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INTEGRATED BIOREFINING RESEARCH AND TECHNOLOGY CLUB THIRD CALL: ENHANCING THE VALUE OF DRIED DISTILLERS GRAINS WITH SOLUBLES

IBTI CLUB BACKGROUND AND PROGRESS

Biorefining can be defined as the fractionation and processing of renewable biomass feedstocks for industrial applications. Drawing parallels with refining fossil oils, biorefineries will have to be highly efficient, produce minimal waste streams and allow the fractionation of raw materials and recovery of multiple products. Ideally they will be able to produce as wide a range of bulk and high value chemical products as is currently available from petrochemical feedstocks. In terms of bulk supply, these feedstocks will be primarily derived from terrestrial and aquatic plants, as these are responsible for photosynthetic primary productivity and carbon fixation.

The development of biorefining into commercially viable and sustainable industrial processes is clearly a major undertaking, which will require interdisciplinary research encompassing the biological and physical sciences interface. With this in mind, three science themes have been identified for the IBTI Club.

- **Optimisation of feedstock composition**
- **Integrative bioprocessing**
- **Enhancing product value**

While it is recognised that the current focus on biorefining is as an adjunct to biofuel production, the diversity of products derived from renewables could radically change this paradigm in the near future. The initiative takes a broad view of the types of desirable outputs obtainable from biorefining. For example the following products have all been identified as potentially useful outputs of future refining processes:

- Speciality oils varying in carbon chain length, desaturation and substitution
- Surfactants
- Polymers, oligomers and their monomeric precursors
- Heteroaromatic and pseudoaromatic compounds
- Flavours and nutraceuticals
- Terpenoids
- Cosmeceuticals, essential oils, vitamins
- Phytopharmaceuticals
- High-value chiral intermediates and products

While this list is not exhaustive it does illustrate the breadth of scope of the initiative.

Currently supported research

The first call for research proposals from the IBTI Club provided support for four research projects totalling £1.8M. The second call provided support for 5 projects, again totalling £1.8M. Summaries of the projects supported through the first call can be found on the web here: www.bbsrc.ac.uk/ibticlub.

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IBTI CLUB THIRD CALL: ENHANCING THE VALE OF DDGS

The IBTI Club's third call specifically focuses on using Dried Distillers Grains with Solubles (DDGS), as a feedstock for production of higher value products. DDGS was selected as a feedstock on the basis that it is a side product of grain-to-bioethanol production that will become increasingly abundant in the UK as more bioethanol plants come on line, and would complement existing production from whisky distilleries. DDGS is primarily made up of protein and insoluble cell wall components. Different distilleries and bioethanol plants use different processes, enzymes and drying regimes; as a result of these differences, and variations in the grain used as a feedstock, DDGS composition can vary considerably, limiting its use as a feedstock for industrial processes. Its high protein content makes it useful as animal feed, but if the issues of variation in composition can be overcome, there may be potential to convert DDGS to higher value products, particularly if the cell wall fraction can be further processed. Although DDGS can be used as a feedstock for fuel production, it contains relatively low amounts of monomeric and polymeric sugars potentially resulting in dilute product streams. Working with dilute process streams adversely affects process economics. Novel methods of cheaply and effectively fractionating DDGS to give more concentrated streams would simplify extraction/purification procedures and improve process economics.

This call will therefore focus on two of IBTI Club's three main science themes, namely:

Integrative bioprocessing

Biorefining will require the development of more efficient and advanced microbial bioprocesses, which can be integrated both with separation technologies and with chemical transformations. In addition, significant advances in the associated engineering and scale-up will be required. The great advantage of microbial processes is the ability to resolve most of the available carbon sources and substrates in complex feedstocks to relatively small numbers of synthetically useful building blocks. Therefore, one of the most important targets for the potential user community will be met from studies which seek to promote a high degree of substrate utilization from a real or artificially constituted biorefinery feedstock, with specific substrate consumption rates, as important engineering targets. These improvements at the microbial level must be matched by the design of simple and effective product recovery and purification processes such that the added value of chemical building blocks produced can be captured.

