy costs against product yield and quality (e.g. Bals and Dale 2011). The companies KMC and Hamlet Protein have both established full-scale industrial plants for protein extraction from potatoes and soybean, respectively. The comprehensive experiences of the two companies will be applied on green biomass and provide a strong knowledge-base for rapid progress. KMC has made its potato protein process line available to the project for large scale green biomass test runs.

Scientific novelty: (i) To characterise how the composition of different types of green biomass and processing conditions such as temperature, pressure, water content and processing time affect the yield and quality of extracted protein and storable fibres; (ii) To understand how unwanted secondary plant metabolites compromising feed quality or having an adverse effect on animal production, health or product quality can been removed or deactivated.

Research and innovation activities: (i) Integrated extraction and production of high-quality protein with use of the residual organic matter for industrial and energy production. Green biomasses giving a high dry matter yield and proteins with a desirable composition will be selected and tested in collaboration with project 1; (ii) Dewatering and drying of storable fibre products so that they can be affordably transported to a central biorefinery for further processing with less severe and cheaper hydrothermal pretreatment; (iii). Up-scaled wet fractionation, extraction and recovery of leaf protein by integration of existing knowledge and technologies in full-scale plants as well as in a complete pilot plant combined with anaerobic digestion of residual organic matter in an upflow anaerobic sludge blanket reactor for production of electricity and heat for internal use in the plant; (iv) Evaluation of the nutritional value of the obtained protein products using chemical analysis and biological experiments with relevant animals in order to examine effects on animal production and health and the effect on product quality of milk and meat; (v) Recycling of nutrients (nitrogen, phosphorus, potassium) from the green biomass streams; (vi) In collaboration with companies, new feed proteins of high quality for use in milk and meat production will be developed and animal performance, health and product quality will be tested; (vii) In collaboration with companies, equipment for optimization of in-field pretreatment of biomass for biorefineries will be optimized. The research work will mainly be based in competence centre 1 (Biomass), but will deliver biomass streams to activities in competence centres 2 (Separation) and 3 (Conversion).

Commercial potential: Through optimised use of biomass for food, feed, industrial and energy purposes, the following products will be produced: (i) protein for sustainable milk production, (ii) high value protein for piglet and pig production, and (iii) pelletized fibre fraction as a feed for a centralised biorefinery and for energy production. This will support increased growth in the mentioned sectors and reduce the dependency on e.g. imported protein and energy. The developed platform will be the basis for further research in extraction of high-value products (e.g. dyes, vitamins and minerals). Increased biomass production and production of a protein feed can mitigate the controversy about the use of land for food/feed or energy production. Modern intensive dairy production as well as pig and poultry production is highly dependent on quality protein feed. Today 70%, corresponding to 45 million tonnes, of the EU consumption of protein is imported primarily from Brazil, Argentina and USA. Most

projections predict higher prices on protein feed in the future caused by increased demand on animal products due to improved prosperity and growing populations. Dependency on imported protein and ethical aspects on the use of protein sources that otherwise would be used for human consumption may threaten the Danish animal food production and export.

Milestones: (i) Models of scenarios of decentralised pretreatment plants (technology, energy, use or recycling of streams, transportation logistic) (M12); (ii) Lab-size protein extraction unit for optimisation of processes (M24); (iii) New chemical analyses for characterisation of protein composition and quality aspects (M30); (iv) Construction of pilot plant (M30, co-funded from other sources); (v) Processes in full-scale and pilot plants optimised (M48); (vi) test and validation of protein products in animal experiments for effects on performance, health and product quality (M54).

Project leader: AU (Anders Peter Adamsen). *Additional key partners:* KMC (Ole Bandsholm Sørensen), Hamlet Protein (Katrine Hvid Ellegård), ARLA (Anna Flysjö), DLG (Kongskilde, Ole Green), KU (Jan K. Schjørring), AAU (Lene Lange, Peter Kamp Busk), AU (Søren Krogh Jensen). *Total budget:* 16.2 mill. DKK.

4.1.3. Upgraded sugar streams from biomass

Objectives: To provide an improved knowledge and technology base for efficient processing of the key raw materials for the biobased economy, i.e. plant biomass and carbohydrate product streams from plant raw materials. This project will develop the “sugar-platform” focusing on the conversion and separation technologies targeting innovation in the biomass processing industry. For each process and product stream, the project will aim to define the required technologies needed to bring the processes to the market. The target process objectives are: Production of a range of biomass mono-saccharide streams, including C6 and C5 sugar streams of specified purities designated for different defined purposes. Dewatering concepts. Production of lignin with improved properties for biorefining.

In this revised project the processing behavior of different biomass raw materials, not just straw, will be investigated. Selective separation will be a major part of the research effort, which is mainly tied to Competence Centre 2. However, the research will also naturally have close ties to conversion, and is therefore also tied to Competence Centre 3.

