Optimized Fuels for Sustainable Transport

Project co-funded by the EUROPEAN COMMISSION FP7
Directorate-General for Transport and Energy Grant No. 218890

Deliverable 1.5

Short Rotation Coppice Plantations

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Concepts for establishment and operation methods for short rotation coppice (SRC) projects for EU bioenergy plants (including practical activities on demonstration fields)

Public

Work package:	WP 1
Deliverable No:	D 1.5
Reviewer:	Dr. Simon Kühner / SYNCOM
Due date of deliverable:	M 40
Actual date of delivery:	12/03/13
Version:	Final Draft
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Dissemination level:	PU

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1. Summary

Demand for woody biomass increases rapidly in the process of meeting the ambitious renewable energy targets in Europe - but most of the EU's energy wood volumes, originating from forestry and residues are already utilized. At the same time, the largest additional biomass potential is based on agricultural crop-land. Thus, short rotation coppice (SRC) plantations have great potential contributing to renewable heat, power and fuel production in Europe.

Also under an environmental perspective, SRC is advantageous vs. annual energy crops such as corn, rape-seed and grain. Among other benefits the CO_2 reduction potential of fast growing trees per ha is roughly 3-times larger compared to "first generation" energy crops.

Over the past years the SRC plantation value chain has been developed and optimized. The OPTFUEL project has significantly contributed to define and implement cooperation structures between farmers and large bioenergy projects and to develop best practice examples of SRC projects in different regions. More than 200 ha have been successfully established in Germany and Poland between 2009 and 2011.

Normally farmers are still hesitant to plant fast growing trees on crop-land. Thus, it is important to approach them with a well-balanced cooperation proposal that lowers the hurdles from the beginning. The main characteristics of the cooperation contracts, which were developed by CHOREN/Lignovis are: a binding off-take/supply contract with terms of at least 15 years, the absorption of establishment costs of SRC plantations by the biomass off-taker and annual pre-payments for farmers in exchange for harvesting rights.

In consequence, the strong commitment of the biomass off-taker to implement joint SRC plantations and taking a large share of the associated risk was the main factor for a successful cooperation with farmers.

The most relevant aspects for implementation of a successful SRC project are described in chapter 4. Besides the selection of the right tree species and respective varieties, a thorough soil preparation and intensive weed control with a combination of chemical and mechanical measures have the most relevant influence on successful establishment of a SRC plantation.

Although SRC plantations are generally offering considerably higher ecological benefits compared to annual energy crops, there are possibilities to make SRC plantations even more beneficial for the environment. Different measures and their economic implications are discussed in chapter 5.

Based on the experience of the establishment, management and harvesting of the OPTFUEL plantations CHOREN/Lignovis has built up considerably know-how over the past years which is continuously further on applied in new SRC plantations that are planted for Lignovis clients in the future.

2. Introduction

The SRC activities under OPTFUEL have been initially started to develop a domestic, sustainable and secure biomass supply for industrial BTL production in Germany. After CHOREN's insolvency, the OPTFUEL biomass activities were continued by Lignovis GmbH (a management buy-out of CHOREN's biomass department) and additionally focussed on other industrial biomass consumers besides 2nd generation biofuel producers. Especially in the heat & power sector, the actual demand for woody biomass is growing constantly all across Europe.

Several mechanisms such as feed in tariffs, quotas and investment subsidies incentivise the generation capacities for biomass to energy in Europe. According to the National Renewable Energy Plans (NREAPs) of the EU member states the total installed biomass power capacity is expected to increase from 24 GW today to 43 GW in 2020.[1] A growth that is equivalent to 19 average sized nuclear power stations. EU member states expect that the final energy consumption from biomass (including solid, liquid and gaseous sources) will increase from 82 million t_{oe} in 2010 to 135 million t_{oe} in 2020.[2] This is almost twice as much as the expected growth of wind energy in the same period.

Most of Europe's economically accessible wood quantities from traditional sources are already in utilization. Also biomass volumes in form of agricultural residues and wood waste can only be increased on a limited basis in Europe. In total the EU domestic feedstock volumes are restricted and will not suffice to meet Europe's growing primary energy demand. Recent studies by McKinsey, Vattenfall or Eurelectric & Pöyry confirm this trend and predict a significant supply gap for woody biomass.[3] Biomass imports and domestic energy crops, such as SRC plantations, must fill the evolving gap.

Figure 1: SRC harvest at 3-year-old OPTFUEL plantation near Freiberg, Germany in 2012

While large hard coal power plants (especially with deep sea port access) tend to co-fire pellets due to technical requirements and might use their existing supplementary logistic chains for imports, medium sized and decentralised bioenergy plants usually rely on domestic biomass sources. Especially combined heat and power plants (CHP) are built in direct vicinity to their heat consumers, while access to international raw material markets is of mi-

[1] Eurelectric (2011), p.8
[2] 42% of the final bioenergy will be from sold biomass sources. Eurelectric (2011), p.21
[3] See McKinsey (2008), Vattenfall (2011) and Eurelectric (2011) for more in depth analysis.

nor importance for their site selection process. These plants often lack alternative sources once the biomass supply is getting tight in their region.

Dedicated energy wood production in SRC plantations is a cost efficient option to

- increase the energy wood supply in one region permanently and in a sustainable way,
- diversify the supplier and sourcing portfolio of the biomass consumer,
- lower logistic costs and ecological footprint by minimising the catchment area,
- decouple biomass supply from cyclical fluctuation of the forest and timber industry,
- lower resource competition with timber and pulp & paper industry and to
- increase local value creation and energy self-sufficiency.

Regarding heat production, where biomass is competing with natural gas and heating oil, wood chips from energy wood plantations are delivered at lower costs[4] already today while fossil fuel prices tend to rise continuously. New installations of biomass boilers by the private, public and industrial sector will further drive the demand for domestic biomass sources.

Several European states support electricity production specifically from energy wood plantations. For example: in the UK, there is an Energy Crop Uplift within the ROC (renewable obligation certificate) system and in Germany the feed in tariff for electricity from biomass under EEG (Renewable Energy Law) is escalated, if biomass from SRC plantations is used by the power stations. To support the establishment of new plantations, SRC programmes have been initiated under the European Agricultural Fund for Rural Development (EAFRD) in many EU-member states.

Despite the broad prospects and political goals of energy wood production, the actual development SRC plantations in Europe is moderate. Although detailed official numbers are not available, experts estimate that the total EU SRC plantation area does not exceed 70,000 hectares.[5] Given, that the German government stated a target of 450,000 ha until 2020 in its projections for Germany only, there is still a long way to go.

As farmers play the key role in rapidly scaling up the SRC plantation area in Europe, cooperation models with biomass consumers to jointly set up new plantation will be discussed in the following chapter. The cooperation model which has been successfully applied for the OPTFUEL plantations will be described in detail.

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[4] EGIX monthly indexed wholesaleprice of natural gas published by EXX on 12th November 2012 was 27.33 €/MWh, prices of SRC wood chips free field site start at ~ 20 €/MWh

[5] Sweden has the biggest share (~ 15,000 ha), followed by Hungary, Italy and Poland (~ 7,000 ha each). Germany's SRC plantations cover app. 5,000 – 6,000 ha in 2012.

3. Development of cooperation concept for long term SRC supply

3.1. Barriers for farmers to increase SRC production rapidly

In their role as managers of agricultural land farmers are holding a critical position in respect to scaling up European SRC production. In Work Package 7 the socio-economic constraints still interfering with the broad introduction of SRC plantations were examined in Germany and Poland.[6] As most farmers did not have any experiences in SRC production so far, the investment in SRC plantations comes with a set of uncertainties concerning plantation management and economic performance.

Still, the economic viability of SRC in comparison to biogas or conventional crops (esp. when cereal prices are at record heights) is doubted among farmers. Farmers demand for a reasonable and reliable income. But profits depend largely on annual yields, which are still hard to anticipate for producers unexperienced in SRC. However, when looking at the paying capabilities of CHP or heating plants, attractive profits of SRC plantations are feasible. A future broad biomass demand by several customers in one region will stabilize biomass prices on appropriate levels.

SRC specific machinery for weed control and harvesting are currently not yet available from service companies in all regions. At the same time buying special equipment is not an option for farms which want to dedicate only a small parcel of land to SRC. Hence, a critical mass of SRC plantations in one region is needed to attract service providers to get involved in special SRC services.