Resolution of the bottlenecks in this area of bioprocessing will require research at the interfaces between chemistry, engineering, microbial fermentation, enzymology and the physical barriers to biological processes, and research projects are expected to be multidisciplinary.

Enhancing product value

While it will be possible to tailor many products from biorefining for subsequent use in industrial applications, it is also recognised that major by-products may be of limited economic value. The processing of these bulk by-products into new higher value chemical entities with wider applications is an immediate challenge for the successful implementation of biorefining. Areas of interest include the use of novel chemical and biochemical processing as well as fractionation methods to recover high-value products.

Allied to biofuel production, a topical example is the recovery of useful molecules from ethanol fermentation residues, such as DDGS. This represents a considerable biological and chemical challenge; DDGS is composed primarily of protein and insoluble cell wall components (Figure 1), which require further processing for conversion to useful products.

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Unlocking the industrially useful organic entities in these polymers will require the development of enzyme and chemically mediated reactions and enabling technologies. Proposals specifically considering the use of DDGS for feed are not within the scope of this call. Research into the use of DDGS as animal feed is already being funded through the ENBBIO LINK project and there are further opportunities to apply for business-led funding in this area through TSB's Sustainable Protein Production competition (for details see: <http://www.innovateuk.org/content/competition/collaborative-research-and-developmentsustainable-protein-production.ashx>).

In an alternative strategy, the biotransformation of low-value products into fine chemicals by retaining synthetically useful functionality represents a further mechanism for adding value to biorefining. Similarly, in other industries such as sugar refining and paper production current by-product streams contain potentially useful chemical feedstocks; it is hoped that it may be possible to adapt the processes developed for DDGS through this call for use in other industries. Unlocking the economic potential of these chemical intermediates requires specific bioprocessing and/or chemical conversion.