In the new partnership in the Bio-Value SPIR Program, Novozymes has retained its massive support to this “sugar-platform” encompassing collaboration for development of:

1. Integrated separation and enzymatic conversion processes,
2. Suitable enzyme immobilization technologies for advanced separation and biomass sugar upgrading,
3. Physico-chemical separation principles fitting biomass streams and lignin purification,
4. A new knowledge base for designing better process equipment for biomass pretreatment, hydrolysis, and separation for biorefinery purposes.

KMC’s role in the project mainly relates to

1. Enzymatic polishing of potato protein
2. Potato fiber processing
3. (Via project 2, test facilities for large scale processing and separations)

State-of-the-art: Until now the development goal for biomass processing has been to achieve cost-effective pretreatment and full hydrolysis for maximizing the glucose yield. The result is complex hydrolysate mixtures harboring inhibitors, carbohydrate degradation products and lignin-derived phenolics, in addition to various biomass monomers (Du et al. 2010). Lignin, glucose, and C5 hemicelluloses, mainly xylose, secondly arabinose, hold promise for upgrading in various biorefinery processes (Dumon et al. 2012). The current state-of-the-art approach uses the enzymes as a replacement for acid catalysis, not exploiting the exquisite selectivity of enzymes to catalyse release of specific compounds from the biomass in a controlled manner. Also, exploitation of the viscosity drop in the enzymatic hydrolysis and design of improved separation techniques that can abolish physical and chemical enzyme inhibitions are novel approaches having significant potential. Surprisingly limited efforts have targeted separation of C5, C6, purified lignin and other

components during the enzymatic biomass conversion. There is a lack of knowledge tying the structural traits and molecular changes of biomass types to physical behaviour, separation, and processability.

Scientific novelty: Provision of a fan of biomass derived sugar streams of a purity optimised for biorefinery purposes conjunct with separation of the lignin to obtain new product streams. This includes understanding of: (i) the impact of biomass substrate structural traits for enzymatic processability, incl. heteroxylans;(ii) separation of compounds of similar structure, (iii) reaping of compounds at low concentrations; (iv) physical chemistry of lignin in the context of carbohydrate separation; (v) kinetics of synergistic enzyme reactions in viscous biomass.

Research and innovation activities: The research work will focus on integrating biomass pretreatment, enzymatic conversion, and separation technology to obtain designated C6 and C5 streams of specified carbohydrate composition and purity. The work will include removal of e.g. inorganic salts, acetate, phenolics, and other selected minor products, and separation of lignin from the carbohydrate streams. The effort will also target enzymatic xylan degradation, viscosity lowering effects, and separations for utilising glucose, xylose, and arabinose for different biorefinery purposes. Esterases and other designated enzymes will be evaluated for selective removal of defined components. Immobilization of enzymes for liquid catalysis will be explored to open new prospects for using C5 sugars as building blocks in new engineered bioproducts. In general, the data obtained will be used for setting up mass balance models to assess process economics and technology potentials for industrial scale processes. The effort will also aim to define and model optimal mixing, pH control, contact methods, and filtrations, in order to provide a better basis for design of new process regimes and equipment for biorefinery processes. The research is mainly based in competence centre 2 (Separation), but will receive biomass materials and data from competence centre 1 and deliver streams to partners in competence centre 3 (Conversion) for explorative biorefinery purposes. There will also be a close interaction between the competence centres in relation to delivering feed-back which is required for tailoring biomass composition to end-product optimization.

Commercial potential: The commercial success of the biorefining concept critically depends on its ability to meet the economic and technical targets of the chemical industry. An upgraded monosaccharide and lignin feed stream for chemical production would lead to more efficient production conditions for chemical and fermentation processes, and lower downstream purification costs. In many chemical applications the final product must be produced in very high purity (>99 wt%) and traces of compounds such as acetate and phenolics can have a strong negative impact on product quality. According to McKinsey & Co. and others, development of new technologies and efficient processes for biochemicals could lead to sales of approx. 573 billion US dollars by 2025.

Milestones: (i) Integrated process for separation and enzymatic conversion for monomers of wheat straw and minimum one more plant based biomass (M42); (ii) Lab-scale demonstration of enzyme-assisted, reactive separation to obtain higher purity (specified) C6 streams and similarly purer C5 streams from wheat straw and minimum one more type of biomass (M30); (iii) Mapping of the behaviour of different biomass raw materials for processing (M24) (iv) New process for separation of sugar and lignin (M36); (v) Lab-scale demonstration of sequential separation of C6 and C5 streams for high purity (M42); (vi) Esterases and other speciality enzymes evaluated for selective removal of defined components (M54); (vii) Suitable enzyme immobilization technologies developed for C5 and C6 upgrading (M56); (viii) Quantitative models for biorefinery reactions and process regimes established (M60); (ix) Potato protein polishing method developed (M18

Project leader: Novozymes (Lars Saaby Pedersen). *Additional key partners:* Novozymes (Anne Goldbech Olsen), KMC (Ole Bandsholm Sørensen), DTU (Anne Meyer, Manuel Pinelo), KU (Claus Felby, William Willats). *Total budget*~26.8 mill. DKK.