If farmers are considering establishing SRC on a large share of their available land, a restructuring of the farm might be required. As SRC plantations demand for an extensive management, a large scale conversion of a farm with high machinery and personal capacities might result in overcapacities and cutbacks. However, only a small number of farmers are willing to reduce their traditional business activities yet.

The cooperation with biomass off-takers might be one way to lower risks on both sides and will be discussed later on. Subsidies for the establishment of SRC plantations also help to lower the investment risk of farmers. The height and prerequisites of those programs differ on national (in Germany even on federal) level. In some countries, subsidies cover up to 40 percent of establishment costs. In practice however, some programs suffer from a lack of publicity among farmers, a high minimum investment demand[7] or an in-house competition of de-minimis subsidies[8]. The accessibility and feasibility of SRC support programs must be improved to allow for a broader application by farmers.

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[6] Syncom GmbH (2012)
[7] e.g. in the German Federal State of Lower Saxony, the minimum investment volume is 50,000 € (only planting material) which equals 30 to 50 ha.
[8] De-minimis subsidies, which are not subject to authorization of the European Commission, are limited to 200,000 € within 3 fiscal years for one company.

3.2. Needs of biomass project developers and operators

This report focuses on bioenergy plants with an annual demand exceeding 10,000 bone dry tons (bdt) which equals a thermal capacity of more than 6 MW. The results however might also be adapted case specific to smaller projects. Mid-sized plants enclose heat, heat & power and power only plants. While electricity is fed into the grid in most cases, heat is used for industrial (process heat or steam) and domestic (district or local) heating applications. Depending on local heat off-take, CHP projects are either heat or power driven. This purpose is determining the running hours, and in consequence the feedstock demand over the year.

Larger biomass combustion plants, which exceed 50 MW capacity, are in most cases power only projects. For such dimensions, an appropriate heat off-take is hard to realize. Due to technical reasons, handling and storage issues and to save logistic costs resulting from a large catchment area, biomass projects exceeding 100 MW tend to rely on pelletised biomass. Hence, biomass from SRC plantations would need a respective pre-treatment step before being delivered to such plants.

Besides dedicated biomass combustion, co-firing biomass in coal fired power plants poses another attractive marketing potential for SRC wood. However, if the use of biomass is not obliged or financially supported, utilities would only be interested in biomass co-firing when prices for coal and carbon certificates are high. Additionally, co-firing is usually only possible if biomass is pelletized before.

Due to economies of scale, commercial bio-refinery projects are assumed to start at a relatively big size. CHOREN's Sigma scale BTL plant was planned with a capacity equivalent to 640 MW thermal capacity. Depending on the technology applied, the quality of the supplied biomass might be subject to higher quality restrictions regarding particle size, ash melting point as well as water, ash and chlorine content. Standards for biomass quality are existing for all bioenergy projects and needed to be fulfilled by the supplier.

Currently the energy wood market develops rapidly but traditional biomass sources from forestry are limited. As harvesting, gathering & transportation costs are making up for the biggest share of expenses of low value wood, additional volumes might be mobilized at higher prices but only to a limited extend. Especially midscale projects with a relatively small catchment area and no alternative raw material sources are exposed to price risks once the market is getting tighter. Looking at the development of the recycled wood market in Germany as an example, where prices have tripled within less than 8 years[9], wood consumers are well advised to develop biomass sourcing options which enables them to mitigate price risks.

Especially if the compensation for the plant's products is fixed (e.g. via feed in tariffs), higher raw material prices cannot be transferred to higher product prices. Hence, bioenergy projects need a long-term biomass supply, where prices are calculable over a long period.

[9] The price for recycled wood class II&III (chemical treated) has risen from ~ 7€/t in 2003 to ~25€/t in 2011. Class IV (contaminated) has even risen from -8 to 25 €/t in the same time. See DBFZ (2012), page 21

In the face of these developments, creditors tend to demand a sound sourcing concept or even a proof of a reliable supply agreement before final investment decision. In consequence, a secure, long-term biomass supply offers the potential to lower financing costs.

Today, reliable long-term energy wood supply agreements (between 5 and 20 years) are usually not offered on the market. Normally, it is up to the biomass consumer to strategically develop the available biomass volumes in the specific catchment area. To avoid raw material shortages and increasing feedstock prices, a deep biomass market must be build up in co-operation with all stakeholders along the value chain. The increase of biomass volumes might contradict with the intention of established actors (e.g. forest owner would like to profit from increasing wood prices in tight markets) but also offers a chance to new market players (e.g. farmers) to benefit from the growing bioenergy sector.

In conclusion, farmers and bioenergy projects should cooperate to jointly develop an effective biomass production and supply relationship, which is of benefit to all partners.

Figure 2: Prepared field for OPTFUEL SRC establishment in Brandenburg, Germany in 2010

3.3. Design of cooperation concept

Within the OPTFUEL Task 1.1.2: "*Strategy development for optimized biomass logistics of different feedstock qualities and sources"*, biomass from SRC plantation was identified as a major biomass source for a large-scale BTL plant in Schwedt. The share of SRC chips in the sourcing portfolio was planned be increased to 34% until 2020, which sums up to 380,000 bdt/a. Assuming an average mean annual increment (MAI) of 11 bdt/ha in the respective areas in Brandenburg, this would equal a plantation area of almost 35.000 ha. This would have caused a relevant influence in the agricultural production around Schwedt.

So far, SRC plantations have almost been not existent in that region. Hence, a sophisticated cooperation model which allowed a fast and tangible development of plantation capacities was required. Besides supplying the planned BTL project, the established SRC plantations also performed as flagship projects, motivating other farmers to consider SRC on their own land.

Although current biomass projects are much smaller (the typical size of CHP plants, subject to the German EEG, is around 5 MW_{el} and 10 MW_{th}) the challenges remain the same: securing a long term, sustainable and cost efficient biomass supply. In consequence the cooperation concept, which was developed for the CHOREN BTL plant, also suits small and mid-scale bioenergy projects in the same way.

For the development of the SRC cooperation concept, the prepositions of farmers and landowners were compared to the needs of bioenergy projects. While some requirements of the stakeholders complement each other, some are in opposition with those of the counterpart:

Needs of farmer/ land-owner		**Needs bioenergy Projects**		**Implication for concept design**
Mitigation of long term off-take risk (20 years average life time of SRC plantation)	vs.	Mitigation of long term supply risk (~ 20 years recovery period of bioenergy plants, 20 years fixed feed-in tariff for EEG[10] power plants in Germany)	→	Develop long term supply / off-take agreement
Reasonable & reliable income	vs.	Calculable feedstock costs	→	Develop fair pricing mechanism / distribution of risks
Low logistic costs	vs.	Low costs and attractive energy/green house gas (GHG) balance of feedstock logistics	→	Localize plantations in vicinity to bioenergy project

[10] German Renewable Energy Law (Erneuerbare Energien Gesetz – EEG)

Low harvesting and plantation management costs (need of special machinery)	vs.	Low mobilization, administration and harvesting costs (to lower feedstock costs)	→	Establishing a critical amount of plantations in one region allowing an efficient utilization of special machinery (e.g. by a contractor)
Conservation of soil quality and status of farmland	vs.	Sustainable feedstock sourcing with low ecological impact and life cycle GHG gas emission	→	Establish energy wood plantations
Administrative support for authorization and potential subsidies for plantation	vs.	Public and administrative support for authorization and potential subsidies for bioenergy project	→	Stress on local value and job creation
Annual returns from farm land	vs.	Payment after delivery	→	Periodic (pre-)payments

Table 1: Implications to align needs of farmers and bioenergy projects

The concept was designed to allow for a quick increase of SRC plantation in the OPTFUEL regions. To convince farmers to shift to a new cultivation method, cultivation risks were mostly taken by the biomass user while farmers could also benefit from higher than expected yields. In future SRC production cooperation, the risks and chances could be shared more equally among partners, as the farmer's experience with SRC is rising.

The CHOREN cooperation concept can be divided in three pillars:

(1) Sharing investment (plantation establishment) and yield risks

(2) Provide yield compensation on a regular basis

(3) Agree on a long term supply and off-take contract > 15 years

Figure 3: 4 months old OPTFUEL Plantation in Brandenburg, Germany in 2009

Plantation establishment and management

To lower the investment risk and capital demand of the farmer, the biomass user may participate in the plantation establishment. In return, the biomass user receives the right to buy the total yield of that plantation at a fixed price over a > 15 year period. Depending on the agreement the plantation management measures (i.e. weed and pest control) are financed by one of the partners or jointly. On most OPTFUEL plantations, the expert team from CHOREN/Lignovis executed the SRC specific activities.