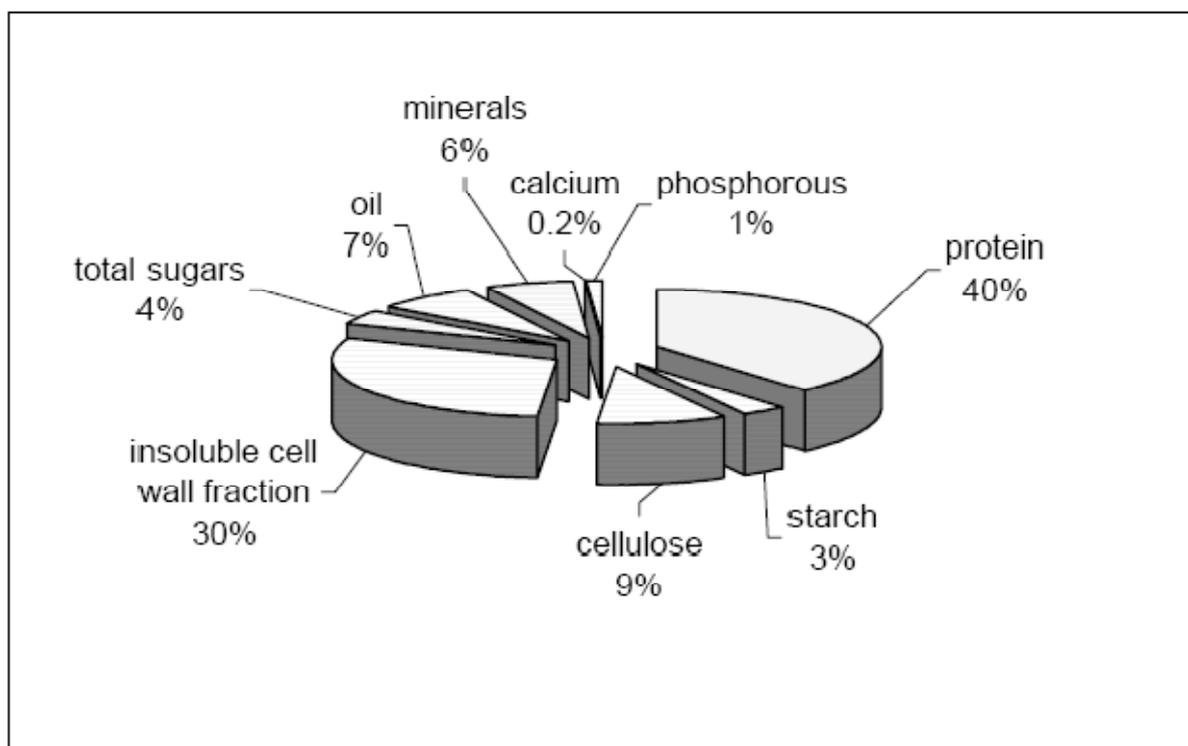


Figure 1: Benchmark composition of wheat DDGS based on a modern bioethanol facility with a 99% conversion efficiency of starch and sugars to alcohol.¹

¹ Figure from "Opportunities and implications of using the coproducts from biofuel production as feeds for livestock", Cottrill *et al.* 2007 (see http://www.hgca.com/publications/documents/nonfood/RR66_Final_Research_Review.pdf for more details)

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ENHANCING THE VALUE OF DDGS

Grant applications are invited for the third call of the IBTI Club. The closing date for applications is **4pm Tuesday 5 July 2011**. There is a two stage application procedure. Initially, proposals must be submitted on the Outline Application form. Approximately **£1.7M** is available for grant awards in this round. The funding is from a common pot with contributions from the BBSRC, EPSRC and Industry. Further details on specific guidelines for the call are in **Annex 1**.

All applications must focus on enhancing the value of Distillers Dried Grains with Solubles (DDGS), a side product of grain-to-bioethanol production that will become increasingly abundant in the UK as more bioethanol plants come on line. DDGS is currently primarily used as animal feed, but there is the potential for it to be converted into higher value products, such as commodity chemicals and fine and speciality chemicals, and this call focuses on the generation of such higher value products. The call should be of interest to scientists with a biological (*e.g.* microbiology, biochemistry, biocatalysis) and/or a physical science (*e.g.* chemistry, engineering, separations technology) background.

The emphasis on integration across the value chain means that a successful proposal will require a broad range of skills and expertise. Applications are therefore encouraged from cross-disciplinary consortia. The emphasis on cross-disciplinarity in this call is intended to promote an integrated approach to the entire DDGS value chain. BBSRC will run an Advice Workshop on **16 June** to provide applicants with the opportunity to discuss their proposals with the Club's industry members.

All potential applicants are strongly encouraged to attend the Advice Workshop in June, since it will offer an opportunity to ask advice of the IBTI Club's industry members.

The Steering Group is proposing to fund only one or two relatively large grants, from cross-disciplinary consortia which are expected to take an integrated approach to the transformation / processing / refining of DDGS. A diagram of a generic biorefinery, showing the breadth of processes that could potentially be used to extract value from DDGS, is attached at **Annex 2**. Applicants are asked to use this diagram to show how their proposal addresses multiple aspects of the biorefining of DDGS across the whole value chain covered by their proposal. The Steering Group would prefer cross-disciplinary applications encompassing multiple research groups, however, applications from individual laboratories will also be considered.