4.1.4 Lysine production from a biomass-based sugar platform

Objectives: Develop and demonstrate a microbial production of the amino acid lysine from C5 and C6 sugar streams based on low cost feedstocks which are competitive with the starch-based process.

State-of the-art: Lysine is used extensively world-wide in feed production, and currently produced commercially via fermentation of sugars from first generation feedstocks. The production organism is *Corynebacterium glutamicum*, which is unable to convert C5 sugars (Blombach and Seibold 2010). Furthermore the *C. glutamicum* process is aerobic and a major part of the sugar input is respired to CO_2 in a side flux required for NADPH re-generation. Therefore, new production organisms for more efficient bioconversion of both C5 and C6 sugar streams from biomass into lysine are required to make the production cost-effective.

Scientific novelty: Two routes are suggested for developing the microbial processes: (i) *C. glutamicum* is engineered for xylose metabolism, inhibitor tolerance and co-factor re-generation, and (ii) a new process is developed based e.g. on lactic acid bacteria. The latter has the advantage of more freedom to operate since lysine producing *C. glutamicum* is heavily covered in patents.

Research and innovation activities: (i) Comparison of growth and lysine production by inhibitor-resistant bacteria on different carbohydrate feed streams; (ii) Engineering of *C. glutamicum* for xylose metabolism. The genes xylA and xylB required for xylose metabolism from *E. coli* or *L. lactis* are expressed and optimised in *C. glutamicum;* (iii) Adaptive evolution of *C. glutamicum* for enhanced tolerance to inhibitors from lignocellulose hydrolysates; (iv) Co-factor engineering of *C. glutamicum* for enhanced NADPH production; (v) Engineering of *L. lactis* for lysine production. A plant isolate of *L. lactis* capable of xylose fermentation is converted to a lysine producer via engineering and/or direct selection/screening for lysine secretion; (vi) Fermentation optimization for conversion of sugar streams from biomass hydrolysates to lysine in lab scale; (vii) Purification; (viii) Investigation of exploitation potential for microbial biomass and residuals; (ix) Up-scaling of processes. The research work is mainly based in competence centre 3 (Conversion), but will receive C6 and C5 streams from competence centre 2 (Separation) and give feed-back on purity requirements.

Commercial potential: The global market for lysine is in the range of 1500 Kt/yr (Feedinfo, 2010) with an annual growth of 5-7%. Prices are fluctuating around DKK 20/kg mainly due to fluctuating sugar prices. A cost competitive process would open for a larger market partly replacing high protein feeds like soybeans.

Milestones: (i) Strains with tolerance towards inhibitors from lignocellulose hydrolysates selected (M12); (ii) Strains of *C. glutamicum* capable of conversion of C5 sugars to lysine constructed (M24); (iii) Strains with improved co-factor regeneration constructed (M36); (iv) A strain of *L. lactis* capable of secreting lysine into the growth medium identified (M45); (v) Optimised process for lysine production from biomass hydrolysate, including scale-up in collaboration with industrial partners (M58).

Project leader: DLG (Kjeld Raunkjær Kjeldsen). *Additional key partners:* Novozymes, DTU (Peter Ruhdal Jensen, Christian Solem). *Total budget:* 10.1 mill. DKK.

4.1.5 Value-added products from catalytic conversion of carbohydrate feed streams

Objectives: Develop novel catalytic processes for the chemical conversion of carbohydrate streams into value-added products including methyl lactate.

State-of the-art: Recent results have shown that direct catalytic conversion of sugars in methanol can produce smaller C2-C4 products such as methyl lactate and methyl vinylglycolate in good yield. In particular, zeotype catalysts such as Sn-Beta demonstrate good selectivity and activity at temperatures in the range of 140-180 °C (Holm et al. 2010). Previous work on catalytic conversion of sugars like the Bilik reaction (Petrus et al. 2001) has given less attractive product mixtures.

Scientific novelty: The project includes development of new processes based on ground-breaking catalytic processes developed by members of the team. In addition, it will

provide basic understanding of the involved processes, providing the foundation for developing new efficient catalysts and process conditions.

Research and innovation activities: Two closely interacting subprojects will be carried out: (i) A project targeting the understanding of the importance of different catalyst preparation parameters in relation to catalyst performance. The ultimate purpose is to develop new catalytic materials for direct catalytic conversion of sugars. This will enable the control of which products are produced from sugars using catalysts and the ability to tailor a catalyst for a particular product; (ii) Study of the migration of carbon atoms in the sugars and other mechanistic aspects during catalytic conversion, providing crucial insight into the molecular transformation that takes place using different zeotype catalysts and model catalysts. Based on these studies, methods for upscaling as well as methods for upgrading the formed intermediates will be developed in a subsequent project within the SPIR platform. The research work is mainly based in competence centre 3 (Conversion), but will receive streams from competence centre 2 (Separation) and interact with both centre 1 and centre 2 in optimizing the quality of raw and processed biomass streams.