It has be taken into account, that an in-house plantation management of the biomass off-taker also demands for a specialized SRC team within the bioenergy company. As this was the case for CHOREN, other biomass user may more efficiently cooperate with companies that are specialised on the SRC plantation value chain. Responsibility and management costs could also be handed over to the farmer. In return the farmer's share of the plantation's returns is increased which motivates the farmer to optimise the plantation management on his expenses. At status, this option is only recommended if the cooperation partner is an experienced or at least highly motivated farmer who is in dialog with specialised SRC service providers.

Figure 4: Field preparation and SRC planting on an OPTFUEL field in Brandenburg, Germany in 2009

Yield compensation for farmer

As farmers are used to annual returns from the management of their land, biomass users might increase willingness of SRC cultivation by providing annual payments to farmers in exchange for harvesting rights – although SRC plantations are normally harvested only every three years. Taking this in account, the OPTFUEL concept involved a yearly payment which was calculated on the basis of an agreed price for energy wood stumpage (standing trees on the field) and the assumed mean annual increment (MAI) of the plantation, depending on the respective growing conditions.

The biomass price has been fixed over the contract period, including an annual adaption to the inflation rate. Under OPTFUEL the German consumer price index of the Federal statistic office was used. For other bioenergy actors it might be suitable to use a fix factor for price adaption (e.g. 2% per year) or link the biomass price to other price indices such as electricity, gas or forestry wood chips.

The annual payment is considered as a pre-payment for the future yields to cover the running costs of the farmers' activities. After the harvest, the yield is measured. If the total yield exceeds the assumption, which was the basis for the annual payment, the biomass user will additionally pay for the volumes above the estimation. If the yield was lower, the farmer might accept a lower annual payment. In an early stage of SRC development, it might also be necessary to agree on a bottom line of a minimum annual compensation for the farmer to overcome SRC related reluctance and lack of experience.

In general, yield risks and prospects should be covered to a certain extent by the biomass off-taker to facilitate project implementation. As soon as SRC has become a "conventional crop", the farmers should take full responsibility and risk of the biomass production (with or without long term supply contracts).

Figure 5: Wood chips from a 3 year old SRC plantation near Freiberg, Germany in 2012

Long term contracts

A generic cooperation contract was developed in consultation with CHOREN's legal department and a law office specialised in agricultural law. The draft was discussed with cooperating farmers and individually adapted to specific requirements. The cooperation contracts were designed to cover the full lifetime of a SRC plantation (15 to 20 years). At the end of the contractual period, it is the farmers decision if the plantations are re-cultivated by the biomass off-taker or to continue the plantations on own risk. The contract's features are summarized in the following figure:

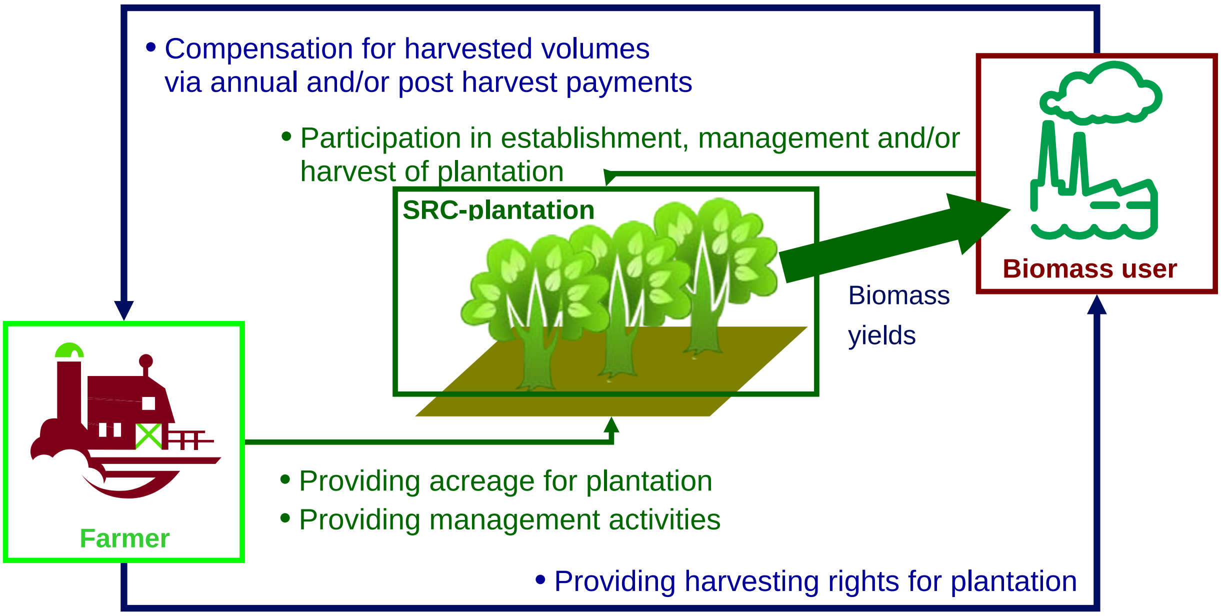

Figure 6: Joined biomass cooperation concept

3.4. Discussion of cooperation concept

Additional investment cost for bio-energy projects

For farmers (especially for small and medium scale) the initial SRC investment of 2,200 - 3,000[11] €/ha might be a fundamental hurdle affecting the decision of establishing a plantation.

The investment in agriculture is a relatively new field for most actors that are active in the development of bio-energy projects. However, a participation in the SRC biomass value chain should be understood as an investment in a secure, long term and stable feedstock supply from a regional source. Compared to the overall investment cost of a new CHP (combined heat and power) project, the additional investment demand to secure 20% of the feedstock via SRC plantations is rather modest.

For a midscale CHP project the additional investment enabling supply of 20% SRC wood chips accounts for only around 10% of the plant's total invest – even if calculated at the upper end of the establishment cost range for SRC plantations and modest yield expectations:

Case study - midscale CHP plant *(qualifying for German Renewable Energy law)*					
Total plant invest	20.000.000	€			
Electrical capacity	5	MW_{el}	SRC share	20	%
Thermal capacity	10	MW_{th}	SRC yield	10	bdt/ha/a
Biomass demand	35.000	bdt/a	SRC plantation area	700	Ha
Establishment cost	3.000	€/ha			
Total SRC investment	2.100.000	€			
Share of total plant invest	**10,5**	**%**			

Table 2: SRC investment share for a midscale CHP project

For projects with more sophisticated technology, like BTL plants (bio-refineries), which have significantly higher specific investment cost, a parallel investment in SRC plantation establishment becomes even more attractive. To source 20% of the feedstock demand of an industrial scale sized BTL plant, the additional SRC investment accounts for approx. 6% of the total invest only:

Case study - large scale biorefinery *(BTL Sigma plant reference)*					
Total plant invest	1.000.000.000	€	SRC share	20	%
Rated thermal capacity	640	MW_{el}	MAI	10	bdt/ha/a
Biomass demand	1.000.000	bdt/a	SRC plantation area	20.000	ha
Establishment cost	3.000	€/ha			
Total SRC invest	60.000.000	€			
Share of total plant invest	**6,0**	**%**			

Table 3: SRC investment share for large scale biorefinery project

[11] Including site preparation, planting material, planting, pre-emergent herbicides and weed control within the first year

The OPTFUEL Task 1.1.2: *Strategy development for optimized biomass logistics of different feedstock qualities and sources* outlined a feedstock base of 34% biomass from SRC. If the total volumes would be produced from SRC plantations under the described cooperation principles, this equals an investment share of 10% of the total plant invest. It is assumed, that in practice the bioenergy projects would need to invest in SRC plantations only in the beginning. If a bioenergy company builds up a strong SRC cluster in one region, other farmers and agricultural organisations will follow building up plantations on their own expenses. Long term supply agreements could be offered to these producers to facilitate the development of a strong supplemental SRC supply.

Taking into account that a long-term secure biomass production mitigates the investment risks significantly, also the interest rate for debt financing might be reduced by the creditor. This effect could significantly further increase the attractiveness of an SRC investment and should be calculated for each bio-energy project individually.