Priority Research Challenges

The Steering Group has identified several key research challenges that are of particular relevance to this call:

- Improving process technologies
 - separation of the protein component of DDGS from the fibres / carbohydrates
 - chemical modification of fibres to enhance function
 - fractionation/extraction processes *e.g.* extrusion, ionic liquids or supercritical fluids; improved membrane and other separation techniques; low-energy water removal
 - process simplification and intensification, enhanced resource efficiency, *e.g.* improvement of feedstock utilisation, and product value enhancement
- Developing novel processes and engineering solutions that are insensitive to variability in the DDGS feedstocks
- Microbial processing of DDGS, specifically:
 - improving digestion during fermentation

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- addressing the problems associated with inhibitor production
- Optimising the utilisation of all components of DDGS; DDGS contains a range of components in addition to sugars and protein, which can cause problems during processing. It may be possible to devise approaches that use these components in a manner that adds value and minimises the issues in processing.
- Addition of other materials to enhance suitability and functionality, as adjuncts to pre-treatment and / or as a means of directly affecting the achievable range of products, such that more valuable products can be formed
- Take account of the inherent variability in DDGS as a feed-stock

Other Important Considerations

- **Economics:** for biorefineries to be feasible the technology must be scalable and economically viable; applicants are expected to demonstrate the feasibility of their projects from this perspective.
- **Social and Environmental Considerations:** New technologies for biorefining must be socially and environmentally acceptable and sustainable. Tools such as life cycle analysis could be applied to assess the environmental impact, sustainability and efficiency of resource utilisation of new processes and products.

Proposals must fall within the remit of BBSRC and / or EPSRC, however, applications are welcomed from consortia that include social, economic or environmental scientists with the skills and expertise required to address these issues.

Skills and training

The skills and training aspects of the proposals will also be assessed; biorefineries will require cross-disciplinary skills in biology, chemistry and engineering. Grant applications must clearly indicate how they will incorporate the training, mentoring and experience necessary to equip researchers with these skills.

Applicants may, if they wish, request advice from the IBTI Club Academic Coordinator, Professor Christopher J. Knowles (chrisjknowles@btinternet.com).

GUIDELINES FOR CALL

- The objectives of the proposed research must fit with the scientific challenges detailed in this document and the science proposed must fall within the remit of BBSRC and EPSRC.
- Outline proposals must be submitted in the first instance.
- Research proposals from cross-disciplinary consortia are encouraged. This approach recognises the wide range of skills, knowledge and expertise required for an integrated approach to the challenges of biorefining.

CRITERIA FOR ASSESSMENT

The primary criteria for assessment are the quality of science proposed and the strategic relevance to the IBTI Club. It is expected that any proposal that goes on to be funded through the Club will be competitive against comparable international work and will demonstrate alignment with the Club's aims. Proposals will be assessed against the following criteria:

• **Scientific Excellence**

The extent to which the proposal meets the highest international standards of current research in its field. High performance against this factor will indicate a project of the highest standard, competitive with the best activity anywhere in the world, demonstrating originality and innovative potential.

• **Strategic Relevance to the IBTI Club**

Demonstrate alignment with science themes and priority topics, relevance to the biorefining industrial sector, and balance of overall Club research portfolio.

• **Economic and Social Impact**

The extent to which the output of the research will contribute knowledge that shows potential for economic return or societal benefits to the UK.

• **Timeliness and Promise**

The extent to which the proposal is particularly appropriate at the present time, or offers longer-term benefits over and above the direct value of the research.

• **Cost Effectiveness**

The extent to which the resources requested, relative to the anticipated scientific gains, represent an attractive investment of BBSRC funds.

• **Staff Training Potential of the Project**

Where resources are requested for postdoctoral or other research staff, the extent to which the proposed project will provide research training and development opportunities of benefit both to the individual(s) employed, and to the wider science and/or industry base beyond the completion of the specific project.