Commercial potential: While e.g. methyl lactate has a negligible world market, the derived products such as lactide, lactic acid and polylactic acid have a rapidly growing market, presently ¼ million Mt with kg prices averaging DKK 20/kg. In addition, the development will lead to new primary products such a solid state catalysts for the world market.

Milestones: (i) Separation of by-products from HTAS' samples by column chromatography and identification of byproducts (M22); (ii) Experimental investigation of mechanisms for formation of key by-products using spectroscopic methods and isotope labeling completed (M40); (iii) Studies of conversion of isotope labeled trioses with zeolite catalysts completed (M28); (iv) Identification of carrier materials for efficient conversion of sugars (M16); (v) Identification of active sites and stability of catalysts (M40).

Project leader: HTAS (Esben Taarning). *Additional key partners:* HTAS (Kresten Egeblad, Martin Holm), DTU (Anders Riisager, Peter Fristrup), AU (Troels Skrydstup, Henrik Helligsø Jensen). *Total project budget:* 14.1 mill. DKK.

4.1.6 Value-added products from lignin

Objectives: Development and comparative evaluation of new methods for conversion of lignin into value-added products such as phenols and functional binders.

State-of the-art: Lignin is an important constituent of all biomass, amounting to 15-30 wt% or up to 40% by energy. In fact, in a second generation ethanol plant, lignin is the largest product stream albeit with a low value, mainly as solid fuel of less than DKK 1/kg. To render biorefining processes attractive, it is important to get a higher value out of this stream. It is made up of cross-linked phenolic alcohol units, and is the only one of the biomass polymers that is dominated by aromatics, making it interesting as a source of aromatic chemicals. The main available forms of lignin is soluble lignosulphate from sulphite treatment of lignocellulose and solid lignin powder from steam explosion and subsequent enzymatic treatment of lingocellulose. Depending on the original biosource and the pretreatment process the intermediate the macromolecular structure varies significantly. In any case the depolymerisation of lignin is a challenge. Most work in this field has been directed towards gas phase hydrocracking/pyrolysis, leading to less attractive gas and liquid phase products, primarily targeting fuel applications. Chemical liquid phase conversion of lignin has a larger potential for forming well-defined products, and a few of them have even found commercial applicability, such as vanillin production from wood lignin (Borregaard). Initial results from other more integrated attempts in this direction have been published recently (Zakzeski et al. 2012). Interestingly, grass lignin seems to give higher amounts of well-defined products such as guaiacol (Zhang et al. 2008).

With the introduction of biorefineries a new type of lignins will become available compared to current lignins from the pulp and paper industry. Thus, there is an increased need for developing and adapting methods for depolymerisation of biorefinery lignin as well as the pathways towards specific precursors and chemicals.

Scientific novelty: The proposed project will apply an integrated conversion and refining approach, aiming at developing sustainable processes for value-added products such as phenolic binders, guaiacol, other phenols and methanol. Special emphasis will be on the initial solubilisation and depolymerisation using catalysed supercritical hydrothermal treatments with step temperature changes but also enzymatic approaches may be used. Chemical analysis and separation of the formed product mixtures will be a major research challenge. The development of partly depolymerized lignin as well as repolymerized lignin monomers for binding to mineral fibers will be a key element in the project. Using the integrated biorefining approach, unexploited fractions will be considered for liquid fuel applications.

Research and innovation activities: (i) Fractionation and development of efficient depolymerisaton processes for different plant based lignin sources; (ii) Hydrothermal conversion of lignin fractions including lignosuphate to form aromatic chemicals;(iii) Fractionation of formed product mixtures (vi) Development of new ligninbased binders for mineral fibers (v) Efficient analysis methods with feedback to process optimisation; (vi) Development of efficient separation methods; (vii)Construction and testing of a kg scale continuous HTL plant (viii) Comparative feasibility analysis.

The research effort is mainly in competence centre 3 (Conversion), and will provide feed back on and receive streams of lignin from varying origin from project 3 - competence centre 2 (Separation) as well as from industrial partner Borregaard. I may be decided to make 1-3 dedicated testruns on Borregaards BALI test facility, for budgetary reasons 1 testrun is included in the budget.

Commercial potential: A wide range of products can be obtained from lignin and thus the commercial potential is more difficult to estimate. One feasible product is guaiacol, with a growing world market of 23.000 Mt and a price in the range of DKK 30/kg. Other products such as phenol have much larger markets (10 million Mt), but correspondingly low prices (DKK 10/kg). Binders have a huge market also exceeding the present market of binders for mineral fibers, with prices in the DKK5-10/kg range Methanol and hydrogen have a large market and prices in the range of DKK 5/kg. By following chemical treatment, the residual lignin components will be a potential basis for high grade fuels.

