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Deliverable D7.4: Final assessment of the economic, social/legal/political sustainability of the BIOCORE biorefining system

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**Dissemination level:** PU
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1 Introduction

All bio-refineries need to be assessed through the entire value chain for environmental, economic, and social sustainability. Impacts across the three sustainability domains (economic, social and environmental) govern the potential benefits and risks that may accrue to society, especially local communities that are closely associated, or indirectly affected, by adoption of these technological systems. On the other hand, legal and political structures and norms as they exist at the local, state and national levels at the proposed location of the bio-refinery will influence the success and failure of the industrial intervention by creating different levels, nature of impact on economic, social and environmental domains of sustainability.

This deliverable provides the final assessment of the economic, social/legal/political sustainability of the BIOCORE biorefining system. These assessments have been conducted in Tasks 7.3 (Economic assessment and market analysis) and 7.4 (Social, legal, and political assessment) in the project.

Both tasks ran from M10 (December 2010) to M42 (August 2013). Task 7.3 under the lead of NOVA assessed the economic implications associated with the BIOCORE systems and the most promising reference systems. Task 7.4, under the leadership of TERI assessed the possible social impacts of BIOCORE bio-refinery systems as well as the legal and political constraints, bottlenecks and driving forces towards a significant increase of bio-based BIOCORE systems.
Integration of Task 7.3 and 7.4 in the overall sustainability assessment and harmonization of BIOCORE

The Interim Report on Sustainability Benchmarking provided by IFEU and IUS (last version dated 30 June 2011) described a number of common settings for sustainability assessment. Further specifications and system descriptions have been provided by IFEU for the final dataset (IFEU 2013 and IFEU 2013a). These are described briefly below and comments are made as to how these settings have been complied within Tasks 7.3 and 7.4.

2.1 System boundaries

According to the interim report by IFEU and IUS, system boundaries specify which unit processes are part of the product system and are thus included in the assessment, e.g. whether the entire - or a partial - life cycle will be analysed.

The proposal for the sustainability assessment in BIOCORE foresees to take into account the entire value chain (life cycle) from cradle to grave, i.e. from biomass production to the distribution and usage of final products. The economic data for the product life cycle up to the biorefinery gate is provided by WP1.

The focus of the techno-economic evaluation in Task 7.3 is on the biorefinery plant itself and more specifically on a defined set of model biorefinery schemes.

The boundary conditions in Task 7.4 are similar to the environmental LCA characteristics of defining a system boundary covering: (1) biomass collection/growth, (2) transportation and storage, (3) biorefinery, (4) transportation and distribution, and (5) use. The biorefinery products are compared to conventional reference products to find out their relative social sustainability and understanding the associated legal and political sustainability implications, but the boundary excludes the use and end phase of the product.

2.2 Technical reference

According to the Interim Report on Sustainability Benchmarking, the technical reference describes the technology to be assessed in terms of plant capacity and development status/maturity. The plant capacities have been decided on together with the case study regions (see below). According to the proposal, two development statuses: “early implementation industrial plant”, and “mature, full industrial plant” were to be considered so that each corresponds to a future point in time (see below).

In the final dataset, only the mature technology has been assessed in order to allow for a fair comparison of biorefineries to existing technology (IFEU 2013a).

2.3 Time frame

According to IFEU 2013a, the reference time for the mature biorefinery was set to 2025. As IFEU 2013a notes, this time was set because a whole “ecosystem” of biomass provision,
conversion technology and adaption of consumer products to new biobased intermediates and polymers as raw materials will not be established within a few years from now. Besides the development status of the biomaterials sector, other sectors will also change by 2025, especially, for example the energy sector. Since these changes imply too many uncertainties to be handled with, both Task 7.3 and 7.4 do not model this time frame explicitly but only make isolated projections where possible.

2.4 Geographical coverage

WP1 has proposed five case study regions with combinations of feedstocks and capacities and these have been agreed upon by the whole consortium (Table 1). The assessment in Task 7.3 implies an implementation of the BIOCORE schemes in any of these locations. However, the actual calculations are more of a generic nature since the basic assumption of the sustainability assessment is that a BIOCORE plant could be implemented in any location. The main scenarios are based on European conditions. The scenarios dealing with rice straw, which is a promising feedstock in India, are modelled according to Indian conditions. Furthermore, the assessment only covers domestic biomass production. I.e: imported biomass from outside Europe and India, respectively, is not considered as a feedstock for the BIOCORE biorefineries.

Table 1: Regional case studies

<table>
<thead>
<tr>
<th>Property</th>
<th>France</th>
<th>Germany</th>
<th>Hungary</th>
<th>India 1</th>
<th>India 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Beauce</td>
<td>Mid-West</td>
<td>South-West</td>
<td>Barnala (Sangrur)</td>
<td>Faridkot</td>
</tr>
<tr>
<td>Main feedstock</td>
<td>Wheat straw</td>
<td>Hardwood (diameter &gt; 5 cm)</td>
<td>Straw/SRC poplar/Hardwood</td>
<td>Rice/wheat straws</td>
<td>Rice/wheat straws</td>
</tr>
<tr>
<td>Additional feedstock</td>
<td>Niche crops (miscanthus) 0-20%</td>
<td>Softwood 0-10%</td>
<td>Ratio changed</td>
<td>Ratio changed</td>
<td>Ratio changed</td>
</tr>
<tr>
<td>Capacity*</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150 &amp; 500</td>
<td>150</td>
</tr>
<tr>
<td>Study partner</td>
<td>SOLAGRO</td>
<td>NOVA</td>
<td>SZIE</td>
<td>TERI</td>
<td>TERI</td>
</tr>
</tbody>
</table>

* 1,000 t of dry feedstock

For Task 7.4, based on the initial understanding of the situation and scope and timeline of the project, collection of primary data through scoping studies, site visits surveys, interviews and focus group discussions with multiple stakeholders was done in the sites in India and use of available secondary information was made for the European case study sites.
2.5 Functional unit

The functional unit determines how results are presented and interpreted. While it will be usually possible to convert results into other units, it is still helpful to agree on common functional units. The proposal by IFEU and IUS was to base results on

- 1 tonne of dry biomass (raw material basis) and
- 1 ha of land (area basis).

In the case of Task 7.3, all results can easily be expressed per tonne of dry biomass input since the input capacities are given. Since yields of the considered feedstocks vary widely between locations and since both primary feedstocks and residues as well as agricultural and forestry biomasses are taken into account, a conversion per ha of land has not been made. The social assessment using the sLCA will be oriented and expressed in functional units as far as possible, but it is not possible to do the assessment based on the functional units proposed above for all social indicators.

2.6 Inter-project harmonization

As for the environmental sustainability assessment and as requested by the EC, both Task 7.3 and 7.4 had made an effort to harmonize their methodologies with the two other FP7-biorefinery projects, Eurobioref and Suprabio (Piotrowski et al. 2012). Boths tasks have had active exchanges and meetings with both other projects and have agreed on a number of issues that could or could not be harmonized.
3 Economic sustainability assessment (Task 7.3)

The economic evaluation of an investment project for an industrial process includes the estimation of investment and operating costs, revenues, profits and other performance indicators.

The level of detail in which Task 7.3 was able to conduct the economic evaluation depended on data availability for those processes that had been developed in BIOCORE. Main partners for data exchange were IFEU and NTUA. The final data set provided by IFEU constituted the basis for the whole sustainability assessment in WP7 (IFEU 2013).

3.1 Research methodology and framework

A techno-economic evaluation typically aims to answer a number of interrelated questions about an industrial process. These usually are:

1. What is the overall economic performance of the whole project?
2. What contributions do single cost items have on the overall costs?
3. What are the total costs of the main process steps?
4. What is the economic performance of a specific product?

To answer the first question, the biorefinery processes themselves can be regarded as a “black box” with certain inputs and outputs. Total revenue is calculated by multiplication of physical outputs and market prices obtained from the market research and balanced against total costs. These market prices may or may not include a “GreenPremium” (see section 3.1.3) of a certain level. Since it is likely that some of the biorefinery concepts will not be economically viable without support, this analysis includes the assessment of the necessary level of subsidies.

The second question is also within the scope of Task 7.3 as will be shown below. The third and fourth question, however, would require an allocation of mass and energy flows, revenues and costs to single process steps and products. Each biorefinery scheme is a multifunctional system, i.e. one that delivers several goods and/or services, or, simplified, “co-products”. In the case of a multi-output process, the problem of allocation of costs arises if one wants to make a statement about the production costs of one single output. Since the biorefinery process streams are interrelated, it is not straightforward how to accomplish this allocation. Also a substitution approach, which requires that for each multi-product process, one of the products can be clearly identified as the main product and all others as co-products is not straightforward for the techno-economic assessment. The techno-economic assessment therefore focuses on the assessment of each biorefinery scheme as a whole.

3.1.1 Outline of the BIOCORE CAPEX model

The total investment needed for a project, also called Capital Expenditures (CAPEX), can be roughly divided into the sum of the fixed capital investment (FCI) and working capital investment (WCI).
According to Sinnott 1999 (p. 243), the FCI is the total cost of the plant ready for start-up. It includes the cost of:

1. Design, and other engineering and construction supervision,
2. All items of equipment and their installation,
3. All piping, instrumentation and control systems,
4. Buildings and structures,
5. Auxiliary facilities, such as utilities, land and civil engineering work.

The FCI is a once-only cost that is not recovered at the end of the project life, other than the scrap value. The FCI includes the complete construction cost of the plant with all its processing and handling equipment as well as its ground preparation and non-process structures and equipment.

FCI would also include the investment for purchasing land to build the plant on. However, this investment is left out of the analysis of BIOCORE for two reasons: First, the surface area needed for the plant is unknown. Second, the sustainability assessment should be location independent and the cost for land varies widely between locations. Land is the only part of the FCI that is not depreciable so that the remainder constitutes the depreciable FCI.

The WCI includes the initial cost of resources, such as feedstock and catalyst, as well as money required for labour and services required to start operation of the plant. WCI is the additional investment needed, over and above the fixed capital, to start up the plant and operate it to the point when income is earned. It includes the cost of:

1. Start-up.
2. Initial catalyst charges.
3. Raw materials and intermediates in the process.
4. Finished product inventories.
5. Funds to cover outstanding accounts from customers.

A typical figure for the working capital of petrochemical plants is 15% of the fixed capital, i.e. about 13% of the total investment. According to Peters and Timmerhaus 1991, typical values for the WCI are between 15-20% of the FCI. However, this estimate has been made for conventional chemical plants. For biorefineries, the estimate of the WCI may be different. For example, Humbird et al. 2011 chose an estimate of 5% of the FCI for their lignocellulosic biomass to ethanol production plant (Humbird et al. 2011, p. 68). In the inter-project harmonization document for the economic assessment, a value of 4% has been chosen for the base case (Piotrowski et al. 2012).

Due to the very early design stage of the BIOCORE processes, it is not possible to calculate CAPEX directly from the plant design. However, there are several methods to rapidly estimate total investments costs (see e.g. Sinnott 1999, p. 248f.).

Additionally to such methods, Lange 2001 showed that the “power loss” of a process, defined as the difference between the Lower Heating Values (LHV) of the plant intake (including feed and fuel streams) and that of the product stream leaving the plant, is a good indicator for plant investment costs. Therefore, the energy balance, known from the process flow sheets, can be used as a first approximation of investment costs. However, Lange 2001
also showed that this relation is less reliable for small-scale, heat-neutral reactions and in the case of batch processes used for manufacturing fine and specialty chemicals.

Lange 2001 also presented a second correlation approach for estimating the fixed capital investment (FCI), based on the sum of energy transfer duties of all process segments, roughly equivalent to the total rated power of the process equipment (Figure 1).

Figure 1: Correlation between energy transfer duty and investment costs
Source: Lange 2001
Note: According to the original source, the figure shows “the investment costs correlation and energy transfer duty of process segments for syngas manufacture, syngas conversion, fuel and chemical conversion, and various auxiliaries”.

For the BIOCORE CAPEX estimation, this last approach appears to be most suitable for the very limited level of process data available. As will be shown below, estimates of the total rated power can be derived from the dataset provided by IFEU.

The original equation that Lange 2001 found was:

\[
\text{FCI [Mill. USD 1993]} = 2.9 \times \text{Rated Power [MW]}^{0.55}.
\]

The conversion of this formula into Euro in 2010 results in the following formula:

\[
\text{FCI [Mill. EUR 2010]} = 3.3 \times \text{Rated Power [MW]}^{0.55}
\]

This conversion was achieved by first adjusting for inflation (using the CPI inflation adjustment, 1 USD in 1993 is equivalent to 1.51 USD in 2010) and then converting USD into EUR (1 USD in 2010 being equivalent to about 0.75 EUR in 2010).

Efforts have been made to validate this model to estimate FCI (and eventually total CAPEX by accounting for the WCI). For this purpose, data on other bio-based processes have been searched for. This proved difficult because data on the rated power are typically not published and also not readily available from other sources. Nevertheless, a few data points could be added to the graph as shown in Figure 2 below. First, actual business data was obtained for a starch plant (orange data point). Then, respective data was found for an investment to convert an ethanol to a butanol plant (Larsson et al. 2008). Finally, data was
used by the BIOCORE partner ECN for their ethanol-based organosolv process (van der Linden 2013).

![Correlation between the rated power and fixed capital investment of selected processes](image)

**Figure 2: Validation of the CAPEX model**

Source: nova 2013

As can be seen from these data entries, the proposed correlation appears to fit rather well. Although further analyses are not possible with such few data points, it appears that the bio-based processes tend to lie above the curve, meaning that their CAPEX are higher at the same rated power compared to petrochemical processes, which confirms our intuition. Note that this does not say anything about differences in production costs.

Still, there is a further limitation for the application of this model. From the BIOCORE data, the actual rated power of the equipment is not known but needs to be inferred from their unintegrated energy demand. However, the unintegrated energy demand of a process will differ between process configurations, for example depending on the assumed conversion efficiencies. Since it would be illogical to assume differences in CAPEX simply due to differences in conversion efficiencies, we will therefore assume a typical configuration of a process for the CAPEX estimation.

### 3.1.2 Outline of the BIOCORE OPEX model

According to Turton et al. 2012, the annual operating expenditures (OPEX) can be grouped into direct or variable manufacturing costs (DMC), fixed manufacturing costs (FMC) and general expenses (GE). The following Table 2 shows the types of cost items as grouped into these categories following Turton et al. 2012.
Table 2: Cost items included in direct costs, fixed costs and general expenses.

<table>
<thead>
<tr>
<th>DMC</th>
<th>FMC</th>
<th>GE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials</td>
<td>Depreciation</td>
<td>Administration costs</td>
</tr>
<tr>
<td>Utilities</td>
<td>Local taxes and insurance</td>
<td>Distribution and selling costs</td>
</tr>
<tr>
<td>Operating labour</td>
<td>Plant overhead costs</td>
<td>Research and development</td>
</tr>
<tr>
<td>Direct supervisory &amp; clerical labour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance and repairs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating supplies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory charges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patents and royalties</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Turton et al. 2012

Ideally, all cost items listed above would be calculated directly. However, only limited data is available for the BIOCORE processes and, in particular, no equipment sizing is possible. Therefore, estimation procedures are necessary.

According to Turton et al. 2012, OPEX can be determined when the following costs are known or can be estimated:

1. Fixed capital investment (FCI)
2. Cost of operating labour (C\textsubscript{OL})
3. Cost of utilities (C\textsubscript{UT})
4. Cost of raw materials (C\textsubscript{RM})

This result follows from the assumption, as described in Turton et al. 2012 (p. 206), that all other cost items are fixed factors of these four cost components shown above. The procedure for estimating FCI has been explained in section 3.1.1 above and, as will be detailed below, the costs of operating labour, utilities and raw materials (feedstock and operating materials) can be directly calculated from the BIOCORE process data. The model therefore provides a robust and transparent means of estimating both CAPEX and OPEX from limited data.

Turton et al. 2012 present typical corresponding multiplication factors for each of the OPEX components shown in Table 2, combined from several literature sources. In the following, we are discussing each of these multiplication factors.

3.1.2.1 Direct manufacturing costs

Variable or direct manufacturing costs (DMC) represent operating expenses that vary with production rate. In the following, each position in the total DMC and their calculation are explained.

Raw materials

This includes the biomass feedstock as well as other operating materials and auxiliaries needed in the process. Due to the importance of the biomass feedstock for the whole process, we split total raw material costs into biomass costs (C\textsubscript{BM}) and other operating material costs (C\textsubscript{OM}).

Indicative procurement costs for biomass are available from the BIOCORE project since these have been jointly modelled by Task 1.2 and Task 1.3. Feedstock procurement costs up to
farmgate/roadside have been modelled by Task 1.2 while models of Task 1.3 calculated additional costs up to the factory gate (mainly transport and logistics costs).

The quantities of the other operating materials needed for the processes can be obtained from the flowsheets and prices of each material from market research.

**Utilities**

According to Towler and Sinnott 2013, the word “utilities” is used for the ancillary services needed in the operation of any production process. These typically include (Towler and Sinnott 2013, p. 104):

1. Electricity
2. Fuel for fired heaters
3. Fluids for process heating
   a. Steam
   b. Hot oil or specialized heat transfer fluids
4. Fluids for process cooling
   a. Cooling water
   b. Chilled water
   c. Refrigeration systems
5. Process water
   a. Water for general use
   b. Demineralized water
6. Compressed air
7. Inert-gas supplies (usually nitrogen)

The quantities required can be obtained from the energy balances and the flowsheets and prices are obtained from market research.

**Operating labour**

The assessment of operating labour costs ($C_{OL}$) also requires an estimation procedure because the working time needed for operating is not included in the flowsheet data. One common way of estimation is based on the number and type of equipment.

In this method, first all major equipment needed for the process is counted. Then, multiplication factors are applied to relate each equipment to the necessary working units, i.e. the number of workers needed per unit and shift. Thus, the total number of required working units is obtained. The necessary multiplication factors were derived from Dimian 2003 (p. 592). There, respective multiplication factors were listed for a number of unit operations. For those types of unit operations for which no working unit estimation was available, a typical value of 0.35 has been assumed (Table 3).
Table 3: Multiplication factors for equipment types

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Multiplication factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactors: batch/continuous</td>
<td>0.75</td>
</tr>
<tr>
<td>Distillation columns</td>
<td>0.40</td>
</tr>
<tr>
<td>Dryers: spray/rotary</td>
<td>0.75</td>
</tr>
<tr>
<td>Filters (vacuum)</td>
<td>0.25</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>0.40</td>
</tr>
<tr>
<td>Evaporators</td>
<td>0.25</td>
</tr>
<tr>
<td>Other equipment</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Source: Dimian 2003 (p. 592); value for other equipment added by nova due to missing information.

The above factors indicate how many operators are needed for one unit at any given time. Using these factors, the number of operators actually needed in the plant can be calculated as follows. It is usually assumed that a plant operates 24 hours and 365 days a year. Assuming 8-hour shifts, there are therefore 1,095 shifts per year. Each operator typically works 49 weeks a year and 5 shifts per week, so in total 245 shifts. Therefore, in order to fill all of the 1,095 shifts per year, i.e. to have one operator at the plant at any given time in the year, about 4.5 operators need to be hired. The amount of operators needed at any given time in the year is calculated by multiplying the number of each equipment with their respective multiplication factors and this figure is then multiplied with 4.5 to arrive at the total number of operators that need to be employed by the plant.

This number is then multiplied by the number of hours worked by these operators in a year. Typically, one operator works 49 weeks in a year, 5 days a week and 8 hours a day, resulting in 1,960 hours.

This amount of working hours in a year is then multiplied with the average gross employers labour cost per hour. The three-year average (2008-2010) labour cost in industry (except construction) in the EU-27 amounted to about 20 EUR/h. This labour cost will be used for the base scenario.

Direct supervisory and clerical labour

These are costs of administrative, engineering and support personnel. Turton et al. 2012 link the costs for direct supervisory and clerical labour to the costs of operating labour (Col) with a factor of 0.10-0.25. For the base case we are therefore using the average factor of 0.18 * Col.

Maintenance and repairs

These are costs of labour and materials associated with maintenance. Turton et al. 2012 are proposing a factor of 0.02-0.10 linked to FCI. According to Chauvel et al. 2003, it is customary in the heavy industry sectors (refining, petrochemical, major intermediates, inorganic chemistry, metalworking etc.), to estimate maintenance expenses at an average of 4% of the cost of the plant, i.e. of the battery limits investments, as well as for general services and storage (Chauvel et al. 2003, p. 152). However, this percentage is very dependent on the kind of products that are processed and the type of equipment. Concrete constructions, which are both static and corrosion-resistant, require only minimal maintenance. Therefore, the maintenance cost may be lower, e.g. 3%, for general services and storage, while being higher,
e.g. 4% for the production units. When the products are very aggressive, and special equipments may be required, costs may reach as much as 10% per year of the battery limits investments. Overall, to treat maintenance cost as a fixed percentage of investments is a simplification because expenses may diminish substantially, if not entirely, if the units are shut down for a longer time period.

In the inter-project harmonization document for the economic assessment, a value of 2% of FCI had been decided on for maintenance and repairs, so one at the lower end of the estimations given above. This value is used for the base case.

*Operating supplies*

According to Turton et al. 2012, these are “costs of miscellaneous supplies that support daily operation not considered to be raw materials. Examples include chart paper, lubricants, miscellaneous chemicals, filters, respirators and protective clothing for operators etc.” (Turton et al. 2012, p. 204).

For this cost item, Turton et al. 2012 propose to use 10-20% of maintenance and repairs or, equivalently, on average $0.003 \times \text{FCI}$.

*Laboratory charges*

The annual cost of the laboratory analyses required for process monitoring and quality control is a significant item in most modern chemical plants. Sinott 1999 propose as a rough estimate of laboratory charges 20-30% of operating labour cost or 2-4% of the total production cost. Turton et al. 2012 use a factor of $(0.1-0.2)\times\text{C}_{\text{OL}}$ or on average $0.15 \times \text{C}_{\text{OL}}$.

*Patents and royalties*

These are costs of using patented and licenced technology. Turton et al. 2012 use for these a multiplication factor of $(0-0.06)\times\text{COM}$, or on average $0.03 \times \text{COM}$, which will be used for the base case.

### 3.1.2.2 Fixed manufacturing costs

Fixed manufacturing costs are independent from the production rate. The main cost items subsumed under this heading include depreciation, local taxes and insurance and plant overhead costs. These are shortly explained below.

*Depreciation*

The investment required for the project is recovered as a charge on the project. Capital is often recovered as a depreciation charge, which sets aside a given sum each year to repay the cost of the plant. The plant is not necessarily replaced at the end of the depreciation period. The depreciation sum is really an internal transfer to the organisation's fund for future investment.

If the plant is considered to "depreciate" at a fixed rate over its predicted operating life (so-called straight-line method), the annual sum to be included in the operating cost can be
easily calculated. In the inter-project harmonization for the economic assessment, an investment life of **15 years** was assumed for the base case and a straight-line depreciation. The FCI is therefore depreciated over 15 years so that 1/15 (0.067 * FCI) of the initial FCI accrue each year of operation.

**Local taxes and insurance**
A plant usually has to pay various taxes (local and regional taxes, property taxes, licence and other payments, environmental protection) and insurances against damages to the production units and also for materials and products tied up in this equipment and also against damages caused to third parties and the environment. These costs are periodic in nature and have to be paid at about the same amount every year unless significant changes have been made to the manufacturing complex being insured.

The inter-project harmonization for the economic assessment had concluded to assume as an estimate 1% of FCI for insurances but did not account for local taxes. In comparison, Turton et al. 2012 propose a factor of (0.014-0.05)*FCI or on average 0.032*FCI for both local taxes and insurances. To take taxes into account, we will assume **2% of FCI** as the charges for local taxes and insurances.

**Plant overhead costs**
Overhead costs are costs incurred by non-productive components or its ancillary services and have to be carried by all productive activities. These typically include general management, plant security, medical, canteen, general clerical staff and safety and plant technical personnel not directly associated with and charged to a particular operating area. Alternatively, some of these costs could be attributed to supervision costs (Sinnott 1999, p. 264). Overhead costs can be expected to rise with the scale of the manufacturing facilities. Here, it is customary to take a fixed percentage of about 1% of the investment costs (Chauvel et al. 2003) or 50-100% of labour costs (Sinnott 1999, p. 264).

Turton et al. 2012 propose a factor related to both operation labour costs and FCI. Following their proposal, we are estimating plant overhead costs in the base case as **0.708 * Col + 0.036 * FCI**.

**3.1.2.3 General expenses**

General expenses account for additional overhead necessary for carrying out business. The main items subsumed under this heading include administration costs, distribution and selling costs and research and development costs.

**Administration costs**
This heading covers the direct operating supervision: the management directly associated with running the plant. These costs will depend on the size of the plant and the nature of the process.

Turton et al. 2012 estimate administration costs to be 15% of the sum of operating labour costs, direct supervisory and clerical labour costs and maintenance and repairs. By making
use of the estimates shown above, this equates to $0.177\text{Col} + 0.003\text{FCI}$. This estimate will be used for the base case.

**Distribution and selling costs**

On top of actual production costs, there are sales expenses, general overheads and costs for research and development to consider. These costs are estimated by Turton et al. 2012 as lying between 2-20% of COM. For the base case we will therefore use the average of $0.11\text{COM}$.

**Research and development**

These are all costs of research activities related to the process and products and include salaries and funds for research-related equipment and supplies etc. (Turton et al. 2012, p. 205). Turton et al. 2012 estimate these costs as $0.05\text{COM}$, i.e. 5% of annual manufacturing costs.