Land availability

Land access is still the major barrier for implementation of the SRC concept. Grain prices have increased over the past years, reducing the willingness of farmers to commit into multi-year plantation and supply contracts. Here, farmers have to be convinced of the benefits of long term cooperation (e.g. secure income, low risk, etc.) and SRC plantations in general (e.g. improved soil quality, erosion protection, etc.).

Due to raising grain and rapeseed prices, attractive feed-in tariffs for electricity from biogas and the revival of land as an investment asset, the land prices and leases have been constantly risen over the past years. Bio-energy projects can therefore also search for land, which is only of reduced value for conventional agriculture, but offers relatively good conditions for the specific needs of SRC plantations (e.g. light sandy soils with access to the ground water table). Depending on the price of the final product (electricity, heat, biofuel, etc.) the plant operator, might offer a more attractive land use option for farmers compared to other land uses. Especially German CHP plants feeding electricity to the grid under the renewable energy law and started operation after 2012 receive a very attractive feed-in tariff for electricity produced from SRC, and could therefore offer attractive conditions to the farmer.

Long term commitment and securities

As indicated above, some farmers might want to avoid long-term commitments for their land, especially if land is only leased farmers are often unable to commit to long term SRC contracts without the involvement of the respective landowner. Here a profound and open discussion is necessary, showing the benefits of SRC as stated in chapter 3.1.

As both parties commit to a long-term supply and off-take agreement, the cooperation bears certain risk. If one partner is unable to full-fill the contractual obligations, the investment of the other partner might be at risk. For example, the farmer could lose regional biomass off-take, while the biomass user could lose the investment in the plantation as well as biomass volumes in the future. This should be considered when designing a cooperation contract.

Nevertheless, the contract should be kept simple; otherwise, farmers usually do not feel comfortable and avoid cooperation.

In the case of CHOREN's insolvency, most farmers either signed new contracts with Lignovis or with a Vattenfall daughter company which aims to supply a CHP project in Berlin with SRC wood chips. Others decided to operate the plantations on own account in the future.

Organisational challenges

Depending on the degree of participation of the biomass user in plantation projects and the SRC experience of partners involved, the biomass user needs appropriate SRC in-house expertise. For larger projects, this might even imply the establishment of a SRC specific department (e.g. Vattenfall, RWE, Viessmann, CHOREN). Smaller projects could contract a specialised SRC company for consultancy or management services.

It is important to mention, that the business culture and habits of companies with a more technical or financial background (i.e. the biomass user) normally differs significantly from companies and representatives from an agricultural background. These “cultural” differences should be taken into consideration, especially during the acquisition process for new agricultural partners. Also internal work-flow, organisation and decision processes should be designed to cope agricultural operations, which demand a higher flexibility and responsiveness.

3.5. Alternative cooperation concepts

The OPTFUEL cooperation concept was designed to build up a critical mass of plantations in a wider target region to increase experience and lower entrance barriers for farmers in respect to SRC production. In this concept, the biomass user takes a significant share of the investment and operational risk. For future projects and when farmers are more accustomed to SRC production this might change.

In general the most suitable cooperation concept should be designed for each project individually, taking project size, potential partners, local agricultural structure and other factors into account.

Long-term off-take agreements

The cooperation model could be varied by changing the depth of the biomass user's integration in the biomass production, the time span of the contract and modalities of compensation. This could even lead to a simple long-term biomass off-take contracts including defined pricing with the farmers.

Farmers forming producer groups

Farmer could also join forces with third parties to build up an efficient SRC production chain. Potential partners for a producer group could be financial intuitions, biomass trading companies or especially specialised SRC service companies. The internal structure of the group would depends on the background and capabilities of the partners. The biomass off-taker could either sign an off-take agreement with a newly founded producer-group legal entity or with one of the group members who himself holds contracts with the other partners.

Cooperation with water supply companies

In areas with a high nitrate pollution of groundwater the cooperation with local water work authorities might be feasible to build up large SRC plantation cluster if also wood chips demand is existent. In some regions in the German federal state Lower Saxony for example, high nitrate inputs of intensive agriculture (mineral and organic fertilizer) and excess of manure from large scale livestock farming seriously affected the available drinking water quality. Limits of nitrate concentrations have been exceeded and lay-offs of waterworks in affected regions have been discussed.

According to the experience from OPTFUEL plantations and academic research, the fertilisation of SRC plantations is considered as normally not necessary and does not provide a significant rise in productivity.[12] Hence, SRC plantations are assumed as a cultivation method, which could significantly lower the nitrate concentration in ground water. To increase the quality of drinking water and to lower the expenses for chemical and technical treatments to remove nitrate, waterworks could financially support the establishment of SRC plantations in critical water catchment areas. There is still research demand to determine the amount of

[12] See also Scholz, Hellebrand & Höhn (2004) and Rödl, A. (2008)

financial support based on the nitrate avoidance potential of SRC and the avoided treatment costs.[13]

However, in regions with excess (liquid) manure, SRC plantations are only one part of the solution. Transport systems have to be set up to transfer the manure to other regions. Due to relatively high logistic costs compared to the value of the manure, the support of the water-works will be necessary also for that process.

[13] Recently, the community of Kaufering started a best practce demonstration project, in which the local waterworks pays an one-time establishment grant (650 €/ha) and annual management fee for SRC plantations (250 €/ha), see Pertl, L. (2009)

4. Best practice SRC production method

The following best practice methods are derived from experience on OPTFUEL plantations in Germany and Poland and hence focus Central European sites.

4.1. Soil preparation

Careful soil preparation is very important to achieve good growing results in the first year. It is recommended to plough in autumn before the designated planting date. Directly before planting, the soil is to be prepared with a conventional seedbed combination. The seedbed should be even and with fine grained topsoil.

Figure 7: Soil preparation of SRC field in Saxony

Figure 8: Soil preparation of SRC field in Western-Brandenburg

4.2. Planting layout

The specific plantation layout depends on the selected species, the projected rotation period, the intended harvesting chain as well as the preferred management machinery. The following variables must be determined in the plantation planning process:

- Double or single row
- Distance between the rows
- Planting density, which determines the distance within the rows
- Size of headlands
- Direction of rows
- If necessary, passages within the plantation (e.g. for harvesting, hunting corridors, restrictions due to transmission lines, etc.)

All OPTFUEL plantations in respective regions have been planted with the same row distance, continuously in single or double row to use the same weed control systems (e.g. rototillers) for all fields. This avoids redundant machinery and transportation cost).

When deciding on the row distance, the width of the harvesting machinery must be considered. If the row distance is too low, the harvesting operations will get complicated beginning with the 2^{nd} harvest, as soon as the tree rows are taking more room. The distance should be calculated generously, however, if the distance is too high, the trees might not be able to close the foliage between the rows in the 2^{nd} year, and weeds are not shaded-out. Typical row distances for single row are between 2.2m and 3m. Double rows offer the advantage of faster foliage closure as trees are spread more evenly over the field. On the other hand, weed control in double rows requires more specific equipment and not all existing harvesting technologies can be used.

Planting density depends on length of rotation and the selected species. The following table lists indicative values, which have been successfully used for the OPTFUEL plantations in Germany and Poland.

	Poplar	Willow
3 year rotation (single and double row)	10,000 trees/ ha	13,500 trees/ ha
5 to 10 year rotation (single row)	5,000 trees/ ha	-

Table 4: Recommended planting densities according to OPTFUEL results

The size of the headlands depends on the preferred harvesting machinery. This should provide enough room for harvesting operations. If whole stems are harvested and stored at field side, the necessary space for the storage should also be taken into consideration. Within the

OPTFUEL harvesting activities a minimum headland length of 10 to 15m was identified for commercial field chipper harvests.

The direction of the rows should be determined according to individual plantation preconditions, trying to maximize the net plantation area (by reducing the headland area). Off course access routes must be taken in into account. If the rows become very long (e.g. exceeding 500m for short rotation) an additional passage might be considered to facilitate harvesting and plantation management.

