Challenges and opportunities for lignocellulosic ethanol biorefineries:

A SWOT analysis based on the BIOLYFE concept

Questionnaire

Dear participant of the 3rd ICLE,

In this document you find a questionnaire which is part of the BIOLYFE SWOT analysis and complements the BIOLYFE SWOT workshop that will took place during the 3rd ICLE on April 3rd, 17:15 – 19:00.

The main objective of the survey is to weight the strengths, weaknesses, opportunities and threats identified in the preliminary SWOT analysis of BIOLYFE 2nd generation bioethanol production based on your expertise. In the following pages, you find 4 tables with SWOT arguments:

1. A general SWOT analysis on cultivation of lignocellulose crops for the production of 2nd generation bioethanol
2. A SWOT analysis for Arundo donax (main feedstock for BIOLYFE)
3. A SWOT analysis for straw as feedstock for 2nd generation bioethanol plants (secondary feedstock for BIOLYFE)
4. A SWOT analysis on bioethanol production and use in a BIOLYFE plant

Please indicate (with an "x" in the respective column) how relevant you consider the mentioned strengths, weaknesses, opportunities and threats for the success or failure of 2nd generation bioethanol plants. You also have the opportunity to express your disapproval (with an "x" in the first column) or add further arguments.

Additionally, you are invited to share some ideas and recommendation on how the weaknesses and threats you considered most relevant could be overcome.

We would appreciate very much your cooperation and thank you cordially in advance for your support.

You can send us completed questionnaires until end of May 2013.

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Table 1: General SWOT analysis on cultivation of herbaceous lignocellulose crops for the production of 2nd generation bioethanol

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Strengths	S1: **Renewable resource**: can be used as alternative to fossil fuels. Contribution to **energy security.**					
	S2: Can contribute to **rural development** by creating new income opportunities for farmers.					
	S3: Can contribute to **climate change mitigation.**					
	S4: Introduction of new crops offers the **chance to increase crop species diversity** and reduce pest pressures caused by mono-cropping systems.					
	S5: **No *direct* competition to food**: lignocellulose is not digestible for humans.					
	S6: In many cases **easy to grow and high yielding** → high energy and land use efficiency.					
	Any strength missing? Please add!					
Weaknesses	W1: **Need for arable land** (in some cases: only marginal land) to cultivate the crops → land becomes an increasingly scarce resource. There is increasing competition for the limited arable land (*indirect* competition for food and feed).					
	W2: New crops in most regions**: farmers lack knowledge** and experience regarding cultivation of lignocellulose crops for energy.					
	W3: **Infrastructure and logistics for biomass supply not fully developed** in all regions with high biomass potential.					
	W4: **Storage facilities not yet available**					
	W5: **Lignocellulose processing approaches are considered commercial only at large scale**.					
	W6: In most cases higher eutrophication, acidification and ozone depletion compared to fossil fuels.					
	Any weakness missing? Please add!					

Table continues →

→ **Continuation of table 1: General SWOT analysis on cultivation of herbaceous lignocellulose crops for the production of 2nd generation bioethanol**

I

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Opportunities	O1: **Rising market opportunities for biofuels** as fossil fuels become scarcer.					
	O2: New crops, that have shortly entered into the focus of agricultural research → **still high potential for enhancement of the currently available genetics and management practices**.					
	O3: Robust plants could be **cultivated on marginal land** not suitable for other purposes.					
	O4: Global sustainability **certification schemes** for biofuels are established or under development (GBEP, RSB) facilitating a proof of sustainability to positively influence public perception.					
	Any opportunity missing? Please add!					
Threats	T1: **Market price might be too low** compared to production costs (competition with other energy carriers).					
	T2: Rising **land scarcity** can lead to unsustainable biomass provision (less surplus land available for bioenergy production at global scale because of **rising demand for food and feed**; rapid increase in demand for bioenergy can **bring food prices up and increase hunger**; increased **risk of harvest failures**; **risks for endangered species and possible increase of greenhouse gas emissions**).					
	Any threat missing? Please add!					

Do you have any recommendation to overcome the weaknesses and threats you considered most relevant for successful cultivation of lignocellulosic herbaceous bioenergy crops?