### 3.1.2.4 Formula for the estimation of COM

From applying all of the multiplication factors discussed above, the final estimation procedure for DMC, FMC and GE is as follows:

**DMC:**
- Raw materials: Actual prices
- Utilities: Actual prices
- Operating labour: See below
- Direct supervisory and clerical labour: $0.18\text{Col}$
- Maintenance and repairs: $0.02\text{FCI}$
- Operating supplies: $0.003\text{FCI}$
- Laboratory charges: $0.15\text{Col}$
- Patents and royalties: $0.03\text{COM}$

**FMC:**
- Depreciation: $0.067\text{FCI}$
- Local taxes and insurance: $0.02\text{FCI}$
- Plant overhead costs: $0.708\text{Col} + 0.036\text{FCI}$

**GE:**
- Administration costs: $0.177\text{Col} + 0.003\text{FCI}$
- Distribution and selling costs: $0.11\text{COM}$
- Research and development: $0.05\text{COM}$

Summing up all of the above and solving for COM leads to the following equation:

\[
\text{COM} = 0.184\text{FCI} + 2.735\text{Col} + 1.235(\text{CUT} + \text{CRM})
\]
The annual manufacturing costs can therefore be estimated using figures for FCI, COL, CUT and CRM. As will be shown below, all of the necessary data can be derived from the dataset provided by IFEU.

### 3.1.3 Market analysis, product prices and GreenPremium

The aim of the market analysis in Task 7.3 has been to assess product price ranges for the BIOCORE products that are used as parameters in the techno-economic evaluation. By conducting a preliminary assessment of market prices for conventional products and rough estimations for premiums for the bio-based equivalents, Task 5.4 had laid the groundwork for the thorough market research for the BIOCORE products in Task 7.3. The results of Task 5.4 are written down in Deliverable 5.3 (Kokossis et al. 2011).

Task 7.3 then performed a market analysis for those BIOCORE products and their competing bio-based products and their conventional equivalents (chemicals and fuels) as references that had been selected as the outcome of the decision-making process following the Value Chain Meeting in Paris (19-20 April 2011). The results of this market research have been compiled in product factsheets and distributed to BIOCORE partners for comments (see Annex VII). From the list of products that had been selected, only a small subset has actually been submitted for a detailed sustainability assessment (see section 3.2).

Market potentials and corresponding market prices of BIOCORE products may be very different depending on the assumed application of these products. For the economic assessment it is therefore very important to have clearly defined the product uses. One standard use option for each product in each scenario has therefore been described in the dataset by IFEU (IFEU 2013).

The market research comprised the analysis of data banks (e.g. ICIS Pricing, Eurostat, UN Comtrade, WTO, IMF, Worldbank), literature and expert interviews. Where possible, longer-term historical data on markets and prices were used in order to understand the past and anticipate future trends. As said above, BIOCORE partners themselves have been be the first source for expert knowledge.

An important determinant for the market potential for BIOCORE products is the willingness of customers to pay more for these products compared to conventional substitutes, i.e. the “GreenPremium”. In order to better understand the logic and market mechanisms behind GreenPremiums, Task 7.3 has produced an analytical paper on this issue (see Annex VI for the full paper).

The GreenPremium is basically understood as the extra-price market actors are willing to pay for a product just for the fact that it is “green” or in our specific case “bio-based” (= derived from biomass).

In this paper, the nova-Institute has proposed for the first time a comprehensive definition of GreenPremium (see Figure 3):
GreenPremium price is the additional price a market actor is willing to pay for the additional emotional performance and/or the strategic performance of the intermediate or end product the buyer expects to get when choosing the bio-based alternative compared to the price of the conventional counterpart with the same technical performance.

Figure 3: Definition of GreenPremium
Source: nova 2013

Based on this definition, the results of this paper clearly prove that GreenPremium prices exist and are paid in value-chains of bio-based chemicals and plastics. A relevant group of market actors are already paying GreenPremiums throughout examined branches and in variable levels between 10% and 100%.

The analysis shows that willingness of market actors to pay GreenPremium prices is dependent on two factors:

- The additional emotional performance compared to the conventional counterpart
- The additional strategic performance compared to the conventional counterpart

The emotional performance is subjectively valued and mainly caused by the end consumer preference. The GreenPremium effect is passed on through the value chain as consumer pull.

The value of a product's strategic performance that leads to GreenPremium is depending on the market position and framework of the company and the branch.

The results indicate that companies pay GreenPremiums primarily for the strategic benefits, even though image and marketing aspects can be key decision factors. Strong drivers for strategic performance are (expected) public regulations to be met (e.g. non-degradable plastic bag bans in Italy or Asian countries), the opportunity to gain market potential or feedstock supply chain aspects.

This shows that willingness to pay a GreenPremium prices has to be understood as an investment, on which companies expect a (delayed) return.

In practice, however, companies do not always succeed to enforce a GreenPremium price on their customers, especially in long-term existing supply chains with established products. On the other hand, there are new investments for bio-based plastics (e.g. PE, PET, PP), which only have been developing upon demand, which in turn includes necessarily a confirmed willingness to pay GreenPremium prices for intermediates over a longer period.

Results indicate that a relevant group of companies are paying a GreenPremium price of around 10-20% for bio-based intermediates, plastics and polymers. This can be found in a
wide range of different applications and branches as the full report (Annex VI) impressively shows.

Even much higher GreenPremium prices are possible (50-100% and beyond) under very specific market conditions and in a limited timeframe. This can be due to market scarcity (e.g. PE, PP) which in turn is compensated by additional image effects (exclusivity). The main reasons for achieving these high GreenPremium levels are:

- Huge image benefit or significant strategic advantages for the producer (e.g. scarcity and exclusive access to a bio-based material),
- material costs account for a small share of overall production costs,
- in niche markets which are very sensitive to emotional performance,
- when GreenPremium expenses can be fully and directly passed on along the value-added chain.

Based on the analysis of selected supply chains, empirical data show that in most cases the GreenPremium level decreases towards the end of the supply chain (end consumer). One reason is that the material costs share (including the GreenPremium) of the total costs decreases along the value chain. Another reason is that without a confirmed GreenPremium price for the intermediates, the whole value-chain would not have been implemented at all.

The following Figure 4 shows the results of all expert interviews and surveys undertaken and analysed in the context of this study. A table containing detailed information on analysed cases of bio-based materials, products and companies can be found in Annex VI.
Figure 4: Development of GreenPremium prices along the value-added chain of different bio-based chemicals, plastics and end products.

Note: Coloured lines are representing one value-added chain, single dots represent single findings.
Source: nova 2013

The figure shows the identified GreenPremium levels depending on where they are paid in the value chain - for example, the polymer producer buys a building block from the chemical company and might pay a GreenPremium for it or the end consumer buys the final product and might pay a GreenPremium to the distributor.

The range of reported GreenPremium prices in the various branches and applications analysed lies between 10 and 300% above the conventional petrochemical product with the same technical performance. Most of the GreenPremium price findings are in the range of 10 to 20% for bio-based intermediates, polymers and compounds, followed by the range 20 to 40%. Higher GreenPremium prices could only be obtained in specific cases.

For the end consumer, the range of GreenPremium prices for bio-based products goes from 0% (car, cosmetics, bottle) to 25% (wall plug, toy) with, in the middle, a 10% GreenPremium for organic food with bio-based packaging.

These are huge extra prices compared to biofuels. A recent US survey shows that even consumers involved in the biofuel sector only accept 1-3% higher prices for biofuels with the same technical performance as fossil fuels. For more details, please refer to Annex VI.
3.1.4 Economic performance measures

Given the calculated production costs and revenues from product selling, economic performance measures for the whole biorefinery plant can be derived. The aim is to compare the economic performance of different biorefinery concepts, processes and products.

Therefore indicators of economic performance are needed. These are usually derived from Discounted Cash Flow models (DCF) and include the Net Present Value (NPV) and Internal Rate of Return (IRR), the Payback Time and the Return on Investment (ROI) of the project.

An investment is typically characterised by negative cash flows at the beginning of the project (the investment) and positive cash flows generated by selling the products during the operating time of the plant (the typical project lifetime lies between 15-25 years and for the inter-project harmonization, a lifetime of 15 years had been chosen as the common base case).

All information on cash flows along the lifetime of a plant can be summarized in a table that contains information about forecast sales and selling prices, sale income less operating costs, net cash flows and the discounted net cash flow at a certain discount rate (for the inter-project harmonization, a discount rate of 5% had been chosen). The Net Present Value (NPV) is defined as the sum of discounted net cash flows:

\[
NPV = \sum_{i=0}^{n} \frac{Net\ cash\ flow_i}{(1+i)^p}
\]

The decision criterion for the evaluation of an investment project is that the NPV should be at least zero or positive. The choice of a higher discount rate implies a higher discount, i.e. devaluation of future cash flows, which could reflect higher risks of the project.

The Internal Rate of Return (IRR) is defined as the discount rate at which the NPV is just equal to zero (DeFusco et al. 2011). The higher the IRR, the more favourable the investment project appears because it implies that future cash flows could be discounted at a higher discount rate until the NPV would become zero.

When comparing different scenarios, NPV and IRR may lead to different results. This situation is exemplified in Figure 5. In this example, the project P1 has the highest NPV at lower discount rates while the project P2 has the highest IRR.

![Figure 5: The relation between NPV, discount rate and IRR](image)

Source: nova 2011
This example highlights the importance of choosing an appropriate discount rate. The discount rate reflects both the risks of a project and time preference. The higher discount rates are, the sooner future cash flows loose their weight in calculating the NPV.

Different performance measures may therefore lead to conflicting results. At the coarse level of detail at which the techno-economic evaluation of BIOCORE is situated, it makes sense to concentrate on only one performance measure for the overall comparison because the main aim of the analysis is to produce a ranking of the different processes that can give indications on which processes to focus further efforts.

For this primary measure we have chosen the IRR. The IRR is a very popular indicator for the evaluation of an investment project. According to expert and information and secondary sources, an IRR of 25% is usually considered “as the threshold for securing capital investment in new processing technology” (Brown et al. 2012, p. 82). This threshold will therefore be used as a benchmark which BIOCORE will have to achieve in order to become attractive for investors.

It should be noted that the benchmark of an IRR of 25% is not equivalent to an annual interest rate of 25%. To make the difference clear and to put the IRR of 25% into perspective, a simple comparison can be made. Instead of investing the original capital into a biorefinery, it could be put into a bank account and earn annual interests. Then, the interest rate can be determined that would result in the same future value at the end of the project lifetime of 15 years. For the case of an IRR of 25%, this equivalent interest rate lies at about 7% p. a.

Many BIOCORE product portfolios will not be economically viable on their own but will depend on some kind of support mechanisms. Without such mechanisms, the economic performance measures are likely to be negative. The gap between calculated performance and the threshold to economic viability (i.e. when e.g. IRR = 25%) indicates the level of necessary support. This necessary level of support will be calculated for the situation without and with (varying) levels of GreenPremium.

3.1.5 Strategies for reaching profitability targets

As stated above, it is likely that only few or none of the BIOCORE processes will reach the target of an IRR of 25%. We will not stop at this finding but will ask what measures could be taken for reaching this profitability target.

The first objective could be to increase revenues. Since the physical product outputs are given, this would have to be achieved through higher product prices. We will therefore look, first, at the impacts of increased prices for all biorefinery end products through a politically motivated price support mechanism. Since any such subsidy system would need strong arguments in order to attain political support, we will compare the level of necessary price support for BIOCORE products with the current support for biofuels. Second, we look at the effects of increased market prices for single end products through the GreenPremium mechanism.

The second objective could be to cut costs. Those production costs could be defined that would generate the desired profitability, i.e. the so-called target costs. The basic idea of
Target Costing (TC) is to begin the costing of new products starting with the achievable market price derived from the market research to derive the allowable costs by subtracting a desired profit from this market price. The rationale behind this approach is that in complex processes, end products tend to be more expensive than the market allows if this is not prevented early in the design stage.

3.2 The dataset

The dataset on which the economic sustainability assessment has been conducted has been provided by IFEU. This dataset contains complete mass and energy balances for a selected number of biorefinery scenarios. In each of these scenarios, it is assumed that 150,000 t dry matter of biomass feedstock enter the preprocessing stage. It is furthermore assumed that the plant operates 8,000 hours per year.

The scenarios differ in their feedstock, their product portfolios and their specific types of production processes (IFEU 2013). Four scenarios have been designated as main scenarios (see Table 4).

Table 4: Main biorefinery scenarios for the economic sustainability assessment

<table>
<thead>
<tr>
<th>Scenario short name</th>
<th>Feedstock</th>
<th>C5</th>
<th>C6</th>
<th>Lignin</th>
<th>Subscenarios?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xyl/IA</td>
<td>Wheat straw</td>
<td>Xylitol (Biotech)</td>
<td>Itaconic acid</td>
<td>Unmodified lignin</td>
<td>Y</td>
</tr>
<tr>
<td>Xyl/Eth</td>
<td>Wheat straw</td>
<td>Xylitol (Biotech)</td>
<td>Ethanol</td>
<td>Unmodified lignin</td>
<td>Y</td>
</tr>
<tr>
<td>Eth/IA</td>
<td>Wheat straw</td>
<td>Ethanol</td>
<td>Itaconic acid</td>
<td>Unmodified lignin</td>
<td>Y</td>
</tr>
<tr>
<td>SHF Eth</td>
<td>Wheat straw</td>
<td>SHF ethanol</td>
<td></td>
<td>Unmodified lignin</td>
<td>Y</td>
</tr>
</tbody>
</table>

As can be seen from Table 4, the main end products produced from the three biomass fractions are xylitol (from C5 sugars), itaconic acid (from C6 sugars), ethanol (from C5 and/or C6 sugars) and unmodified lignin from the lignin fraction. This lignin may be used e.g. for the production of PF resins.

For each of the four main scenarios, IFEU has defined bandwidths in the form of sub-scenarios (standard, favourable and less favourable). The favourable sub-scenario for example depicts an implementation with efficient energy integration, low amounts of material inputs, high conversion efficiencies and at the same time less by-products for energy generation.

Additionally to these four main scenarios, further scenarios have been defined by IFEU with the aim of studying specific impacts of scenario variations (Table 5). As can be seen from Table 5, sub-scenarios have not been defined for all of these additional scenarios.

To begin with, the first main scenario is modified to allow for catalytic production of xylitol instead of biotechnological production as in the base case. However, this additional scenario with catalytic xylitol production should only be regarded as a preliminary sensitivity analysis, since high uncertainties in the data remain. Second, the main scenario with joint production of ethanol from both C5 and C6 sugars through separate hydrolysis and fermentation (SHF) is modified. Instead of joint SHF, ethanol may be converted separately...
from C5 and C6 sugars (scenario Eth/Eth or ethanol may be produced through simultaneous saccharification and fermentation (scenario SSF Eth). Furthermore, ethanol may be converted further into ethylene as a precursor for PVC (scenario PVC).

Another scenario looks into the impacts of high purity production of itaconic acid, incl. recycling. This sub-scenario (Xyl/IA Rec.) is compared to the first main scenario (Xyl/IA).

So far, all scenarios used wheat straw as feedstock. Now, the other feedstocks assessed in BIOCORE (hardwood, rice straw, miscanthus and SRC poplar) are looked at, again by comparison with the first main scenario.

All scenarios require energy in the form of electricity and heat. The electricity demand is partly covered by purchasing electricity from the grid and partly from an internal Combined Heat and Power (CHP) plant that is partly fuelled from natural gas and partly from biogas. The biogas plant is fed with the process water that only contains small amounts of dry matter. The digestate of this biogas plant contains nitrogen and phosphate, so that these can be sold as fertiliser. No information is available on other potentially marketable minerals or nutrients.

Further two scenarios assess how the internal use of lignin as a source for energy impacts on the process profitability. For comparison, the first (Xyl/IA) and fourth (SHF Eth) main scenarios are used.

Instead of using the lignin as a source of energy, additional straw may be bought in order to substitute natural gas. This is analysed in the scenario Xyl/IA straw en., based on the first main scenario. The assumption of this scenario is that all of the natural gas demand is replaced by straw.

One final scenario, the so-called “fallback option”, assumes a simplified product portfolio for the case that the other options are not feasible. In this scenario, the biorefinery markets the C5 sugars in syrup as an animal feed, the cellulose fraction as paper pulp and the lignin is again used as an internal energy source.
Table 5: Additional biorefinery scenarios for the economic sustainability assessment

<table>
<thead>
<tr>
<th>Scenario short name</th>
<th>Feedstock</th>
<th>Products</th>
<th>Sub-scenarios?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Xylitol production process:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xyl Cat/IA</td>
<td>Straw</td>
<td>Xylitol (Catalytic)</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td><strong>Ethanol process:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eth/Eth</td>
<td>Straw</td>
<td>Ethanol</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td>SSF Eth</td>
<td>Straw</td>
<td>SSF ethanol</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td>PVC</td>
<td>Straw</td>
<td>Ethylene</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td><strong>Recycling of itaconic acid:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xyl/IA Rec.</td>
<td>Straw</td>
<td>Xylitol (Biotech)</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td><strong>Different feedstock:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xyl/IA hardw.</td>
<td>Hardwood</td>
<td>Xylitol (Biotech)</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td>Xyl/IA rice</td>
<td>Rice straw</td>
<td>Xylitol (Biotech)</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td>Xyl/IA misc.</td>
<td>Miscanthus</td>
<td>Xylitol (Biotech)</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td>Xyl/IA pop.</td>
<td>SRC poplar</td>
<td>Xylitol (Biotech)</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td><strong>Use of lignin for energy:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xyl/IA lig. en.</td>
<td>Straw</td>
<td>Xylitol (Biotech)</td>
<td>Crude lignin (energy)</td>
</tr>
<tr>
<td>SHF Eth/lig. en.</td>
<td>Straw</td>
<td>SHF ethanol</td>
<td>Crude lignin (energy)</td>
</tr>
<tr>
<td><strong>Use of straw for energy:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xyl/IA straw en.</td>
<td>Straw</td>
<td>Xylitol (Biotech)</td>
<td>Unmodified lignin</td>
</tr>
<tr>
<td><strong>Fallback product portfolio:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FB</td>
<td>Straw</td>
<td>Feed (sugars in syrup)</td>
<td>Crude lignin (fuel)</td>
</tr>
</tbody>
</table>

The whole sustainability assessment in BIOCORE is done on this dataset as it was the purpose of the sustainability assessment to evaluate possible implementations of the BIOCORE biorefinery in 2020.

In this dataset, the biorefinery schemes described above are structured into four conceptual blocks. These are the pretreatment stage, the fractionation (organosolv process), the downstream processing (conversion of CIMV fractions into marketable products) and the production of by-products (Figure 6).
3.3 Economic sustainability assessment – Results

In the following, the results of the economic sustainability assessment for the aforementioned processes are presented. First, the results of the market analysis on product prices are presented (section 3.3.1). Then, an assessment of the CAPEX (section 3.3.2) and OPEX (section 3.3.3) for each scenario and a direct comparison of selected scenarios (section 3.3.4) follow. These estimations lead to conclusions about the economic viability of these scenarios, evaluated along profitability indicators, followed by a discussion about how to reach profitability targets (section 3.3.5).

3.3.1 Results of the market analysis on product prices (incl. GreenPremium)

In this section, we discuss the end products considered in the BIOCORE scenarios, i.e. their nature, markets, applications, prices (including possible GreenPremiums) and trends. This is
a slightly extended version of the information contained in the products factsheets that cover all intermediate and end products considered in the BIOCORE project (see Annex VII).

### 3.3.1.1 Bio-Xylitol

Xylitol is an organic compound that is found in the fibres of many fruits and vegetables. It can be extracted from various berries, oats and mushrooms, as well as fibrous material such as corn husks, sugar cane bagasse and birch. Xylitol is roughly as sweet as sucrose with only two-thirds the food energy.

The main use of xylitol is as a sweetener, i.e. in chewing gums and pastilles or as an additive in oral hygiene products and other pharmaceutical products. Apart from these traditional applications, xylitol has also been tested as a co-monomer with terephthalate or sebacic acid for polyester production.

Industrially, xylitol is currently produced from sugar. The chemical method of xylitol production is based on the catalytic hydrogenation of D-xylose or xylose-rich hemicellulose hydrolysate. This method is energy intensive and probably the biocatalytic production has a better carbon print, although a detailed LCA should be performed to confirm this hypothesis.

BIOCORE xylitol is either based on biocatalytic production, using microbial strains developed by VTT, or biotechnological production. In the former case, C5 sugars are fermented to bio-xylitol.

Several price estimations for xylitol are available. The export price of xylitol from China varied between about 2,000 EUR/t in November 2010 and about 2,700 EUR/t in May 2012; ex-factory prices of 68% xylitol (liquid) in that period were between about 620-680 EUR/t (CCM International). For crystal xylitol, higher prices are paid of 5,300-6,000 EUR/t, FOB (Zhengzhou Sigma Chemical Co., China). The BIOCORE processes produce crystal xylitol by self-crystallization, so that the price for crystal xylitol should be used as the reference price. However, the global demand for xylitol amounts to about 160,000 t (with an expected growth rate per year of about 5%) and one BIOCORE plant would in fact produce about 10% of this global demand. It can therefore be expected that this will have some effect on the world market price. While the actual effects are uncertain, a level of 3,500 EUR/t may be in a realistic range. We will therefore use this price for the base case.

Xylitol is produced mainly by Danisco Sweeteners, Roquette Frères, Zhejiang Huakang Pharmaceutical, Shandong Futaste Pharmaceutical and Shandong LongLive BioTech. Other producers are, for example, Lonza, SPI Polyols, Aleron, Hebei Baosuo, Shandong Yucheng Futian Pharmaceutical, Henan Huixian Hongtai Chemical Industrial. At least in China, there are more than 50 producers.

No limitation for the technical substitution potential of 1G xylitol by 2G xylitol exists since both are the same molecule. For xylitol, no GreenPremium is expected due to the fact that also the reference product is sugar based.
3.3.1.2 Feed from C5 syrup

In the fallback option scenario, the C5 syrup may be used as animal feed. The feed value of the C5 syrup is approximately comparable with that of molasses, which is a sugar-rich by-product from sugar crop processing. The price for sugar beet molasses in Europe varied between about 120-160 EUR/t (ISO 2012). The price that CIMV currently fetches for their C5 syrup was reported to be around 360 EUR/t. As a realistic price that may be fetched for this product in the medium term as feed we will therefore assume about 200 EUR/t.

No GreenPremium can be expected for the use of the C5 syrup as feed.

3.3.1.3 2G Ethanol

Ethanol is usually made by the fermentation of a carbohydrate (starch, sugar or cellulose) to the alcohol, followed by distillation and other processing to make it suitable for use as a fuel, solvent, chemical feedstock or for alcoholic beverage consumption. 2G ethanol uses cellulose as feedstock instead of sugar or starch. 2G ethanol has full substitution potential with reference to 1G ethanol.

Considerable research is being focused on developing processes that can produce ethanol from low-cost, non-food feedstocks. The industry is hoping to develop economical cellulosic ethanol, derived from the fermentation of cheap forms of biomass.

Fuel constitutes the single largest single use of ethanol by far. However, there are many other applications, ranging from alcoholic beverages to chemical feedstocks, antiseptics, antidotes, solvents and others. Ethanol is used as a base chemical for other organic compounds. These include ethyl halides, ethyl esters, diethyl ether, acetic acid, ethyl amines, and, to a lesser extent, butadiene.

It is used as an antiseptic in medical wipes and in most common antibacterial hand sanitizer gels at a concentration of about 62% v/v as an antiseptic. Ethanol kills organisms by denaturing their proteins and dissolving their lipids and is effective against most bacteria and fungi, and many viruses, but is ineffective against bacterial spores.

Ethanol works as an antidote against poisoning by other more toxic alcohols, in particular methanol and ethylene glycol, by successfully competing for the alcohol dehydrogenase enzyme, lessening metabolism into toxic aldehyde and carboxylic acid derivatives.

Ethanol is miscible with water and is a good general purpose solvent. It is found in paints, tinctures, markers, and personal care products such as perfumes and deodorants. It may also be used as a solvent or solute in cooking, such as in vodka sauce.

Global production of conventional ethanol was around 86 bln litres in 2010, compared to 74 bln litres in 2009. The United States and Brazil are the world’s top producers, accounting together for 90% of global production.

Most conventional ethanol (approximately 70% of global production) is derived from the fermentation of sugar crops, including sugarcane, sugar beets or molasses. Brazil and many tropical countries use sugarcane or molasses, while France, the largest producer in Europe, uses mainly sugar beets. The United States and eastern Canada use mainly corn kernels; in
western Canada, wheat is the main feedstock. In China, corn, cassava and sweet potatoes are used. In Italy, ethanol is produced from waste from wine manufacture. Any long-term global forecast is speculative, as actual growth will depend on a number of economic and technical factors, as well as possible changes in legislative and regulatory policy.

The biggest consumer of ethanol are the United States, accounting for 55% of world production in 2010, followed by Brazil (20%), China (8%) and Western Europe (7%).

Worldwide capacity of 2G Ethanol was estimated at 120 mln litres in 2010, fragmented into many demonstration plants, and thereof 100 mln litres based on 26 plants in the United States due to large public grants. Significant capacity extension is expected over the next years.

Current production fails to meet expectations: The US Environmental Protection Agency projected that its regulations would compel fuel suppliers to use 1,900 mln litres of cellulosic biofuel in 2012. By the end of last year, it had recognised that it would have to cut that mandated amount to just 33 mln litres.