4.3. Species and variety selection

Selection of proven, high-yielding and healthy willow and poplar clones is crucial to achieve good result. It is very important to consider the regional origin and suitability of selected planting material for every project. E.g. some Italian clones (P. deltoids x P. nigra) have shown increased susceptibility to bark rust decease (Cryptodiaporthe populea) on German and Polish OPTFUEL fields starting with the 3rd growing season, after excellent performance in the first two years. It is assumed that cold wintertime climate conditions in central Europe was a critical stress factor leading to severe damages by bark rust on the Italian clones. Other poplar clones such as Max1, Max3, Max4, NE42, 10/85 (equivalent for Matrix) performed well and offer good bark rust resistance.

The use of diverse tree species and clones on larger projects also enhances the resilience against pests and diseases of the plantation as a whole. In total roughly one third of the OPTFUEL plantation area was planted with willow and two thirds with poplar clones. On very wet sites, alder may be a good alternative to willows and poplars. Robinia (black locust) might be planted additionally on very sandy soils. However, adjacent poplar plots outclassed all OPTFUEL Robinia trials so far. As a result, Lignovis recommends diversifying a plantation with mostly poplar and willow varieties.

The following poplar clones have shown best growing results combined with resilient growth on the OPTFTUEL fields:

Clone name	Breeding parents	Characteristics
Max 1 Max 3 Max 4	P. maximowiczii x P. nigra	Very high yield potential, fast growth in first 3 years, high survival rate, low yield differences between different Max clones, excellent tolerance of high planting densities, suitable for wide spectrum of soil types, good drought resistance, irregular tree form (not suitable for log timber production), bark rust resistant (Cryptodiaporthe populea), good leave rust resistance (Melampsora larici-populinea)

NE 42 (equivalent to Hybride 275)	P. maximowiczii x P. trichocarpa	Very high yield potential, high survival rate, rather slow development of above ground biomass in first two years after planting, relatively high tolerance to late frosts, very good tolerance to high planting densities, suitable for wide spectrum of soil types, also suitable for relatively cold climate conditions, good drought resistance, bark rust resistant, good leave rust resistance
Matrix 49, Matrix 24 (equivalent to 10/85)	P. maximowiczii x P. trichocarpa	New clone which has been approved in Germany in 2010 after a long testing period, very high yield potential, bark rust resistant, good leave rust resistance
Jacometti 78B	P. x euramericana	Moderate yield potential, high survival rate, relatively fast growth in first years after planting, very suitable for heavy soils, susceptible to water logging, prefers nutrient rich and aerated soils , prefers warm climate conditions, moderate susceptibility to bark rust, moderate leave rust resistance
Androscoggin	P. maximowiczii x P. trichocarpa	Moderate yield potential, high survival rate, relatively high tolerance to late frosts, very good tolerance to high planting densities, suitable for wide spectrum of soil types, good drought resistance, bark rust resistantmoderate leave rust resistance

Table 5: Recommended poplar clones for Central European sites

Additionally poplar clones from a Belgian breeding program (Grimminge, Oudenberg, Vesten, Muur) have been tested with good results on some OPTFUEL plantation sites.

Specifically, the following willow varieties have shown good growing results on the OPTFTUEL fields:

Variety name	Breeding parents	Characteristics
Tordis	(Salix schwerinii x S. viminalis) x S. vim.	high yield and free from leaf rust, one of the best available varieties in productivity
Inger	Salix triandra x S. viminalis	very high yield potential, very good drought resistance, grows straight and is a good complement in mixed plantations
Sven	Salix viminalis x (S. schwerinii x S. viminalis)	High yield, almost free from leaf rust, lancet-shaped leaves and a straight stem, fewer shoots than Tora

Tora	Salix schwerinii x S. viminalis	Yield potential very good, almost free from leaf rust, insect damages on shoots are less common, less preferred by game animals

Table 6: Recommended willow clones for Central European sites

4.4. Planting

Timeframe of planting

Planting starts in springtime when temperatures rise and sites are getting accessible again. Late frost can damage the shoots of young trees thus a later planting date is advantageous in that respect whereas risk of drought is increasing. Mid of March to and end of May are assumed as core planting time in Central Europe. Under wet weather conditions, planting can be performed in June as well.

Planting machinery:

Different planting techniques have been tested and assessed within the OPTFEUL project. The plantation establishment with a modified “Step-Planter” (developed by the Swedish company Salix Maskiner / Canditec) has been identified as most cost efficient for the planting of high density plantations (> 8.000 cutting/ha). The Step-planter is producing approx. 20cm long cuttings from willow as well as poplar during the planting process. Then the cuttings are pressed into the ground with a piston (approx. two cuttings per second). In general, whole rods are more cost efficient in production, storage and transport compared to cuttings. The „Step-planter“ technology is highly adjustable in respect to row distance, double-row, single-row, distance of plants within the row.

Figure 9: Planting poplar with the “Step-planter” (planting material is delivered in boxes to the field side)

If plantations shall be established at a low planting density or if soils have a high clay content a “Spapperi” planting machine (Spapperri s.r.l.) or a “Rotor-planter” planting machine (developed and built by the Italian company Ferrirotor) might be advantageous, as a those machines offer a higher precision. Nevertheless, if the money which is saved by using the Step-planter, instead of planting more expensive cuttings, is used for optimal weed control, the resulting plantation at the end of the first growing season normally looks considerably better.

Planting material

The preferred diameter of the planting material depends on planting machinery. Thicker cuttings might be more robust to dry weather conditions directly after planting, but also put a strain on machinery and increase the costs for logistics and storage (higher volumes of planting material). For the modified „Step-planter“ rods with a diameter between 0.8 and 2.7 cm are used. Recommended length of rods is 120 - 230 cm. If cuttings are used, the normal length is 20 cm, which is appropriate for most sites under good management conditions.

Planting material should be stored and transported at temperatures between 0°C and -4°C. Exposure to sun light or wind has to be avoided also during the planting time to prevent drying-out. Material, which is delivered to the field, should be kept wet, covered or packed in boxes.

4.5. Weed control

Effective weed management within the first 5 months after establishment holds the biggest impact on successful plantation development. Normally as the first step, pre-emergent herbicides are applied shortly after planting. Under ideal conditions, pre-emergent herbicides keep the SRC plantations free of new weeds until the middle of the first growing season. But sometimes the effect of the pre-emergent herbicides is rather low and mechanical weed control needs to start fast.

For mechanical weed control, special rototillers or other cultivation equipment (e.g. disc harrow, row crop cultivator, etc.) are used.

Figure 10: Mechanical weed control with a tractor mounted rototiller from Badalini

Selective herbicides are applied if necessary over top on willow and poplar fields to control specific weeds. Shielded spraying systems offer the possibility to apply relatively cheap total herbicides (e.g. Round-Up). On OPTFEUL plantations a tractor mounted spraying system was used successfully.

Figure 11: Chemcial weed control with shielded spraying system

Especially on sites with low water availability the competition from weeds must be eliminated effectively and frequently. Hence, new plantation must be monitored regularly to enable a quick response.

Weed management activities are recommended until the plantation has developed a dense foliage cover to shade competing weeds. Under normal conditions, weed control actions have to be executed in the first and second year after establishment and if necessary also thereafter. After each harvesting one mechanical or chemical (with shielded spraying equipment) weed control measure is advisable at the beginning of the commencing growing period.

Ecological farmers can substitute herbicide applications by more intense mechanical weed control. In any case, it should be considered that SRC plantations are very environmentally friendly as they require no further chemical weed control after the year of establishment if a dense plantation has developed based on low weed competition in the first year.

4.6. Pest control

Insects

In general, insecticides should be applied only if the plantation's survival is endangered or significant financial losses could occur. Costs for chemical measures should be balanced with the expected outcome. It has to be taken into consideration, that also natural antagonists mightl be affected. The application of selective insecticides should be considered if they are available. On OPTFUEL fields, the population of harmful insects normally collapsed after a while due to parasites and natural predators.

Insecticides have to be applied within the right time frame (before oviposition) to stop the first generation to breed the next one. On young or recently harvested plantations (where an infestation might have the biggest impact) normal agricultural sprayer can be applied. For plantations with mature trees, special sprayers from pomiculture might become necessary.

Fungi

Bark rust (Cryptodiaporthe populea) caused severe damages on several OPTFUEL fields. However, the damages were limited to certain poplar clones. Especially Italian clones, which are successfully cultivated under warmer climate conditions, have shown increased susceptibility.

To reduce the risk of fungi, only varieties which are adapted to the respective climatic region should be used. Increased stress factors like draught, late frosts, weeds or stagnant moisture might also increase the trees' susceptibility. In general, Lignovis recommends diversifying species and varieties on one field. This also includes a mixture of poplar and willow if feasible. A diverse plantation is considered to be more resilient.