Milestones: (i) Feasibility report on different pretreatment processes for forming a liquid lignin feed (M21); (ii) Methods for characterization of lignin feed from different sources verified (M18); (iii) Evaluation report on oxidative and hydrothermal depolymerisation routes (M32); (iv) Report on initial results from development and testing of lignin binders(M50); (v) Standardized methods for GC-MS and LC-MS established (M20); (vi) Efficient separation and purification processes for lignin monomers developed (M50). (vii) Demonstration of new kg scale hydrothermal conversion plant (M24); (viii) Comparative technical, environmental and economic feasibility analyses of selected processes completed (M56);

Project leader: Rockwool(Dorthe Lybye)/AU(Ib Johannsen) *Additional key partners:* HTAS (Esben Taarning), Borregaard (Guldbrand Rødsrud), Rockwool (Dorthe Lybye), DTU (Anker Jensen), AU (Bo Brummerstedt Iversen, Marianne Glasius), KU (Claus Felby). *Total project budget:* 16.4 mill. DKK.

4.1.8 Platform for socioeconomics, sustainability and ethics

Objectives: To link the results from the R/I projects into a production/value chain context based on the assumption that increased production of biomass and biobased products will have economic as well as organisational impact on a number of production sectors.

Research activities: Coherent and integrated methodologies will be developed for comparative assessment of micro- and macroeconomic potentials, sustainability, ethical aspects and regulatory issues for biorefinery based production/value chains. All assessments and analyses will be performed within the same generic methodology framework. Comparative analyses will be performed between existing fossil based production chains and biorefinery

based production chains as well as between different biorefinery based production chains. Both existing data as well as project generated data will be used for the comparisons and analyses.

In cooperation with the partners in the R/I projects, a number of production/value chains will be described and initial economic and sustainability analyses will be carried out. Specific analyses based on data from the ongoing R/I projects will be carried out to guide decisions in the individual projects. Examples of issues for specific analyses are (i) allocation of green versus yellow biomass for different biorefinery processes, (ii) the cost of different storage methods for biomass versus the quality for processing and (iii) combination of biomass types and storage methods to ensure cost-effective all year supply of biomass for individual biorefinery based production chains.

Based on the results from the initial analyses, a number of production/value chains from field to product will be selected for further analysis for technical and economic feasibility, sustainability, ethical and legal issues. The selected value chains will include value chains from field to final products like lignin, lysine and protein. A final consumer product, for example milk will also be selected for analysis.

The microeconomic analysis and sustainability analysis (LCA) at value chain level will be based on quantitative microeconomic methods and quantitative LCA methodology. The macroeconomic analysis will be performed at sector level on selected optimised production chains. An integrated model framework will be used to analyse the economic effects, including employment, of an increased production of biobased raw materials. The analysis will be done for the agricultural sector, connected sectors and other specified relevant sectors including a biorefinery sector. Description of the effects of incentives and barriers related to ethical, institutional framework and legal regulation issues which are foreseen to influence an increased production and use of biomass for biorefinery purposes will be done at society level.

Milestones: (i) Data format for economic and environmental assessment agreed on by platform partners and the individual R/I projects (M9); (ii) Generic quantitative microeconomic simulation model ready for test run (M24); (iii) Methods for sustainability assessment adapted and described (M24); (iv) Full production/value chains for analysis selected in collaboration with project partners (M30); (v) Models for sector analyses adapted and tested (M36); (vii) Framework and methodology for analyses of ethical and legal issues described (M58).

Project leader: KU (Morten Gylling). *Additional key partners:* DTU (Michael Hauschild), AU (Tommy Dalgaard, John E. Hermansen), ARLA (Anna Flysjö), KU (Jørgen Dejgaard). *Total budget:* 5.9 mill. DKK.

4.1.9. SME Innovation Platform

Scope: Ensure SMEs an easy-accessible and flexible innovation platform in the BIO-VALUE SPIR (i.e. a platform in the platform) to enforce innovation and employment in Denmark by developing a new sector to support the biobased society.

Objective: An important part of BIO-VALUE SPIR is to ensure that innovation in SMEs comes into play in relation to the BIO-VALUE objectives and content, and to ensure that SMEs can reap knowledge into innovation continuously from the R/I activities. The SME Innovation Platform provides a mechanism to ensure that SME companies can get quick and easy access to BIO-VALUE SPIR activities through smaller innovation projects, established and operated on SME business premises with technical and project management assistance from the GTS Institute AgroTech and with integration to one or more of the six core R/I projects of the BIO-VALUE SPIR. At the same time, the establishment of this 'platform in the platform' provides a flexible working procedure for handling intellectual property rights (IPR).

Novelty of the project: The 'platform in the platform' gives SMEs opportunities to work with their specific innovation projects integrated into the overall research themes that the BIO-VALUE SPIR contains. The SME involvement will be facilitated by co-funding from the part (15%) of the BIO-VALUE SPIR budget which is not targeted for specific activities at the start of the platform period. These funds will be used as innovation vouchers ensuring SMEs access to specific technical cooperation, innovative methods and effective project management. The SME program will be guaranteed an integral role throughout the entire governance model, developed for the BIO-VALUE SPIR.