SPECIAL CONDITIONS

Recognising the financial support for the programme from industrial members of the Club, it should be noted that special conditions will be attached to any research grants from the IBTI Club. A letter from the institution's technology transfer office or equivalent, acknowledging that the institution is able to accept those conditions relating to IP, will be requested at the full application stage. The conditions are as follows:

Early Access

Commercial parties are entitled to early access to results from research funded by the Club. To ensure this grant holders must:

- Give at least 28 days notice of an intention to publish, outside of the Club, results from research funded by a Club grant. The material for proposed publication should be submitted to the Industrial Liaison Coordinator along with the notice of intent to publish. The Coordinator will distribute a copy of the same to each of the Commercial Parties who shall have fourteen (14) days from receipt of such copy to inform the Coordinator if in their view the proposed publication may
 - i. dilute or prejudice the value of proprietary information of a Commercial Party
 - or
 - ii. jeopardise the application for Resulting IPR protection
 - or
 - iii. otherwise inhibit future exploitation of the results and whether a Commercial Party has an interest in exploiting those results.
- Produce annual progress reports. A form will be available on the IBTI Club website for Grant Holder to complete and Grant Holder will be notified in advance when the final report will be due.
- Attend and present the results and progress of Club funded research at 6-monthly Club Dissemination Events. Grant holder will be notified of the dates and format of their presentation.
- Give advance notification of any opportunities to exploit intellectual property arising from their grant to the Commercial Parties.

Access to Resulting IPR

Commercial Parties are entitled, if they wish, to engage in good faith negotiations with the Research Organisation for terms of access to the Resulting IPR to allow further development or commercial exploitation of results, such access rights preferably to include the right to sublicense. This must be offered before access to Resulting IPR can be offered to third parties outside the Club. An interested Commercial Party can exercise its option right by giving notice to the Grant Holder within one month of the date of receipt of notice of Results or Resulting IPR.

Good Faith Negotiations

Good faith negotiations would imply a willingness to reach agreement with Commercial Parties on the terms and conditions of a commercial licence, to desist from publishing the Results or making offers to third parties while negotiation with Commercial Parties are ongoing and, if such agreement is not reached within a reasonable period (for example four months from the exercise of the option) that the Research Organisation would not seek to enter into negotiations with third parties on terms substantially more favourable to such third parties.

APPLICATIONS PROCEDURE

There is a 2-stage application process:

- Outline Applications will be submitted through Je-S. The closing date for outline applications is **4pm on Tuesday 5th July 2011**.
- Successful outline applicants will be:

- Invited to write a full application in September 2011 for submission by Tuesday 1st November 2011 (dates to be confirmed).
- Asked to an interview with the IBTI Club Steering Group. The interview is an opportunity for the Steering Group to ask for further details and clarification of the programme of research as described in the full application. Applicants should note that once peer review is completed, there can be no further changes to the programme of research submitted in their full proposal.
- Pathways to Impact will be required for grant applications that are selected for the second stage, full grant applications, and should refer to the biorefineries process diagram (**Annex 2**), indicating which aspects of biorefining the proposal will address.

ASSESSMENT

Outline applications will be assessed by the IBTI Club Steering Group and will not be externally reviewed. Full applications will be externally peer reviewed prior to final assessment by the IBTI Club Steering Group. The decision to fund full applications will be announced in January 2012. Further details on assessment are as follows:

- The criteria of scientific excellence and strategic relevance are given equal weight in the assessment of proposals and applications must pass on both criteria to be considered fundable
- The Steering Group consists of 7 academic members (nominated by BBSRC and EPSRC) and 7 industrial representatives (chosen by the industrial Club members).
- For assessments conducted by the Steering Group, each full proposal has two Introducing Members (IMs). One IM is from academia and the other is from industry.
- The procedure for dealing with conflicts of interest (e.g. where a Steering Group member has pre-existing links to an applicant) is the same as for other BBSRC Research Committees. Conflicted individuals leave the room while the proposal is being discussed.
- Outline and full proposals may be circulated to company members of the IBTI Club that are not represented on the Steering Group to seek their views. Any comments provided by company members will be taken into account by the Steering Group when the proposal is assessed.

ELIGIBILITY

UK Higher Education Institutions, Independent Research Organisations and BBSRC-sponsored institutes are eligible to apply.