Wild game

Browsing of wild game leads to yield losses, but only in rare cases to significant commercial. Young willow stands in the first growing season after establishment bear the highest risk.

On OPTFUEL fields, construction of fences, which is often proposed in literature, was dismissed as being too expensive for larger plantations. Chemical repellents have only been applied on some plantations. As game animals prefer willow as feedstock, plantations in regions with a high deer population might be planted with poplar varieties only.

4.7. Harvesting & logistics

Different harvesting chains have been tested on the OPTFUEL plantations. This included a whole stem harvester ("Stemster", developed by Nordic Biomass) with separate chipping as well as direct field chippers from different manufacturers (Krone/Hüttmann, NewHolland, JohnDeere/Salix Energy Europa). So far, the field chipper line has been identified to be more cost effective on the OPTFUEL plantations. However, the whole stem harvesting chain as well as the direct chipping line still hold potentials for significant cost reductions.

A diameter of approx.15 cm seems to be the threshold for current SRC harvesting technologies. For larger diameters, forestry equipment such as feller-buncher systems are appropriate. Within a short rotation cycle of 3 years, a diameter above 15 cm are normally not achieved.

Ideally harvesting operations are executed when the ground is frozen. On wet soils, heavy machinery might get stuck and deep furrows are produced.

5. Ecological enhanced SRC plantation

Compared to conventional agriculture, like wheat, canola or maize for biogas production, SRC plantations normally offer a significantly better overall ecological performance. The most relevant ecological aspects are:

- Extensive, low-input field management vs. conventional farming and other annual energy crops
- Very low quantities of herbicides and other chemical plant protection measures required
- No nitrate wash out in ground water as only small fertilizer amounts needed to achieve full productivity
- Significant reduction of erosion problems
- High and complementary biodiversity potential
- Efficient connection of biotope areas via SRC plantations
- Optimized micro climate, filtering of air pollutants as well as windshield function
- Enrichment of soil organic matter and additional sequestration of atmospheric CO2
- Adding diversity to areas dominated by intensive agriculture
- Habitat for wildlife and insects

To even more improve the ecological benefits of SRC plantations the German NGO “NABU” (Nature and Biodiversity Conservation Union) is eager to develop a concept for more ecologically advanced SRC plantation standards in the coming years. Those standards are meant to be voluntarily and might be combined with an additional annual “environmental bonus” for the plantation owner.

In 2011 CHOREN/Lignovis started a joint project with the NABU representatives to design and establish a SRC plantation concept which serves both – ecological and economical purposes. The requirements and measures were discussed with the NABU and finally implemented on an approx. 4 ha field in Eastern Brandenburg.

Lignovis will continue the monitoring of the field in the coming years beyond the OPTFUEL project duration. Finally, the yield of this plantation will be compared to conventional SRC plantations with similar growing conditions.

The expected yield difference will be quantified supporting the discussion for additional support programs for SRC with higher ecological performance. Thus, the test trial in Brandenburg will serve as a demonstration field for enhanced ecological SRC farming for NGOs, research institutes and interested farmers.

5.1. Requirements and different approaches for ecological SRC concepts

Based on publications of the Federal Agency for Nature Conservation as well as other environmental associations the NABU outlines basic requirements for ecological sensitive SRC plantations.[14] These should not only lower theoretical negative impacts of SRC cultivation but also facilitate the positive effects on the plantation's environment. In cooperation with the NABU Lignovis identified appropriate principles and measures, which should be practicable and keep economic losses at reasonable levels.

Besides operational aspects and the selection of tree species/clones, also the selection of a suitable site might have large influence on the ecological performance of an SRC plantation. In general, SRC plantations develop their whole ecological potential, when they are diversifying the agricultural structure in one region and are adapted to regional preconditions.

On most agricultural crop-land sites SRC plantations are advantageous in compared to annual crops. To avoid potential negative impacts on nature and habitats, grassland with high conservation value should not be considered for SRC plantations.

The following measures have been identified as suitable for implementation in test trials, to assess their effectiveness concerning ecological benefits and economic impact.

Approach	Expected ecological benefits	Expected practicability and economic performance	Implementation in OPTFUEL
Irregular plantation structures with gaps	Increase diversity of plantation	no additional establishment expenses, but gaps cause loss of yields	Yes
Plant different poplar and willow clones in mixed patterns	Increased diversity of SRC causes higher overall biodiversity (better habitat quality)	No significant additional establishment expenses, no impact on harvesting, mixture of varieties might increase resilience of plantation, varieties with lower growth rates will be suppressed by higher yielding varieties – lower average biomass yields are expected.	yes
Flower strips on the edge and on headlands of plantation	Higher phytodiversity and habitat quality increases overall biodiversity	Additional costs for drilling and mowing, no disturbance of harvest and low additional demand for land	Planned, but not implemented
Bushes (domestic species) on the edges	Increases diversity of plantation structure and provided nesting ground for birds	Additional costs for establishment and management, low additional demand for land	No
Integration of domestic tree	Increase habitat quality	Additional costs for establishment, higher specific land and	Yes

[14] NABU (2012)

species in mixed patterns		harvesting costs due to lower yields	
Partially harvesting of plantation	Increase diversity of plantation structure and maintains wind-break function	Higher specific harvesting costs due to smaller harvesting areas (fixed call out fee of harvesting equipment)	planned
No herbicides application	Avoid chemical impairment to fauna and flora	Increased demand for mechanical weed control, potentially lower yield expectations	partially

Table 7: Assessment of measures to further improve ecological performance of SRC plantations

5.2. OPTFUEL concept and best practice

Based on these approaches CHOREN developed trial plantation with a net area of 3.65 ha in cooperation with the NABU in 2010. The plantation was set up with an SRC experienced agricultural partner in the Schwedt region, in direct vicinity to other OTFUEL plantations. Those plantations all lie within the EU bird sanctuary *Randow Welsebruch*.

The following approaches have been implemented in the OPTFUEL ecological enhanced SRC plantation concept:

Approach	Practical implementation on plantation
Create irregular structures with gaps	gaps have been intentionally left free during planting process (4 x 10 m² skylark plots), 81% planted in double rows and 19% in single row
Plant different poplar and willow clones, partly in mixed patterns	81% poplar (8 clones), 8% willow species (3 clones), willows were mixed into poplar rows, 11% un-bread domestic tree species
Flower strips on the headlands	is planned for the following vegetation period, but has not been implemented yet
Integration of domestic tree species in mixed patterns	11% domestic tree species (8 species), planted in 3 rows at southern long side
Partially harvesting of plantation	Different rotation periods (3 years for double row, 7 - 10 years for single row
No herbicides application	Herbicides were not applied on a part of the plantation

Table 8: Measures applied in OPTFUEL ecological enhanced SRC plantation

The plantation is planned to be harvested at different stages of development. The poplar and willow section planted in double rows should be harvest every 3 years, while the poplar section planted in single rows should be harvested in longer terms around 7 - 10 years. As the domestic species show a lower mean annual increment, first harvest will be after 10 years at earliest. Poplar for short rotation was planted at a density of ~ 13,000 cuttings/hectare and willow at density of 15,000 cuttings/ hectare. Poplars for the longer rotation and domestic varieties have been manually planted at a density of 5,000 trees/ hectare.

The trees grown in short rotation are planned to be harvested with special short rotation harvesting machinery (e.g. field chipper, whole stem harvester, etc.). The trees grown in longer rotations are planned to be harvested with forestry machinery (e.g. feller-buncher) or manually with chain saws.