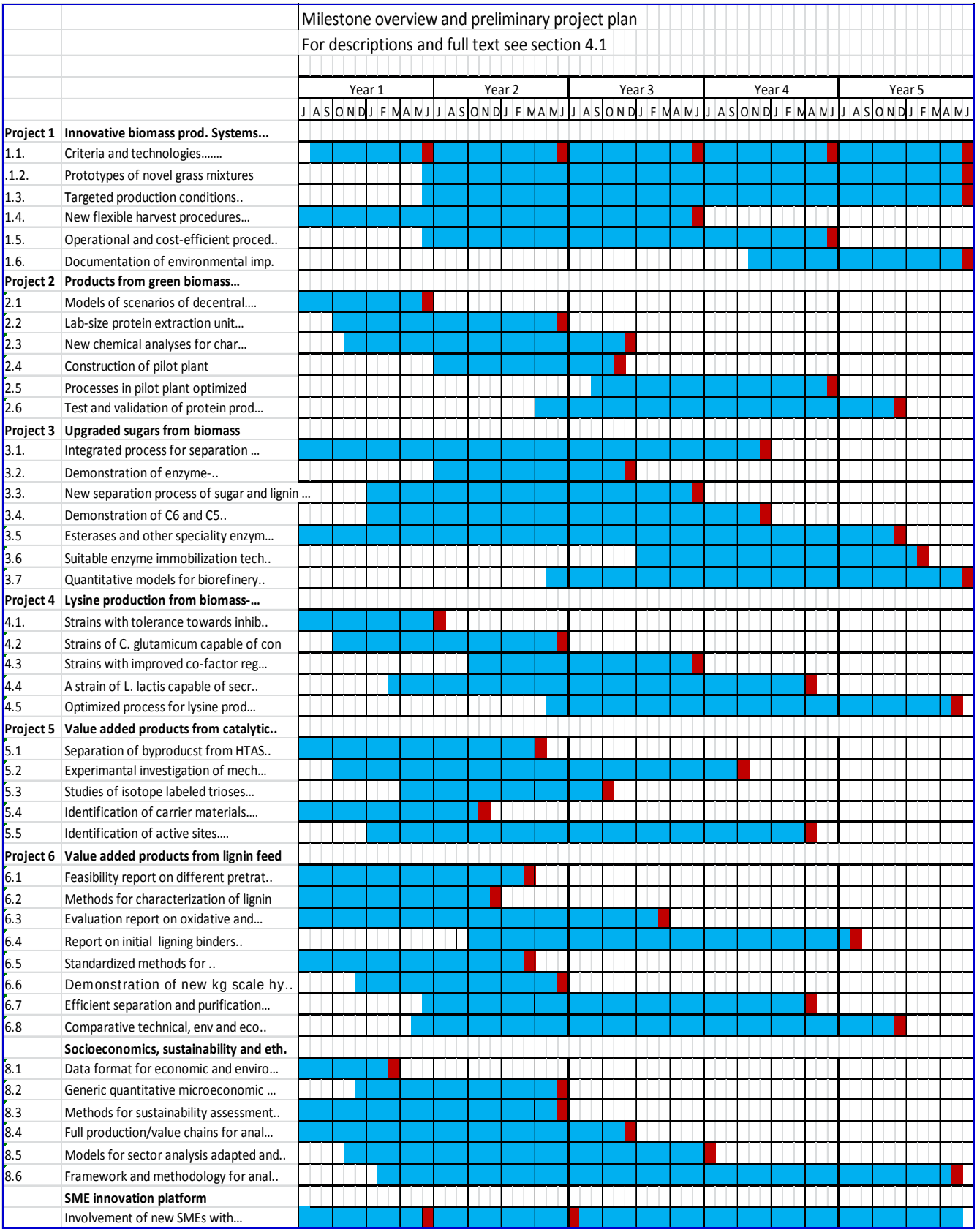
Research and innovation activities: This platform ensures an entrance where SMEs can access the BIO-VALUE SPIR with specific innovation projects and with an opportunity to leave the platform again when the innovation project is completed. The conditions are that defined specific innovation projects are based on a 50:50 financing principle, are driven by the innovation needs of SMEs and are supported by the created knowledge in the BIO-VALUE SPIR. All SPIR partners will be responsible for the contracted entry with SMEs. The involvement will be facilitated by: (i) Proactive efforts towards potential SMEs (in collaboration with the innovation networks InbioM and Biopeople); (ii) Matchmaking between SME issues and BIO-VALUE SPIR knowledge; (iii) Development and execution of concrete innovation projects; (iv) Establishment of a flexible agreement incl. IPR rules; (v) Implementation of the results obtained at the participating SME companies. The project will also work to ensure businesses an international outlet through cooperation with InbioM's Europe Enterprise Network. As the platform on a continued basis will be based on innovation opportunities of SMEs, the number and names of all SMEs cannot be identified at this time, but several SMEs have already declared their interest in and willingness to contribute to the BIO-VALUE SPIR (Enclosure E). At least 50% of SME activities will be initiated within the first 2 years of the BIO-VALUE SPIR.