Price indications significantly differ depending on the region and on grade (fuel grade, food grade, industrial grade). The following Figure 7 therefore compares domestic ethanol prices in Germany, Brazil and the US. The average across these three market prices was about **780 EUR/t** between 2010-2012, which we use for the base case. Furthermore, price indications for 2G ethanol may differ, but entrepreneurs confirm nearly competitive production to 1G ethanol. Lower prices in the future are expected due to larger plants and technical improvements (higher conversion rates of biomass to ethanol). No GreenPremium is expected with reference to 1G Ethanol.

![Ethanol prices (99%) in Germany, Brazil and the US](image)

Figure 7: Ethanol price (99%) in Germany, Brazil and the US, 2010-2012
Source: ICIS Pricing
Notes: FD = Free delivered, FOB = Free on board

### 3.3.1.4 Ethylene

Bioethylene can be readily produced through the dehydration of bioethanol (according to ARKEMA, this is already done in several locations e.g. in Brazil, India and France) or through the cracking of bionaphtha (according to ARKEMA, this is not existing on industrial scale). Bionaphtha is produced during the processing of renewable feedstocks in processes such as Fischer Tropsch fuel production.
Petrobased ethylene is produced in the petrochemical industry by steam cracking. In this process, gaseous or light liquid hydrocarbons are heated to 750–950 °C, inducing numerous free radical reactions followed by immediate quench to stop these reactions. This process converts large hydrocarbons into smaller ones and introduces unsaturation. Ethylene is separated from the resulting complex mixture by repeated compression and distillation.

Petrobased ethylene in naphtha steam crackers is a coproduct of propylene, C4s and aromatics. In addition, ethane is always a coproduct of natural gas, and has to be used. In some locations like the Middle East it might even have a negative value for the producer, so its production is not easy to be substituted.

Refineries are also a source of ethylene. Cheap natural gas (methane) can be turned to ethylene by oxidative coupling of methane (OCM) technologies. Methanol to olefins technologies (Licensors: UOP and Lummus) are now being implemented in China.

Ethylene is used as a feedstock in the manufacture of polymer plastics, fibers and other organic chemicals that are ultimately consumed in the packaging, transportation and construction industries and in a multitude of industrial and consumer markets. Nondurable or consumable end uses, in particular packaging, make up more than half of ethylene derivative consumption worldwide. One plastic resin, polyethylene, accounts for 55–60% (other sources state 46%) of the total use of ethylene.

Worldwide production of petrobased ethylene in 2011 was 142 mln t (107 mln t in 2005). European capacity was around 25 mln t. As of 2010, at least 117 companies in 55 countries were producing ethylene.

Global demand for ethylene is forecast to grow at about world average GDP growth rates over the next five years, or around 3.4% per year. This growth has been boosted by the hasty rebuilding of the supply chain inventory of packaged goods, all the way to retail and business outlets in developed and even developing economies. Major consumption regions are the United States, Western Europe, Middle East, Africa and China, accounting for approx. for two-third of global demand.

Because ethylene is one of the largest-volume petrochemicals worldwide, with such a diverse derivative portfolio, ethylene demand is sensitive to both economic and energy cycles. Moreover, because of the size and broad use patterns of its markets, ethylene is often used as a surrogate for the performance of the petrochemical industry at large.

Worldwide production capacity of bio-ethylene was between 0.75-0.80 mln t in 2012. Significant capacity extension is expected (e.g. by BRASKEM).

The following Figure 8 shows the spot price for petrobased ethylene in Europe, which averaged about 1,000 EUR/t between 2010-2012. Price estimations for bio-based ethylene range between 900-1,500 EUR/t depending on regions and feedstocks. We will therefore use a price level of 1,000 EUR/t for the base case.
Since ethylene is the precursor for the production of PE and PET to be used in consumer goods or packaging, a GreenPremium exists as a result of consumer pull. Also, companies try to avoid price uncertainties with regard to its petro-based counterpart and hence strive for a second raw material pillar resulting in an additional GreenPremium based on its strategic advantage.

The willingness of companies to pay a GreenPremium for Bio-PE or bio-based ethylene, respectively, can be confirmed empirically: Several companies stated their willingness to pay 30% and more for Braskem’s Bio-PE. Given its early place in the value chain and hence, a minor impact on end application costs, the GreenPremium for MEG (mono ethylene glycol) used for the production of PE, for example, is around 80%. However, this GreenPremium may only exist as long as there is a small market for biobased PE.

3.3.1.5 Itaconic acid

Itaconic acid is a granulated light yellow powder that can be processed into a polymer which may be used to replace petroleum-based polyacrylic acids which are used in diapers, feminine pads, detergents, cosmetics, inks and cleaners.

Itaconic acid is an unsaturated C5 dicarboxylic acid. It is industrially produced by fermentation of carbohydrates such as glucose using fungi such as *Aspergillus terreus*. Also, there is potential to produce itaconic acid from wood through aerobic fungal fermentation of xylose.

*Aspergillus terreus* is the chief fungus used. With a glucose substrate (C6 sugars), yields are in the range of 40%-60%. Yields from C5 sugars are in the range of 15%-30%.

Research promises enhanced production by using different genetically modified microorganisms. Common feedstocks for itaconic acid production are corn and rice. Full substitution potential of itaconic acid from lignocellulosic feedstocks is expected.
So far, the use of itaconic acid in industry has been limited by the high cost of its production. The U.S. Department of Energy identified itaconic acid as among the top twelve candidates for chemical production from biomass. However, itaconic acid related projects are less funded compared to other molecules.

There is still a need for new biotechnology innovations that would help to reduce the production costs, such as innovative process development and strain improvement to allow the use of a low-quality carbon source. Furthermore, itaconic acid will always have competition from other diacids such as succinic and adipic acid in different applications.

Itaconic acid is primarily used as a speciality monomer or co-monomer for synthetic resins, synthetic fibers, plastics, rubbers, surfactants, and oil additives; primary co-monomer use in the production of styrene-butadiene-acrylonitrile and acrylate latexes with applications in the paper and architectural coating industry. The global production of itaconic acid was estimated to have amounted to 41,400 metric tons in 2011 (Weastra 2012). Almost the entire production had taken place in China. According to Weastra 2012, styrene-butadiene rubber (SBR) was the main single application with 43.9%.

![Figure 9: Global itaconic acid market shares by applications in 2011](Source: Weastra 2012)

There is further usage potential in the manufacture of acrylic fibers, detergents (e.g. dispersant and soil anti-redeposition in laundry and automatic dishwasher detergents), adhesives, thickeners and binders, and a range of other products. Further potential is also seen in biomedical fields, such as dental, ophthalmic and drug delivery.

According to BIOCORE partners, BIOCORE itaconic acid could e.g. replace terephthalic acid in the production of polyesters or methylmethacrylate in the production of polyacrylates.

Weastra 2012 further state that the market price for itaconic acid usually fluctuates between about 1,350-1,500 EUR/t. A quotation from one of the largest producers (24% market share according to Weastra 2012) even indicated a price of 1,600 EUR/t FOB Shanghai in October 2011. For the base case we will assume a price of 1,500 EUR/t.

The BIOCORE schemes assessed in this report could produce each about 10,000-30,000 t/a of itaconic acid, i.e. almost the whole current world production. Evidently, this would have
strong implications on the prices that BIOCORE itaconic acid could achieve. However, the Weastra 2012 study expected the itaconic acid market to grow rapidly and to reach more than 400,000 metric tons by 2020. We therefore expect that a full industrial-scale BIOCORE plant in 2020 will only have a moderate impact on world market prices for itaconic acid.

As a precursor for products to be used in consumer goods/design, a GreenPremium can be expected as a result of consumer pull. Given its early place in the value chain and hence, a minor impact on end application costs, the GreenPremiums for itaconic acid can be expected to be high (20% - 100%, in individual cases more).

3.3.1.6 Unmodified lignin

The lignin obtained from the organosolv process could be used for various material uses. CIMV has established a trademark for their lignin (Biolignin™) and advertises it as a direct substitute for phenols in most of its industrial applications. These include glues and the plastics polyurethanes, polyesters, phenolic resins and exoxy resins.

According to CIMV, their contract price for Biolignin™ is at 1,450 EUR/t dry matter (Benjelloun 2011). In order to get a better idea about the feasible price ranges for lignin, the price for phenol may be used as a reference (Michels et al. 2009, p. 219). According to the ICIS pricing database, the spot price for phenol in North-West Europe was on average over the years 2007-2012 about 1,200 EUR/t. The price provided by CIMV is therefore in a realistic range, although a bit high. In order to account for uncertainties in the technical properties and substitutability of lignin for phenol, we therefore use a slightly lower price of 1,000 EUR/t.

3.3.1.7 Fertiliser

As said above, the digestate coming out of the biogas plant contains nitrogen and phosphate, which can be sold as fertiliser. In order to assess the fertiliser value of this digestate, the volumes of both elements as obtained from the IFEU dataset had been valued with the average price of nitrogen and phosphorus between 2008 and 2010 in France, where the CIMV pilot plant is located. This average price was 952 EUR/t for nitrogen and 1,080 EUR/t for phosphorus (Figure 10).

![Nutrient prices in France, 2008-2010, in €/kg](image)

Figure 10: Prices for nitrogen and phosphorus in France, 2008-2010
Source: Agreste 2013
3.3.2 Results on CAPEX

As explained in section 3.1.1, the CAPEX have been estimated by making use of the correlation between the rated power and the fixed capital investment.

The total rated power of the plant has been calculated as follows. First, the unintegrated heat demand of the organosolv step and the downstream processing of the C5, C6 and lignin fraction has been added up and adjusted for the heat losses to the atmosphere (1.25% in the favourable case, 2.50% in the standard case and 5.00% in the less favourable case). Then, the unintegrated total power and cooling demand from the pretreatment step to the downstream processes has been added. The resulting figure has been divided by the annual operating time of 8,000 h to arrive at the estimate for the rated power in MW, adjusted for a 10% surcharge to arrive at the connected power. The same has been done for the calculated connected power of the biogas and CHP plant.

By applying the formula shown in section 3.1.1, the estimate for FCI is derived and, by adding 4% for working capital, the estimate for the total CAPEX. The results for all scenarios are shown in Figure 11. One problem in this approach arises due to the fact that the energy demand differs between the standard, favourable and less favourable sub-scenarios, and thus would the CAPEX estimate. This, however, is counterintuitive because the same equipment would need to be bought independent of the process configuration. Therefore the same CAPEX estimated for the standard sub-scenario has been applied to the other two sub-scenarios.

As can be seen from Figure 11, the CAPEX estimate varies between 123 mln EUR for the fallback option and 161 mln EUR for the scenario with ethylene production for PVC.

![Figure 11: Results for CAPEX](Source: nova 2013)
3.3.3 Results on OPEX

In this section, the results on OPEX are presented and discussed. The analysis is structured into biomass feedstock, operating materials, utilities, operating labour, other direct manufacturing costs, fixed manufacturing costs and general expenses.

3.3.3.1 Feedstock

All scenarios use wheat straw as feedstock except variations of the first main scenario using hardwood, rice straw, miscanthus or SRC poplar. In all cases it is assumed that the full demand of the biofinery (150,000 t or 500,000 t) would be supplied from one single feedstock source. The problem of finding adequate price levels to be chosen for the economic assessment lies in the fact that the need to supply such large quantities infers a large radius from which the feedstock would need to be supplied from. This inevitably drives up logistics costs per tonne feedstock. These have been modelled in a supply chain model which is documented in Deliverables 1.4 and 1.5. While the costs up to the farmgate/roadside have been assessed in Deliverable 1.2.

Without going into detail, the supply chain model assessed the cost-optimal location of a biorefinery plant within each of the case study regions and allowed for mixed feedstocks in those case studies where multiple feedstocks were assumed. However, since the dataset for the economic assessment does not provide for mixed feedstocks, the theoretical procurement costs are needed for the situation in which the full demand of the plant would have to be provided by either wheat straw, rice straw, hardwood, miscanthus or poplar. The results of this calculation are shown in Figure 12. At first glance, the very high costs for barley straw in the French case study are striking. This result is due to the fact that barley growing areas are fragmented around the periphery of the region so that the straw needs to be transported over long distances in order to collect 150,000 t. In reality, barley would therefore hardly be the feedstock of choice for this region. By contrast, basically zero transportation costs were assumed for SRC poplar in Hungary since it was concluded in the supply chain model that the poplar plantations could be located just around the biorefinery plant.

![Comparison of feedstock prices](source:nova_2013)

Figure 12: Comparison of feedstock prices
Source: nova 2013
Since the techno-economic assessment is not performed for a specifically defined location, the need arises to derive quasi-average procurement costs from the case study results. In order to take the results of the supply chain model into account, we have therefore taken the averages between the calculated costs at farm gate and the procurement costs including transportation and storage from each case study and each feedstock. For wheat straw, we choose again the average of this calculated cost from the French and Hungarian case study which results in about 110 EUR/t DM. For rice straw, we take the 80 EUR/t DM as obtained from the Indian case study (the rounded average between the cost at farm gate and the cost including transportation and storage). For hardwood, the procurement of forest wood is assumed which resulted in both Hungary and Germany in the same price level of about 70 EUR/t DM. For miscanthus, we only have the results from the French case study which we round to 100 EUR/t DM. Finally, for SRC poplar, the assumption of near-zero transportation costs appears to be less realistic in most cases. We therefore assume a surcharge of 15 EUR/t for storage and transportation (as in the case of the hardwood case study in Germany) and arrive at a price of 80 EUR/t DM.

3.3.3.2 Operating materials

Apart from the biomass feedstock, the assessed biorefinery concepts consume some or all the following operating materials and auxiliaries:

- Organic acids (acetic and formic acid)
- Hydrogen peroxide
- Cellulase
- Sodium hydroxide
- Ammonia
- Monopotassium phosphate
- Ammonium sulfate
- Saccharomyces cerevisiae yeast
- Nickel
- Hydrogen (catalytic process only)

The results for each of these operating materials are presented and discussed below.

Organic acids

The organic acids acetic acid and formic acid are used during the organosolv process to separate the biomass in its three main components (cellulose, lignin and C5 syrup).

Both acids are colourless liquids. Acetic acid is the main component of vinegar (apart from water; vinegar is roughly 8% acetic acid by volume), and has a distinctively sour taste and pungent smell. Formic acid has a highly pungent, penetrating odor at room temperature. It is miscible with water and most polar organic solvents. It has many uses spanning from preservative to tanning agent and intermediate for synthesis.

For the base case, 460 EUR/t are assumed for acetic acid and 750 EUR/t for formic acid. Both prices are average figures for the EU-27 for 2010 derived from the Eurostat database.
(Eurostat 2013). The average spot price of acetic acid in Europe in 2010 was 464 EUR/t according to the ICIS Pricing database, so very much in line with the Eurostat data.

**Hydrogen peroxide**

Hydrogen peroxide (H₂O₂) is a strong oxidizer. It is a clear liquid, slightly more viscous than water. In dilute solution, it appears colorless. Due to its oxidizing properties, hydrogen peroxide is often used as a bleach or cleaning agent. It is used in the BIOCORE process in the delignification step of the cellulose obtained from the organosolv process.

According to expert information from project partner ARKEMA, the price for hydrogen peroxide fluctuates between 500-550 EUR/t. For the base case, a price of **525 EUR/t** has been assumed.

**Cellulase**

Cellulase is a mixture of enzymes able to convert cellulose to a pool of fermentable sugars. In the BIOCORE project these are used to obtain fermentable C6 sugars from the cellulose produced in the organosolv process. Usually they are obtained from the fungus *Trichoderma reesei*. They can either be produced on site using a sidestream of nutrients for the fungus fermentation or they can be delivered as "ready to use" to the biorefinery.

There is great uncertainty regarding the price for cellulase because enzymes are sold by activity, not by tonne. The needed enzyme activity, however, is not exactly known for the BIOCORE processes. Furthermore, current prices from enzyme producers are confidential and could not be used for the analysis. The estimation of enzyme costs therefore relies on a literature review. Hong et al. 2013 studied cellulase costs for lignocellulosic ethanol production from on-site and off-site production and found costs of about 4-7 USD/kg of protein (about 3,000-5,000 EUR/t) for on-site production (similar costs are also reported by Humbird et al. 2011) and 4-9 USD/kg for off-site production (about 3,000-7,000 EUR/t). Due to the high uncertainty of actual costs in the case of the BIOCORE processes, we take a more conservative estimate of **8,000 EUR/t** of protein for the base case.

**Sodium hydroxide**

Sodium hydroxide (NaOH) is the principal strong base used in the chemical industry. It is a white solid, and is a highly caustic metallic base and alkali salt. In the BIOCORE process, NaOH is used in the deacidification of the pulp, as pH controlling agent in the fermentations and in the PF resin manufacture.

As the base case price we are assuming **370 EUR/t**. This is the price derived from the Eurostat Prodcom database for 2010 for the EU-27.

**Ammonia**

Ammonia (NH₃) is a colourless gas with a characteristic pungent smell. It contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to food and fertilizers. In the BIOCORE process ammonia is used as nutrient in fermentations often in the form of salts.
As the base case price we are using 310 EUR/t of NH₃. This is the average spot price of ammonia in Europe in 2010 according to the ICIS Pricing database (ICIS 2013).

**Monopotassium phosphate**

Monopotassium phosphate (KH₂PO₄) is a soluble salt which is used as a fertilizer, food additive and fungicide. It is a source of phosphorus and potassium. It is also a buffering agent. In the BIOCORE process, it is used in the fermentations as buffering agent and phosphorus and potassium supply.

As the base price, we are using 870 EUR/t which is the average price for phosphates in the EU-27 in 2010 according to the Eurostat Prodcom database.

**Ammonium sulphate**

Ammonium sulphate, (NH₄)₂SO₄, is an inorganic salt with a number of commercial uses. Its most common use is as a soil fertilizer. In the BIOCORE process it is used as nutrients source for fermentations.

The base price for ammonium sulphate of 110 EUR/t is the average price in the EU-27 in 2010 according to the Eurostat Prodcom database. This price is in line with other international sources (Fertilizerworks 2013).

**Saccharomyces cerevisiae**

Saccharomyces cerevisiae is the well-known baker’s yeast. It is used to convert glucose to ethanol. In the BIOCORE process it is possible not only to convert C6 sugars (glucose) but also C5 sugars (xylose) to ethanol due to a genetically modified strain of *Saccharomyces cerevisiae*.

The base price of 970 EUR/t is the average price for baker’s yeast in the EU-27 for 2010. The genetically optimized yeast may however be more expensive so that we use 1,000 EUR/t as the base price.

**Nickel catalyst**

Catalysts are needed to increase the rate of a chemical reaction and improve the overall energy balance of a process, because they lower the activation energy during the transition from substrate to product. In the BIOCORE process a catalyst is needed for the catalytic production of xylitol from xylose.

The so-called Raney Nickel, derived from a nickel-aluminum alloy, is used as catalyst. Raney Nickel is a fine-grained solid containing about 90% nickel usually added with molybdenum to increase reactivity and selectivity (BIOCORE D5.5, p. 124). The activity of the Raney Nickel decreases during the process but can be regenerated by washing with an alcohol (mainly ethanol) solution (BIOCORE D5.5, p. 141).

According to the Eurostat Prodcom database, the price for nickel alloy plates and sheets was about 15,000 EUR/t in the EU-27 in 2010, that of nickel alloy bars and rods about 19,000 EUR/t and that of Nickel powders and flakes about 23,000 EUR/t. These price indications are
in line with quotes for Raney Nickel found on business platforms. As the price for the base case we will therefore apply 19,000 EUR/t for the nickel catalyst.

However, new catalyst typically does not have to be bought every year but may be reused for a limited number of cycles. Since there is uncertainty about the number of cycles that would be feasible, the cost analysis assumes for the base case that new nickel catalyst would only have to be bought every other year, so that the annual costs amount to **9,500 EUR/t**.

**H2 (catalytic process only)**

Hydrogen (H₂) is a colorless, odorless, tasteless gas. Its industrial production is mainly from the steam reforming of natural gas and less often from more energy-intensive hydrogen production methods like the electrolysis of water. In the BIOCORE process it is used to reduce xylose to xylitol with the nickel catalyst.

For the base case, we are using a hydrogen price of **3,000 EUR/t**. According to the Eurostat Prodcom database, the average price of hydrogen was about **16 EUR/m³** in the EU-27 in 2010.

The following Table 6 summarises the unit costs in EUR/t that are applied for all operating materials in the base case.

<table>
<thead>
<tr>
<th>Operating material</th>
<th>Price in EUR/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>460</td>
</tr>
<tr>
<td>Formic acid</td>
<td>750</td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>525</td>
</tr>
<tr>
<td>Cellulase</td>
<td>8,000</td>
</tr>
<tr>
<td>NaOH</td>
<td>370</td>
</tr>
<tr>
<td>NH₃</td>
<td>310</td>
</tr>
<tr>
<td>KH₂PO₄</td>
<td>870</td>
</tr>
<tr>
<td>Ammonium sulfate</td>
<td>110</td>
</tr>
<tr>
<td><em>S. cerevisiae</em></td>
<td>970</td>
</tr>
<tr>
<td>Nickel</td>
<td>9,500</td>
</tr>
<tr>
<td>H₂ (catalytic process only)</td>
<td>3,000</td>
</tr>
</tbody>
</table>

Source: nova 2013

The following Figure 13 shows an overall comparison of the estimates of annual costs for operating materials for the standard scenarios. As can be seen, the costs for the organic acids and hydrogen peroxide are very similar between the different scenarios. Together, these account for about 40% of operating material costs in most scenarios. Costs for cellulase alone account for another 40% and even 50% in the scenarios based on SHF and SSF ethanol. Another large cost contributor is NaOH with about 15%. The remaining operating materials are of minor importance, with the exception of the nickel catalyst. However, the costs for the catalyst, accounting for about 30% of operating material costs in the Xyl Cat/IA scenario may be further reduced if more extensive recycling turned out to be feasible.
3.3.3.3 Utilities

The concept of utilities has been explained in section 3.1.2.1. From the list of conceivable utilities, the evaluated biorefinery concepts all use water, electricity and steam. Electricity is either obtained from the grid or from conversion of by-products into electricity in a biogas plant. Steam is generated either with natural gas or with lignin or straw as a source of energy.

Water (Tap water and process water)

Water is used in many steps of the BIOCORE process, as fermentation medium, as solvent and as transport medium. Usually, a distinction is made between tap water and process water. The cooling demand is satisfied by discharging heated water to a river for which no costs are assumed.

Tap water is the water that is directly extracted from the public supply system to the biorefinery while process water is the water that has already been used in the process. It can be reused in the same step or in other steps. Process water may need to be treated to remove wastestreams that are in it.

For the base case, the price for tap water is valued at 1.3 EUR/m³, which was the average industrial water price in several European countries in the late 1990s (EEA 2003).

Electricity

Most of the electricity demand is covered by purchasing power from the public grid. For this, the inter-project harmonization document (Piotrowski et al. 2012) stipulated to use a price of 0.0923 EUR/kwh, which was the average electricity price for industrial users in the EU-27 in

Figure 13: Annual costs of operating materials for the standard scenarios
Source: nova 2013
2010. The remaining electricity demand is covered from an internal CHP plant that is partly fuelled from natural gas and partly from biogas.

Steam
As stated above, the total heat demand is satisfied through a CHP plant that uses natural gas and biogas. Also the natural gas price has been harmonized between SupraBio, Eurobioref and BIOCORE and determined at 7.802 EUR/GJ (0.0281 EUR/kwh), which was the average natural gas price for industrial users in the EU-27 in 2010.

In three of the scenarios (see Table 5), the lignin is used to fuel the CHP plant instead of selling it as a product. Thus, costs for natural gas are saved but revenues from selling the lignin are foregone. Furthermore, in the “straw powered” scenario, additional cereal straw is bought in order to fully replace the natural gas demand by straw.

The following Figure 14 shows the overall comparison of the estimates for annual utility costs for the standard scenarios as well as the favourable and less favourable sub-scenarios. Overall, utilities make up a cost share of about 10-30 mln EUR, from which tap water contributes about 5%, electricity from the grid about 20% and natural gas about 75%.

Figure 14: Utility costs for the standard scenarios
Source: nova 2013

Utilities are saved by process integration. However, the degree to which integration is feasible differs between processes. This is captured in the IFEU dataset by assuming different percentages of overall heat and cooling savings by integration (between 40-80%), depending on the type of process as well as the sub-scenarios (favourable, standard, less favourable).

An allocation problem arises now in the quantification of utility demand up to the organosolv process: The percentage of savings by integration is only given for the whole process, but when applying these savings to the organosolv process, the utility demand of the integrated organosolv step appears to vary between processes. This is counterintuitive.
since the organosolv process itself does not differ between the processes. In order to show the distribution of utility costs between the different process steps (preprocessing, organosolv, C5 and C6 processes), the following figure therefore only looks at the unintegrated heat demand. For those scenarios with combined C5 and C6 processes, the respective shares are shown by a shaded area.

Apparently, the organosolv step is by far (about 60-80%) the most significant contributor to the overall heat demand. This result is in line with the finding of Dale et al. 2012 who present a comparison of different pretreatment technologies. In this comparison, the organosolv process came out as one that is very energy, capital cost and water demanding (Dale et al. 2012, p. 897). On the one hand, this result raises concerns about the choice of the fractionation technology. On the other hand, it could also suggest that there may be advantages for sugar or starch based feedstocks that do not need to undergo intensive pretreatment. This hypothesis, however, would have to be tested in a comparative analysis.