Table 2: SWOT analysis on cultivation of Arundo donax for the production of 2nd generation bioethanol

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Strengths	S1: Arundo is a **perennial crop** (no seeding and tillage needed except in the first year; lowers erosion risk compared to cultivation of most annual crops).					
	S2: **Arundo is a particular robust crop, suitable for low input cultivation and cultivation on marginal land** (does not require large amounts of fertilisers; low demand for pesticides and herbicides; high resistance against pest because of noxious chemicals in stems; resistant to stagnant moisture; tolerant to salinity; established plant is drought resistant; can survive low temperatures when dormant).					
	S3: Fast growing and **high yielding** → efficient land use; high return of energy per invested energy unit.					
	S4: **Flexible harvesting time** → less storage capacities needed.					
	S5: **Existing harvesting technologies** can be used with minor adaptations.					
	Any strength missing? Please add!					
Weaknesses	W1: Arundo is a **perennial crop** (binds the farmer for many years to his decision; low yields in the first 2 years → other material has to be used as additional feedstock).					
	W2: Arundo is a **new cultivar → lack of knowledge and experience** (**few if any commercially available cultivars**; **necessary nutrient input** not yet well researched; **farmers lack knowledge and experience** in arundo production for energy; large scale cultivation of arundo does not exist at the moment; f**ew production cost data available**; **lack of knowledge on arundo genome**).					
	W3: Freshly harvested arundo **biomass has some weak properties** (moisture at harvesting time too high for storage → **drying needed**; Arundo donax biomass has **high ash and chlorine content**).					
	W4: **Risks for environmental sustainability** (Arundo is **invasive to natural ecosystems** by dispersal from agricultural fields; Arundo is suspected to **alter hydrological regimes** in semi-arid areas because of high transpiration).					

Table continues →

→ **Continuation of table 2: SWOT analysis on Arundo donax as energy crop**

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Weaknesses (continued)	W5: Difficulties in cultivation (**sensitive to frost damage after the start of spring growth** or while it is still a seedling; arundo can become a **weed in following crops** that is very hard to remove).					
	W6: Some report very **high expenditure for planting**: Large amount of rhizomes or nodes needed with partly high costs.					
	W7: **Sterile plant** → lack of sexual reproduction – low genetic variability and genetic improvement more difficult.					
	Any weakness missing? Please add!					
Opportunities	O1: **High gross margins** for farmers because of high yields and low expenditures.					
	O2: **Development of new varieties and agricultural practices** (to overcome the agricultural weaknesses, in particular invasiveness and high water demand; development of management practices to overcome the risk of invasiveness; development of propagation techniques / seeding techniques that lower costs of planting).					
	O3: High ability to remove pollutants from water and soil → can be used for **phytoremediation** purposes (A. donax is a plant only slightly affected by the presence of metals in the rhizosphere. Therefore high biomass production in polluted areas can be achieved by arundo cultivation).					
	Any opportunity missing? Please add!					
Threats	T1: **Low acceptance because Arundo donax is known as invasive** in some regions.					
	T2: **New pests** may occur if Arundo donax is cultivated in large scale.					
	Any threat missing? Please add!					

Do you have any recommendation to overcome the weaknesses and threats you considered most relevant for successful cultivation of Arundo donax as an energy crop?

Table 3: SWOT analysis on the use of straw as feedstock for the production of 2nd generation bioethanol

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Strengths	S1: Additional **income opportunity for farmers** without change in production patterns.					
	S2: Agricultural byproduct → **no additional land use**.					
	Any strength missing? Please add!					
Weaknesses	W1: **Risk for soil degradation** (regular high extraction rates reduce soil fertility and increase erosion risk; increases extraction of nutrients → need for higher mineral fertiliser inputs).					
	W2: **Low biomass yield per hectare** (wheat: up to 8 t per hectare if 100 % of the straw is extracted, but this is not recommendable). Reduction of straw length on high yield cultivars.					
	W3: Main **driver for straw availability is demand for grain, not straw demand for bioethanol plants** → risk for feedstock scarcity.					
	W4: **Harvest only once a year**. Storage facilities needed for year round storage (high volume because of low density of balls, rain protection needed).					
	W5: **Harvest is in time with high agricultural work load**: seasonal workers and new machineries needed.					
	W6: **Competition** with traditional uses (in particular use for animal bedding) and other innovative uses (in particular combustion, thermochemical conversion, biorefineries for production of high value chemicals).					
	Any weakness missing? Please add!					
Opportunities	O1: **Subsidies for 2nd generation biofuels from residues may rise** because of their lower competition to food production; this can increase income opportunities in straw refining.					
	O2: **New varieties of cereals** with longer stalk may become available, thereby giving a larger biomass production per hectare. This could give a new paradigm of combination of feed and fuel production.					
	Any opportunity missing? Please add!					