CONTACTS

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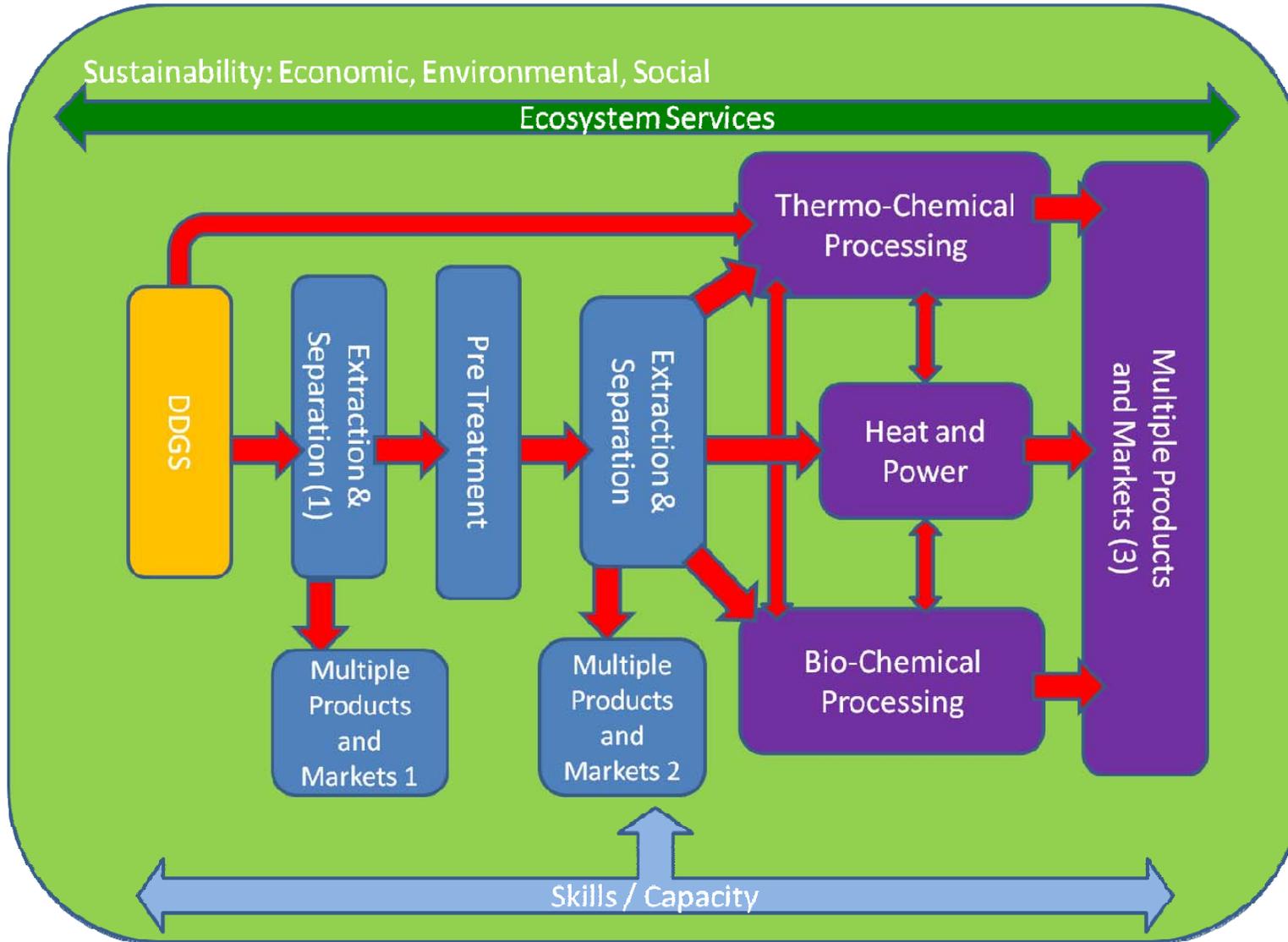