![Shares of process steps in total unintegrated heat demand](image)

Figure 15: Shares of process steps in total unintegrated heat demand for the standard scenarios
Source: nova 2013

### 3.3.3.4 Operating labour

The following Figure 16 shows the results for annual operating labour costs for each scenario. As explained in section 3.1.2.1, these estimates were calculated based on the number and type of equipment, multiplication factors and the gross employers labour cost of 20 EUR per hour. As a result, annual costs for operating labour vary between about 2.2 million Euro for the fallback option and 5.5 million Euro for the scenario Xyl Cat/IA. The estimate for operating labour costs is highest for Xyl Cat/IA mainly due to the higher number of heat exchangers required for the catalytic xylitol production.

There are no differences between the standard and the favourable and less favourable sub-scenarios since there are no differences between these in the type and number of equipment.
3.3.3.5 Other direct manufacturing costs (DMC)

The other direct manufacturing costs only vary slightly between the scenarios (Figure 17). In the standard scenarios, DMC vary between about 6-9 mln EUR. The variation of the scenarios into favourable/less favourable cases causes a variation in the range of 2-4 mln EUR. Overall, the other DMC make up a share of about 7% of total COM in the standard case.
3.3.3.6 Fixed manufacturing costs (FMC)

Fixed manufacturing costs (depreciation, taxes and insurance, plant overheads) make up about 15-20 mln EUR per year or 18% of total COM. Since it was assumed that FMC only depend on FCI and C\textsubscript{OL}, there is no variation between the standard and the favourable and less favourable sub-scenarios.

![Fixed manufacturing cost estimates (in mln EUR)](image)

Figure 18: Fixed manufacturing costs  
Source: nova 2013

3.3.3.7 General expenses (GE)

Different to the FMC, general expenses (GE) differ between the standard cases and the favourable/less favourable sub-scenarios since the model proposes these to depend not only on the FCI and C\textsubscript{OL}, but also on the annual manufacturing costs (COM). The results in Figure 19 show that estimates are in the range of about 15-20 mln EUR.
3.3.3.8 Overall comparison of OPEX

The following Figure 20 shows the overall comparison of annual manufacturing costs (OPEX). For the standard cases, OPEX tend to lie at around 100-115 mln EUR, in the less favourable sub-scenarios increasing up to about 150 mln EUR, in the favourable ones some fall below 80 mln EUR.
Figure 21 shows the average distribution of the different cost items across all standard scenarios.

![Pie chart showing shares of annual manufacturing costs across all standard scenarios]

Figure 21: Shares of annual manufacturing costs across all standard scenarios  
Source: nova 2013

3.3.4  Direct comparison of selected scenarios and discussion

In the following, we look in detail into the results for selected groups of scenarios in order to highlight the effects of changes in the process configurations.

3.3.4.1  Main scenarios

As explained in section 3.2, four of the analysed scenarios had been designated as main scenarios. In this section, the economic results of these main scenarios, in the standard configuration, are directly compared with each other. Figure 22 shows that in the standard situation, none of the scenarios are able to generate profits, although the first scenario Xyl/IA that produces xylitol, itaconic acid and lignin, clearly performs best. The second scenario, Xyl/Eth, that produces ethanol from the C6 fraction instead, is characterized mainly by higher utility costs and lower revenues. The third scenario, Eth/IA, differs from Xyl/IA only in the utilization of the C5 fraction for ethanol instead of xylitol. Mainly due to much lower yields, and revenues, from ethanol from the C5 fraction, this scenario leads to much higher losses. Finally, the scenario that produces ethanol jointly from C5 and C6 sugars through separate hydrolysis and fermentation (SHF), leads to the highest ethanol yields, which, however, cannot compensate for the revenues foregone for xylitol and itaconic acid.
Excursus 1: Comparison of SHF Eth scenario results with the CIMV economic analysis

Les paramètres nécessaires sont manquants ou erronés.

In order to highlight how changing some of the parameters introduced above would change the results, we perform a few sensitivity analyses. Due to the large number of parameters, it is only possible to look at a few of them which may be expected to have significant impacts. We therefore focus on four parameters, namely the natural gas and electricity price, the hourly wage rate and the estimate for the fixed capital investment (FCI). The latter two parameters are expected to have significant impacts because several other cost items had been assumed to be linked to these (see section 3.1.2). However, the results in Figure 23 show that the wage rate has relatively little impact, which is in line with the minor contribution of labour costs to total costs of manufacture. Also the estimate for for FCI has less impact compared to the electricity and natural gas prices.

Figure 22: Overall comparison of main scenarios  
Source: nova 2013

Figure 23: Sensitivity analyses on selected input parameters for the main scenarios
3.3.4.2 SHF Eth: Comparison with other ethanol-based processes

For four of the assessed biorefinery schemes, ethanol (or, in a further step, ethylene) is the main product and as a by-product, lignin is produced for material use. The overall comparison of all scenarios has already shown that these scenarios fare poorly compared to those with the production of xylitol and itaconic acid. On the one hand, this is due to the high energy demand of the distillation step (see Figure 14), and on the other hand due to low revenues from selling ethanol.

Figure 24 shows that the scenario with separate hydrolysis and fermentation (SHF Eth) still performs better compared to the simultaneous saccharification and fermentation (scenario SSF Eth) and the separate conversion from C5 and C6 sugars (scenario Eth/Eth). Regarding the scenario that converts ethanol further into ethylene for PVC production, it was therefore assumed that this conversion process would be an add-on onto the SHF scenario. As Figure 24 shows, this process leads to higher costs and lower revenues compared to the scenario SHF Eth.

Figure 24: Overall comparison of biorefinery schemes with ethanol or ethylene as main products
Source: nova 2013

3.3.4.3 Xyl/IA and SHF Eth: Comparison of lignin utilization

Apart from using lignin as a material, it may also be used for energy for partly replacing natural gas. The effects of such a use of lignin for energy has been studied for two of the main scenarios – Xyl/IA and SHF Eth. As Figure 25 shows, in both scenarios, the savings in natural gas fail to compensate for the forgone revenues from selling the lignin. This result may even be more in favour of the material use of lignin if it can be marketed for higher value applications such as lignin-based PF resins.
Figure 25: Overall comparison of processes that use lignin for energy or as material
Source: nova 2013

3.3.4.4 Xyl/IA: Recycling of itaconic acid

The production of high purity itaconic acid including recycling may provide advantages due to higher product yields. This has been studied in an alternative to the main scenario Xyl/IA. However, according to Figure 26, the only slightly higher yields in itaconic acid do not justify the higher energy demand for this process, so that this alternative process would incur additional losses.

Figure 26: Overall comparison of processes with and without recycling of itaconic acid
Source: nova 2013

3.3.4.5 Xyl/IA: Comparison of different feedstocks

For evaluating the sensitivity of feedstock choice, the first main scenario (Xyl/IA) has also been developed based on hardwood, miscanthus, rice straw and SRC poplar. The effects of changing the feedstock are shown in Figure 27.
Both the Xyl/IA scenario with the feedstocks hardwood and SRC poplar generate by far the best result with annual profits in the range of 15-20 mln EUR. While the annual costs of manufacture are very similar to the scenario based on wheat straw, the difference mainly stems from the higher products yields, owing to the higher shares of usable components in hardwood and SRC poplar compared to wheat and rice straw and miscanthus (Table 7).

### Table 7: Composition of assessed feedstocks

<table>
<thead>
<tr>
<th>Component</th>
<th>Wheat straw</th>
<th>Rice straw</th>
<th>Hardwood</th>
<th>SRC poplar</th>
<th>Miscanthus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemicellulose / xylose</td>
<td>21%</td>
<td>21%</td>
<td>29%</td>
<td>21%</td>
<td>19%</td>
</tr>
<tr>
<td>Cellulose / glucose</td>
<td>36%</td>
<td>36%</td>
<td>46%</td>
<td>48%</td>
<td>42%</td>
</tr>
<tr>
<td>Lignin</td>
<td>20%</td>
<td>15%</td>
<td>23%</td>
<td>24%</td>
<td>23%</td>
</tr>
<tr>
<td>Sum of usable components</td>
<td>77%</td>
<td>72%</td>
<td>98%</td>
<td>93%</td>
<td>84%</td>
</tr>
<tr>
<td>Ash</td>
<td>6%</td>
<td>15%</td>
<td>0.5%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Others</td>
<td>17%</td>
<td>13%</td>
<td>1.5%</td>
<td>5%</td>
<td>14%</td>
</tr>
</tbody>
</table>

Source: IFEU 2013a

### 3.3.4.6 Xyl/IA: Effects of scale

All scenarios have been developed for a capacity of 150,000 t dry matter, expect for the case of rice straw. In this case, the work of WP1 has revealed that also a capacity of 500,000 t could be feasible in the selected case study region in India. The effects of upscaling the plant’s capacity are therefore explored only by taking the example of rice straw in India.
Figure 28 shows the results from changing the capacity in the Xyl/IA standard scenario from 150,000 t to 500,000 t of rice straw. Since the function for the estimation of the fixed capital costs (FCI) is non-linear (see section 3.1.1), costs do not increase at the same rate as the revenues do. The model therefore accounts for returns-to-scale. Due to these assumed returns-to-scale, when moving to a capacity of 500,000 t of rice straw, this may in fact lead to high annual profits as Figure 28 shows.

![Figure 28: Comparison of capacities in the rice straw scenario](image)

**Source:** nova 2013

In the inter-project harmonization document (Piotrowski et al. 2012), it had been decided to apply the following scale relationship for capital costs: Cost B = Cost A (Scale B / Scale A)^0.7. The default value of the scale factor (0.7) had been chosen in line with literature and engineering convention (Peters et al. 2003). When applying this formula to the FCI as estimated for a capacity of 150,000 t, the results indicate annual profits in the range of 30 mln EUR for the larger capacity of 500,000 t, compared to about 40 mln EUR as obtained from the current model. Apparently, the current model implies greater returns-to-scale. Evidently, the actual effects of upscaling the capacity could only be proven by empirical evidence.

### 3.3.5 Results on economic sustainability of assessed BIOCORE value chains

In the following, we present the results on the overall economic viability of the assessed biorefinery concepts.

#### 3.3.5.1 Calculation of necessary product price support

As said above, the Internal Rate of Return (IRR) is the main profitability indicator for the overall comparison of all scenarios. The benchmark, at or above which an investment will be considered to be favourable, is set to an **IRR of 25%**.

As shown above, in the standard configuration, almost all of the biorefinery schemes would currently make annual losses. Only a few (Xyl Cat/IA and Xyl/IA based on poplar and hardwood) would make profits, but these would not be sufficient to achieve an IRR of 25%. With the given set of parameter values, we therefore conclude that they would need some kind of support mechanism in order to reach the target of 25% IRR which would render an investment interesting.
One possible support mechanism would be the direct price support on the sold production of the biorefinery. In a first instance we assume that all sold products would be supported by a certain percentage on top of the market prices assessed in section 3.3.1 without GreenPremium. The results in Figure 29 clearly show that the first main scenario (Xyl/IA) and all of its variations would need the lowest overall price support in order to reach the target of 25% IRR (indicated by green colour). Only in the favourable sub-scenarios, the Xyl/IA scenarios based wheat straw, hardwood, poplar, miscanthus and rice would even be able to achieve an IRR above 25% without support.

The dotted vertical lines in Figure 29 indicate actual current price support levels for biodiesel and bioethanol in Europe. These lie between about 45% in the case of average European support levels for biodiesel (Jung et al. 2010, p. 66) and 70% in the case of bioethanol support in Germany (nova 2012). The support resulting from the biofuel mandate can be illustrated by taking the example of Germany. According to the German biofuel quota act (Biokraftstoffquotengesetz), distributors of Otto and Diesel fuels have to pay a fine if they do not comply with the requirement to add fixed amounts of biodiesel and bioethanol. The existence of these fines leads to the situation that the distributors’ purchasing price of biodiesel and bioethanol could rise exactly by the amount of these fines (60 ct/l of biodiesel and 90 ct/l of bioethanol) before a mineral oil company would rather accept the fine than complying with the quota. For a treatment of biofuel support mechanisms in other European countries, see e.g. Jung et al. 2010.

Figure 29: Necessary price support to reach IRR = 25%, without GreenPremium
Sources: nova 2013, Jung et al. 2010
* Price support levels for biodiesel (black dotted lines; on average about 45% in the EU in 2010 and 50% in Germany in 2012) and bioethanol (blue dotted lines; on average about 60% in the EU in 2010 and 70% in Germany in 2012).
This example shows that the necessary price support for some of the selected biorefinery schemes could be quite moderate compared to the actually existing current support for biofuels. In the standard sub-scenarios, all biorefinery schemes based on the main scenario Xyl/IA, except the one with use of lignin for energy, could become profitable with a price support level well below 50%.

The results from section 3.3.1 indicate that itaconic acid could fetch GreenPremiums of 20-100%. For an assessment of the impact of this price premium we assume a GreenPremium of 50%. Furthermore, ethylene could fetch a GreenPremium of at least 30%. As Figure 30 shows, the GreenPremium for itaconic acid could cut the remaining necessary price support down further so that even the standard sub-scenarios of Xyl/IA based on hardwood and poplar could become very close to profitability without any further support. The GreenPremium for ethylene, however, could not bring the PVC scenario anywhere near profitability.

Figure 30: Necessary price support to reach the target of IRR = 25%, with GreenPremium
* Price support levels for biodiesel (black dotted lines; on average about 45% in the EU in 2010 and 50% in Germany in 2012) and bioethanol (blue dotted lines; on average about 60% in the EU in 2010 and 70% in Germany in 2012).

**3.3.5.2 Calculation of the impacts of capital investment support**

In the new framework of the European Bioeconomy by DG Research & Innovation and the Public Private Partnership Bio-based Industries Consortium (BIC) it will be possible to get financial support for demonstration plants (40% average) and for flagship plants (average 15%). In combination with other programmes, e.g. regional development or member states support, the capital investment could be in total reduced by 50% in some cases.

We therefore calculate in addition the impacts of a reduction of CAPEX to 50% on profitability. The following Figure 31 shows the impacts of such a support mechanism on the remaining necessary price support (with GreenPremium). With such CAPEX reduction, the standard sub-scenarios of the first main scenario Xyl/IA based on hardwood, miscanthus and
poplar as well as the scenario with catalytic xylitol production could now reach the target of an IRR of 25% without any further subsidies.

Figure 31: Necessary price support to reach the target of IRR = 25%, with GreenPremium and a CAPEX cut of 50%

* Price support levels for biodiesel (black dotted lines; on average about 45% in the EU in 2010 and 50% in Germany in 2012) and bioethanol (blue dotted lines; on average about 60% in the EU in 2010 and 70% in Germany in 2012).

3.3.5.3 Calculation of necessary cost savings

Apart from increasing revenues, the profitability target could also be reached by cutting costs in order to achieve the target or allowable costs that would provide an IRR of 25%. Figure 32 basically mirrors Figure 29 and shows the allowable costs as a percentage of actual costs.

As an example, in the standard configuration of the Xyl/IA scenario based on hardwood, costs of manufacture would have to be cut by 21% or to about 90 mln EUR in order to achieve the target costs. This could of course be achieved in many different ways and feedback from technical partners would be needed in order to identify those cost drivers that are too expensive for the value there are contributing to the process. In the case of the Xyl/IA scenario based on hardwood, the target costs could for example be achieved by cutting the other direct manufacturing costs, general expenses and fixed manufacturing costs to 55% of their original amount. Alternatively, the target costs could be achieved by cutting the costs for operating materials and utilities to 50%.
### 3.4 Conclusions and outlook

This report has first presented a newly developed model for a techno-economic evaluation (TEE) of biorefinery processes in a situation of limited data availability (for example no data for sizing of the equipment). The starting point of the analysis was the estimation of the capital expenditures (CAPEX) based on the calculated rated power of all equipments of the whole plant. Applied to the dataset that formed the basis for the sustainability assessment in the BIOCORE project, this model has proved to achieve reasonably good and coherent results. The analysis covered four main scenarios and thirteen variations of these, including sub-scenarios that simulated standard, favourable and less favourable process conditions.

The four main scenarios produce as their main products itaconic acid, xylitol and lignin (scenario Xyl/IA), xylitol, ethanol and lignin (scenario Xyl/Eth), ethanol, itaconic acid and lignin (scenario Eth/IA) and ethanol through separate hydrolysis and fermentation and lignin (scenario SHF Eth). The last one of these main scenarios is also currently developed by the French company CIMV, so that it was possible to compare the modelling results with the economics as projected by CIMV. The modelling results were reasonably close the calculations by CIMV and where deviations were found it was possible to find good reasons to explain these. The newly developed, coarse model provides therefore, given the limited available data, satisfactory results.

According to the results of our analysis, in the standard scenarios (which were defined based on experts’ input regarding the most plausible technological performance in 2025), only a few of the biorefinery schemes based on straw are able to generate profits. Moving from straw to woody feedstock improves the picture (see below). However, none of these scenarios are able to achieve the target of an internal rate of return of 25%, which is the
standard threshold usually considered necessary to attract capital investment in the Chemical Industry.

However, a few of these biorefinery schemes could pass over this threshold either under more favourable process conditions or with moderate subsidy levels. Also if customers turn out to be willing to pay GreenPremiums on selected products, the profitability target could be achieved for some of the schemes.

For those scenarios with moderate subsidy levels needed, these lie below 20% output price support in selected cases, which is well below the current support for biofuels (e.g. for biodiesel on average about 45% in the EU and 50% in Germany and for bioethanol about 60% in the EU and 70% in Germany). Given the strong political will to develop biorefineries in Europe and the higher value-added of biorefineries compared to just producing biofuels from biomass, this result provides a strong support for biorefineries.

An alternative support instrument which results in a CAPEX cut has also been assessed. This support instrument has been developed within the new framework of the European Bioeconomy by DG Research & Innovation and the Public Private Partnership Bio-based Industries Consortium (BIC). According to this programme, it will be possible to get financial support for demonstration plants (40% average) and for flagship plants (average 15%). In combination with other programmes, e.g. regional development or member states support, the capital investment could be in total reduced by 50% in some cases. With such an instrument in place, profitability for many scenarios would be significantly increased.

Furthermore, the analysis has also shown that the biorefinery product portfolio determines profitability to a large extend. All BIOCORE processes that are focused on ethanol are expensive and provide only low revenues. Policies targeted at bioethanol production therefore apparently set wrong incentives. Rather, policies should be directed towards value-adding chemicals and polymers.

The impact of returns to scale have been assessed for one of the scenarios, which was based on rice straw in India. In this scenario, the effect from moving from 150,000 t to 500,000 t was very significant and lead to annual profits in the range of 40 mln EUR compared to losses of about 10 mln EUR. This result provides a strong case for higher biorefinery capacities.

Also the choice of the feedstock has been shown to be an important determinant for profitability. The chemical composition, especially the shares of usable components, i.e. cellulose, hemicellulose and lignin, determines products output and thus revenues. This effect can make a difference in the range of 20 mln EUR when moving from wheat straw as feedstock to hardwood (according to the assumptions, the share of usable components in hardwood was 98% compared to 77% for wheat straw).

The scenarios presented above all assumed one single feedstock. In reality, however, a multi-feedstock supply is much more realistic and also more sustainable in the long-run: Short supply or price spikes of one feedstock could be better buffered in a multiple feedstock scenario.

As another finding of the techno-economic evaluation of the selected biorefinery processes, it has been shown that the organosolv process itself is the largest contributor to utility costs
(about 60-80%). This is an interesting finding and it raises questions about the choice of the fractionation technology as well as the focus on lignocellulosic feedstocks that need to undergo intensive pretreatment such as organosolv in our case – in contrast to sugar and starch, which can be directly used.

Lessons learned:

- The economic analysis shows clearly that a biorefinery can and will be much more profitable compared to a pure biofuel plant.
- This is due to higher value added from high-value chemical building blocks and chances to receive GreenPremium prices for some of the bio-based chemicals or polymers (in contrast to fuels).
- A biorefinery should produce as little as possible low-value chemicals like ethanol and try to valorize lignin-derived chemicals on the highest level.
- The existing political framework is only in favor of biofuels. A new policy in favor of biorefineries could bring new investments, value added and employment to Europe - and in addition would even show more CO₂ reduction. The recent PPP activities with support for demonstration plants and flagship investment are the first visible steps in the right direction.
- The analysis supports high capacity biorefinery concepts.
Social, legal and political considerations play a key role with regard to acceptability and market diffusion of new technologies. Social sustainability in the context of Bio-Commodity Refinery (BIOCORE) implies that the systems, structures and the relationships formed by the biorefinery actively support the capacity of current and future generations to evolve within a sustainable livelihood framework. Evaluating social sustainability of BIOCORE first needs an appropriate identification of linkages between the bio-refinery supply chain and possible social structures followed by identification of suitable indicators to make such linkages measurable and finally their measurement and assessment. Critical social structure would typically include job creation, human rights, displacement, conflict with other forms of livelihoods, possible impact on local, national and global dynamics, ability to meet end-users and consumer needs compared to reference products, etc. Measurement of these issues through suitable indicators can either be undertaken based on stakeholder discussion and learning their perception, or through detailed review of literatures. Because of the complex nature of undertaking such social assessments, a combination of both approaches is more helpful in presenting robust comprehensive results.

The potential and existing conflicts between the different stakeholders also need to be looked at. In this context, the legal and political aspects of sustainability explore efforts to address pressing sustainability concerns through policies, legislation, conventions, directives, treaties, and protocols. Many countries have implemented policies to foster production and use of biofuels. Economic instruments including tax exemptions or reliefs, feeding tariffs or quotas, or strong policies such as the European Renewable Energy Directive (RED) have been put in place. Legal framework has also been strengthened to promote the use of biofuels in the countries through various policies and legislations. One good example is the national biofuel policy of India where the focus of the programme has been on the use of non-edible feedstocks and molasses (produced as a byproduct of sugarcane based processes) for biodiesel and bioethanol production. It is also important to understand the various laws that have direct and indirect effects on the overall sustainability of current and future operations of biorefineries. At the same time corrective measures could be put forward that may help in managing possible negative impacts.

4.1 Research methodology and framework

The social, legal and political aspects of sustainability of the BIOCORE project will be carried out using a broad and established social sustainability appraisal framework. The methodology involves identification of the stakeholders along the BIOCORE supply chain and possible sustainability issues arising from BIOCORE operations, identification of suitable indicators for sustainability measurement and analysis of results. The social assessment is divided into a general assessment (independent of location for the 3 sites in Europe) of social impacts using a combination of social impact assessment (SIA) and social life cycle assessment (sLCA) and a more detailed, as well as site-specific assessment for the case studies in India using the Multi-criteria analysis.
As part of the legal and political assessment, identification and evaluation of country/region specific policies related to aspects of the different legal and political issues for the different parts of the supply chain will be looked at.

4.1.1 **Assessment of social, legal and political sustainability: Background and state of the art**

This section presents the background and existing state of art in context of social, legal and political sustainability assessment.

4.1.1.1 **Social Sustainability**

The term “social” relates to human society and its members (Wordreference.com, 2008). Hence social sustainability implies reducing poverty, fair distribution of benefits arising from developmental projects, and that dignity for human life is ensured, among others. This is more than meeting the basic human needs such as the right to health care, education and housing (Dömling, 2002). Additional issues to be covered are aspects such as employment rates, equal opportunities, equal treatment of gender and political participation. However, the social dimension is only one of the three dimensions/pillars of sustainability and needs to be combined with the assessment across the other pillars to arrive at any comprehensive sustainability assessment.

A number of sustainability indicator frameworks have been developed. The United Nations Commission on Sustainable Development has developed indicators for countries to assess their progress towards sustainable development (UN, 2007). These indicators provide information on social, economic, environmental and institutional aspects of sustainable development. These indicators are prepared from a macro perspective and are relevant at national levels rather than for business purposes and at a project level. The Global Reporting Initiative (GRI) framework has over 100 environmental, economic and social indicators divided in the following categories: economic, environment, human rights, product responsibility, product and service, and society (GRI 2011). While the framework considers certain parts of supply chains, it is not following the life cycle approach, thus missing on some life cycle stages, such as transport, use and final disposal of products. A number of authors have applied the GRI framework to different industries including the mining and minerals sector (Azapagic 2004), water industry (Christen et al. 2006) and the pharmacy industry (Veleva et al. 2003). The IChemE sustainability metrics (IChemE 2002) also considers all three dimensions of sustainability. The environmental indicators include emissions, waste and effluents as well as resource use; economic indicators include investments, value, profit and tax; and the social indicators include society and workplace. However, the IChemE sustainability metrics are suitable for companies rather than for sectors, products or technologies; besides, it is specific to companies operating in the process sector. Labuschagne et al. (2005) have also developed criteria for assessing sustainability of the process industry.

Thus previous authors have outlined the sustainability framework for bio-energy systems (Elghali et al. 2007; Mikkilä et al. 2009; Krotscheck et al. 2000). However, to date, there are no
sustainability indicator frameworks for integrated bio-refineries. This work attempts to contribute towards the development of such a sustainability assessment framework for the bio-refinery sector by considering social, legal and political dimensions. The main challenge of incorporating the social dimension in any assessment is the inherent complexity, since it is determined by a number of factors such as personal behaviors and perceptions, moral values, interactions and relations in different social groups. The social dimension may also have a strong regional character, could be different from case to case and contain a certain level of subjectivity in terms of importance. Identifying specific social issues for the case of biorefinery is difficult, as this sector is not established yet. However, some of the general social issues that apply to other industrial systems are also applicable to this supply chain. These include employment provision, health and safety, impacts on local communities and energy security which are some of the social indicators used in this work. Additionally, certain social impacts (especially those that relate to the impacts on the local community) could be perceived very differently from region to region and even if they could be quantified, their results could not be placed against and compared to those of another biorefinery that belongs to a different production chain somewhere else (even if the products are the same).