Table continues →

→ **Continuation of table 3: SWOT analysis on straw as feedstock for the production of 2nd generation ethanol**

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Threats	T1: Withdrawal of straw from conventional uses → negative economic and social effects for those who used straw for conventional purposes, e. g. for animal bedding.					
	T2: "Temptation" to extract unsustainably high rates of straw if no mandatory environmental sustainability criteria applied.					
	T3: Increased frequency of droughts because of climate change decreases straw availability and increases competition with forage and bedding production.					
	T4: Market price might be too low compared to production costs.					
	Any threat missing? Please add!					

Do you have any recommendation to overcome the weaknesses and threats you considered most relevant for successful use of straw as feedstock for bioethanol plants?

Table 4: SWOT analysis for the biomass conversion in a BIOLYFE 2nd generation bioethanol plant and the use of bioethanol as fuel

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Strengths	**General aspects**					
	S1: Biomass based fuels are politically supported by European legislation (RED → creating high demand).					
	S2: Second generation ethanol is not directly competitive to food → high acceptance.					
	S3: Industrial scale pilot plants are existing.					
	S4: The bioethanol plant is relatively flexible in respect to the feedstock.					
	S5: For fermentation, biomass does not have to be dry as it is for thermochemical conversion or combustion → suitable for biomass with higher moisture content at harvest.					
	S6: Lower hazard risk compared to thermochemical conversion because of reduced temperature and pressure processes involved.					
	S7: The technologies for the production of second generation bioethanol could be adapted to alternative processes more easily than gasification and anaerobic digestion that pose constrains in terms of gas cleaning and upgrading before utilisation.					
	S8: Numerous processes for the conversion of the C5 and C6 sugars into value added chemicals are already available. This facilitates a flexible utilisation of the plant, not only for the production of second generation bioethanol but also for numerous chemicals, thus facing any market oscillation.					
	Pre-treatment and viscosity reduction					
	S9: The pre-treatment method used (w/o acids) allows cheaper construction.					
	S10: Low concentration of inhibiters in Chemtex two-step steam explosion process.					
	S11: High viscosity reduction in continuous mode processing could be achieved (patent application).					
	SSF process					
	S12: Simultaneous fermentation of C5 and C6 sugars by one GMO yeast strain → high efficiency.					
	S13: A big part of the feedstock (both C6 and C5 sugars) can be converted into ethanol.					
	Solid-liquid separation, distillation & dehydration					
	S14: Possibilities to work at high dry matter contents in SSF, giving lower separation costs.					

Table continues →

→ **Continuation I of table 4: SWOT analysis for the biomass conversion in a BIOLYFE 2nd generation bioethanol plant and the use of bioethanol as fuel**

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Strengths	**Side streams and process integration**					
	S15: Lignin use for green electric power generation → additional earnings.					
	S16: As compared to biogas production, ethanol is a more valuable product (can be used as replacement for gasoline in most car engines).					
	Final product, distribution and use					
	S17: Ethanol can also be used for chemical industry (e. g. as basis for ethylene production with a potential large market in the polymer industry).					
	S18: Infrastructure for distribution of low blend ethanol is easily implemented in existing infrastructure. There are good examples for the successful developing of a complete infrastructure for bioethanol blends (e. g.: E85 in Sweden).					
	S19: Lower greenhouse gas emissions and lower primary energy demand compared to fossil gasoline (if ethanol is not made of biomass cultivated on land with formerly high organic carbon storage).					
	Any strength missing? Please add!					
Weaknesses	**General aspects**					
	W1: BIOLYFE demonstration plant not yet fully running: no data on real performance of the plant available.					
	W2: Insecurity of feedstock supply: limited availability of sustainably extractable agricultural residues (straw) and sustainably cultivated energy crops (arundo, sorghum) in Europe. Other lignocellulosic biorefinery concepts compete for the same biomass (i. e. thermochemical biorefineries, biogas production).					
	W3: At the current stage of technological development, lignocellulose ethanol production is considered to be economic only at large-scale industrial facilities → risk of insufficient or unsustainable feedstock supply.					
	W4: Each change of the feedstock could cause high adaptation costs.					
	W5: High investment costs provide a barrier for the implementation of further commercial lignocellulose ethanol plants.					
	W6: Use of GMO yeasts: Security requirements, residue treatment needed.					
	Pre-treatment and viscosity reduction					
	W7: Mild pre-treatment conditions lower the sugar yield after enzymatic hydrolysis.					