The plantation layout is outlined in the following figure:

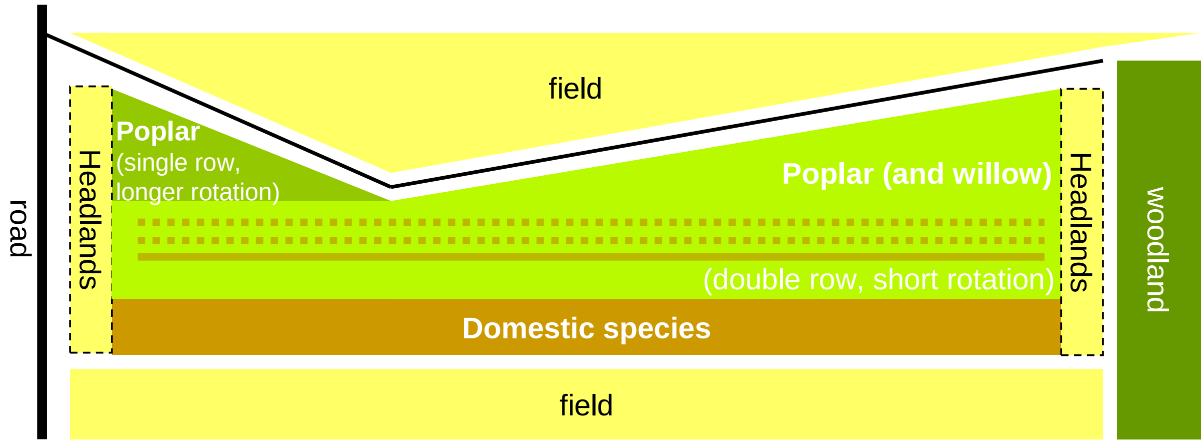

Figure 12: Plantation layout of ecological SRC plantation in Schwedt region

A well-balanced species composition provides nourishing and breeding grounds for mammals, birds and insects. At this field hazel, birch, beech, sycamore, ash and alder species have been planted. Despite the risk of damage caused by browsing mammals, a game fence has not been installed due to high costs.

As mechanical weed control systems only eliminate weed competition between the rows but not between the single plants within the planting rows, the effectiveness of mechanical weed control in the first month after planting is normally lower in comparison to the application of pre-emergent herbicides. This might result in considerably lower average biomass yields depending on site-specific conditions. Additionally, the number of mechanical treatments is higher to achieve similar results compared to a combination of chemical and mechanical weed control. Experienced farmers in ecological agriculture have successfully established SRC plantations without any herbicides in the past, nevertheless this cannot be recommended in general as not applying herbicides requires a foresighted site preparation, specific knowledge and increased use of special machinery.

Figure 13: Mechanical weed control on ecological enhanced SRC plantation near Schwedt (June 2011)

Also the application of insecticides and fungicides should be minimised in ecological enhanced plantations. The risk of pests on the total plantation can be reduced by a diverse composition of tree species and support of natural predators. This includes hawk perches for rodent control or the systematic arrangement of piles from collected stones to attract reptile and mammal predators. In general, a high a high plantation biodiversity provides a broad feeding base for predators of all kind, resulting in an above average population.

Regarding the ecological advanced plantation concept, some elements have also already been realized in older OPTFUEL and CHOREN plantations and are still promoted by Lignovis today. E.g., one plantation is specifically established and managed as wind breaker to lower erosion effects. In addition, block wise planting of different poplar and willow varieties on a single plantation site is a common practice to enhance the diversity of a plantation. Hence, the research activities of the NABU to assess the ecological benefits of SRC have been expanded to other OPTFUEL plantations in the Schwedt region.[15]

5.3. Calculation of additional costs compared to common SRC

Due to its complexity and lower average yields an ecological enhanced SRC plantation normally causes additional costs and lowers revenues over the plantation's lifetime. Based on the ecological enhanced plantation in the Schwedt region as an example, Lignovis calculated the total cash flows of such plantations and compared them to a hypothetical conventional SRC operation on the same site. The main impact factors – MAI for the double row plots and the biomass price – remained the same. Differences in biomass yields occur due to the lower MAI of domestic trees (and to a minor extent also of single rows with longer rotations). Additionally the weed control costs for a conventional SRC planation are lower.

[15] NABU R&D project „Untersuchung von Maßnahmen zur naturschutzfachlichen Aufwertung von KUP" which is funded by the German Federal Agency for Nature Conservation; duration: June 2012 till November 2014

The calculation is based on costs and revenues without taking inflation rates over the plantations life-time into account (only simple accumulation of annual cash flows). The returns are before taxes and potential EU subsidies for the farmer. Costs for administration are not included. As this calculation aims at the comparison of two cultivation systems, total costs and revenues of plantations might slightly differ in practice, but the proportion of these two calculations will remain approximately similar.

Accumulated costs and revenues of ecological enhanced and SRC plantation over whole life cycle (21 years) at 2012 prices								
	per hectare				**for total plantation (3.65 ha)**			
	Enhanced	**Standard**	***En - St***		**Enhanced**	**Standard**	***En - St***	
Plantation Establishment costs	2.477	2.450	***27***	[€/ha]	9.043	8.943	***100***	[€]
Weed control in first 2 years	762	490	***272***	[€/ha]	2.782	1.789	***993***	[€]
Weed control after each harvest	1.068	600	***468***	[€/ha]	3.900	2.190	***1.710***	[€]
Headland costs	341	0	***341***	[€/ha]	1.245	0	***1.245***	[€]
Recultivation costs	2.000	2.000	***0***	[€/ha]	7.300	7.300	***0***	[€]
Harvesting costs	8.405	8.041	***363***	[€/ha]	30.677	29.350	***1.327***	[€]
Total costs	15.054	13.581	***1.472***	[€/ha]	54.946	49.571	***5.375***	[€]
Total revenues	17.798	19.440	***-1.642***	[€/ha]	64.962	70.956	***-5.994***	[€]
Accumulated Cash Flow	2.744	5.859	***-3.115***	[€/ha]	10.016	21.385	***-11.369***	[€]
Annual average Cash Flow	131	279	***-148***	[€/ha/a]	477	1.018	***-541***	[€/a]
Accumulated yield	198	216	***-18***	[bdt/ha]	722	788	***-67***	[bdt]

Additional expenses for biomass from ecological enhanced SRC compared to normal SRC:	**15,75** **€/bdt** wood chips free field
	148,3 **€/ha/a**

Table 9: Accumulated costs and revenues of ecological enhanced and standard SRC plantation (at 2012 prices)

The ecological enhanced plantation concept results in higher expenditures for weed control. In the following years, the costs for weed control remains higher as it is expected that a higher intensity of mechanical weed control measures need to be applied.

Assumptions:		
	Enhanced SRC	Normal SRC
Total plantation size:	3,65 ha	3,65 ha
Structural elements:	8 % long rotation, 11% domestic, 0,3% skylark plots	-
Headlands with flower strips	0,15 ha	-
Double row		
MAI 1st / 1+n rotation	6 / 11 bdt/ha/a	6 / 11 bdt/ha/a
Weed control 1st year	pre-emergent herbicide, 1x rototiller, 2x disc harrow	pre-emergent herbicides, 1x specific herbicide, 1x rototiller, 1x disc har.
Weed control 2nd year and after each harvest	1 rototiller, 1 disc harrow	1 herbicide
Planting technology	Step Planter (20 cm cuttings)	Step Planter (20 cm cuttings)
Harvesting technology	Field chipper	Field chipper
Single row		
MAI 1st / 1+n rotation	6 / 11 bdt/ha/a	-
Weed control 1st year	1x rototiller, 2x disc harrow	-
Weed control 2nd year and after each harvest	1x rototiller, 1x disc harrow	-
Planting technology	Manual	-
Harvesting technology	whole stem harvester and chipper	-
Domestic		
MAI 1st / 1+n rotation	3 / 4 bdt/ha/a	-
Weed control 1st year	pre-emergent herbicide, 1x manual 2x disc harrow	-
Weed control 2nd year and after each harvest	pre-emergent herbicide, 1x manual 2x disc harrow	-
Planting technology	Manual (saplings)	-
Harvesting technology	whole stem harvester and chipper	-
Wood chips price free field site	90 €/bdt wood chips	90 €/bdt wood chips

Table 10: Assumptions for calculation of SRC production

Especially due to the low yields of the domestic tree species (which account for 11% of the plantation area), the total revenues of an ecological enhanced SRC project are considerably lower compared to a normal SRC plantation. This affects the overall revenues considerably.

If an average inflation factor of 2.5 percent is applied, the average additional expenses for ecological SRC production over the whole life time are:

Additional expenses for biomass from ecological enhanced SRC compared to normal SRC (2.5% p.a. inflation)**:**	**20,30 €/bdt** wood chips free field
	191,1 €/ha/a

Table 11: Accumulated costs and revenues of ecological enhanced and standard SRC plantation (at 2012 prices)

5.4. Results

The difference of accumulated cash flows of the ecological enhanced and normal SRC plantation operation over 21 years sums up to 3,161€ per hectare. Calculated on a total yield basis the additional costs and lost revenues amount to app. 16 € per bdt (which equals 17% of the assumed biomass price of 90 €/bdt wood chips. Per ha the economic difference of an enhanced and a standard SRC plantations is app. 150 € per hectare and year. These numbers are calculated without price escalation at 2012 prices for the whole lifetime. The main factors for the different margins are the considerably lower yields of the plantation plots with domestic trees. Additionally, higher transport costs of special machinery and increased expenditures for manual and mechanical weed control increase the costs for plantation management.