4.1.1.2 Legal and Political sustainability

In addition to the social factors, the legal and political framework has an important role in the sustainability of bio-refineries. They can create potential barriers for the development of biorefineries. For example, the established regulations may not fit with the technical standards. The legal and political aspects of sustainability explore efforts to address pressing sustainability concerns through policies, legislation, conventions, directives, treaties, and protocols. It looks into the effectiveness of international law versus national law in protecting the environment, and about the effect of current laws on future generations. They analyze the efficacy and shortcomings of present legal instruments, private and public policies, social movements, and conceptual strategies - offering readers a prelude of steps we must take to develop laws and policies that will promote sustainability. Absence of proper legal and political framework can create potential barriers for the development of biorefineries. For example, the established regulations may not fit with the technical standards. Upscaling biorefineries from research to industrial application phase calls for consistent and stable policies over a significant period of time, backed up by efficient legal framework, opportunity to access funds, environment that supports continuous R&D with adequate pool of trained scientists, priority on the use of agricultural and forestry residues as feedstock in biorefineries, and realisation of some pilot project plants in different geographical areas etc.

4.1.2 Stakeholder Categorization

Identifying the relevant stakeholders in the context of a bio-refinery and categorizing them is an important part of the methodological framework. Owing to the complexity of the supply chain, which involves various feedstocks, processing routes and products, the industry has a diverse range of stakeholders with different sustainability interests. The stakeholders include
farmers, government, suppliers, customers, local communities, local authorities, and NGOs and employees (Gold and Seuring 2010). We consider a quadrate to include these stakeholders that is presented in Figure 33.

![Stakeholders Quadrant](image)

Figure 33: Mapping Stakeholders in context of a biorefinery
Source: Diaz-Chavez, 2003, 2006

### 4.1.3 Analytic Hierarchy Process (AHP)

One of the major approaches widely used for socio-economic impact assessment is the multi-criteria analysis (MCA). MCA is a decision-making tool which is primarily developed for complex multi-criteria problems that may include qualitative or quantitative aspects (or both) of the problem in the decision-making process (CIFOR 2007). MCA has found growing application in recent times particularly in the decision making process associated with environmental sustainability since such decisions are often complex, multi-faceted, and involve different stakeholders with different priorities and agendas. Many decisions surrounding environmental sustainability that has social dimensions need to draw upon multidisciplinary knowledge bases, incorporating natural, physical, and social sciences, politics, legal issues and ethics. This means that group decision processes are called for as they have advantages over individual processes. This gives more perspectives for consideration, and enhances the chances of having natural systematic thinking (Linkov and Ramadan 2004).

The identification of appropriate and relevant indicators is essential as it defines the breadth and intensity of the impact assessment. Some of the qualitative indicators can be quantified and ranked through a preference scale. Such scale of preference will be able to create a hierarchy of ranking and the method of Analytical Hierarchical Process (AHP) (a type of Multi Criteria Analysis) will suggest the relative preference and ordering of the preferences. AHP is a method of measurement for formulating and analyzing decisions. T.L. Saaty in 1980 provided a theoretical structure for the AHP (a decision support tool) that can be used to solve complex decision problems taking into account tangible and intangible aspects. The tool supports decision and policy makers to make decisions based on primary and secondary information. The AHP decomposes a decision problem (research question) into elements, according to their common characteristics, and levels, which correspond to the common characteristic of the elements. This tool has the flexibility to take into consideration both (multiple) quantitative and qualitative factors, to handle different groups of actors and to combine the opinions expressed by different experts, and capture perceptions of multiple...
stakeholders on the relative severity of different socio-economic impacts. This will help in prioritizing the impacts and also help in mitigating the adverse impacts. Figure 34 depicts the decision tree in the context of the prepared AHP.

![Decision Tree Diagram](image)

Figure 34: Decision tree
Source: Author’s own compilation

Cross comparison of sustainability sub indicators can be done during a point of time in spider analysis. Spider analysis can also compare the relative position of each sub indicators vis-à-vis each other under each of the specific criteria of sustainability. The objective of the spider analysis will be to find out how various indicators under different specific criteria, sub-criteria of sustainability has moved over time in selected sites, owing to the potential impact of setting up of a biocommodity refinery. Spider analysis is a useful tool for the study as it helps us cross compare different indicators during a point of time. Spider analysis will direct us on how under the social criteria of sustainability (as shown in Figure 35), the identified sub-criteria are placed in comparison to each other at a particular point of time of measurement across the identified sites of our study.

![Spider Analysis Diagram](image)

Figure 35: Spider analysis
Source: Author’s own compilation
4.1.4 Social Life Cycle Assessment (SLCA) Framework

For the general assessment of social impacts a combination of social impact assessment (SIA) and social life cycle assessment (sLCA) was used (Diaz-Chavez, 2012). The following figure shows the overall methodology and where the tools and techniques can be applied in BIOCORE. From the steps shown in the Figure 36, social life cycle assessment (sLCA) shows a direct link with three of the techniques: identifying stakeholders, creating a baseline (inventory) using indicators and identifying the chain of impacts.

Les paramètres nécessaires sont manquants ou erronés.

Figure 36: Adapted social impact assessment to BIOCORE case studies
Source: modified from UNEP, 2009

For the analysis, a list of selected criteria was used for the case studies in Europe and in India as shown in Table 8. The Quality of life parameter is not considered as it would need reference data and a project that demonstrates actual improvement or worsening of the situation to be able to conduct any assessment.

<table>
<thead>
<tr>
<th>No</th>
<th>Parameter</th>
<th>Characteristics/Criteria</th>
<th>Level assessment of sustainable development</th>
<th>Stage of the supply chain</th>
<th>Type of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trade of feedstock</td>
<td>Incentives and barriers</td>
<td>EU/National</td>
<td>Feedstock</td>
<td>Qualitative</td>
</tr>
<tr>
<td>2</td>
<td>Identification of stakeholders along the supply chain</td>
<td>Producers (farmers)</td>
<td>Local</td>
<td>All</td>
<td>Qualitative, literature and interviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regulators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Policies and regulations</td>
<td>International</td>
<td>National and International</td>
<td>All</td>
<td>Qualitative (section 5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>National</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Potential biorefinery location Logistic</td>
<td>Availability of feedstock</td>
<td>National and local</td>
<td>Feedstock, Transport and storage, Biorefinery</td>
<td>Included in Reports of WP1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current use of residues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential for supply of feedstock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Land use tenure</td>
<td>Land ownership rights</td>
<td>National</td>
<td>Feedstock</td>
<td>Qualitative, literature</td>
</tr>
<tr>
<td>6</td>
<td>Community participation</td>
<td>Acceptance of community</td>
<td>Local</td>
<td>Feedstock,</td>
<td>Qualitative,</td>
</tr>
<tr>
<td>No</td>
<td>Parameter</td>
<td>Characteristics/Criteria</td>
<td>Level of assessment</td>
<td>Stage of the supply chain</td>
<td>Type of data</td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
<td>---------------------</td>
<td>------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>to:</td>
<td></td>
<td>Transport and storage, Biorefinery</td>
<td>interviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Residue of feedstock used for biorefinery</td>
<td></td>
<td></td>
<td>HSDB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Dedicated feedstock for biorefinery use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Biorefinery for construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indigenous communities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Quality of life</td>
<td>Improvement of quality of life</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improvement of livelihoods</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improvement of socio-economic conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Rural development and Infrastructure</td>
<td>Sanitation</td>
<td>National level</td>
<td>Feedstock, Transport and storage, Biorefinery</td>
<td>Qualitative, hotspot database</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Roads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Jobs creation and wages</td>
<td>Labour involved on residues collection or dedicated crops</td>
<td>National</td>
<td>Feedstock, Transport and storage, Biorefinery</td>
<td>Qualitative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jobs created for biorefinery</td>
<td>Local</td>
<td></td>
<td>Interviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jobs created for transportation</td>
<td>National</td>
<td></td>
<td>Hotspots database</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wages paid according to national/regional regulation (minimum wage)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Poverty reduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Gender equity</td>
<td>Inclusion of women</td>
<td>National</td>
<td>Feedstock, Transport and storage, Biorefinery</td>
<td>Hotspot database</td>
</tr>
<tr>
<td>11</td>
<td>Labour conditions</td>
<td>ILO conventions and human rights including:</td>
<td>National</td>
<td>Feedstock, Transport and storage, Biorefinery</td>
<td>Hotspot database</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Child labour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Right to organise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Indigenous rights</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Forced labour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Health and safety</td>
<td>Compliance with health and safety regulations at the different supply chains</td>
<td>National</td>
<td>Feedstock, Transport and storage, Biorefinery</td>
<td>Qualitative</td>
</tr>
<tr>
<td>13</td>
<td>Competition with other sectors</td>
<td>Competition of residues use for biorefinery and impact on other industries and sectors that affects negatively</td>
<td>Local</td>
<td>Feedstock, final products</td>
<td>Qualitative</td>
</tr>
</tbody>
</table>

Source: Author’s own compilation

In addition, an assessment on hotspots developed by the Hotspot Database (HSDB)\(^1\) was included according to the corresponding or similar sectors for a biorefinery included in the HSDB (e.g. agriculture, forestry, chemical industry, electricity).

System boundary
The sLCA is limited to stakeholders and impacts along the supply chain as per figure below. Other stages in other supply chains are not considered and some of the impacts can only be assessed at a national level. Stakeholders for each case study are considered at the local level.

Les paramètres nécessaires sont manquants ou erronés.

Figure 37: BIOCORE supply chain for sLCA and stakeholders
Source: Author’s own compilation

4.1.5 Questionnaires and Surveys

The survey questionnaire was prepared by converting the identified social sustainability issues into questions to arrive at qualitative and quantitative estimates of the sub-indicators to be analysed. For the detailed case study of India using the method of AHP, basic background information was collected in addition to asking the stakeholders who were being surveyed to provide an assessment of the degree of their responses to the questions listed, where the degree could be assessed on a scale as indicated under the possible responses to the questions. If the particular question was not of relevance to the stakeholder, the rank assigned to it was on a lower side of the scale (1-4). 5-8 stakeholders per category of stakeholders were interviewed as part of the survey. To make this AHP process work, it was important to guide the user to answer the AHP questions in an understandable and simple manner. The survey was conducted in a few randomly selected villages in the two study districts-Barnala/Sangrur and Faridkot of Punjab in India. A scoping visit was first undertaken in some the above villages followed by the final survey.

For the case studies in the EU (France, Hungary and Germany) semi-structured interviews were applied to local stakeholders in order to gather additional information on the social criteria selected.

4.2 Background of the study sites

Three European countries (France, Hungary and Germany) and India were selected as the study regions in the project. One study site, each from the three European countries and two study sites from India were further selected (see Figure 38 and Figure 39).
4.2.1 India

There are two study sites in India and this section presents the locational, geographical and socio-economic characteristics of these sites.
4.2.1.1 Location and geographical characteristics

Figure 40: Study sites in India

As already mentioned, the two selected districts of the Indian case study region are Sangrur-Barnala and Faridkot. Sangrur and Barnala are basically adjacent districts in Southern Punjab. The climate of the area is usually dry and is characterised by a short monsoon. On average, the region experiences 27 rainy days (i.e. days with rainfall of 2.5 mm or more) in a year. The available land in the Sangrur-Barnala region is about 500,000 hectares, while that in Faridkot is 150,000 hectares.

About 90 percent of the land in the study districts are under agriculture\(^2\). The total farm area in the district of Sangrur is 440,000 hectares while in Faridkot the area is 130,000 hectares. Paddy and wheat are common agricultural crops grown here. The area has huge straw potential. Currently, 2.5 million tons of straw are available (1.9 million tons from rice straw and 0.6 million tons from wheat straw) in this area.\(^3\)

The planned capacities for the biorefinery at the selected locations in Punjab have been decided as 500,000 tonnes/year and 150,000 tonnes/year with both the capacities to be modelled simultaneously for Sangrur including Barnala and the smaller capacity to be modelled for Faridkot.\(^4\) The Indian study region being part of a rice-wheat growing area, rice and wheat crop straw, which are abundant agro-residues, were chosen as the biomass feedstock. Currently, rice straw finds limited applications in industries and the unsold quantities are mostly burnt in the field\(^5\) thus posing a major threat to environment and human health. The rice straw finds its applications mostly for, (i) bedding purposes for

\(^2\) Biocore WP1 Final Report, Aug. 2012
\(^3\) Biocore WP1 Final Report, Aug. 2012
\(^4\) IBID
\(^5\) IBID
cattle; and (ii) pulp and paper mills. With regard to wheat, almost 40 percent of wheat straw is used as fodder\(^6\), while 25 percent are used by the pulp and paper industry. Only 10 percent of the wheat straw is burnt (Table 9).

Table 9: Current use of straw (rice and wheat) in the Indian case studies

<table>
<thead>
<tr>
<th></th>
<th>Rice straw</th>
<th>Wheat straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field burning</td>
<td>90%</td>
<td>10%</td>
</tr>
<tr>
<td>Fodder</td>
<td>&lt;10%</td>
<td>40%</td>
</tr>
<tr>
<td>Pulp and Paper industry</td>
<td>&lt;10%</td>
<td>25%</td>
</tr>
<tr>
<td>Others</td>
<td>&lt;10%</td>
<td>25%*</td>
</tr>
</tbody>
</table>

*others include storage for future requirement or export to neighbouring states.

4.2.1.2 Socioeconomic characteristics/issues

As per 2011 census, Sangrur had a population size of 1,654,408 while Barnala has 596,294 persons. Sex ratio is 883 in Sangrur which is slightly higher than 876 in Barnala. Male literacy rates for Sangrur and Barnala were 74.2 and 73.1 percent respectively while female literacy rates were 62.9 and 64.1 percent respectively. According to the 2001 census, Sangrur district had a total of 348,922 households with an average household size of 6 members. There were 697 villages in that district. All of these villages were electrified and had safe drinking water facilities. More than 680 villages were reported to have primary school while primary health centres were available in 214 villages.

Faridkot had a population of 618,008 with a female population 290,887 as per 2011 census. More than 60 percent of the population lived in rural areas. There were 889 females per 1000 males. Literacy rates for males and females were 75.9 and 64.8 percent, respectively. Census data from 2011 reveals that 163 villages in the district had access to safe drinking water and electricity. Primary schools were present in 160 villages, while primary health sub-centres were present in 61 villages.

Table 10 presents the comparative socio-economic statistics for the two selected regions in India.

<table>
<thead>
<tr>
<th></th>
<th>Sangrur/Barnala</th>
<th>Faridkot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>1,654,408 / 596,294</td>
<td>618,008</td>
</tr>
<tr>
<td>Female</td>
<td>7,757,80 / 278,446</td>
<td>290,887</td>
</tr>
</tbody>
</table>

\(^6\) IBID
<table>
<thead>
<tr>
<th>男性识字率</th>
<th>74.2 / 73.1</th>
<th>75.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>女性识字率</td>
<td>62.9 / 64.1</td>
<td>64.8</td>
</tr>
<tr>
<td>性别比例</td>
<td>883 / 876</td>
<td>889</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>年份</th>
<th>家庭数量</th>
<th>876,922</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>348,922</td>
<td>97,690</td>
</tr>
<tr>
<td></td>
<td>房屋</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>有安全饮用水的房屋</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>有电力的房屋</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>基本学校</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>基本医疗中心</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>邮政、电报和电话服务</td>
<td>133</td>
</tr>
<tr>
<td></td>
<td>发车服务</td>
<td>161</td>
</tr>
</tbody>
</table>

**注**：2011年人口普查数据适用于桑格鲁和巴纳拉，而2001年人口普查数据适用于桑格鲁（包括巴纳拉）

**来源**：2001年和2011年印度人口普查

4.2.2  **匈牙利**

4.2.2.1  **地理位置和地理特征**

匈牙利的研究区域包括四个县，即Baranya、Somogy、Tolna和Zala。Baranya、Somogy和Zala的平均海拔分别为44米、108米和144米。平均气温在Baranya通常在6.2-15.1摄氏度之间。平均降雨量在Baranya为619毫米，平均每年有大约98个降雨日（降雨量>0.1毫米）。大多数降雨发生在5月至8月。

![图41：匈牙利研究区域](http://www.weatherforecaster.eu/weather/pecs/hungary/buxx0018#clima)

Figure 41: Study area in Hungary

**来源**：Biocore WP1 Final Report, Aug. 2012

匈牙利的研究区域有多种农业生产，覆盖1600,000公顷的土地。其中大多数是可耕种土地，面积为1,000,000公顷。

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7 [http://www.weatherforecaster.eu/weather/pecs/hungary/buxx0018#clima](http://www.weatherforecaster.eu/weather/pecs/hungary/buxx0018#clima)
utilised agricultural area (UAA), out of which 610,000 ha is used for annual crops. The majority of the cultivators in the region are large farmers\(^8\).

Maize (UAA of 335,000 ha) is the most important annual crop followed by wheat (190,000 ha), barley (53,000 ha) and others\(^9\) (29,000 ha). The UAA of perennial crops and SRC are 40,000 ha and 3,500 ha, respectively. Apart from these, there are natural and temporary grasslands of 7,000 ha and 95,000 ha, respectively. The raw material to be procured from the Hungarian case study will be a mix of straw (both maize and wheat), hardwood and SRC (poplar) in 3:1:1 ratio.\(^{10}\) However, 20 percent of the straw generated in the region can be available for the proposed plant because of high biomass competition.

### 4.2.2.2 Socioeconomic characteristics/issues

Among the four selected counties, Somogy is least densely populated while Baranya is the most densely populated. As per 2001 census, 40 percent of the population are employed while the unemployed population is 10 percent.\(^{11}\) Table 11 presents some basic socioeconomic statistics for these counties.

<table>
<thead>
<tr>
<th>Table 11: Statistics on workforce in counties in Hungary (2001)</th>
<th>Zala</th>
<th>Baranya</th>
<th>Somogy</th>
<th>Tolna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>297,404</td>
<td>407,448</td>
<td>335,237</td>
<td>249,683</td>
</tr>
<tr>
<td>Active persons</td>
<td>127,731</td>
<td>155,085</td>
<td>128,267</td>
<td>98,451</td>
</tr>
<tr>
<td>Employed persons</td>
<td>117,614</td>
<td>136,390</td>
<td>112,498</td>
<td>87,908</td>
</tr>
<tr>
<td>Employees</td>
<td>100,236</td>
<td>115,560</td>
<td>94,680</td>
<td>73,197</td>
</tr>
<tr>
<td>Self-employed persons with employees (employers)</td>
<td>4,876</td>
<td>6,091</td>
<td>4,775</td>
<td>3,206</td>
</tr>
<tr>
<td>Unemployed persons</td>
<td>10,117</td>
<td>18,695</td>
<td>15,769</td>
<td>10,543</td>
</tr>
<tr>
<td>Inactive persons</td>
<td>169,673</td>
<td>252,363</td>
<td>206,970</td>
<td>151,232</td>
</tr>
</tbody>
</table>

Source: Eurostat 2013

### 4.2.3 France

#### 4.2.3.1 Location and geographical characteristics

The Beauce is the French study region located in central France. The Beauce region is surrounded by Maintenon in the North, Châteaudun in the West, Rleans in the South and Malesherbes in the East. The distance to Paris is about 100 km. It covers the area of four departments, viz., Loiret, Eure-et-Loir, Essonne and Yvelines. The Beauce is a vast plateau and part of the Paris Basin. Many rivers flow through the area. The Beauce is characterized by silt soils and flat area. It is a relatively dry region (average annual rainfall 550 mm). The average altitude is 140 meters.\(^{12}\) The average temperature varies between 7.5-15.5 degree

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\(^8\) Biocore WP1 Final Report, Aug. 2012  
\(^9\) Others include rye, triticale, oat  
\(^10\) Biocore WP1 Final Report, Aug. 2012  
\(^12\) Biocore WP1 Final Report, Aug. 2012
In the French study region, agriculture is practiced on 0.8 million hectares of land out of a total land area of 0.9 million. Among the agricultural land, 0.6 million hectares are used for annual crops. Cereals are the major crops in the Beauce region with an average yield of 10 tons per hectare. Some of the main crops grown in the area are: soft wheat (50%), rapeseed (15%), barley (15%) and maize (5%).

The local agricultural market is well developed. All farmers in the region receive CAP subsidies, but no price guarantee is available. Organic farming currently represents less than 3 percent of the UAA. The major competitive use of straw in the region is 66 percent of SOC maintenance and 10 percent of export to the nearby breeding region (for bedding or feeding). The remaining straw can be used as raw materials in the plant.

### 4.2.3.2 Socioeconomic characteristics/issues

As per population census 2009, Essonne is the most densely populated area while Eure-et-Loir is the least in the study region. While Loiret and Loir have a greater proportion of the population working in the agricultural sector compared to the industrial sector, Yvelines and Essonne have the least proportion of the population engaged in agricultural activities\(^\text{14}\). Table 12 presents the socio economic statistics.

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Table 12: Department-wise socio-economic statistics in France (2009)

\(^{13}\) [http://www.weatherforecaster.eu/weather/paris/france/frxx0076#clima](http://www.weatherforecaster.eu/weather/paris/france/frxx0076#clima)

\(^{14}\) INSEE database, National Institute of Statistics and Economic Studies – France
<table>
<thead>
<tr>
<th></th>
<th>Loiret</th>
<th>Yvelines</th>
<th>Loir</th>
<th>Essonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population</td>
<td>653,510</td>
<td>1,407,560</td>
<td>425,502</td>
<td>1,208,004</td>
</tr>
<tr>
<td>Population density</td>
<td>96.5</td>
<td>616.2</td>
<td>72.4</td>
<td>669.5</td>
</tr>
<tr>
<td>Number of households (HH)</td>
<td>278,099</td>
<td>548,804</td>
<td>174,630</td>
<td>467,035</td>
</tr>
<tr>
<td>Per HH average net income (euro)</td>
<td>23,645</td>
<td>34,171</td>
<td>23,460</td>
<td>28,033</td>
</tr>
<tr>
<td>Work participation rate (in %)</td>
<td>73.4</td>
<td>74.7</td>
<td>74.2</td>
<td>74.7</td>
</tr>
<tr>
<td>Unemployment rate (in %)</td>
<td>10</td>
<td>8.3</td>
<td>10.2</td>
<td>9</td>
</tr>
<tr>
<td>Share of agriculture in labor force (in %)</td>
<td>10.8</td>
<td>1.6</td>
<td>16.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Share of industry in labor force (in %)</td>
<td>6.1</td>
<td>4.3</td>
<td>6.7</td>
<td>4.7</td>
</tr>
<tr>
<td>Share of trade, transport &amp; other services in labor force (in %)</td>
<td>59</td>
<td>70</td>
<td>5.3</td>
<td>67.4</td>
</tr>
</tbody>
</table>

Source: INSEE database, National Institute of Statistics and Economic Studies – France

4.2.4 Germany

4.2.4.1 Location and geographical characteristics

![Map of Germany](http://www.nationsonline.org/oneworld/countries_germany.htm)

Figure 43: German study area

Source: [http://www.nationsonline.org/oneworld/countries_germany.htm](http://www.nationsonline.org/oneworld/countries_germany.htm)

The German study region comprises four federal states: North-Rhine-Westphalia (NW), Hessen (HE), Rhineland-Palatinate (RP) and Saarland (SL). The average temperature in the region is 9-10 degree celsius and annual average rainfall is about 800 mm. The region gets its maximum rainfall in June-August. The altitude varies from 45 to 322 m.
45 percent of the total land of 7.7 million hectares are under agriculture while 35 percent are covered with forest. The region has significant availability of hardwood with 64 percent being currently used for heating.

4.2.4.2 Socioeconomic characteristics/issues

As per recent data, Hessen (HE) is the most densely populated state while Rhineland-Palatinate (RP) is the least densely populated in the study area. While GDP is highest for NW, GDP per capita is highest for HE. On the other hand, GDP is lowest in SL but GDP per capita is lowest in RP. But, average household income is lowest for SL and highest for NW.

4.3 Legal and Policy Assessment – Results

This section presents the analysis of the legal and political framework that exists in the study sites and discusses the sustainability issues in the context.

4.3.1 Case of India

4.3.1.1 Matrix of policies, laws and guidelines in relation to biofuels value chain

The approach to biofuels adopted in India, in particular, is somewhat different to the current international approaches and to an extent avoids the conflict with food security. It is based solely on non-food feedstocks to be raised on degraded or wastelands that are not suited for agriculture, thus avoiding a possible conflict of fuel vs. food security (National Biofuel Policy of India). The Indian government’s energy policy tries to support renewable energy by providing incentives on a federal and state government level. One of the main objectives is the supply of energy and electricity to rural areas (International Business Publications, 2003). Table 13 shows an overview of biofuel policies in India.