Table continues →

→ **Continuation II of table 4: SWOT analysis for the biomass conversion in a BIOLYFE 2nd generation bioethanol plant and the use of bioethanol as fuel**

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Weaknesses	**SSF process**					
	W8: Still high costs for enzymes, even though remarkable cost savings and efficiency increase could be achieved by using CTec3 instead of conventional cellulases.					
	Solid-liquid separation, distillation & dehydration					
	W9: Product separation is energy intensive → lowers economic and environmental performance.					
	Final product, use and distribution					
	W10: Low acceptance of biofuels by some car drivers.					
	W11: E85 not suitable for all types of engines.					
	W12: Infrastructure and flex-fuel-fleet not yet well developed in Italy.					
	Any weakness missing? Please add!					
Opportunities	**Social, legal, political and economic opportunities**					
	O1: Biomass based products are considered in particular environmental friendly by some → eventually willingness to pay bio-based premium.					
	O2: Growing market for all kinds of alternative fuels, including bioethanol, expected as a result of decreasing petroleum reserves / increased cost of production of these fuels and increasing worldwide demands for fuels.					
	O3: Advances in biotechnology (enzymes as well as yeast) may increase the yield in the future.					
	O4: Funding available for research and development of lignocellulose ethanol plants in Europe.					
	Technical opportunities					
	O5: All process energy could be produced internally if CHP is used.					
	O6: Processing of lignin to high value added products may increase economic performance of bioethanol plants.					
	O7: The production of second generation bioethanol can be coupled with the production of additional chemicals such as furans and phenols (biorefinery) thus making the plants much more profitable.					
	O8: 2nd generation ethanol production is technically feasible for decentralized processing. Technological development might make second generation ethanol process also economic at smaller scale and hence lower the risk of a too high and unsustainable regional biomass withdrawal.					
	O9: Development of technologies and processes suitable for a wide range of feedstocks: This will enable multifeedstocks processing thus reducing the risk of feedstock scarcity.					
	O10: Flex-fuel care might become more common and hence the market for ethanol as fuel in Europe may increase.					
	Any opportunity missing? Please add!					

Table continues →

→ **Continuation III of table 4: SWOT analysis for the biomass conversion in a BIOLYFE 2nd generation bioethanol plant and the use of bioethanol as fuel**

		I disagree to this argument	Low relevance	Medium relevance	High relevance	Very high relevance (possible show stopper)
Threats	**Social, legal, political and economic threats**					
	T1: Uncertain development of oil price and hence of biofuel prices.					
	T2: Low acceptance of bioethanol by some car drivers.					
	T3: Low acceptance of biomass because of food vs. fuel issues.					
	T4: The economic crisis in Europe may cause difficulties to acquire the capital needed for establishing large-scale lignocellulose ethanol plants.					
	T5: Low public acceptance of the using of genetic engineering to improve the performance of microorganisms (yeasts, bacteria for enzyme production).					
	T6: Biofuels are competing with alternative energy sources for mobility (electromobility etc.). The future of mobility and engines might be not in the field of biofuels because of the low acceptance and limited feedstock availability.					
	T7: Infrastructure for ethanol fuels (e. g. E85) not a high priority on the European level in comparison to other alternative fuels, such as natural gas.					
	Technical threats					
	T8: The industrial plant may show a different performance than the models predicted.					
	T9: Other conversion technologies might be more efficient and might lower the prices to a level that is not acceptable for a BIOLYFE system plant.					
	Any threat missing? Please add!					

Do you have any recommendation to overcome the weaknesses and threats you considered most relevant for successful conversion of lignocellulose to ethanol and use of bioethanol as fuel?