Figure 1a: Overview of a biorefinery

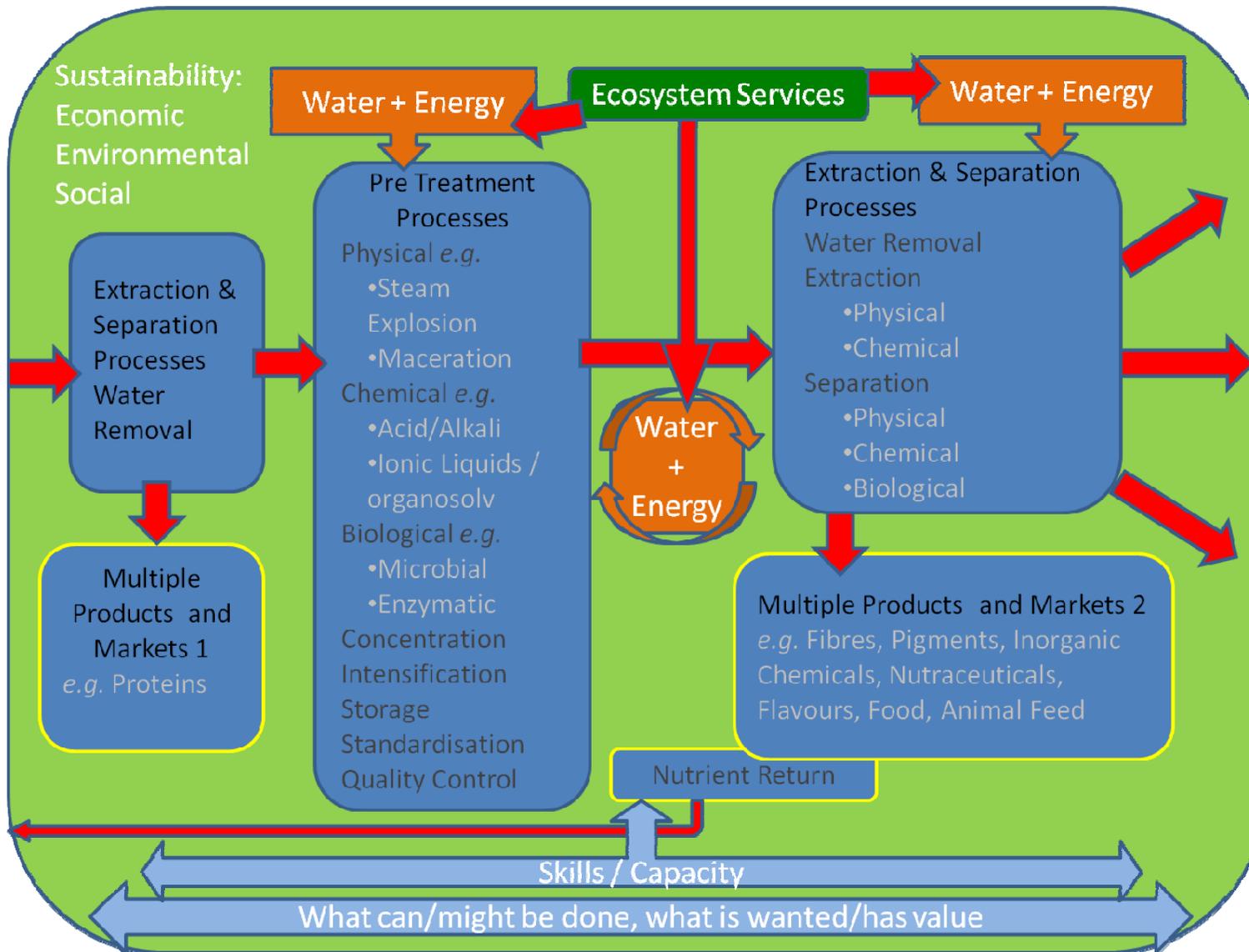


Figure 1b: examples of the methods used and products generated in the preparation of feedstock for processing in a biorefinery