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<table>
<thead>
<tr>
<th>Policy</th>
<th>Year</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Biodiesel Mission</td>
<td>2003</td>
<td>Announced in 2003. Replace 20% diesel consumption by 2012. Target of 13 million tonnes of diesel by 2013. Program divided into two phases. Phase-1: 2003-2007, 400000 ha (Rs 1500 crore investment; States were identified. Phase-2: Target reduced to 5%; however, the mission stagnated due to reasons like uncertainty in land tenure, food vs. fuel debate, global oil price vulnerability. Included several micro missions covering promotion of large-scale plantation of feedstock crops in forests and wastelands, procurement of seeds and oil extraction, blending, trade and R&amp;D.</td>
</tr>
<tr>
<td>Ethanol Blending Program</td>
<td>2002</td>
<td>Mandatory blending of 5% ethanol in 9 major sugar producing states and 4 UTs. Low procurement price (INR 14.9/l) + sub 75 p; revised policy increased it to around INR 23/L, whereas the costs were INR 30/l based on CACP cost guidelines. Scale up, in 2007 for mandatory usage all over India (10% blending for major sugarcane producing states and 5% blending for rest). Growing gap of demand and supply. Average target met 2%. Mentions use of second generation feedstocks like rice straw and grains for biofuel production in the long run within India. But expressed uncertainty.</td>
</tr>
<tr>
<td>National Biofuel Policy</td>
<td>2009</td>
<td>Announced in 2009, nodal ministry MNRE, co-ordination with other ministries, like MoRD, MoEF, MoP&amp;G, DBT, etc. 20% blending of biofuels by 2017. Promotion for cultivation, production and use of biofuels to increasingly substitute other application. Policy discussion around second generation feedstock like agri-residue (rice straw, wheat straw etc) for bioethanol generation along with non-edible seeds and molasses as feedstock for biodiesel and bioethanol production in the country. Formation of two committee to promote biofuel production and usage.</td>
</tr>
<tr>
<td>Integrated Energy Policy</td>
<td>2006</td>
<td>Blending to be done subject to commercial viability. It explores incentives for developing research on second generation biofuel feedstocks for bioethanol. Import tariff on ethanol, independent of use, at a level not greater than the price of petroleum products. Ethanol to be priced at its economic cost in relation to petrol but not higher than its import parity price.</td>
</tr>
</tbody>
</table>

Source: Author’s own compilation
4.3.1.2 Legal and political sustainability assessment across the value chain of biofuels

Biofuel policies play an important role in the development of the energy sector. The profitability of biofuel production is significantly influenced by policies affecting multiple sectors such as agriculture, research, industry and trade. Identifying relevant policies and quantifying their specific impacts is difficult given the variety of policy instruments (taxes, subsidies, price support, etc.) and the way they are applied (FAO 2008).

Given the fact that the production of biofuels is intensive in the use of land, state governments become important players in defining and implementing biofuels policies that can be implemented effectively. Different states have different policies in place to promote bio-based and renewable energy and implemented through state agencies like village level administrative units, forest departments, universities, research institutions, etc. Several states such as Chhattishgarh, Uttaranchal and Rajasthan have established nodal organizations and dedicated biofuels boards to coordinate work in this area. The Ministry of New and Renewable Energy (MNRE) is offering certain initiatives, however its policy framework is not exhaustive and most of the measures are peripheral, thereby reducing their impact. Targets set by these groups, such as the biofuel blending programme and renewable purchase mandates, are critical. Yet without enforcement or consistent support, they lose some of their impact.

The focus of biofuel programmes within India has been on non-edible feedstocks (like Jatropha, Pongamia seeds etc.) and on molasses produced as a by-product of sugarcane based processes of bioethanol production for its subsequent blending with gasoline or petrol. It is important to prioritize feedstock-targeted blending mandates that will give a boost to alternative feedstocks besides molasses and make them viable for biofuel production.

In various biofuel program announcements of India it has been highlighted that feedstocks have to be sourced from wastelands without creating any diversion of farm lands for food crops (Chauhan, 2008) to prevent adverse implications for food security. The legal and political regime for biofuels in India has been discursive and not linear with a multitude of contrasting views from different types of institutions and actors. Various agendas have emerged from the national and state level legal and political frameworks which have been translated into different types of actions in the biofuel sector for states of India, leading to both pro- and anti-biofuel views. The second generation based biofuel production concept is quite nascent in India. Only in certain policy declarations post 2008, there has been a mention of the need to develop second generation based biofuel production systems in the long run for India. In order to implement the production of these fuels on a large scale, certain key issues have to be resolved. The second generation biofuel products that are being considered for implementation in India are ethanol, biodiesel, lactic and acetic acid. India is faced with many challenges and gaps, particularly those associated with technology for each of these second generation products under different processes and techniques. Figure 44 summarizes these gaps and challenges.
Currently, the second generation biofuel sector in India is mainly at an R&D stage where R&D is being carried out by the Ministry of Science and Technology along with institutions like the Indian Institute of Technology, the Indian Institute of Science as well as with some private and public companies. A major part of the R&D is also focused on testing out the possibility of second generation biofuel production through feedstocks like algal production, hydrocarbon production, strain improvement, utilisation of spent biomass, and development of automated downstream processing along with the evaluation of open and closed cultivation systems. However significant hurdles in technology development still need to be overcome before second-generation biofuels can be produced at commercial scale, even with the massive investments in R&D observed in recent years. Though it can be seen that there is ample biomass resources in the form of agro-residues to support production of lignocellulosic biofuels, this potential is restricted by current uses of the residues as cattle fodder and applications in certain industries. Much work remains to improve second generation conversion pathways, reduce costs, and improve the performance and reliability of conversion processes (IEA, 2008b). Policies must be carefully crafted to avoid unwanted consequences and delayed commercialization. Demonstration projects need to be set up for biodiesel and bioethanol production, focusing on conversion technologies through Public Private Partnerships (PPP). Grants should be provided to academic institutions, research organizations, specialized centers and industry for promising R&D and demonstration projects.

India lacks mature technologies for second-generation biofuel production from lignocellulosic biomass, which is an abundant source of renewable energy that may be exploited in most parts of the country. Though biomass itself is cheap, the costs of its processing are relatively high. Technologies for biomass-to-biofuel conversion are also under various stages of development. The government should take positive steps towards promoting the use of ethanol and biodiesel as a fuel by providing tax exemptions at least in initial stages. The responsibility of the storage, distribution and marketing of biofuels in India has been with the Oil Marketing Companies (OMCs). India’s biofuel policy exempts
the biofuel sector from central taxes and duties. While biodiesel is exempt from excise duty, bioethanol enjoys a concessional excise duty of 16%. Customs and excise duty concessions are also provided on plant and machinery for the production of biodiesel and bioethanol. While these policies promote the biofuel sector, those promoting the production of feedstock need to be highlighted in order to fully realize the benefits provided on the processing front, since production and processing are interdependent. Though the policy mentions exemption of central taxes and duties on biofuels, sales tax, license fee, permit fee and import taxes still exist, hindering the growth and development of the industry. The policy provides no additional incentives for blenders and retailers of biofuel unlike in other countries.

Further, the design and implementation of environmental performance standards—including the prohibition of practices such as growing invasive species, removing excessive annual crop residue, providing incentive payments for avoided GHG payments, or retaining natural spaces as wildlife corridors—would bolster the sustainability of second-generation feedstocks.

There also has to be a higher focus by the government on carbon trading and renewable energy targets. Legislation and regulations that reflect the benefits of producing bio-products from renewable resources, including nationally consistent and implemented sustainability criteria and frameworks can play an important role.

Integrated biorefineries produce a range of products to optimise the use of the feedstock and improve process economics. There is a need to develop a market for the different bio-based products and improving properties of existing products to increase the competitive advantage of these products versus their petroleum-based reference products. Product design should focus on the properties of bio-based products, using natural formulations to achieve desired effects. In other words, the bio-based products should not only meet the desired usability and durability standards and characteristics of their counterpart produced from reference chemicals, but meet certain sustainability standards that would find larger penetration in the consumer market vis-à-vis non bio-based products. Market-driven research should aim at creating products that consumers want, and it is essential that bio-based products reach at least the same level of quality as their fossil based counterparts. Additionally, valuing biomass for bio-based products such as renewable chemicals and plastics could place pressure on existing uses of biomass e.g. pulp production or co-generation of energy in pulp mills.

Discussion with the stakeholders suggest that there is a lack of shared understanding of the benefits of bio-based products and their potential to reduce our dependence on imported oil and polymers and reducing greenhouse gas emissions. Here, the role of government through its public procurement that reflects and anticipates the development of bio-based products from renewable resources will play an important role.
4.3.1.3 Institutions (including government ministries and departments) involved in the bioenergy planning/applications

There have been many institutions/organizations that have got engaged in biofuel development and promotion in India. These institutions can be broadly grouped into 5 categories:

1. Private companies like Gujarat Oleochem, Haldia Petrochemicals, Indian Glycol Limited, Nandan Biomatrix Limited, Novozymes South Asia, Praj Industries, Tata Chemicals Limited, UOP Honeywell, Reliance Petrochemicals
2. Public Sector organisations like Indian Oil Corporation Limited, Bharat Petroleum Corporation Ltd. Hindustan Organic Chemicals Limited
4. Civil society organizations
5. Government Ministries/Departments

Although the Ministry of New and Renewable Energy (MNRE) is the nodal government ministry for policy formulation for the promotion of biofuels in India, there are several other ministries who are also associated with policy making, developing regulation, promotion and development of the biofuels sector, including introduction of various financial incentives.

Table 14 presents the list of these ministries as well as their responsibilities.

Table 14: Ministries involved in the development of biofuels in India

<table>
<thead>
<tr>
<th>Ministry in Government of India</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>New and Renewable Energy Sources</td>
<td>Policymaking and overall coordination concerning biofuels. Undertake Research and Development (R&amp;D) of various applications of biofuels</td>
</tr>
<tr>
<td>Ministry of Petroleum and Natural Gas (MoPNG)</td>
<td>Marketing biofuels as well as development and implementation of pricing and procurement policy</td>
</tr>
<tr>
<td>Agriculture</td>
<td>R&amp;D of biofuel feedstock through ICAR and IARI (sweet sorghum, jatropha, pongamia oil tree (Millettia pinnata), and inedible oilseeds). Undertake jatropha plantation on non-forest land.</td>
</tr>
<tr>
<td>Ministry of Road Transport and Highway</td>
<td>Plantation along highways and use of biofuel blended fuel. Work with automobile manufacturers” association in India for engine modification, emission norms, etc.</td>
</tr>
<tr>
<td>Ministry of Railways</td>
<td>Undertake plantation of jatropha on wastelands, along rail rights of way, and conduct trials of biodiesel blended fuel in locomotives</td>
</tr>
<tr>
<td>Ministry of Agriculture (MoA)</td>
<td>Research and development on feedstock crops.</td>
</tr>
<tr>
<td>Ministry of Rural Development (MoRD)</td>
<td>Plantation of jatropha on wastelands. Integrate biodiesel program with rural development schemes (such as Mahatma Gandhi National Rural Employment Guarantee Scheme).</td>
</tr>
<tr>
<td>Ministry in Government of India</td>
<td>Responsibility</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Ministry of Science and Technology (MoS&amp;T)</td>
<td>Coordinate R&amp;D with other agencies</td>
</tr>
<tr>
<td>Ministry of Environment and Forest (MoEF)</td>
<td>Biotechnological research on feedstock crops.</td>
</tr>
<tr>
<td>Ministry of Environment and Forest (MoEF)</td>
<td>Ensuring implementation of Tree-Brone Oilseeds (TBO) crop plantations in forest wastelands; and monitoring health and environmental effects of biofuels.</td>
</tr>
</tbody>
</table>


4.3.2 Case of Europe

4.3.2.1 Matrix of policies, laws and guidelines in relation to biofuels value chain

A key driver for the development and implementation of biorefineries is the growth in demand for energy, fuels, and chemicals. Accordingly, the aim of research is in developing new technologies and creating novel processes, products, and capabilities to ensure the growth is sustainable from economic, environmental and social perspectives (IEA, 2007).

In the context of the European Union, several policies, programmes and strategies have included the elements for Research and Development in the topic of biotechnology. These strategic and regulatory documents are presented in Figure 45.

![Figure 45: Overview of strategic and regulatory documents related to the biorefineries concept, research and implementation](image)

Source: Diaz-Chavez, 2012

The concept of biorefineries in the EU is expected to be developed based on the integration with existing industrial value chains (Star Colibri, 2012). It is also expected that the development of biorefineries will be driven by some sectors in the biobased economy including: agro-industry, forest based industry, the energy sector, biofuels industry and the chemical industry.
Therefore, different policy and regulatory policy instruments, along with the participation of stakeholders, help to develop the pathway in order to have a biobased economy in Europe. Some of these instruments more related to biorefineries activities are presented in the following Table 15, indicating their main characteristics.
Table 15: Policy and regulatory instruments related to biorefineries in Europe

<table>
<thead>
<tr>
<th>Type of instrument</th>
<th>Name</th>
<th>Date</th>
<th>Characteristics</th>
<th>Reference</th>
</tr>
</thead>
</table>
| **Strategy**       | **The Europe 2020 Strategy. Replaced the Lisbon Strategy-** | Until 2020 | The Europe 2020 strategy aims to create jobs, and encourage ‘green’ economic growth and create an inclusive society. The strategy's main targets include:  
- raise EU employment rate from 69% to 75%;  
- reduce school drop-out rates to less than 10%;  
- reduce the number of Europeans living in poverty by 25% (equivalent to 20 million people);  
- reduce greenhouse gas emissions by 20% compared to 1990 levels (or by 30% if the conditions are right);  
- 20% of total energy consumption to be from renewable energy and increasing energy efficiency by 20%;  
- 3% of the EU’s GDP to be invested in Research and Development. | http://www.bioeconomy.net/reports/files/KBBE_2020_BE_presidency.pdf |
| **Strategy**       | **Life Sciences and Biotechnology: a Strategy for Europe (2002) – Reviewed in 2007** | Updated to Lisbon Strategy 2020 | The strategy for Europe on life sciences and biotechnology (COM(2002)27) proposes a comprehensive roadmap up to 2010, bringing the sector to the forefront of the frontier technologies which will help the EU achieve the long-term jobs and growth targets established by the Lisbon European Council (March 2000). The "Bio4EU" study. This study (requested by the European Parliament within this) examined the economic, social and environmental consequences of biotechnology. It includes many concrete examples of biotechnology being used in health, food and the environment. | http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative/ |
| **Plan**           | **Eco-innovation Action Plan ETAP** | 2004 | Eco-innovation was developed to promote sustainable and inclusive growth. The new. The Eco-Innovation Action Plan (EcoAP) objective is to boost innovation that reduces pressure on the environment, and bridge the gap between innovation and the market through eco-friendly technologies are good for business and help create new jobs, so eco-innovation is crucial to the economic competitiveness of Europe. The EcoAP includes actions both on the demand and supply side, on research and industry and on policy and financial instruments. The Plan recognizes the key role of environmental regulation as a driver of eco-innovation and foresees a review of environmental legislation. The Plan also puts emphasis on the international aspect of eco-innovation, and on better coordination of policies with international partners. This is a plan for green jobs and green growth. | http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative/ |
| **Initiative**     | **Lead Market Initiative** | 2007, evaluated 2011 | The Lead Market Initiative is the European policy for 6 important sectors that are supported by actions to lower barriers to bring new products or services onto the market. The European Commission, Member States and industry work together to carry out the action plans for the 6 Lead Markets. The policy instruments deal with regulation, public procurement, standardisation and supporting activities. The LMI identified the following markets: eHealth, Protective textiles, Sustainable construction, Recycling, Bio-based | http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative/ |
| Initiative (Package) | Climate and Environment Package | From 2007 | The climate and energy package is a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy targets for 2020. These targets, known as the “20-20-20” targets, set three key objectives for 2020:  
- A 20% reduction in EU greenhouse gas emissions from 1990 levels;  
- Raising the share of EU energy consumption produced from renewable resources to 20%;  
- A 20% improvement in the EU’s energy efficiency | http://ec.europa.eu/energy/policies/package/index_en.htm |
| Plan | Strategic Energy Technology Plan | 2007 | The SET-Plan establishes an energy technology policy for Europe. It’s a strategic plan to accelerate the development and deployment of cost-effective low carbon technologies. The plan comprises measures relating to planning, implementation, resources and international cooperation in the field of energy technology. SETIS is the European Commission’s Information System for the SET-Plan led by the Joint Research Centre. It supports the strategic planning and implementation of the SET-Plan. It makes the case for technology options and priorities, monitors and reviews progress regarding implementation, assesses the impact on policy, and identifies corrective measures if needed. | http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm |
| | Renewable Energy Directive (2009) | | The Directive 2009/28/EC on renewable energy, implemented by Member States by December 2010, sets ambitious targets for all Member States, such that the EU will reach a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy specifically in the transport sector. It also improves the legal framework for promoting renewable electricity, requires national action plans that establish pathways for the development of renewable energy sources including bioenergy, creates cooperation mechanisms to help achieve the targets cost effectively and establishes the sustainability criteria for biofuels. The two main objectives of EU energy policy are increasing security of energy supply and reducing greenhouse gas emissions. | http://ec.europa.eu/energy/renewables/targets_en.htm |
| Policy | Common Agricultural Policy | | The common agricultural policy – ensures adequate European food production goes hand in hand with economically viable rural communities and action on environmental challenges such as climate change, water management, bioenergy and biodiversity. Today, the CAP still has a pivotal role in the European Union, not just because farmland and forests account for more than 90% of land within the EU, but also because it has become an essential mechanism for facing new challenges in terms of food quality, environmental protection and trade. The 2003 reform was a key moment in the CAP’s development, adapting the policy to meet the new requirements of farmers, consumers and the planet. This approach continues to form the basis of the future development of the common agricultural policy of an enlarged Union present on the world stage. When consulted about their views on such reforms in 2010, Europeans said they wanted EU farm policy to help farmers not just to produce food, but also to preserve natural resources and landscapes, improve animal welfare and keep rural communities viable. The EU has published a set of reform proposals that reflect these demands, with an emphasis on sustainable farming practices, innovation, research and the spread of knowledge – as well as | http://europa.eu/pol/agr/index_en.htm |
a fairer support system for European. Furthermore, the Common Agricultural Policy helps agriculture and forestry to provide biomass for energy and encourages the use of bioenergy in rural areas.

| Policy               | Rural Development policy | 2007-2013 | With over 56% of the population in the 27 Member States of the European Union (EU) living in rural areas, which cover 91% of the territory, rural development is a vitally important policy area. Farming and forestry remain crucial for land use and the management of natural resources in the EU’s rural areas, and as a platform for economic diversification in rural communities. The strengthening of EU rural development policy is, therefore, an overall EU priority. More generally, average income per head is lower in rural regions than in towns and cities, while the skills base is narrower and the service sector is less developed. Also, caring for the rural environment often carries a financial cost. The European countryside has a great deal to offer. It provides essential raw materials. The three main objectives of the policy are:
|                    |                          |           | • improving the competitiveness of the agricultural and forestry sector;
|                    |                          |           | • improving the environment and the countryside;
|                    |                          |           | • improving the quality of life in rural areas and encouraging diversification of the rural economy. |

| Fund                | European Agricultural Fund for Rural Development (EAFRD) | LFA since 1975 | Developed to support rural development by the “Aid to farmers in Less Favoured Areas” (LFA) which provides a mechanism for maintaining the countryside in areas where agricultural production or activity is more difficult because of natural handicaps. Five areas are characterised as LFA: Mountain Areas\(^\text{16}\); Intermediate Less Favoured Areas (those in danger of abandonment)\(^\text{17}\); Areas affected by specific handicapped\(^\text{18}\).

| Strategy            | EU strategy for biofuels | 2006 | Developed to support research and innovation to improve production processes and to lower costs. Focus on research and development via the Seventh Framework Programme for Research and Development, the full use of second generation biomass and biofuels (i.e. originating from the processing of ligno-cellulosic feedstock such as straw and forest residues). The development of industry-led European technology platforms such as the European Biofuels Technology Platform, should make it possible to establish a shared European vision and strategy for the production and use of biofuels.

| Regulation          | REACH | 2007 | Registration, Evaluation, Authorisation & restriction of Chemicals
REACH is a European Union regulation concerning the Registration, Evaluation, Authorisation and restriction of Chemicals. The system has several aims: to provide a high level of protection of human health and the environment from the use of chemicals; to make the people who place chemicals on the market (manufacturers and importers) responsible for understanding and managing the risks associated with their use.; to allow the free

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\(^\text{16}\) Areas affected by a short growing season because of a high altitude, or by steep slopes at a lower altitude, or by a combination of the two.

\(^\text{17}\) Areas with land of poor productivity; production which results from low productivity of the natural environment; and a low or dwindling population predominantly dependent on agricultural activity

\(^\text{18}\) Areas that need to conserve or improve the environment; maintain the countryside; preserve the tourist potential of the areas; protect the coastline.
movement of substances on the EU market; to enhance innovation in and the competitiveness of the EU chemicals industry; to promote the use of alternative methods for the assessment of the hazardous properties of substances e.g. quantitative structure-activity relationships (QSAR) and read across.

<table>
<thead>
<tr>
<th>Regulator</th>
<th>European Chemicals Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Although ECHA is not a policy instrument, it is the driving force among regulatory authorities in implementing the EU’s groundbreaking chemicals legislation for the benefit of human health and the environment as well as for innovation and competitiveness. ECHA helps companies to comply with the legislation, advances the safe use of chemicals, provides information on chemicals and addresses chemicals of concern.</td>
<td><a href="http://echa.europa.eu/home">http://echa.europa.eu/home</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Directive</th>
<th>Fuel Quality directive</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Directive establishes the limits on the content of ethanol, ether and other oxygenates in petrol. A standard EN590 is developed which determines the quality of ethanol and biofuels. For biodiesel, an amendment in the standard EN 14214 is being discussed to facilitate the use of a large variety of vegetable oils and non edible oils which are feasible without having no ill effects on the performance and sustainability standards of biofuel like biodiesel.</td>
<td></td>
</tr>
</tbody>
</table>
According to a report produced for the EC to review the progress since 2008 up to 2012 on the use of biomass for transport, energy and heat and cold (Hamelink et al. 2012), the majority of Member States (MS) had a Renewable Energy Sources (RES) - including biomass - growth rate in 2009/2010 above the average annual growth rate required to achieve the 2020 minimum trajectory target. The report also stressed that MS are therefore on track if they keep this up. Still, a large number of MS need to speed up RES developments in order to fulfil their 2020 minimum trajectory target.

4.3.2.2 Legal and political sustainability assessment across the value chain of biofuels

In addition to the policy instruments and regulations directly directed at the biofuel sector (including economic incentives), some sustainability criteria specifically driven for biofuel production and use is set in the Renewable Energy Directive (RED) in terms of sustainability. These are set in Article 17 of the Policy. The RED (EC, 2009) includes environmental criteria for biofuels and reporting obligations for the Commission on the impact on social aspects in the Community and in third countries for increased demand for biofuels (Article 17). These requirements are set in Box 1.

Box 1. RED (2009) Article 17 on sustainability criteria for biofuels and bioliquids

Paragraph (7). “The Commission shall, every two years, report to the European Parliament and the Council, in respect of both third countries and Member States that are a significant source of biofuels or of raw material for biofuels consumed within the Community, on national measures taken to respect the sustainability criteria set out in paragraphs 2 to 5 and for soil, water and air protection. The first report shall be submitted in 2012.

The Commission shall, every two years, report to the European Parliament and the Council on the impact on social sustainability in the Community and in third countries of increased demand for biofuel, on the impact of Community biofuel policy on the availability of foodstuffs at affordable prices, in particular for people living in developing countries, and wider development issues. Reports shall address the respect of land-use rights. They shall state, both for third countries and Member States that are a significant source of raw material for biofuel consumed within the Community, whether the country has ratified and implemented each of the following Conventions of the International Labour Organisation:

- Convention concerning Forced or Compulsory Labour (No 29)
- Convention concerning Freedom of Association and Protection of the Right to Organise (No 87)
- Convention concerning the Application of the Principles of the Right to Organise and to Bargain Collectively (No 98)
- Convention concerning Equal Remuneration of Men and Women Workers for Work of Equal Value (No 100)
- Convention concerning the Abolition of Forced Labour (No 105)
- Convention concerning Discrimination in Respect of Employment and Occupation (No 111)
- Convention concerning Minimum Age for Admission to Employment (No 138)
- Convention concerning the Prohibition and Immediate Action for the Elimination of the Worst Forms of Child Labour (No 182).

Those reports shall state, both for third countries and Member States that are a significant source of raw material for biofuel consumed within the Community, whether the country has ratified and implemented:

- the Cartagena Protocol on Biosafety

The first report shall be submitted in 2012. The Commission shall, if appropriate, propose corrective action, in particular if evidence shows that biofuel production has a significant impact on food prices.”
In October 2012, the EC published a proposal for an amended RED (COM2012 595, 2012): “The aim of the current proposal is to start the transition to biofuels that deliver substantial greenhouse gas savings when also estimated indirect land-use change emissions are reported. While existing investments should be protected, the aims of the current proposal are to:

- limit the contribution that conventional biofuels (with a risk of ILUC emissions) make towards attainment of the targets in the Renewable Energy Directive,
- improve the greenhouse gas performance of biofuel production processes (reducing associated emissions) by raising the greenhouse gas saving threshold for new installations subject to protecting installations already in operation on 1st July 2014,
- encourage a greater market penetration of advanced (low-ILUC) biofuels by allowing such fuels to contribute more to the targets in the Renewable Energy Directive than conventional biofuels,
- improve the reporting of greenhouse gas emissions by obliging Member States and fuel suppliers to report the estimated indirect land-use change emissions of biofuels.”

The proposal also aims at protecting existing investments until 2020. The proposal does not take a position on the actual need for financial support to biofuels before 2020. However, the Commission is of the view that in the period after 2020 biofuels which do not lead to substantial greenhouse gas savings (when emissions from indirect land-use change are included) and are produced from crops used for food and feed should not be subsidised” (COM2012 595, 2012).

The use of biofuels produced from “food crops, such as those based on cereals and other starch rich crops, sugars and oil crops” to meet the 10% renewable energy target of the RED shall be limited to 5%, according to the proposal. Specific issues related to socio-economic topics are not included.