Commercial potential: The economic potential cannot be valued at present as it is dependent on the SMEs' need for innovation and new knowledge from BIO-VALUE SPIR. The starting point of the establishment of innovation projects is that there is a significant commercial potential in each case, and that the company will be able to raise the implementation of the results of the innovation project into products. There is great economic potential in ensuring Danish SMEs an innovation platform that provides an easier take-off for a new sector of technology to support biobased production.

Milestones: Involvement of minimum ten SMEs with a matching funding of 11.3 mill. DKK (M24).

Project leader: AgroTech (René Logie Damkjer). *Key partners*: InbioM (Lars Visbech Sørensen), Biopeople, SMEs and all project partners.

4.2. Project plan with milestones (Gantt diagram)



5. Exploitation of results and publication and dissemination strategy

5.1 Plan for scientific publications

The team of researchers involved in the specified projects all have strong publication records, and they will in collaboration with the PhDs and postdocs ensure a steady flow of peer-reviewed scientific publications (at least 100) published in journals of high impact. The interdisciplinary nature of the collaboration will allow publications in a wide range of journals. In areas where IPRs need to be secured to allow commercial exploitation of results, publications may be delayed in accordance with the patent submission process. International exposure will also be pursued via presentations at international conferences and meetings.

5.2 Plan for research and innovation dissemination to the target group of companies

A public web-based platform for international information dissemination, knowledge exchange and networking will be established based on experiences contributed by all the involved partners. The GTS institute AgroTech will be responsible for coordination of the dissemination of new knowledge to the SMEs. Agreements on collaboration with two already existing innovation networks InbioM and Biopeople have been established. The network VE-Net will be involved in dissemination to the extent that any novel energy technologies will be developed. Also the established BioRefining Alliance, including several of the BIO-VALUE key partners, will serve as a strong partner for creating political attention and for knowledge dissemination.

Frequent workshops will be held to determine and initiate new development activities in which the BIO-VALUE SPIR will act as a catalyst to facilitate collaboration initiatives and the establishment of projects among the participants.

An internal web-based platform will be used to connect competences and networks and to inspire further interaction between the participants. Participants in the BIO-VALUE SPIR can use this a s a tool to search for specific competences and existing relations between all partners in the platform, thus enabling the right match for specific projects or for exchange of ideas.

5.3 Potential commercialisation including IPR

BIO-VALUE is an innovation driven platform with heavy involvement of industrial partners in goal setting, project management and project activities. This will ensure a short path between strategic research and commercialisation. Furthermore, it is expected that the R/I activities will open possibilities for the creation of start-up businesses. The projects have been selected based on both research needs and commercial potential, and amongst the industrial partners a large fraction of the results are expected to be rapidly transformed into commercial assets. As an inherent part of the project work, viable commercial potentials will be secured via IPR submissions prior to publication. In addition to end products, the commercial value may lie in processes or materials (catalysts, enzymes) for production of end-products. SMEs will be encouraged to participate for longer or shorter periods of the total project timeframe.

5.4 Broad dissemination to the public

The BIO-VALUE platform will take advantage of the large public interest in sustainability, biobased production and green products to convey the goals and nature of the platform to a wider public. The delicate balance between food production and industrial uses of biomass will be addressed, and the full potential of a biobased society will be presented. The professional communication entities at the involved partners will be engaged actively by disseminating the knowledge gained in various public media.

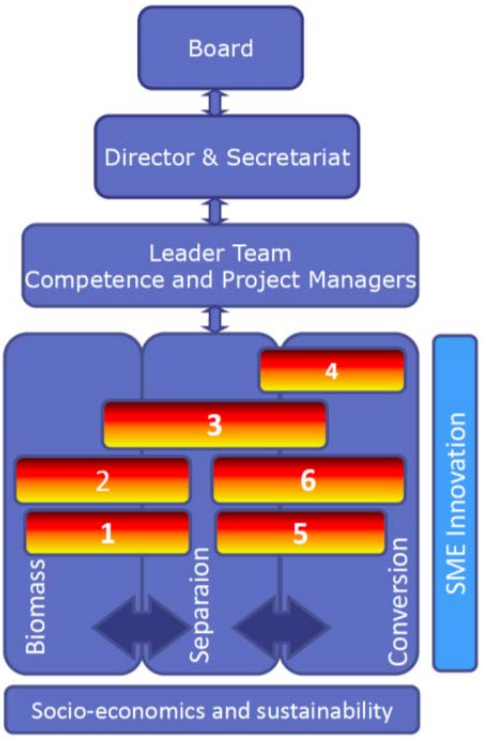
It is the intention that all high school classes in chemistry and biotechnology will be given access to material addressing the potential and scientific challenges going from fossil oil based materials to biobased materials. BIO-VALUE partners will be encouraged to participate in science events such as the Danish Annual Research Promotion Day, high-school and pre-school visits. The broad dissemination activities will involve all partners and will be coordinated by the Program Director. The platform will also exploit the obligation of the involved PhD students to

deliver public dissemination. Some of these activities will be done in collaboration with BioRefining Alliance, which is already sponsored by several partners.