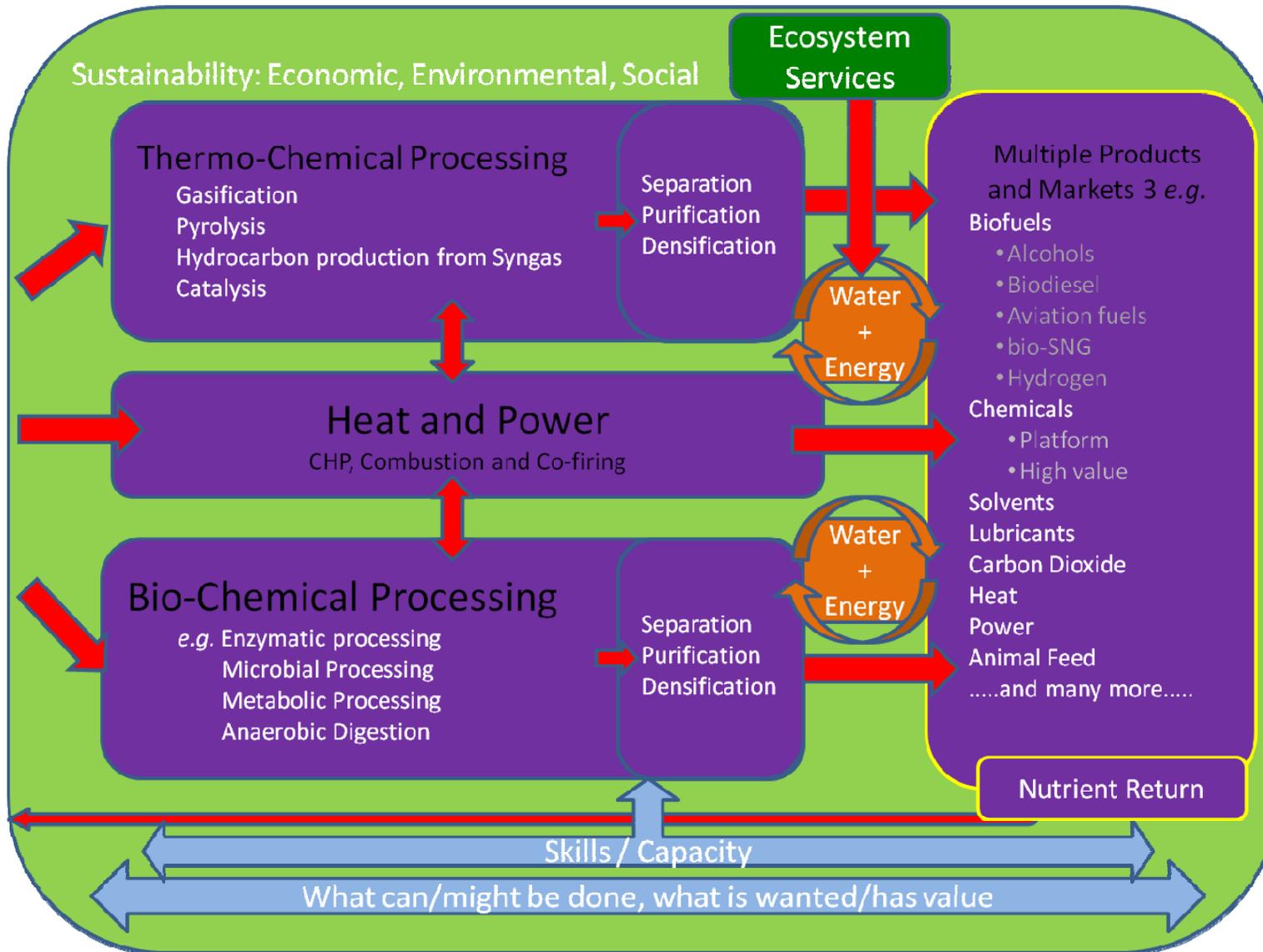


Figure 1c: examples of products and methods used for processing feedstock in a biorefinery