Furthermore, the communication looks to “prepare for the transition towards advanced biofuels and minimise the overall indirect land use change impacts in the period to 2020” (COM 2012, page 8). Box 2 presents the proposal regarding the amendment of Article 18 on sustainability.

Box 2. COM 2012 on the change to Article 18 (4), second sub-paragraph (COM, 2012).

"The Commission may decide that voluntary national or international schemes setting standards for the production of biomass products contain accurate data for the purposes of Article 17(2) or demonstrate that consignments of biofuel or bioliquid comply with the sustainability criteria set out in Article 17(3) to (5). The Commission may decide that those schemes contain accurate data for the purposes of information on measures taken for the conservation of areas that provide, in critical situations, basic ecosystem services (such as watershed protection and erosion control), for soil, water and air protection, the restoration of degraded land, the avoidance of excessive water consumption in areas where water is scarce and on the issues referred to in the second subparagraph of Article 17(7). The Commission may also recognise areas for the protection of rare, threatened or endangered ecosystems or species recognised by international agreements or included in lists drawn up by intergovernmental organisations or the International Union for the Conservation of Nature for the purposes of Article 17 (3 )(b) (ii)."
Additional EU Policies and Directives related to biomass

The EU Directives on Air, Water and Biodiversity also apply in Europe for the case of bioenergy. Each MS has to comply with the Directives through different regulations or Acts at Country level. In February 2010 the European Commission adopted a report on requirements for a sustainability scheme for solid and gaseous biomass used for generating electricity, heating and cooling (COM(2010)11). In this report no binding criteria were suggested on a European level; nevertheless, the Commission formulated recommendations to Member States that do develop sustainability schemes, mainly for imports. It was expected that these biomass types respect compliance with the rules laid down in the Renewable Energy Directive (for liquid biofuels), to ensure greater consistency and to avoid unwarranted discrimination in the use of raw materials.

Some Member States have already introduced rules (some voluntary, some obligatory) to avoid potential undesirable environmental consequences of the use of biomass. Nevertheless, a report for the EC (Biobench, 2013) reviewed that different national legislations with (possibly) incompatible criteria are developed. This report reviewed all issues on sustainability for all MS for the use of solid biomass for energy generation. The summary of the topics covered is shown in Figure 46.

Figure 46: Number of rules and regulations per sustainability topic related to biomass in EU Member States
Source: Biobench, 2013.

It can be observed from Figure 46 that 51 environmental rules and regulations exist in the EU related to biomass and sustainability, and 14 related to economic issues including subsidies and avoidance of competition. Nevertheless, there is no regulation related to social issues. Annex V presents a more detailed review of the policies and regulations for the three cases of BIOCORE in the EU and the international conventions that are applicable to all case studies.
4.3.2.3 Institutions (including government ministries and departments) involved in the bioenergy planning/applications

At the EU level, different institutions are involved according to the different policies and regulations as shown in previous sections. These include Directorate Generals (DG) on Energy, Agriculture, Environment, Regional Development, Industry, Research, Trade, Transport (EU, 2005).

At the national level, other stakeholders are involved including the private sector, the government, academic institutions, social organisations (NGOs) and the general public. These may also vary at the national, regional and local level.

The stakeholders’ analysis was included in the BIOCORE reports of case studies within WP1. The particular stakeholders for the socio-economic assessment considered for the three case studies are presented in this report.

The local stakeholders identified in the Beauce region included the agricultural sector, industry, government and NGOs (Vernhes, 2012).

Table 16: French local stakeholders

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Stakeholder Sector</th>
<th>Stage of the supply chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonneval cooperative</td>
<td>Agriculture (cooperative)</td>
<td>Feedstock</td>
</tr>
<tr>
<td>FDSEA 28</td>
<td>Agriculture (union)</td>
<td>Feedstock</td>
</tr>
<tr>
<td>Confederation paysanne</td>
<td>Agriculture (union)</td>
<td>Feedstock</td>
</tr>
<tr>
<td>Valbiom cluster/ Chamber of Agriculture / Chamber of Industry and Trade</td>
<td>Biomass valorisation</td>
<td>Feedstock, Transport and storage</td>
</tr>
<tr>
<td>Agrodynamique / Axereal</td>
<td>Biomass valorisation</td>
<td>Feedstock, Transport and storage</td>
</tr>
<tr>
<td>Cosmetic Valley</td>
<td>Industry</td>
<td>Biorefinery</td>
</tr>
<tr>
<td>CIMV</td>
<td>Industry</td>
<td>Biorefinery</td>
</tr>
<tr>
<td>Former Chamber of Agriculture (Centre) / Sofiproteol</td>
<td>Industry</td>
<td>Feedstock</td>
</tr>
<tr>
<td>Eure et Loir department</td>
<td>Government</td>
<td>All</td>
</tr>
<tr>
<td>DDT 28</td>
<td>Government</td>
<td>All</td>
</tr>
<tr>
<td>Green Party (EELV) 28</td>
<td>Government</td>
<td>All</td>
</tr>
<tr>
<td>Eau Secours 28</td>
<td>Government (water)</td>
<td>Feedstock and biorefinery</td>
</tr>
<tr>
<td>WWF France</td>
<td>NGO</td>
<td>Feedstock</td>
</tr>
<tr>
<td>Biocore / Inra</td>
<td>Government/Research</td>
<td>All</td>
</tr>
</tbody>
</table>

Source: Author’s own compilation

For the Hungarian case study the mapping of stakeholders is shown in Figure 47. Additionally, 151 stakeholders from the four categories were interviewed for gathering additional data.
Les paramètres nécessaires sont manquants ou erronés.

<table>
<thead>
<tr>
<th>National authorities, regulations:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• NFM (Ministry of National Development)</td>
</tr>
<tr>
<td>• VM (Ministry of Rural Development)</td>
</tr>
<tr>
<td>• NIFU (National Development Agency)</td>
</tr>
<tr>
<td>• MHE (Hungarian Energy Office)</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Regional/Local authorities, regulations:</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>• NPU – regional operational programs and managing authorities</td>
</tr>
</tbody>
</table>

**Figure 47:** Stakeholders for the Hungarian case study.
Source: Author’s own compilation

Notes: Pannon Egyetem – University of Pannonia; KRF – Károly Róbert College; PTE – University of Pécs; DE – University of Debrecen; SZTE – University of Szeged

For the case study in Germany it was possible to make a more detailed analysis of the stakeholders in the same four categories where direct links, indirect and needed links were identified according to the methodology by Diaz-Chavez (2010).

**Figure 48:** Stakeholders for the German case study.
Source: Author’s own compilation
4.4 Social Sustainability Assessment – Results

4.4.1 Results of social ‘sustainability assessment’ based on Multi-Criteria Analysis approach (using AHP) – Case of India

As noted in the methodology section of this report, AHP is a methodology used to formulate and analyse decisions. The AHP divides the problem or questions in the research into elements, according to their common characteristics that can then be divided into levels. The advantage of the AHP tool is that it considers both quantitative and qualitative factors to handle different groups of actors. It allows users to assess the relative weight of multiple criteria or multiple options against given criteria in an intuitive manner. In case that quantitative ratings are not available, policy makers or assessors can still recognize whether one criterion is more important than another.

The AHP tool has been used as one of the tools for the social sustainability assessment in this study. While assessing sustainability of BIOCORE, a list of both qualitative and quantitative indicators across various domains (Annex II) was identified to address sustainability of a biorefinery. These indicators were then used to design the AHP questionnaire which facilitated a dialogue with the selected stakeholders and helped collect their perceptions in the context of assessing social sustainability of bio-refineries in the State of Punjab in India. Although there is a potential for a biorefinery setup based on biomass in an area where there are high levels of agricultural production, a social sustainability assessment has not yet been conducted for this potential biorefinery set up. The absence of such an assessment could hinder industries and organizations to set up such an infrastructure fearing different kinds of sustainability risks and concerns. The risks, or barriers involved, which are also highlighted by the study (by the way of showing the indicators with the lowest scores), would be useful in understanding what we have currently and what needs to be done in the near future. Assigning a score to different sustainability indicators helps in understanding the problems and addressing them before such an infrastructure is put in place, showing forward thinking about the sustainability aspects and helping address the factors that could hinder sustainability.

The two study sites in the State of Punjab in India were the districts of Sangrur (including parts of adjoining district of Barnala) and Faridkot. Sangrur (and its adjacent district, Barnala) are located in Southern Punjab while Faridkot is located in South-Western Punjab. The surveyed farmers belonged to the villages - Bhogpur/Jalandhar, Attari/ASR, Handiaya, Thaula, Faguala, Manavindi, Dhaula Pind, Burjamasta Pind, Ryunwalla Pind in the two districts. Both these areas produce wheat and rice crops.

The first step of the AHP analysis for the study was to define the goal. The goal was defined as “To check which indicator supports best, the feasibility\(^\text{19}\) for Biocore to be set up (according to the different stakeholders).” Once the goal was defined, the alternatives, which in simple terms meant the sustainability indicators and the different stakeholders (or the term child in the software), were defined. These broad sustainability indicators for the study, in line with the broad domains of the study, were selected as:

\(^{19}\) Here, the term feasibility is being used to show support for the sustainability of a biorefinery
1. Production and availability of feedstock
2. Employment
3. Health, environment and food security
4. Rural development
5. Research and Development
6. Other issues related to political, legal and economic barriers

The stakeholders who were consulted and perceptions captured were the following:

1. Farmer
2. Policy Maker
3. Transporter / Aggregator
4. Panchayat Member
5. Competing Industry

It must be noted that all stakeholders were not affected by each identified potential sustainability indicator and therefore, a tree was created to state the goal, stakeholders and the sustainability indicators relevant for the different stakeholders, as seen in the Figure 49. The figure shows how the goal, the stakeholders (or the term child used in the software) and the sustainability indicators (or the term alternatives used in the software) are linked.

Figure 49: Analytical Hierarchy Process Tree
Source: Authors own framework used in AHP

It is important to also note here that different sub-indicators were further defined under these broad indicators to study the sustainability issues in detail. The primary survey then attempted to capture responses through questions on the identified sub-indicators from each stakeholder group (Figure 50).

---

20 A village council
Some of the specific issues looked at for the social sustainability assessment under the broad indicators were the following:

1. **Production and availability of feedstock** included the availability of biomass for use in a biorefinery, willingness to shift cropping patterns to rice and wheat, the role of Panchayat in deciding the cropping patterns, etc.,

2. **Employment** included current limitations in employment opportunity, openness in exploring and taking non-agricultural activities (particularly industrial employment), working conditions in competing industries, willingness to work in a biorefinery, strength of labour unions, child labour issues, etc.,

3. **Health, environment and food security** included health impacts due to working conditions in competing industries, food security impacts during to the presence of a biorefinery, environment, water and land related stress in the area related to industrial activity, etc.,

4. **Rural Development** included improvement in physical infrastructure due to industrialization, 

5. **Research and Development** included the extent to which investment in research and development has occurred in clean/bio energy and the need for such investments, 

6. **Other issues** included current political and administrative barriers in setting up a biorefinery, creation of new economic opportunities for locals, etc.
Stakeholders’ response to the above issues was collected based on a questionnaire survey. Data were collected from various stakeholders corresponding to the hierarchical structure, on a scoring scale using the questionnaire. A score of one meant that the indicator sustainably supports biorefinery while a score of zero meant the indicator does not sustainably support biorefinery. The responses of the stakeholders were converted into suitable numbers and were finally used in the Expert Choice Software in order to arrive at a combined score.

4.4.1.1 Result and analysis with respect to goal

The sustainability indicators were evaluated (the term synthesised was used by the software) with respect to the goal of looking at how the selected indicators sustainably supported biorefinery. Figure 51 shows how the different indicators sustainably support Biocore. Here, the analysis states that if a biorefinery is set up in the selected region, there will be enough production and availability of feedstock to run the biorefinery. However, interactions from the field survey revealed that there are some concerns associated with the collection, drying logistics and storing of the straws, and they need proper management if the agro-residues can be utilized in the long run. Farmers will also need to be convinced about the advantages of collecting and selling their straw. Selling rice straw could provide new income possibilities to the farmers and reduce the levels of harmful air pollution and damages to soil flora and fauna.

Results also reveal that there would not be any constraint with regard to human capital. Further issues like (child) labour related conflicts would pose limited challenges. One of the main socio-economic benefits that came out during the interaction with the stakeholders is the improvement in local employment due to future presence of a biorefinery in the state. There is a lot of disguised unemployment in the state, and the stakeholders felt that with adequate industry specific training, the currently unemployed can find significant employment potential along biomass conversion processes. This can also be supported from the report by the World Economic Forum on ‘The Future of Industrial Biorefineries’, that points out at the creation of job opportunities, particularly in rural areas where incomes and economic prospects are currently moderate. However, it is important to mention that certain case studies have found that biorefinery operations may have the potential to generate significant long-run increases in employment but at the same time short-term displacement effects may take place in the labour market. Thus, though the availability of labour to work in the biorefinery does not come across as a problem as there is surplus labour available in the region and that is looking for alternative employment opportunities, however they will require skill training before they can work in the biorefineries on the biomass conversion processes.

One of the indicators that has been identified to pose a concern to sustainability aspects is that of lack of adequate ‘research and development’. This calls for the need to increase the level of R&D activities to support the setting up of the biorefinery given that the current R&D is insufficient. ‘Rural development,’ is another indicator of concern in the context of support for the sustainability of a biorefinery where the present infrastructure, even with industrialization is not sufficient to support the sustainability of a biorefinery and there may
be a need to invest in infrastructure development. Currently, for the second generation biofuel sector in India, R&D is being carried out by the Ministry of Science and Technology along with institutions like the Indian Institute of Technology, the Indian Institute of Science and some private and public companies. A major part of the R&D is also focused on testing out the possibility of second generation biofuel production through feedstocks like algae by means of growth, hydrocarbon production, strain improvement, utilisation of spent biomass, and development of automated downstream processing along with the evaluation of open and closed cultivation systems. Despite increased interest in expanding second-generation biofuels and progress made in recent years, significant hurdles in technology development still need to be overcome before second-generation biofuels can be produced at commercial scale, even with the massive investments in R&D observed in recent years.

Rural development and infrastructure are important factors determining the sustainability of bio-refineries in the selected sites of Punjab. Since the straw needs to be collected from the various land holdings growing rice or wheat, the logistics of transporting the large volumes of straw required for efficient energy generation, represent a major cost factor irrespective of the bioenergy technology. This can then pose a constraint in the success of biorefineries and lead to increased burning of the residue. The region is faced with rampant open-field burning of rice residues. The main reason for this is the short time gap (about 10-15 days) that is available to the farmers between the harvesting of rice and sowing of wheat. Further, the region grows the coarse variety of rice which increases the likelihood of farmers harvesting rice using the combine-harvester, which in turn scatters the residue and therefore makes the burning of biomass almost certain. Infrastructure support for storage and continuous supply of feedstock to the biorefineries lacks in the region. Thus to ensure enhanced reliability of biomass supply as feedstock to the biorefinery in and out of season at both a local and regional scale will require development of appropriate logistics infrastructure.

Figure 51: Synthesis with respect to Goal
Source: Authors own calculations

4.4.1.2 Result and analysis with respect to stakeholders

Farmers

The farmers were selected from both of the study regions, Sangrur (including Barnala district) and Faridkot of Punjab. When the sustainability indicator was evaluated based on
the response received from farmers, ‘Health, environment and food security’ also emerged as a supportive indicator for the sustainability of a biorefinery. This shows that the adverse health impacts due to existing industrial activities has been low, the food security issues may not arise with the presence of a biorefinery as it will be based on biomass, and significant environment related issues are not expected to emerge with the setting up of the biorefinery.

‘Rural development’ is considered a barrier and may not support the sustainability of a biorefinery setup according to the farmers. This implies that the current infrastructure, even with industrialization, has not provided support for the sustainability of a biorefinery to be set up. ‘Research and development’ and ‘other issues’ have been given a score of zero (.000) because questions were not asked to the farmers on these sustainability indicators (Figure 52).

| Synthesis with respect to: Farmer |  
|----------------------------------|---|
| Overall Inconsistency = .00     |   |
| Production and availability of feedstock | 1.000 |
| Health, environment and food security | .983 |
| Employment | .601 |
| Rural development | .599 |
| Research and Development | .000 |
| Other Issues | .000 |

Figure 52: Synthesis with respect to farmer
Source: Author’s own calculations based on the survey data collected

**Policy makers**

Policy makers were a mix of both central and state (Punjab) government officials who were from various government departments and ministries. The sample of stakeholders surveyed included representatives from the State Council for Science and Technology, Department of Agriculture, Punjab Government and the Ministry of Rural Development. Most of these policy makers were highly educated, with some even holding a doctorate in their respective fields of study.

Policy makers show similar results as the evaluation with respect to the goal. From the perspective of the policy makers, ‘production and availability of feedstock’ followed by ‘employment,’ provides the highest support for the sustainability of a biorefinery to be set up. ‘Research and development’ is seen as a barrier for sustainability of a biorefinery (Figure 53).

| Synthesis with respect to: Policy maker |  
|----------------------------------------|---|
| Overall Inconsistency = .00 |   |
| Production and availability of feedstock | 1.000 |
| Employment | .765 |
| Other issues | .682 |
| Health, environment and food security | .577 |
| Rural development | .497 |
| Research and Development | .382 |

Figure 53: Synthesis with respect to policy maker
Source: Author’s own calculations based on the survey data collected
Transporter/Aggregator

Transporters and aggregators whose businesses were around the study sites of Faridkot and Sangrur (including Barnala) were surveyed. Their responses were relatively different from what other stakeholders felt. ‘Production and availability of feedstock’ was the most supportive indicators for the sustainability of a biorefinery to be set up. ‘Other issues’, which include political, legal and economic barriers, was also considered highly supportive for the sustainability of a biorefinery to be set up. Therefore, according to the transporters/aggregators, there were none or very little political, legal and economic barriers in setting up a biorefinery, and in fact, they would support the setting up of a biorefinery. ‘Health, environment and food security’ according to the transporters and aggregators, was a possible barrier for a biorefinery (Figure 54).

Figure 54: Synthesis with respect to transporter/aggregator
Source: Authors own calculations, based on the survey data collected

Panchayat members

The panchayat members or members of the village council were also surveyed from the area. The panchayat members, who are the most decentralised governing bodies at the local level have a very strong idea (apart from the farmers themselves) of the local system not just because they belong to the lowest level of governance, but also because they are also directly involved in agriculture and other local livelihood activities.

According to the panchayat members, presence of adequate human resources would sustainably support biorefineries. However, rural development, according to the panchayat members, can pose a major challenge toward BIOCORE sustainability (Figure 55).

Figure 55: Synthesis with respect to Panchayat member
Source: Authors own calculations, based on the survey data collected

Competing Industry

Competing industry included stakeholders from two different industries:

1. Paper industry which uses the straw of wheat and rice for paper production
2. Local agricultural industries which used straw of wheat and rice for captive power generation
The competing industry felt that ‘production and availability of feedstock’ and availability of adequate human resources with limited political influence would sustainably support BIOCORE. However, rural development, according to them, can pose a major challenge toward BIOCORE sustainability (Figure 56).

<table>
<thead>
<tr>
<th>Synthesis with respect to Competing Industry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Inconsistency = .00</td>
<td></td>
</tr>
<tr>
<td>Production and availability of feedstock</td>
<td>1.000</td>
</tr>
<tr>
<td>Employment</td>
<td>1.000</td>
</tr>
<tr>
<td>Health, environment and food security</td>
<td>.926</td>
</tr>
<tr>
<td>Other issues</td>
<td>.532</td>
</tr>
<tr>
<td>Research and Development</td>
<td>.476</td>
</tr>
<tr>
<td>Rural development</td>
<td>.156</td>
</tr>
</tbody>
</table>

Figure 56: Synthesis with respect to competing industry
Source: Author’s own calculations, based on the survey data collected

4.4.2 Results of social ‘sustainability assessment’ based on a combined approach of Social Impact Assessment (SIA) and Social Life Cycle Assessment (SLCA)

4.4.2.1 Case of Europe

The assessment was done on the criteria selected as indicated in section 4.1.4. Some of the indicators provide background for the assessment (1-6; 13-14) and were assessed with an SIA methodology. The parameters (8-12) assessed with the hotspot database used a scale for the risk from low, medium, high and very high. These parameters were included in the Hotspot index according to the methodology from Benoit et al. (2010). As the assessment includes more than 50 characterized social issues for 20 Social Themes, the amount of data is difficult to assess for decision-making. For this reason, Benoit et al. (2012) recommend to calculate a Social Hotspot Index for each CSS and identify hotspots in the supply chain. The authors constructed the Index by weighting the level of risk identified for each Social Issue. A zero was assigned to social issues with low risk, a 1 was assigned to those that are medium, a 2 to those with high risk, and a 3 for those with very high risk. Summing across all social issues resulted in a total number of weighted hotspot issues to be aware of when working in that country and sector. Thus, social issues are not compared against each other. All issues are weighted equally in the sum and all are considered a risk or negative impact. Positive impacts are not assessed with the Social Hotspot Index.

The summary of the assessment of the case studies is presented in Table 17. The full detailed case studies are presented in Annex V.
Table 17: Summary of social sustainability criteria for the EU case studies.

<table>
<thead>
<tr>
<th>No</th>
<th>Parameter/criteria</th>
<th>France</th>
<th>Germany</th>
<th>Hungary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trade of feedstock</td>
<td>The incentives reported for the National Case in France, are specific for biofuels production. The incentives refer to tax exemptions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Identification of stakeholders along the supply chain</td>
<td>Stakeholders have been identified in section 4.3.2.3</td>
<td>Stakeholders have been identified in section 4.3.2.3</td>
<td>Stakeholders have been identified in section 4.3.2.3</td>
</tr>
<tr>
<td>3</td>
<td>Policies and regulations</td>
<td>Have been identified in section 4.3.2.1</td>
<td>Biomass Action Plan und Deutsches Ressourceneffizienzprogramm (German Resource Efficiency Programme) Lignocellulose Biorefinery (including the Green Biorefinery)</td>
<td>The Hotspot database for the case of Hungary identified as medium level the Indicators and Risk for Potential of Country not passing Labor Laws. Seven Laws related to the sector were identified (although the HSDB does not indicate which ones). For the indicator of “overall legal fragility” of the HSDB, Hungary ranked medium.</td>
</tr>
<tr>
<td>4</td>
<td>Potential biorefinery location Logistic</td>
<td>This criteria was assessed in WP1 for all case studies</td>
<td>This criteria was assessed in WP1 for all case studies</td>
<td>This criteria was assessed in WP1 for all case studies</td>
</tr>
<tr>
<td>5</td>
<td>Land use tenure</td>
<td>Is not a problem in the EU. Between 2000 and 2010, the number of large farms increased by 10% to reach and the average Agricultural Unit (UAA) per exploitation went from 89ha to 105ha meaning that more land is concentrated in fewer hands</td>
<td>Is not a problem in the EU.</td>
<td>Is not a problem in the EU.</td>
</tr>
<tr>
<td>6</td>
<td>Community participation</td>
<td>Interviews in the Beauce regions and concluded that all stakeholders seemed to agree on the fact that the most challenging issue would be the timing: pressing, collecting, transporting and storing such a large amount of straw in such a limited period of time</td>
<td>Results of the interviews in Germany stated that willingness to participate if jobs and prices are competitive.</td>
<td>Results of the interviews in Hungary stated a division on the willingness to sell that farmers, forest owners would sell if the prices are competitive and contracts are clear and for long term.</td>
</tr>
<tr>
<td>7</td>
<td>Quality of life</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>No</td>
<td>Parameter/criteria</td>
<td>France</td>
<td>Germany</td>
<td>Hungary</td>
</tr>
<tr>
<td>----</td>
<td>---------------------</td>
<td>--------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>8</td>
<td>Rural development and Infrastructure HSDB themes: 1. Access to improved drinking water 2. Access to improved sanitation 3. Access to hospital beds</td>
<td>In the case of France for the three criteria selected in the sLCA Hotspot database, the risks are categorized as <strong>Low</strong>.</td>
<td>In the case of Germany for the three criteria selected in the sLCA Hotspot database, the risks are categorized as <strong>Low</strong>.</td>
<td>In the case of Hungary for the three criteria selected in the sLCA Hotspot database, the risks are categorized as <strong>Low</strong>. Transport is an issue in the case study as it is a remote area and road transport is not efficient.</td>
</tr>
<tr>
<td>9</td>
<td>Jobs creation and wages HSDB has three criteria in two themes: ● Potential of minimum wage not being updated ● Wage Assessment</td>
<td>Straw pressing and transport is the main issue. Interviews reported that Agricultural Units may be created. Range of job creation was between 155 to 230 along the supply chain. T HSDB has three criteria in two themes of the Labor rights and decent jobs category). The three criteria have been assessed as <strong>Low risk</strong>.</td>
<td>Interviews results highlighted the creation of jobs in the region if a biorefinery is set up. Regarding wages, the hotspot database has three criteria in two themes of the Labor rights and decent jobs category) The three criteria have been assessed as <strong>Low risk</strong>.</td>
<td>Interviews highlighted jobs creation and the need for high skilled positions in a limited number. Range of jobs creation were from 250 to 2000 (including indirect jobs) The three criteria in the HSDB have been assessed as <strong>Low risk</strong>.</td>
</tr>
<tr>
<td>10</td>
<td>Gender equity HSDB: Overall fragility of Gender equity</td>
<td>The HSDB for the criteria of overall fragility of Gender equity France was assessed as <strong>Low risk</strong>.</td>
<td>For Overall fragility of Gender equity Germany was ranked as <strong>Low risk</strong>.</td>
<td>For Overall fragility of Gender equity Hungary was ranked as <strong>Low risk</strong>.</td>
</tr>
<tr>
<td>11</td>
<td>Labour conditions ● Child Labor ● Forced labor ● Excessive working time ● Freedom of Association ● Collective bargaining rights ● Right to strike</td>
<td>In the HSDB child labor it was reported as no evidence. Out of nine issues assessed four were assessed as Low and five as Medium. It has to be noted that the assessment is done for various sectors, therefore it would be difficult to specify if these issues are related to the agriculture sector.</td>
<td>Most of the indicators in the HSDB were assessed as low risk whilenot having the right to strike was assessed as high</td>
<td>For the five indicators of the HSDB only risk of not having bargaining rights was assessed as high while risk of forced labour and risk of not having freedom of association were assessed as medium. The rest of the indicators were assessed as low.</td>
</tr>
<tr>
<td>12</td>
<td>Health and safety</td>
<td>The implementation of a Safety and Health measures is considered to be according to the EU legislation and National Laws. Additional, it is expected that large industries such as a biorefinery will develop</td>
<td>The implementation of a Safety and Health measures is considered to be according to the EU legislation and National Laws. Additional it is expected that large industries such as a biorefinery will develop a Quality</td>
<td>The implementation of a Safety and Health measures is considered to be according to the EU legislation and National Laws. Additional it is expected that large industries such as a biorefinery will develop a Quality</td>
</tr>
<tr>
<td>No</td>
<td>Parameter/criteria</td>
<td>France</td>
<td>Germany</td>
<td>Hungary</td>
</tr>
<tr>
<td>----</td>
<td>-------------------</td>
<td>--------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td>a Quality Management System and a Health Policies designed to protect people and installations.</td>
<td>Management System and a Health Policies designed to protect people and installations</td>
<td>Management System and a Health Policies designed to protect people and installations</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Competition with other sectors</td>
<td>Competition with other sectors in farming (e.g., bedding for animals), have not yet been investigated. The competition of other chemical producers in the region or at National level, have also not been investigated.</td>
<td>Interviews stated that there will be competition to the current uses. Yes, competition with firewood</td>
<td>Interviews stated that there will be competition for the feedstock. Industry has more possibilities to pay higher prices. There is already a large biomass plant for ethanol production that will be competing for the agricultural residues.</td>
</tr>
</tbody>
</table>

Source: Author's own calculations

**Summary of HSDB France**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential of Minimum Wage not being satisfied</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential of Country not passing Labor Laws</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential of Average wage being Minimum Wage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of Population working with livestock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having Freedom of Association Rights</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having Collective Bargaining Rights</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having right to strike</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having access to improved drinking water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having access to improved sanitation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having access to a hospital bed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Summary of HSDB Germany**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential of Minimum Wage not being satisfied</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential of Country not passing Labor Laws</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential of Average wage being Minimum Wage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of Population working with livestock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having Freedom of Association Rights</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having Collective Bargaining Rights</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having right to strike</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having access to improved drinking water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having access to improved sanitation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having access to a hospital bed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Summary of HSDB Hungary**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential of Minimum Wage not being satisfied</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential of Country not passing Labor Laws</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential of Average wage being Minimum Wage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of Population working with livestock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having Freedom of Association Rights</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having Collective Bargaining Rights</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having right to strike</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having access to improved drinking water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having access to improved sanitation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having access to a hospital bed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author's own compilation based on the HSDB

Note: Green = Low, Yellow = Medium, Orange = High, Blank = No evidence/not applicable
4.4.2.2 Case of India

The summary of the assessment of the India case study is presented in Table 18. The full detailed case studies are presented in Annex V.