6. Participants, organisation and management

6.1. Organisation including governance model, the participating parties' managerial and scientific competences and contribution to research and innovation activities

Decision and strategic management: The Board is composed of nine representatives from the platform partners. To ensure balance between research and innovation, there will be four business representatives, four university representatives and one GTS representative. The Board has the decision-making competence and will meet no less than four times per year. The Board will be responsible for: (i) hiring the Director of the platform, (ii) making strategic decisions regarding the unmarked financial resources and new partners, and (iii) ensure that progress and the stated goals and milestones are achieved.



All the platform partners will be represented at an annual Consortium meeting. Status and future plans with regard to budget and work plan will be presented, and proposals to the Board concerning budgetary changes or changes in the work plan can be agreed upon before being forwarded to the Board for final decision.

Executive and operational level: The Director and the Leader Team will be in charge of the day-to-day management of the platform. The Director will have the executive authority of the Leader Team and is supported by a Secretariat rooted in a department at one of the participating universities. The Director will ensure efficient coordination and information exchange between the different activities as well as the overall progress of the BIO-VALUE platform. The Director will at the start of the platform follow a professional project management course offered by, e.g. the Danish National Advance Technology Foundation.

The *Leader Team* consists of the Director, the leaders of the competence centres, the leaders of the platforms for socioeconomics and SMV innovation, and the leaders of the R/I projects. This team is responsible for progress and for ensuring tight coherence between the research and innovation activities. The project leaders will ensure that the projects are kept on track. Any significant changes in content or scope of the projects can only be done in consensus and with the full support of the sponsoring industrial partners. Larger changes will furthermore require the approval of the Board as well as of the funding agencies. The structure of the BIO-VALUE SPIR will be flexible to ensure that new projects either supported by the pool of unmarked financial resources or by new funding can be initiated.

Managerial and scientific competences: The leaders of the three competence centres will be Professors Jan K. Schjørring, University of Copenhagen (Biomass), Anne Meyer, Technical University of Denmark (Separation) and Ib Johannsen, Aarhus University (Conversion). The involved key persons within each project are listed in section 4.1 and their CVs are included in enclosure C. All leaders have been selected based on their leadership experiences, strong innovation record and specific expertise. The key academic partners have been selected based on strong scientific merits, and particular competences within the projects. The participating universities hold very strong research environments and will contribute to world-class research within the area of biobased society. The GTS/Innovation Network partners have a long experience in transfer of knowledge to SMEs.

7. International dimension

Both the university and company partners have strong international networks which will be exploited to the benefit of BIO-VALUE. This is e.g. evidenced by a large number of co-authored papers (see attached CVs). In addition, the platform has received declarations of participation from key international universities and Research Institutes, including Cornell University (USA), University of Illinois (USA), Mediterranean Agronomic Institute of Chania (GR), Korea Advanced Institute of Science and Technology (KAIST), and United States Department of Agriculture, Wyndmoor, Pennsylvania (enclosure D). These partners as well as other partners from the network will host PhD students from the platform for external research components of their projects. BIO-VALUE SPIR will also serve as a stepping-stone for initiating strong European collaboration and further financing from the European Union. To promote rapid progress with respect to establishment of international collaboration, the BIO-VALUE SPIR will organise an international kick-off workshop during the first 6 months of the project. Close links will be established to the ongoing EUROBIOREF project (eurobioref.org.) in which several of the SPIR partners participates. InbioM is involved in Enterprise Europe Network, which is the EU Commission's network for assisting SMEs, offering tools and opportunities for international matchmaking arrangements, use of technology databases and active partner searches.

8. Legal and ethical aspects

No adverse legal and ethical aspects are foreseen in the project: (i) The project will not make use of any personal data and therefore no ethical or legal issues regarding privacy will be relevant; (ii) No GM animals or plants are foreseen to be used in the project experiments and no issues in relation to the coexistence regulation will be relevant; (iii) Experiments using GM microorganisms will be conducted under confined conditions and the relevant approval for laboratory facilities and activities in the individual projects are in place; (iv) To the extent that feeding trials using live animals will be conducted, the necessary approval of trial protocols will be obtained from the Danish Ministry of Justice. (v) The experiments and field trials to be conducted in the project will have no harmful effects in relation to animal or human health or the environment.

The transition towards a biobased society can potentially open for a number of ethical dilemmas like the food versus non-food use utilisation of biomass, sustainability of increased biomass production etc. The project will address these dilemmas by developing sustainable biorefinery solutions including novel technologies and agricultural production systems which can improve the utilisation of the biomass for a variety of end use purposes and increase the production of biomass in a sustainable way. The project team has access to ethical and legal expertise which will guide the project partners if needed.

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