The calculation indicates the degree of additional support needed to motivate biomass producer operating SRC plantations with the target of maximising ecological benefits. For a practical implementation, it is assumed to be more feasible to link such payments to the hectares of plantations, instead of produced biomass volumes.

When discussing a compensation payment for a period over 21 years, price developments must be considered. Assuming an inflation rate of 2.5 % p.a. the average profit margin of an standard SRC plantation is annually 191€ per hectare and year higher compared to an ecological enhanced plantation. Hence, an additional compensation of app. 200€ per hectare and year would be required to convince farmers establishing plantations with respective components and management practices as described in chapter 5.2.

As the additional measures also go together with higher risks and uncertainties about the real cost structure, 200€ per hectare and year should be assumed as the minimum compensation. If higher requirements are set, e.g. larger share of domestic trees, total absence of pre-emergent herbicides etc., the compensation payment requirements might be even higher to attract farmers.

6. GHG assessment of SRC plantations

As part of the green house gas assessment of the BTL production chain, Lignovis calculated the GHG emissions of a commercial SRC production within the OPTFUEL project under WP7. Based on the experiences from the establishment, management and harvesting of OPTFUEL SRC plantations, Lignovis developed a hands-on calculation tool for greenhouse gas assessment of economical-scale SRC production. The calculation is based on emissions along the full value chain for plantations with an average size of 10 ha and average yields of 11 bdt/ha/a over 21 years life time.[16]

On MJ of SRC wood chips releases 1.837 g CO_{2eq} (0.030 t CO_{2eq}/bdt) along the value chain delivered at intermediate storage near fields site including mass losses. As a result it can be concluded that SRC plantations show an exceptionally good climate gas balance in comparison to other energy crops.

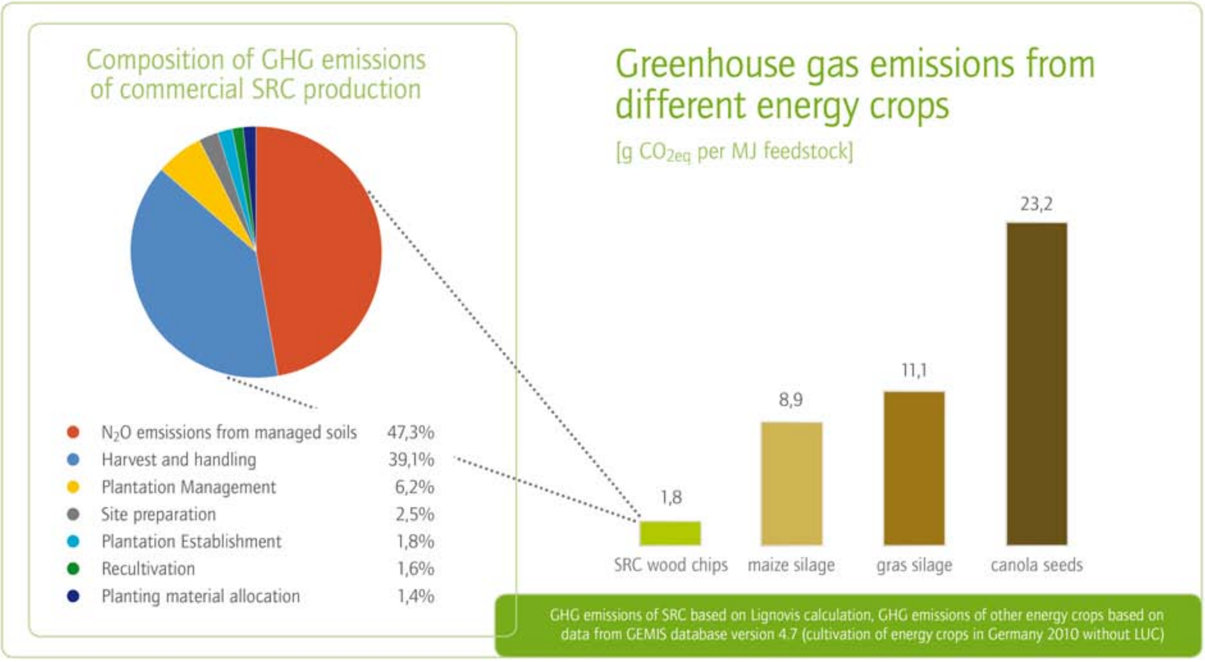

Figure 14: GHG emissions from different energy crops and detailed composition of SRC GHG emissions

For a better comparison, the calculation of the different feedstock did not include the logistics to final customer. A 50 km transport, which was assumed as a baseline for a BTL plant would increase the emissions of SRC chips by 0.517 gCO_{2eq}/MJ (0.009 CO_{2eq}/bdt).

Nitrogen fertilization with the subsequent emissions of N_2O accounts for the major part of CO_{2eq} emissions of conventional agriculture. According to research results and experiences from OPTFUEL plantations, the fertilization of SRC plantations on agricultural land does not provide significant growth benefits, to justify additional expenses and GHG emissions. In

[16] Assumptions: plantation size: 10 ha; tree species: 70% poplar, 30% willow; life time: 21 years, harvest cycle: 3 years; mean annual increment: 11 bdt*ha^{-1}*a^{-1}; harvesting technique: field chipper with transport to intermediate storage; mass loss over whole process: 5%; distance to bioenergy plant: 50 km

practice SRC plantations are normally not fertilized, which should be considered in all calculation models as this massively affects the total GHG emissions.

However, direct and indirect “natural” N_2O emissions (which are normal for every kind of agricultural land use systems) still account for almost 50% of the total CO_{2eq} emissions for the production of wood chips from SRC plantations. Those unavoidable N_2O emissions are mainly caused by microbial denitrification processes in the soil.

In total 2.354 g CO_{2eq} are emitted for 1 MJ wood chips delivered to a biomass consuming plant with a 50 km transport distance. Hence, wood from SRC plantations is a very CO_{2eq} efficient way to produce dedicated feedstock for BTL facilities. In addition, there is still optimization potential, especially regarding the harvesting and logistic chain.

7. References

- Cord-Landwehr, K.; Schwerdfelder, G. (1990): Nitrate load of groundwater by example of the waterworks Holdorf, published in Wasser und Boden, vol.: 42, no.4, 1990
- Deutsches Biomasse Forschungszentrum (DBFZ) (2012): Monitoring zur Wirkung des Erneuerbare-Energien-Gesetz (EEG) auf die Entwicklung der Stromerzeugung aus Biomasse, Berlin 2012
- Eurelectric (2011): Biomass 2020: opportunities, challenges and solutions, Dépôt légal: D/2011/12.105/51
- McKinsey (2008): Perspectives on Electric Power and Natural Gas, Number 1, Winter 2008, p. 24-31
- NABU (2012): Praktische Umsetzung von Maßnahmen bei der Neuanlage und Bewirtschaftung von Energieholzplantagen (Voruntersuchung), Berlin 2012
- Scholz, Hellebrand & Höhn (2004): Energetische und ökologische Aspekte der Feldholzproduktion, published in BORNIMER AGRARTECHNISCHE BERICHTE, issue 35, Potsdam-Bornim 2004
- Rödl, A. (2008): Ökobilanzierung der Holzproduktion im Kurzumtrieb, Johann Heinrich von Thünen Institut, Arbeitsbericht des Instituts für Ökonomie der Forst- und Holzwirtschaft 2008/03
- Pertl, L. (2009): Nachhaltige Klima-Anpassung 2009, presentation, web access: http://elegantweb.servehttp.com/d124-e65b21c3/upload%5CPertl.pdf
- Syncom GmbH (2012): OPTFUEL Deliverable 7.2.: Farmer perception and socio-economic effects of large scale SRC plantations
- Vattenfall (2011): Six sources of energy – one energy system (biomass), Vattenfall's Energy Portfolio and the European Energy System, Stockholm