Table 18: Summary of social sustainability assessment for the case study of India

<table>
<thead>
<tr>
<th>No</th>
<th>Parameter/criteria</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trade of feedstock</td>
<td>Targets and incentives have been discussed in the Policy Section. With regard to barriers in trade in feedstock, the multi-criterion assessment revealed limited impact on the parameter. Interaction with stakeholders also revealed that there are limited barriers with regard to trade/supply or distribution of final products in the market.</td>
</tr>
<tr>
<td>2</td>
<td>Identification of stakeholders along the supply chain</td>
<td>The stakeholder categories along the supply chain considered for the social assessment are presented in section 4.1.2</td>
</tr>
<tr>
<td>3</td>
<td>Policies and regulations</td>
<td>The HSDB indicator on Risk for Overall fragility of Legal System was ranked as medium. HSDB indicator on Risk of country no passing Laws to protect Indigenous population which was ranked medium.</td>
</tr>
<tr>
<td>4</td>
<td>Potential biorefinery location Logistic</td>
<td>This was described in WP1. In the context of the social sustainability assessment is not assessed as the other indicators provide the assessment</td>
</tr>
<tr>
<td>5</td>
<td>Land use tenure</td>
<td>Although the particular case study of India did not report conflicts under land use and land use tenure, the Land Portal (2013) through the Land Matrix Database (2013) reported some cases of land grabbing in India. These case studies were mainly for setting plants for the industrial sector. The portal did not provide additional information about the companies. Nevertheless, the information is updated until 2012 and some of the land grabbings consider a significant amount of land where land rights were not respected. This assessment is presented in full in the annex.</td>
</tr>
<tr>
<td>6</td>
<td>Community participation</td>
<td>The HSDB assessed the number of indigenous population as a percentage of the total and per sector. In this case, India ranked high and for this reason it was included within community participation. However it is important to note that, Schedule Tribes are present in all Indian states and Union Territories (UTs) except in the States/UTs of Haryana, Punjab, Delhi, Pondicherry and Chandigarh. No tribe has been notified as ST in Punjab, according to the Constitution (Scheduled Tribes) order, 1950 as amended by the Scheduled Tribes Orders (amendment) Act, 1976. So at the proposed bio-refinery location, this parameter may not be of the Indian average of high risk.</td>
</tr>
<tr>
<td>7</td>
<td>Quality of life</td>
<td>NA</td>
</tr>
<tr>
<td>8</td>
<td>Rural development and Infrastructure</td>
<td>In the case of India for the three criteria selected in the Hotspot database, the risks are categorized as Medium, High and Very High.</td>
</tr>
<tr>
<td></td>
<td>HSDB themes:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Access to improved drinking water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Access to improved sanitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. Access to hospital beds</td>
<td></td>
</tr>
</tbody>
</table>

[http://censusindia.gov.in/Tables_Published/A-Series/A-Series_links/t_00_005.aspx](http://censusindia.gov.in/Tables_Published/A-Series/A-Series_links/t_00_005.aspx)
<table>
<thead>
<tr>
<th>No</th>
<th>Parameter/criteria</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Jobs creation and wages</td>
<td>The three criteria have been assessed as <strong>Low risk</strong>.</td>
</tr>
<tr>
<td></td>
<td>HSDB has three criteria in two themes:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Potential of minimum wage not being updated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Wage Assessment</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Gender equity</td>
<td>For this indicator, India was ranked as <strong>Very High risk</strong>.</td>
</tr>
<tr>
<td></td>
<td>HSDB: Overall fragility of Gender equity</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Labour conditions</td>
<td>All the criteria were ranked as high in the HSDB except for freedom of</td>
</tr>
<tr>
<td></td>
<td>- Child Labor</td>
<td>association rights that was ranked as medium.</td>
</tr>
<tr>
<td></td>
<td>- Forced labor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Excessive working time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Freedom of Association</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Collective bargaining rights</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Right to strike</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Health and safety</td>
<td>This category is not assessed in the hotspot database</td>
</tr>
<tr>
<td></td>
<td>India has implemented laws, which regulate the measures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the companies have to take to reinforce occupational</td>
<td></td>
</tr>
<tr>
<td></td>
<td>health and safety</td>
<td></td>
</tr>
<tr>
<td></td>
<td>measures. Especially, the Factories Act, 1948, the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mines Act, the Ports Act and the Construction Act refer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>to safety of employees working in the respective</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sectors. For other employees, for example such as those</td>
<td></td>
</tr>
<tr>
<td></td>
<td>employed in shops or establishments, various state</td>
<td></td>
</tr>
<tr>
<td></td>
<td>legislations are enacted, which provide for almost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>similar matters as under the Factories Act[2]. Though</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the consultations with the stakeholders have indicated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>good compliance with these laws and regulations, but</td>
<td></td>
</tr>
<tr>
<td></td>
<td>literature has reported high number of accidents in the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>country in the past, despite there being comprehensive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>legislation.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Competition with other sectors</td>
<td>Stakeholders consider there is competition for the residue with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cattle feed (in case of wheat straw) and some industries,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>particularly the paper and pulp industry, however, the supply</td>
</tr>
<tr>
<td></td>
<td></td>
<td>potential is high which can be tapped by offering a reasonable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>price to the farmers in Punjab. So this factor could be considered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>as a relatively low risk.</td>
</tr>
</tbody>
</table>

Source: Author’s own compilation

---

[2] Labour Laws
Figure 58: Summary of Hotspot Database (HSDB) results for India

Source: Author’s own compilation based on the HSDB

Note: Green = Low, Yellow = Medium, Orange = High, Blank = No evidence/not applicable

4.4.3 Overall assessment

As part of the methodology proposed within the BIOCORE project, a combination of social LCA and social impact assessment is used to assess the case studies in other issues. The socio-economic assessment also considered the assessment of parameters and criteria previously selected and which information has already been stated in the previous sections.

The criteria have been assessed as possible negative and positive impacts and, if negative, how can they be mitigated or which precautions need to be considered. This assessment does not include a complete social assessment, which requires a well-documented project proposal and would need to comply with the national regulations. Nevertheless, it should be noted that a proper Environmental and Social Impact Assessment is recommended to comply with good practice.

The impacts have been classified firstly by type: direct, if the project is producing the impact, or background, if the local conditions are influencing the implementation of the project; as positive, if it is likely to produce a benefit and negative, if on the contrary, they are likely to produce an impact that will not be of social benefit to the country or the local community; neutral if it is considered it will not have effects in any form. If negative, a comment on possible forms to mitigate, reduce or avoid the impact is added. Finally, a risk value is provided as low, medium or high according to the data provided. This risk value indicates the likeliness to present a problem in the future even if the impact was assessed as positive.

The assessments are presented in the following for the three cases in the EU (Table 19) and the case of India (Table 20) for the overall sustainability assessment for biorefineries. Additional information is provided in Annex 7.4.

Cumulative and indirect impacts have not been considered due to the lack of information of the local conditions. This assessment can be considered as a general one to be conducted for biorefineries.
Table 19: Social impact assessment summary for the cases in Europe. (After Diaz-Chavez, 2013).

<table>
<thead>
<tr>
<th>NO</th>
<th>Parameter</th>
<th>Characteristics/Criteria</th>
<th>Type</th>
<th>Impact</th>
<th>Risk</th>
<th>Benefit</th>
<th>Mitigation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Production of feedstock</td>
<td>Incentives</td>
<td>B</td>
<td>+</td>
<td></td>
<td>H</td>
<td></td>
<td>In the EU several incentives are already in place.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Barrier</td>
<td>B</td>
<td></td>
<td>-</td>
<td>H</td>
<td></td>
<td>Look for market opportunities and avoid Financing Insecurity for large investments.</td>
</tr>
<tr>
<td>2</td>
<td>Identification of Stakeholders along the supply chain</td>
<td>Producers (farmers) Regulators Business Traders Research</td>
<td>B</td>
<td></td>
<td>+</td>
<td>H</td>
<td></td>
<td>Identification at local level and the promotion of unions, cooperatives or associations that may help develop the market and the industry at local level.</td>
</tr>
<tr>
<td>3</td>
<td>Policies and regulations</td>
<td>National</td>
<td>B</td>
<td></td>
<td>+</td>
<td>H</td>
<td></td>
<td>A Policy framework is in place in the EU plus National and local policies, programmes and regulations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enforcement</td>
<td>B</td>
<td></td>
<td>-</td>
<td>L</td>
<td></td>
<td>In general for the EU there is no problem with enforcement although the HSDB presented some problems in the Hungarian case.</td>
</tr>
<tr>
<td>5</td>
<td>Land use tenure</td>
<td>Land ownership rights</td>
<td>B</td>
<td></td>
<td></td>
<td>N</td>
<td></td>
<td>This is not a problem in the EU. Land abandonment has been reported as a problem but not in the sense of ownership.</td>
</tr>
<tr>
<td>6</td>
<td>Community participation</td>
<td>Community participation</td>
<td>D</td>
<td></td>
<td>+</td>
<td>H</td>
<td></td>
<td>Community participation in a defined business model and community is necessary as well as consultation with farmers and local stakeholders.</td>
</tr>
<tr>
<td>8</td>
<td>Rural development and Infrastructure</td>
<td>Roads</td>
<td>B</td>
<td></td>
<td>-</td>
<td>L</td>
<td></td>
<td>In general in the EU there is not a problem with infrastructure. Although stakeholders in Hungary reported that roads are not good for transport of feedstock in the suggested region for a biorefinery plant. As a mitigation measure alternative routes, site or storage sites.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water (availability and quality) for the local population</td>
<td>D</td>
<td></td>
<td></td>
<td>N</td>
<td></td>
<td>For the case studies selected in the EU this is not considered to be a problem.</td>
</tr>
<tr>
<td>#</td>
<td>Category</td>
<td>Description</td>
<td>Type of Impact</td>
<td>Risk/Benefits</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>----------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------------</td>
<td>---------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Job creation and wages</td>
<td>Labour involved on feedstock production</td>
<td>D + &amp; -</td>
<td>L H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>It can be a risk for the producers (farms and forestry) to sign contracts for long periods. A third party could be involved to guarantee the investment.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labour involved in production</td>
<td>D +</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Although some jobs may be created, the number will be limited as the biorefinery does not require a large number of employees.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wages paid according to national/regional regulation (minimum wage)</td>
<td>D N</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>This is not highly relevant in the EU.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rural development</td>
<td>D +</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>This could be a better option in abandoned land reported in the EU. In general it is seen as important by stakeholders in the three case studies selected.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Gender equity</td>
<td>Inclusion of women</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Labour conditions</td>
<td>ILO conventions including - Child labour - Right to organise - Indigenous rights - Forced labour</td>
<td>D + &amp; -</td>
<td>L H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ILO conventions have been signed therefore are incorporated within the National Laws.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Health and safety</td>
<td>Compliance with health and safety regulations at the different supply chains</td>
<td>D L M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low negative impacts are considered as few reports exist about this mainly in rural areas. In the industry sector this is regulated.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>There are regulations in place in the EU.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>13</td>
<td>Competition with other sectors</td>
<td>Competition of residues use for biorefinery and impact on other industries and sectors that affect negatively</td>
<td>D + &amp; -</td>
<td>M M</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>This could have a medium negative impact in some regions where competition with the raw material is foreseen or already exist. This was mentioned by stakeholders in the three case studies. Link with the local government and the incentives is necessary to address to minimise completion among sectors.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Type of impact: D direct; B background; Impact + positive; - negative; N neutral
Risk/Benefits: L low; M, Medium; H high; VH very high
Table 20: Social sustainability assessment for the case study of India (Diaz-Chavez, 2013).

<table>
<thead>
<tr>
<th>NO</th>
<th>Parameter</th>
<th>Characteristics/Criteria</th>
<th>Type</th>
<th>Impact</th>
<th>Risk</th>
<th>Benefit</th>
<th>Mitigation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Production of feedstock</td>
<td>Incentives</td>
<td>B</td>
<td>+</td>
<td></td>
<td>M</td>
<td>There are not clear incentives in place that show current benefits for investment in biorefineries activities.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barriers</td>
<td></td>
<td>B</td>
<td>-</td>
<td>L</td>
<td></td>
<td>Local issues related to the collection of the residues</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Identification of stakeholders along the supply chain</td>
<td>Producers (farmers) Regulators Business Traders Research</td>
<td>B</td>
<td>+</td>
<td></td>
<td>H</td>
<td>Identification at local level of stakeholders might help to further develop the market and the industry at local level.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Policies and regulations</td>
<td>National</td>
<td>B</td>
<td>+</td>
<td></td>
<td>M</td>
<td>A Policy framework is in place. Application and enforcement seem to have some issues on transparency.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enforcement</td>
<td></td>
<td>B</td>
<td>-</td>
<td>H</td>
<td></td>
<td>Potential high risk of overall legal fragility system.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>International conventions and agreements</td>
<td></td>
<td>B</td>
<td></td>
<td></td>
<td>H</td>
<td>Law enforcement</td>
<td>Mainly ILO conventions and indicators related to Human rights are a high risk in I (e.g. gender, indigenous population). There is not much data at the local level and per sector.</td>
</tr>
<tr>
<td>5</td>
<td>Land use tenure</td>
<td>Land ownership rights</td>
<td>D</td>
<td>-</td>
<td></td>
<td>M</td>
<td>Transparency on land deals.</td>
<td>Land deals are not an issue for the biorefinery project as it focuses mainly on residues. It would only apply to the land where the facility will be installed.</td>
</tr>
<tr>
<td>6</td>
<td>Community participation</td>
<td>Community participation</td>
<td>B</td>
<td>+ &amp; -</td>
<td></td>
<td>H</td>
<td>Law enforcement and plans to integrate indigenous population</td>
<td>At local level does not seem to be a problem area (see AHP). Nevertheless, at national level there are other indicators that were considered of high risk such as the Number of indigenous population and the no passing ILO conventions on indigenous people.</td>
</tr>
<tr>
<td>8</td>
<td>Rural development and Infrastructure</td>
<td>Road</td>
<td>D</td>
<td>+</td>
<td>L</td>
<td>M</td>
<td>This indicator was not fully analysed although the AHP reviewed the transport of the feedstock and it does</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Water (availability and quality) for the local population</td>
<td>D</td>
<td>-</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanitation infrastructure</td>
<td>D</td>
<td>-</td>
<td>VH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of not having bed at hospital</td>
<td>D</td>
<td>-</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour involved on feedstock gathering</td>
<td>D</td>
<td>+ &amp; -</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour involved in oil production</td>
<td>D</td>
<td>+</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wages paid according to national/regional regulation (minimum wage)</td>
<td>D</td>
<td>+</td>
<td>L</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poverty reduction</td>
<td>D</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender equity</td>
<td>D</td>
<td>H</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- Total drinking water has been assessed as medium rank and therefore any activity at local level needs to consider this indicator.
- Sanitation infrastructure was assessed as very high risk at National level and also within the sectors. This needs to be considered if setting a facility at local level.
- This indicator was assessed and ranked as high at national level. Further review will be needed to assess it at the local level for any future investment.
- In general it is expected that job creation will be involved at different stages of the supply chain. A program to gain skills would need to be in place to benefit the farmers.
- Although some jobs may be created, the number will be limited as an oil mill does not require large number of employees. Skills may be transferred to improve the local conditions.
- For those jobs created the National Laws on minimum wages will need to be applied. The HSDB assessment did not consider this a problem as was ranked as Low. There might be differences per sectors involved in the biorefinery activities.
- Not enough data is available to properly assess poverty reduction possibilities in the region.
- Inclusion of women in the decision-making process at local level.
11  Labour conditions  |  ILO conventions including  
- Child labour  
- Right to organise  
- Indigenous rights  
- Forced labour  |  B  |  + & -  |  H  |  H  |  Main ILO conventions have been signed but there is little information on the enforcement.  
ILO conventions have been signed therefore are incorporated within the National Laws.

12  Health and safety  |  Compliance with health and safety regulations at the different supply chains  |  D  |  |  |  The overall risk of the legal system fragility needs to be considered to enforce the regulations related to health and safety.

13  Competition with other sectors  |  Competition of residues use for biorefinery and impact on other industries and sectors that affects negatively  |  D  |  +  |  M  |  Some competition was reported in the AHD for the use of residues of wheat but not for the rice residues. Therefore there are opportunities.

Source: Author’s own analysis
Type of impact: D direct; B background
Impact + positive; - negative; N neutral
Risk/Benefits: L low; M, Medium; H high; VH very high
4.5 Discussion of results, conclusions and outlook

4.5.1 Legal and policy assessment

At the EU level different Institutions are involved according to the different Policies and regulations show in previous sections (see Figure 5.1). These include Directorate Generals (DG) on: Energy, Agriculture, Environment, Regional Development, Industry, Research, Trade, Transport (EU, 2005).

At National level other stakeholders are involved including the private sector, the government, academic institutions, social organisations (NGOs) and the general public. These may also vary at the National, Regional and Local level.

In the EU there is a considerable number of policy and regulatory instruments in place, at EU and National level related to the activities of biorefineries. Although the Renewable Energy Directive does not consider social criteria in the same regulatory form as environmental criteria, it is still suggested to consider other aspects beyond job creation, e.g. rural development, health and safety, gender issues. As per environmental aspects the suggested “RED2” on solid biomass should be regulated at EU level as there is not a sustainability framework for lignocellulosic feedstock.

A review of voluntary standards, especially for the forestry sector is in place in the EU. Nevertheless, further standards related to the final bio-based products should be considered. For instance, the C content. A new EU standard is under development. The CEN TC411 for lignocellulosic feedstock.

Stakeholders reported a need to create a policy safe environment to support investment. Some policy changes are viewed as a problem by some stakeholders.

4.5.2 Social sustainability assessment

Social sustainability assessment is one of the four pillars in the sustainability framework applied in this project (see Diaz-Chavez, 2006 and methodology section). Social sustainability assessment is generally overseen in supply chain analysis due to the nature of the data required.

The methodology applied for the social sustainability (Diaz-Chavez, 2012a; 2012b) is an innovative combined methodology using the social Life Cycle Assessment tool hotspot database and social impact assessment. The combination of the methodologies allows for better assessment that covers both the national and local level. Despite that, the HSDB considers that the weighting of indicators is done at a national level. It should be noted that the HSDB has been improved and a new portal is on use that is different to the original portal that was used for this assessment. Therefore, an update will be required. Additionally, a combination of qualitative and quantitative data enabled a more robust assessment.
4.5.2.1 Multi-Criteria Analysis (Case of India)

From the Analytical Hierarchy Process, it may be concluded that according to all stakeholders, ‘production and availability of feedstock’ provides the most support for a biorefinery to be set up. This means that there will be enough production and availability of feedstock, the willingness to shift cropping patterns and no interference from the village council on cropping patterns for a biorefinery to be set up. ‘Employment’ is another supportive indicator for the sustainability of a biorefinery. This shows that there would be enough employment generated (in terms of willingness to work as well as openness to working in non-agricultural activities) if a biorefinery is set up along with low levels of child labour, etc. On the other hand, ‘research and development’ may cause barriers for a biorefinery to be set up, i.e. not much investment has been made in the research and development area in clean/bioenergy. ‘Rural development’ is another sustainability indicator of concern which may hinder a possible biorefinery setup, i.e. there has not been much improvement in rural development in the area even with the current levels of industrialization.

For a biorefinery to be set up, although there may be enough production and availability of feedstock and employment would be generated for the biorefinery setup, research and rural development are causes of concern. A biorefinery may need to invest in these two aspects for it to be sustainable. Alternatively, research and rural development could be a spillover of a biorefinery setup. With improved technologies and increasing employment, a biorefinery setup may be able to contribute to an improved research and development and the overall growth and development of the area.

4.5.2.2 Social sustainability assessment using SIA and sLCA

Social sustainability assessment is one of the four pillars in the sustainability framework applied in this project (see Diaz-Chavez, 2006 and the methodology section 4.1.1.1). Social sustainability assessment is generally overseen in supply chain analysis due to the nature of data required. The methodology applied for the social sustainability (Diaz-Chavez, 2012a; 2012b) is an innovative combined methodology using the social Life Cycle Assessment tool, hotspot database and social impact assessment. The combination of the methodologies allows for better assessment that covers the national and the local level. Despite that the HSDB considers sectors (see Annex V) the weighting of indicators is done at a national level. It should be noted that when the HSDB has been improved after the finalisation of this assessment. Therefore, a future update of the sectors assessment is recommended. Additionally, a combination of qualitative and quantitative data enabled a more robust assessment.

In general terms, the social sustainability assessment seems to be positive for the case studies and it is possible to mitigate or prevent some of the potential negative impacts. The local conditions are those that need to be better considered for the establishment of a biorefinery. The BIOCORE assessment offered a review of the overall benefits regarding job creation and rural development as the potential positive social aspects that a biorefinery can bring. Although the number of jobs was suggested by stakeholders in a range of 50 – 500 (depending on the area) rural development is foreseen as a major positive impact in the EU
expanding some services just as transport and storage of the feedstock as well as the pre-
treatment. Some of the main issues to consider on the negative side are the possible
competition with other sectors and the willigness to sell the feedstock to a biorefinery. These
issues will need to be further considered in a case-specific assessment if a biorefinery should
be implemented.

As final recommendations, the following are suggested:

- For the establishment of a biorefinery, a proper feasibility study along with social and
  environmental impact assessment will be required, one that takes into account the
  whole supply chain.
- Local considerations need to be addressed, and for this reason, the mapping of
  stakeholders is essential, alongside canvassing their opinion through focus groups or
  interviews
- The links between the different stakeholders should be considered to maximise
  benefits and minimise barriers such as competition.
- As the investment required is estimated to be significant, it is advisable to consider
  the application of the Equator Principles\textsuperscript{23} mainly for the biorefinery to comply with
  international sustainability standards.
- Further research needs to be conducted at local level on social aspects (e.g. land
  abandonment and rural development initiatives) as well as the application and need
  of standards for future biobased products new to the market.
- A need of social research on health and safety issues on a biobased industry is
  deemed essential.

\textsuperscript{23} \url{http://equator-principles.com/}
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